



Department of
Civil & Environmental Engineering

ROY G. PERRY COLLEGE OF ENGINEERING
PRAIRIE VIEW A&M UNIVERSITY

COURSE MATERIAL

CVEG 4303

WATER RESOURCES ENGINEERING

INSTRUCTOR: *Dr. Emmanuel U. Nzewi, P.E.*

SPRING 2022

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WATER RESOURCES ENGINEERING

SPRING 2022

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**ABET-Formatted
Course Syllabus**

CVEG 4303

Water Resources Engineering

Spring 2022

1.	Course number and name:	CVEG 4303 – Water Resources Engineering
2.	Credits and contact hours:	3 credit hours; 3 contact hours
3.	Instructor's or course coordinator's name:	Dr. Emmanuel Nzewi, PE
4.	Text book: Title:	Hydrology and Hydraulic Systems
	Author:	Gupta, Ram S.
	Publisher, Year & Edition:	Waveland Press, 2017, 4th Edition
	a. Other Supplemental material	Class handouts and notes and related course material provided by the Instructor
5.	Specific course information	
	a. Brief description of the content of the course (catalog description)	CVEG 4303. Water Resources Engineering: 3 semester hours. Control and utilization of water; flood control; water distribution systems; open channel flows; and hydraulic structures.
	b. Prerequisites or Co-requisites	CVEG 3303 (Hydraulics)
	c. ** Indicate whether a required, elective, or selected elective (as per definition provided) course in the program	Required

6.	a. Specific goals for the course specific outcomes of instruction (e.g., The student will be able to explain the significance of	b. Explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.
	current research about a particular topic.) <i>Students will be able to:</i>	<i>The specific goals for the course specific outcomes listed on the left column will address the following student learning outcomes:</i>
	1. Demonstrate an ability to design basic stormwater and sanitary water management systems (storm and sewerage systems); looped water distribution systems	Outcome 1 An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
	2. Demonstrate fundamental understanding of flow in pipe systems – pressurized pipe flow; 3. Demonstrate an ability to use tools for rainfall-runoff modeling and stormwater modeling 4. Demonstrate fundamental understanding of the hydrologic cycle and rainfall-runoff processes 5. Demonstrate an ability to use tools for rainfall-runoff modeling and stormwater management 6. Demonstrate an ability to perform reservoir routing	Outcome 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
7	Brief List of Topics to Be Covered	Course Introduction and review of hydraulics (3 hours) Hydrology and the Hydrologic cycle (3 hours) Statistical analysis of hydrologic data (3 hours) Open channel flow (6 hours) Demand for Water (3 hours) Branched/looped pipe networks and systems (3 hours) Hydrographs/Runoff modeling: Rational Formula (3 hours) Pumps and pump selection (3 hours) Flood mitigation (3 hours) Sewer collection systems (sanitary and storm) (3 hours) Reservoir Routing (3 hours) Urban drainage systems (3 hours)

* For all Engineering programs, indicate subject area from the following: **Math, Basic science, Engineering topic or Other**

** **Required** courses are required of all students in the program, **elective** courses (often referred to as open or free electives) are optional for students, and **selected elective** courses are those for which students must take one or more courses from a specified group

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**Detailed
Course Syllabus**

CVEG 4303 – Water Resources Engineering

Spring 2022

General Course Information

Information Item	Description
Instructor(s):	Dr. Emmanuel U. Nzewi, PE
Section # and CRN:	P01; 21297
Office Location:	Rm 329 SR Collins
Office Phone:	(936) 261-1658
Email Address:	eunzewi@pvamu.edu
Office Hours:	<i>(subject to change):</i> Wed: 1:00 PM – 4:00 PM CT
Mode of Instruction:	Face-to-Face
Course Location:	Rm 205 SR Collins (via Zoom, if necessary)
Class Days & Times:	LECTURES: Tue/Thurs: 1:00 PM – 2:20 PM CT
Catalog Description:	CVEG 4303 Water Resources Engineering: 3 semester hours. Control and utilization of water; flood control; water distribution systems; open channel flows; and hydraulic structures.
Prerequisites:	CVEG 3303 or CVEG 3063 (Hydraulics)
Co-requisites:	None
Computer Use:	Each Student <u>must</u> have a working PVAMU account and <u>functional</u> eCourses (Canvas) access. Each student <u>must</u> have internet access <u>adequate</u> to maintain audio and video connection during Zoom class sessions. Lockdown browser is required during ONLINE exams and as necessary during the course. Access to a printer is required.
Required Text(s):	Gupta, Ram S., Hydrology and Hydraulic Systems , 4 th Edition, Waveland Press, 2017, ISBN-13: 978-1-4786-3091-3
Recommended Text(s):	None
Other Materials	Course notes provided in eCourses/Canvas Reference materials may be introduced/provided, as necessary, over the course of the semester.

Course (Student) Learning Objectives:

	Upon successful completion of this course, students will be able to	Student Learning Alignment [ABET Student Outcomes - SOs]*	Core Curriculum Outcome Alignment
1	Demonstrate fundamental understanding of flow in pipe systems (pressurized pipe flow)	ABET 3 (2)	N/A
2	Demonstrate fundamental understanding of flow in open channel systems (open channel flow)	ABET 3 (2)	N/A
3	Demonstrate fundamental understanding of the hydrologic cycle and rainfall-runoff processes	ABET 3 (2)	N/A
4	Demonstrate an ability to design basic stormwater and sanitary water management systems (storm and sewerage systems)	ABET 3 (1)	N/A
5	Demonstrate an ability to perform reservoir routing	ABET 3 (2)	N/A
6	Demonstrate an ability to use tools for rainfall-runoff modeling	ABET 3 (2)	N/A

Mapping of Program Educational Objectives onto Student Outcomes

PEO	Program Educational Objectives	CE Student Outcomes						
	<i>Graduates from the Civil Engineering program will:</i>	[1]	[2]	[3]	[4]	[5]	[6]	[7]
PEO 1	Have careers in civil engineering or related fields that lead to increasing levels of responsibility and leadership	X	X	X	X	X	X	X
PEO 2	Obtain professional licensure/certifications	X	X					
PEO 3	Complete graduate studies in civil engineering or related fields	X	X	X	X		X	X
PEO 4	Engage in professional development and service	X	X	X	X		X	X

Mapping of CE Course and Student Outcomes [Beginning Fall 2019] Updated Fall 2021

Previous Course No.	New Course No.	Course Title	CE Student Outcomes/SOs						
			[1]	[2]	[3]	[4]	[5]	[6]	[7]
CVEG 4063	CVEG 4303	Water Resources Engineering	√	√					

- 1) an ability to identify, formulate, and solve **complex** engineering problems by applying principles of engineering, science, and mathematics
- 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
- 3) an ability to communicate effectively with a range of audiences
- 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
- 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
- 6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
- 7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Method of Determining Final Course Grade

This course will utilize the following instruments to determine student letter grades		
Course Grade Requirement	Value	Total
1) Two exams (20% each)	40%	400
2) Homework Assignments	10%	100
3) Class Participation (Classwork) and Attendance	10%	100
4) Design Project (Individual)	12%	120
5) TaskStream Assignment	3%	30
6) Final Exam (Comprehensive)	25%	250
Total:	100.00%	1000

Grading Criteria and Conversion:

A = 90 - 100%	D = 60 - 69%
B = 80 - 89%	F = 00 - 59%
C = 70 - 79%	

If a student has stopped attending the course (i.e. **"stopped out"**) at any point after the first day of class but did not officially withdraw from the course and has missed assignments and exams, including the final exam, and performed below the grade level of a D, a **grade of FN** (failed-non attendance) will be assigned for the final course grade to ensure compliance with the federal Title IV financial aid regulations. In contrast, if the student has completed all assignments and exams, including the final exam, but performed below the grade level of a D, a grade of F will be assigned for the final course grade.

Detailed Description of Major Assignments:

Assignment Title or Grade Requirement	Description
Exams	Two (2) written tests designed to measure knowledge of presented course material
Homework Assignments	Written assignments designed to engage students and reinforce course material. Also to provide formative assessment and student feedback over the course of the semester
Class Participation (Classwork) & Attendance	Attendance will be recorded during course. Classwork (short problems) will be assigned to promote student engagement. Online polls or quick response questions maybe part of the course. The Classwork may require submissions in eCourses (Canvas) or to be submitted in class.
Design Project	A design project will be assigned and is a course requirement
TaskStream	Taskstream assignment for course – via eCourses/Canvas
Final Exam	Comprehensive closed book examination at the end of the course.

Course Procedures or Additional Instructor Policies

- Attendance in the class is mandatory and students are expected to report to class on time. Attendance will be taken at the beginning of class and may be taken at the end of class. Please read the included University Class Attendance Policy.
- Turn cell phones and other electronic devices off prior to the start of class. They must remain off while class is in session. If you are expecting an emergency call, please keep the cell phone in silence mode and exit the classroom to take the call. **For online (Zoom) class sessions ALWAYS place your microphone on MUTE and your video OFF during the class unless otherwise instructed.**
- Exam Study guides will be provided for exams and the Final Exam as announced by the Instructor.
- No makeup test(s) will be given. Missed test(s) you will receive zero (0.0) grade. Excused absences will require documentation. A written excuse is required via email to the Instructor. It is the student's responsibility to contact the instructor within ONE week to make up any assignments required during any period of an excused absence from class. Failure to sit for and complete the Final Exam will result in an automatic "F" grade for the course. **A one-time make-up comprehensive make-up exam will be used to substitute for all excused exams.**
- Late homework will not be accepted. Please refer to Homework submission requirements.
- Professionalism includes class conduct and participation in class. Unprofessional classroom behavior will not be tolerated. Students should not hold private conversations in class. All cell phones **MUST** be silenced during class. Disruptive behavior of any kind may result in removal from the classroom or administrative withdrawal from the course.
- For grading/class related appeals (see the PVAMU Undergraduate Catalog)
- Cheating on an exam or homework will minimally result in a grade of zero (0.0). Other forms of academic dishonesty could result in a grade of "F" for the course AND administrative referral with the maximum penalty recommended. **Please refer to the CEE Policy to Eradicate Cheating.**

Taskstream

Taskstream is a tool that Prairie View A&M University uses for assessment purposes. One of your assignments may be required to be submitted as an "artifact," an item of coursework that serves as evidence that course objectives are met. If applicable, more information will be provided during the semester by your department, but for general information, you can visit Taskstream via the link in eCourses. **This course requires a Taskstream Assignment.**

Course Procedures

Assignment Submission

Dates to submit assignments will be provided when it is assigned. LATE ASSIGNMENTS WILL NOT BE ACCEPTED! Submitted homework should be complete, neat, and professionally presented.

Use the following format for all of homework submissions:

1. **Use only engineering paper (not graph paper) for submitting your homework**
2. Your homework should have the following on top of the first sheet
 - a. Full name: LAST NAME, First Name
 - b. Course name and section
 - c. Homework number
 - d. Date of submission
3. Show all steps for arriving to the final answer clearly. Include all appropriate sketches/diagrams.
4. Reference all figures, tables, constant values, equations, and conversions used to complete the problem.
5. Include all the appropriate units throughout the solution. Points will be deducted for answers presented without the appropriate units.
6. Start each problem on a NEW PAGE.
7. Problems should be solved and presented in the order assigned.
8. An elaborate set of guidelines will be provided for any Lab reports.

Exam Policy:

Exams should be taken as scheduled. No makeup examinations will be allowed except under documented emergencies (See Student Handbook).

CEE POLICY TO ERADICATE CHEATING (PROTECT INTEGRITY OF EXAMS)

Cheating is unprofessional, unethical and is antithetical to our core value of "Excellence in Civil Engineering Education," and WILL NOT BE TOLERATED at any level. To combat this serious problem, the Civil & Environmental Engineering (CEE) Department has adopted the following rules to eradicate cheating.

- If a student cheats on a test/assignment, the student shall receive an **automatic zero** for the test/assignment.
- A student who has been determined to have cheated in a course will IMMEDIATELY relinquish his/her leadership position in any of the department's professional organizations.
- If a student cheats multiple times in a course, the student will receive a **grade of "F"** for the course.
- CALCULATORS: The calculators allowed for use in exams may be **restricted** to the **latest** Fundamentals of Engineering (FE) approved calculators. For the latest National Council of Examiners for Engineering and Surveying (NCEES) Fundamentals of Engineering (FE) approved calculators visit ncees.org or <https://ncees.org/exams/calculator/> (The Instructor may also provide a list.)

[This NCEES policy protects the integrity of NCEES exams and has been adopted to do likewise for department's exams.]

GENERAL EXAM GUIDELINES

- 1) All cellphones/smartwatches **MUST** be placed in a book bags during exams and turned off. Book bags **MUST** be placed in front of the classroom and away from students. Students without a book bag must place cellphone/smartwatch (turned off) on Instructor's desk – no exceptions
- 2) Any student possessing a cellphone/smartwatch or any other unauthorized device **WILL** receive an automatic zero for the test/assignment. This is cheating.
- 3) CLOTHING: Hoodies are **NOT** Allowed during exams. No headphones (corded or wireless) are **ALLOWED**.
- 4) Calculator covers are **DISALLOWED** during tests and must be placed in students' book bags during exams.
- 5) There shall be **NO SHARING** of resources during the exam
- 6) **RESTROOM VISIT**: if you need to use the restroom, do so before opening the exam. Once the exam begins, you must submit your work to the instructor if you leave the classroom to visit the rest room (your exam terminates).

Additionally, please see the Section on Academic Misconduct (below).

Spring 2022 Semester [Selected Dates]

January 17	Monday	Dr. Martin Luther King, Jr. Holiday
January 18	Tuesday	Classes/Instruction begin; Late Registration and Add/Drop Begin
Jan 18-Jan 24	Tues - Mon	Late Registration/Late Registration Fee Begins (\$50.00)
Jan 18-Jan 26	Tues - Wed	Attendance Reporting Period. Students who do not attend class during this period will have their courses removed and financial aid reduced or cancelled
February 02	Wednesday	12 th Class Day (Census Date) Final Day to Drop/Withdraw from Course(s) without Academic Record (A Financial Record will still exist)
February 03	Thursday	Withdrawal from Courses with Academic Record ("W") Begins
Mar 10 - Mar 12	Thurs-Sat	Mid-Semester Examination Period
March 16	Wednesday	Mid-Semester Grades Due
Mar 14 - Mar 19	Mon-Sat	Spring Break
Mar 18	Friday	Spring Break (Non-class Day/University Open)
April 06	Wednesday	Final Day to Withdraw from Course(s) with Academic Record ("W")
Apr 15	Friday	Good Friday (No Classes)
May 02	Tuesday	Final Day to Withdraw from the University (from all courses) for the Spring 2022 16-week session
May 03	Wednesday	Last Class Day
May 05 - May 12	Thurs-Thurs	Final Examination Period
May 12	Thursday	Final Grades due for Graduation Candidates (12:00 pm)
May 14	Saturday	Commencement
May 17	Tuesday	Final Grades due for all other students (11:59 PM)

Semester Calendar (Subject to change)

Week 1: Topic(s)	Course Overview and Syllabus/Review of Basic Hydraulics
Chapter(s):	Instructor's Notes
Assignment(s):	None
Week 2: Topic	Review of Selected Hydraulics Topics/Single Pipe systems
Chapter(s):	Chapter 15
Assignment(s):	Classwork/Homework
Week 3: Topic(s)	Single Pipe systems
Chapter(s):	Chapter 15
Assignment(s):	Classwork/Homework
Week 4: Topic(s)	Pipe Networks & Pumps
Chapter(s):	Chapter 15
Assignment(s):	Classwork/Homework
Week 5: Topic(s)	Demand for Water
Chapter(s):	Chapter 1
Assignment(s):	Classwork/Homework
Week 6: Topic(s)	The Hydrologic Cycle
Chapter(s):	Chapters 2, 3, 4
Assignment(s):	Classwork/Homework
Week 7: Topic(s)	The Hydrologic Cycle
Chapter(s):	Chapters 2, 3, 4/Review for Exam #1
Assignment(s):	Exam #1
Week 8: Topic(s)	Surface Water Flow and Hydrograph Analysis (Unit Hydrograph)
Chapter(s):	Chapter 9
Assignment(s):	Classwork/Homework
Week 9: Topic(s)	Hydrograph Analysis (Unit Hydrograph) & Reservoir Routing
Chapter(s):	Chapters 9 and 12
Assignment(s):	TaskStream Submission/Classwork/Homework
Week 10: Topic(s)	Urban Drainage Systems & Rational Method
Chapter(s):	Chapter 16
Assignment(s):	Assignment of Course Project/Classwork
Week 11: Topic(s)	Urban Drainage Systems & Rational Method
Chapter(s):	Chapter 16
Assignment(s):	Classwork/Homework
Week 12: Topic(s)	Open Channel Flow/Review for Exam #2
Chapter(s):	Chapter 14
Assignment(s):	Exam #2
Week 13: Topic(s)	Open Channel Flow
Chapter(s):	Chapter 14
Assignment(s):	Classwork/Homework
Week 14: Topic(s)	Open Channel Flow/Hydraulic Structures
Chapter(s):	Chapter 14 & Chapter 13
Assignment(s):	Classwork/Homework
Week 15: Topic	Presentation of Course Project by students
Chapter(s):	Chapter 14 & Chapter 13
Assignment(s):	TaskStream Submission
Week 16: Topic	Final Exam (Comprehensive)

Syllabus Revision(s):

The instructor reserves the right to make changes to the course syllabus as necessary. It is the student's responsibility to keep up with any changes posted on eCourses/Canvas and/or changes announced in class.

Student Support and Success

John B. Coleman Library

The John B. Coleman Library's mission is to enhance the scholarly pursuit of knowledge, to foster intellectual curiosity, and to promote life-long learning and research through our innovative services, resources, and cultural programs, which support the Prairie View A&M University's global mission of teaching, service, and research. It maintains library collections and access both on campus, online, and through local agreements to further the educational goals of students and faculty. Website: <https://www.pvamu.edu/library/>; Phone: 936-261-1500

Academic Advising Services

Academic Advising Services offers students a variety of services that contributes to student success and leads towards graduation. We assist students with understanding university policies and procedures that affect academic progress. We support the early alert program to help students get connected to success early in the semester. We help refer students to the appropriate academic support services when they are unsure of the best resource for their needs. Faculty advisors support some students in their respective colleges. Your faculty advisor can be identified in PantherTracks. Advisors with Academic Advising Services are available to all students. We are located across campus. Find your advisor's location by academic major at www.pvamu.edu/advising. Phone: 936-261-5911

The University Tutoring Center

The University Tutoring Center (UTC) offers free tutoring and academic support to all registered PVAMU students. The mission of the UTC is to help provide a solid academic foundation that enables students to become confident, capable, independent learners. Competent and caring staff and peer tutors guide students in identifying, acquiring, and enhancing the knowledge, skills, and attitudes needed to reach their desired goals. Tutoring and academic support are offered face-to-face in the UTC, in virtual face-to-face sessions (<https://www.pvamu.edu/student-success/sass/university-tutoring-center/>), and through online sessions (<https://www.pvamu.edu/pvplace/>). Other support services available for students include Supplemental Instruction, Study Break, Academic Success Workshops, and Algebra Study Jam. Location: J. B. Coleman Library, Rm. 307; Phone: 936-261-1561; Email: pv tutoring@pvamu.edu; Website: <https://www.pvamu.edu/student-success/sass/university-tutoring-center/>

Writing Center

The Writing Center provides well-trained peer tutors to assist students with writing assignments at any stage of the writing process. Tutors help students with various writing tasks from understanding assignments, brainstorming, drafting, revising, editing, researching, and integrating sources. Students have free access to Grammarly online writing assistance. Grammarly is an automated proofreading and plagiarism detection tool. Students must register for Grammarly by using their student email address. In addition, students have access to face-to-face and virtual tutoring services either asynchronously via email or synchronously via Zoom. Location: J. B. Coleman Library, Rm. 209; Phone: 936-261-3724; Website: <https://www.pvamu.edu/student-success/writing-center/>; Grammarly Registration: <https://www.grammarly.com/enterprise/signup>

Academic Early Alert

Academic Early Alert is a proactive system of communication and collaboration between faculty, academic advisors, and PVAMU students that is designed to support student success by promptly identifying issues and allowing for intervention. Academic Early Alerts help students by providing a central location to schedule advising appointments, view advisor contact information, and request assistance. Students who recognize that they have a problem that is negatively affecting their academic performance or ability to continue school may self-refer an Academic Early Alert. To do so, students will log in to PV Place and click on Academic Early Alert on the left sidebar. Phone: 936-261-5902; Website: <https://www.pvamu.edu/student-success/early-alert/>

Student Counseling Services

The Student Counseling Services unit offers a range of services and programs to assist students in maximizing their potential for success: short-term individual, couples, and group counseling, as well as crisis intervention, outreach, consultation, and referral services. The staff is licensed by the State of Texas and assists students who are dealing with academic skills concerns, situational crises, adjustment problems, and emotional difficulties. Information shared with the staff is treated confidentially and in accordance with Texas State Law. Location: Hobart Taylor, 2nd floor; Phone: 936-261-3564; Website: <https://www.pvamu.edu/healthservices/student-counseling-services/>

Office of Testing Services

Testing Services serves to create opportunities by offering a suite of exams that aid in the students' academic and professional success. Currently, we administer entrance (HESI A2), college readiness (TSI assessment), Prior Learning (CLEP, DSST), and proctored exams. Location: Wilhelmina Delco, 3rd Floor, Rm. 305; Phone: 936-261-3627; Email: aetesting@pvamu.edu; Website: www.pvamu.edu/testing

Office of Diagnostic Testing and Disability Services

The Americans with Disabilities Act (ADA) is a federal anti-discrimination statute that provides comprehensive civil rights protection for persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you believe you have a disability requiring an accommodation, contact the Office of Disability Services. As a federally-mandated educational support unit, the Office of Disability Services serves as the repository for confidential disability files for faculty, staff, and students. For persons with a disability, the Office develops individualized ADA letters of request for accommodations. Other services include learning style inventories, awareness workshops, accessibility pathways, webinars, computer laboratory with adapted hard and software, adapted furniture, proctoring non-standardized test administrations, ASL interpreters, ALDs, digital recorders, Livescribe, and a comprehensive referral network across campus and the broader community. Location: Hobart Taylor, Rm. 1D128; Phone: 936-261-3583; Website: <https://www.pvamu.edu/disabilityservices/>

Center for Instructional Innovation and Technology Services (CIITS)

Distance Learning, also referred to as Distance Education, is the employment of alternative instructional delivery methods to extend programs and services to persons unable to attend college in the traditional manner. The Center for Instructional Innovation and Technology Services (CIITS) supports student learning through online, hybrid, web-assist, and 2-way video course delivery. For more details and contact information, visit: <https://www.pvamu.edu/dlearning/distance-learning-2-2/students-2/>; Phone: 936-261-3283

Veteran Affairs

Veterans Services works with student veterans, current military and military dependents to support their transition to the college environment and continued persistence to graduation. The Office coordinates and certifies benefits for both the G.I. Bill and the Texas Hazlewood Act. Location: Evans Hall, Rm. 102; Phone: 936-261-3563; Website: <https://www.pvamu.edu/sa/departments/veteranaffairs/>

Office for Student Engagement

The Office for Student Engagement delivers comprehensive programs and services designed to meet the co-curricular needs of students. The Office implements inclusive and accessible programs and services that enhance student development through exposure to and participation in diverse and relevant social, cultural, intellectual, recreational, community service, leadership development, and campus governance. Location: Memorial Student Center, Rm. 221; Phone: 936-261-1340; Website: <https://www.pvamu.edu/studentengagement/>

Career Services

Career Services supports students through professional development, career readiness, and placement and employment assistance. The Office provides one-on-one career coaching, interview preparation, resume and letter writing, and career exploration workshops and seminars. Services are provided for students at the Northwest Houston Center and College of Nursing in the Medical Center twice a month or on a requested basis. Distance Learning students are encouraged to visit the Career Services website for information regarding services provided. Location: Anderson Hall, 2nd floor; Phone: 936-261-3570; Website: <https://www.pvamu.edu/careerservices/>

University Rules and Procedures

Academic Misconduct

Academic dishonesty is defined as any form of cheating or dishonesty that has the effect or intent of interfering with any academic exercise or fair evaluation of a student's performance. The college faculty can provide additional information, particularly related to a specific course, laboratory, or assignment.

You are expected to practice academic honesty in every aspect of this course and all other courses. Make sure you are familiar with the *University Administrative Guidelines on Academic Integrity*, which can be found on the [Academic Integrity webpage](#). Students who engage in academic misconduct are subject to university disciplinary procedures.

As listed in the *University Administrative Guidelines on Academic Integrity*, the University Online Catalog, and the Student Code of Conduct, the following are examples of prohibited conduct. This list is not designed to be all-inclusive or exhaustive. In addition to academic sanctions, any student found to have committed academic misconduct that is also a violation of criminal law may also be subject to disciplinary review and action by the Office of Student Conduct (as outlined in the Student Code of Conduct).

Forms of Academic Dishonesty:

1. Cheating: Deception in which a student misrepresents that he/she has mastered information on an academic exercise that he/she has not learned, giving or receiving aid unauthorized by the instructor on assignments or examinations. Examples: unauthorized use of notes for a test; using a "cheat sheet" on a quiz or exam; any alteration made on a graded test or exam which is then resubmitted to the teacher;
2. Plagiarism: Careless or deliberate use of the work or the ideas of another; representation of another's work, words, ideas, or data as your own without permission or appropriate acknowledgment. Examples: copying another's paper or answers, failure to identify information or essays from the internet and submitting or representing it as your own; submitting an assignment which has been partially or wholly done by another and claiming it as yours; not properly acknowledging a source which has been summarized or paraphrased in your work; failure to acknowledge the use of another's words with quotation marks;
3. Collusion: When more than one student or person contributes to a piece of work that is submitted as the work of an individual;
4. Conspiracy: Agreeing with one or more persons to commit an act of academic/scholastic dishonesty; and
5. Multiple Submission: Submission of work from one course to satisfy a requirement in another course without explicit permission. Example: using a paper prepared and graded for credit in one course to fulfill a requirement and receive credit in a different course.

Nonacademic Misconduct

The university respects the rights of instructors to teach and students to learn. Maintenance of these rights requires campus conditions that do not impede their exercise. Campus behavior that interferes with either (1) the instructor's ability to conduct the class, (2) the inability of other students to profit from the instructional program, or (3) campus behavior that interferes with the rights of others will not be tolerated. An individual engaging in such disruptive behavior may be subject to disciplinary action. The Office of Student Conduct will adjudicate such incidents under nonacademic procedures.

Sexual Misconduct

Sexual harassment of students and employees at Prairie View A&M University is unacceptable and will not be tolerated. Any member of the university community violating the university's sexual harassment policy will be subject to disciplinary action. In accordance with the Texas A&M University System guidelines, your instructor is obligated to report to the Office of Title IX Compliance (titleixteam@pvamu.edu) any instance of sexual misconduct involving a student, which includes sexual assault, stalking, dating violence, domestic violence, and sexual harassment, about which the instructor becomes aware during this course through writing, discussion, or personal disclosure. The faculty and staff of PVAMU actively strive to provide a learning, working, and living environment that promotes respect that is free from sexual misconduct, discrimination, and all forms of violence. If students, faculty, or staff would like assistance or have questions, they may contact the Title IX Coordinator at 936-261-2144 or titleixteam@pvamu.edu. More information can be found at www.pvamu.edu/titleix, including confidential resources available on campus.

Pregnancy, Pregnancy-related, and Parenting Accommodations

Title IX of the Education Amendments of 1972 prohibits sex discrimination, which includes discrimination based on pregnancy, marital status, or parental status. Students seeking accommodations related to pregnancy, pregnancy-related conditions, or parenting (reasonably immediate postpartum period) are encouraged to contact Student Disability Services or the Dean of Students' Office for additional information and to request accommodations.

Non-Discrimination Statement

Prairie View A&M University does not discriminate on the basis of race, color, sex, religion, national origin, age, disability, genetic information, veteran status, sexual orientation, or gender identity in its programs and activities. The University is committed to supporting students and complying with The Texas A&M University System non-discrimination policy. It seeks to establish an environment that is free of bias, discrimination, and harassment. If you experience an incident of discrimination or harassment, we encourage you to report it. If you would like to speak with someone who may be able to afford you privacy or confidentiality, there are individuals who can meet with you. The Director of Equal Opportunity & Diversity has been designated to handle inquiries regarding the non-discrimination policies and can be reached at Harrington Science Building, Suite 109 or by phone at 936-261-1744 or 1792.

Class Attendance Policy (See the University Online Catalog for Full Attendance Policy)

Prairie View A&M University requires regular class attendance. Attending all classes supports the full academic development of each learner, whether classes are taught with the instructor physically present or via distance learning technologies such as interactive video and/or the internet. Excessive absenteeism, whether excused or unexcused, may result in a student's course grade being reduced or in the assignment of a grade of "F." Absences are accumulated beginning with the first day of class during regular semesters and summer terms. Each faculty member will include the University's attendance policy in each course syllabus.

Student Academic Appeals Process

Authority and responsibility for assigning grades to students rest with the faculty. However, in those instances where students believe that miscommunication, errors, or unfairness of any kind may have adversely affected the instructor's assessment of their academic performance, the student has a right to appeal by the procedure listed in the University Online Catalog and by doing so within thirty days of receiving the grade or experiencing any other problematic academic event that prompted the complaint.

Technical Considerations

Minimum Recommended Hardware and Software:

- Intel PC or Laptop with Windows 10 or later version; Mac with OS High Sierra*
- Smartphone or iPad/Tablet with Wi-Fi*
- High-speed Internet access
- 8 GB Memory
- Hard drive with 320 GB storage space
- 15" monitor, 800x600, color or 16 bit
- Sound card w/speakers
- Microphone and recording software
- Keyboard & mouse
- Most current version of Google Chrome, Safari, or Firefox

Note: Be sure to enable Java & pop-ups in the Web browser preferences

* Smartphones, Google Chrome books, and Android tablets may not be supported. iPads are the only tablets supported.

Participants should have a basic proficiency of the following computer skills:

- Sending and receiving email
- A working knowledge of the Internet
- Microsoft Word (or a program convertible to Word)
- Acrobat PDF Reader
- Windows or Mac OS
- Video conferencing software

Netiquette (online etiquette)

Students are expected to participate in all discussions and virtual classroom chats as directed. Students are to be respectful and courteous to others on discussion boards. Foul or abusive language will not be tolerated. Do not use ALL CAPS for communicating to others AS IT CAN BE INTERPRETED AS YELLING. Avoid slang terms such as "wassup?" and texting abbreviations such as "u" instead of "you." Limit and possibly avoid the use of emoticons. Be cautious when using humor or sarcasm as tone is sometimes lost in an email or discussion post, and the message

might be taken seriously or sound offensive.

Video Conferencing Etiquette

When using Zoom, WebEx, or other video conferencing tools, confirm the visible area is tidy, clear of background clutter, inappropriate or offensive posters, and other distractions. Ensure you dress appropriately and avoid using high traffic or noisy areas. Stay muted when you are not speaking and avoid eating/drinking during the session. Before the class session begins, test audio, video, and lighting to alleviate technology issues.

Technical Support

Students should go to <https://mypassword.pvamu.edu/> if they have password issues. The page will provide instructions for resetting passwords and contact information if login issues persist. For other technical questions regarding eCourses, call the Center for Instructional Innovation and Technology Services at 936-261-3283 or email ciits@pvamu.edu.

Communication Expectations and Standards

Emails or discussion postings will receive a response from the instructor, usually in less than 48 hours. Urgent emails should be marked as such. Check regularly for responses.

Discussion Requirement

Online courses often require minimal to no face-to-face meetings. However, conversations about the readings, lectures, materials, and other aspects of the course can occur in a seminar fashion. The use of the discussion board will accomplish this. The instructor will determine the exact use of discussion boards.

It is strongly suggested that students type their discussion postings in a word processing application such as Word and save it to their PC or a removable drive before posting to the discussion board. This is important for two reasons: 1) If for some reason your discussion responses are lost in your online course, you will have another copy; 2) Grammatical errors can be greatly minimized by the use of the spell-and-grammar check functions in word processing applications. Once the post(s) have been typed and corrected in the word processing application, copy and paste to the discussion board.

COVID-19 Campus Safety Measures

To promote public safety and protect students, faculty, and staff during the coronavirus pandemic, PVAMU has adopted policies and practices to limit virus transmission.

- **Self-monitoring** - Students should follow CDC recommendations for self-monitoring. Students who have a fever or exhibit symptoms of COVID-19 should participate in class remotely and should not participate in face-to-face instruction.
- **Face Coverings** - Face coverings (cloth face covering, surgical mask, etc.) are recommended in classrooms, teaching laboratories, common spaces such as lobbies and hallways, public study spaces, libraries, academic resource, and support offices, and outdoor spaces where 6 feet of physical distancing is challenging to maintain reliably.
- **Physical Distancing** - Physical distancing should be maintained between students, instructors, and others in course and course-related activities where possible.

Personal Illness and Quarantine - Students required to quarantine are to participate in courses and course-related activities remotely and must not attend face-to-face course activities. Students should notify their instructors of the quarantine requirement. Students under quarantine are expected to participate in courses and complete graded work unless they have symptoms that are too severe to participate in course activities. Students experiencing personal injury or illness that is too severe for the student to attend class qualify for an excused absence. To receive an excused absence, students must provide appropriate documentation to the Office for Student Conduct, studentconduct@pvamu.edu.

End of Semester Course Assessment Report

This summary contains the following Information

1. Performance Statistics

- **Total number of students in class**
- **The class average performance (stated as %) in each course outcome assessed in this class and the two previous times course was assessed.**
- **The acceptable class average for the class in each outcome area as set by your Department.**
- **Percentage of students who scored below the expected average in each outcome.**

2. Implementation Summary

- **Brief summary of plans implemented during the semester based on last assessment report**

3. Perceived Problems

- **Instructor's critical evaluation of perceived problems that affected students' performance.**

4. New Plans for Addressing Problems

- **Instructor's plans for addressing the perceived problems the next time the class is taught.**

5. Overall Trend over last three assessment periods

- **Instructors summary of overall performance trend for each outcome measured over the last three periods.**

**ASSESSMENT RESULTS FOR CURRENT AND PAST THREE
ASSESSMENT PERIODS [if available]**

Program Outcomes Assessed in this Course

ABET Outcome 1	<i>An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics</i>
ABET Outcome 2	<i>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</i>

**Assessment Summary of Class Semester Averages for Outcomes:
Spring 2022**

Expected semester class average = 70%

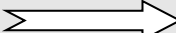
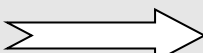
	ABET Outcomes	
	1	2
Semester	Class Average (%)	Class Average (%)
Spring 2022 16 students*	80	69
Spring 2021 17 students	49	56
Spring 2020 19 students	72	80
Comments on data	*Data reported are for students completing the course for the assignments included in the assessment analysis.	

END OF SEMESTER COURSE OUTCOME ASSESSMENT REPORT

CVEG 4303 – Water Resources Engineering - Spring 2022

Report Prepared by: Emmanuel U. Nzewi, *PhD, PE*

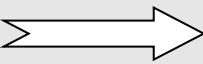
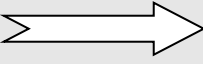
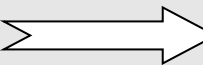
Report Date: May 23, 2022

Semester	Analysis Type	Number of Students	Outcome 1				Outcome 2			
			Ability to identify, formulate, and solve complex engineering problems (CEPs) by applying principles of engineering, science, and mathematics				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 factor			
			Expected Class Average /	Expected Percent of students at or above average	Class Average	% Students meeting Expected Average	Expected Class Average /	Expected Percent of students at or above average	Class Average	% Students meeting Expected Average
Spring 2022*	Direct	16	70	70	80	81	70	70	69	50
Spring 2021	Direct	17	70	70	49	35	70	70	56	23
Spring 2020	Direct	19	70	70	72	58	70	70	80	63
Implementation Summary	Items implemented from previous report or after meeting previous instructor 		Students were presented with open ended problems and worked in groups on one and individually on another. It appeared the group project may have resulted in uneven work by student members. Another project in which individual effort was required caused all students to engage fully in the exercise. Students performed well, in general. This tactic should be explored further in the future.				The use of Excel to solve problems requiring iterative solutions was emphasized. In-class work, used to obtain rapid feedback from students, appeared to work well. However, it does take away time from delivery of course topics. It was used for the timely identification of topics and concepts topics that required additional attention in class.			
Perceived Problems	Perceived problems are directly related to the PC and the sub items under them 		A few students showed low competency in areas – especially math intensive calculations – in the course. This hampered progress in class – because additional review				Homework performance did not correlate well with competency in class topics. Attention needs to be directed toward obtaining more reliable feedback from students.			
Plans for Addressing Problems	Plans for address specific measures to address PC and their sub areas 		Additional open-ended projects requiring both group and individual effort would be advisable.				Additional in-class work would be attempted in the future with rapid feedback rather than homework problems.			
Overall Trend over Periods	Ascertain if there were improvements over previous semesters		Performance was generally good.				Students appeared to do better than in the previous semester. Still more work needs to be done to address persistent low competency in critical areas.			
Were Expectations Met?			YES				NO			

END OF SEMESTER COURSE OUTCOME ASSESSMENT REPORT
CVEG 4063-WATER RESOURCES ENGINEERING
SPRING 2021

Report Prepared by: Dr. Iftekhhar Ahmed, P.E.

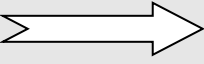
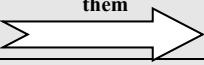
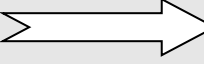
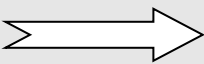
Report Date: May 21, 2021

Semester	Analysis Type	Number of Students	Outcome 1 Ability to identify, formulate, and solve complex engineering problems (CEPs) by applying principles of engineering, science, and mathematics				Outcome 2 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 factor			
			Expected Class Average /	Expected Percent of students at or above average	Class Average	% Students meeting Expected Average	Expected Class Average /	Expected Percent of students at or above average	Class Average	% Students meeting Expected Average
Spring 2021	Direct	17	70	70	49	35	70	70	56	23
Spring 2020	Direct	19	70	70	72	58	70	70	80	63
Spring 2019	Direct	21	70	70	67	45	70	70	83	95
Implementation Summary	Items implemented from previous report or after meeting previous instructor 	Students were encouraged to read the required textbook to reinforce the <i>complex concepts</i> presented in the lecture. Repeated assignments were presented on critical concepts namely, reservoir routing, channel design and storm hydrograph generation from unit hydrograph. Class was fully online.					Public safety and welfare supportive flood control design project was implemented. Students were exposed to computer -based hydrologic model (Excel) of reservoir routing to assist with unlined channel design using attenuated peak discharge; a holistic approach to flood control.			
Perceived Problems	Perceived problems are directly related to the PC and the sub items under them 	Did not received notable performance feedback from students. All time low averages were recorded on assignments and tests. Traditionally a take home test average has been above 80% whereas this term, that average was just 53%. Couple of students notably remained off-the-grid that they did not follow lecture notes or the required textbook.					Did not received notable performance feedback from students. All time low averages were recorded on assignments and tests. Traditionally a take home test average has been above 80% whereas this term, that average was just 53%. Couple of students notably remained off-the-grid that they did not follow lecture notes or the required textbook.			
Plans for Addressing Problems	Plans for address specific measures to address PC and their sub areas 	Face-to-face lecture should improve matters back to normal.					Face-to-face lecture should improve matters back to normal.			
Overall Trend over Periods	Ascertain if there were improvements over previous semesters	This term's performance was a trend setter in the negative scale. Such low performance was never recorded for this course. Rather than a trend, this was an anomaly.					This term's performance was a trend setter in the negative scale. Such low performance was never recorded for this course. Rather than a trend, this was an anomaly.			
Were Expectations Met?		NO					NO			

END OF SEMESTER COURSE OUTCOME ASSESSMENT REPORT
CVEG 4063-WATER RESOURCES ENGINEERING
SPRING 2020

Report Prepared by: Dr. Iftekhhar Ahmed, P.E.

Report Date: May 15, 2020

Semester	Analysis Type	Number of Students	Outcome 1 Ability to identify, formulate, and solve complex engineering problems (CEPs) by applying principles of engineering, science, and mathematics				Outcome 2 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 factor			
			Expected Class Average /	Expected Percent of students at or above average	Class Average	% Students meeting Expected Average	Expected Class Average /	Expected Percent of students at or above average	Class Average	% Students meeting Expected Average
Spring 2020	Direct	19	70	70	72	58	70	70	80	63
Spring 2019	Direct	21	70	70	67	45	70	70	83	95
Implementation Summary	Items implemented from previous report or after meeting previous instructor 		Quizzes were offered for the Hydrology section in the early part of the semester to encourage students to read the book to reinforce the <i>complex concepts</i> presented in the lecture. Those sincere enough benefited from this.				Public safety and welfare supportive flood control design project was implemented. Students gained technical expertise with computer -based hydrologic model (Excel) of reservoir routing to assist with unlined channel design using attenuated peak discharge; a holistic approach to flood control.			
Perceived Problems	Perceived problems are directly related to the PC and the sub items under them 		Few students could not spend enough time on their assignments due to other curricular activities. The quality of work was not good.				Signs of plagiarism were noted among a same small group of students from the pre-requisite class where same behavior was noted. This project was last offered in Spring 2018. So, solutions were most likely available from past students.			
Plans for Addressing Problems	Plans for address specific measures to address PC and their sub areas 		Encourage students to prepare and use weekly schedule to manage time to their best potentials.				New project implementation is recommended annually so students do not rely on solutions from past students which tend to float in academic environment.			
Overall Trend over Periods	Ascertain if there were improvements over previous semesters		Some students continue to struggle in open channel hydraulics and application of specific energy concept, and do not spend enough time to understand it.				This new outcome was laid out in Spring 2019 for the first time. The trend looks positive in this short time but continuity depends on future students' aptitude.			
Were Expectations Met?			YES				YES			

**Grade Sheet Showing
Student and Class Performance in Outcomes**

Grade Sheet Showing Student & Class Performance in Course Outcomes
CVEG 4303 – Water Resources Engineering - Spring 2022

ABET Outcome 1 <i>An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics</i>			ABET Outcome 2 <i>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</i>		
	90.9			97.8	
	84.1			70.0	
	87.6			76.9	
	81.8			52.8	
	64.1			63.6	
	95.9			78.9	
	51.5			70.6	
	51.8			25.0	
	84.1			49.7	
	94.1			75.3	
	75.3			67.2	
	97.6			88.6	
	94.1			82.8	
	71.8			53.3	
	80.6			79.2	
	79.7			68.9	
Average = 80% % Students > Expected AVG [70] = 81%			Average = 69% % Students > Expected AVG [70] = 50%		

III.

TESTS

[03]

CVEG 4303
WATER RESOURCES ENGINEERING
SPRING 2022

Title of Assignment: Exam 01

TOPICS COVERED in Exam 01

Exam 01 covered the following topics:

1. Basic hydraulics of pipe flow: Reynolds Number, characterization of flow; friction factor/Moody Diagram application
2. Determination of equivalent pipe length for pipes arranged in series
3. Basic open channel flow computations: flowrate, velocity
4. Forces on a submerged surface
5. Simple looped pipe systems: application of continuity and energy conservation
6. Determination of head provided by a pump in a piping system: Application of Energy equation

ABOVE
AVERAGE



CVEG 4303-P01

Dr. Szewi

Department of Civil & Environmental Engineering

Water Resources Engineering

Exam 01



Spring 2022

Thurs. Mar 10, 2022, 01:00 PM, SR Collins 205

Submit the entire exam the order given

Name (PRINT)

REYNOLDS

In all the problems you must provide enough details and description of the solution method to demonstrate your knowledge of the solution method. A substantial portion of the grade will be based on your methods.

400

All necessary equations are provided except for elementary relationships you are expected to master. This is a **CLOSED** book exam. Please **turn off all cell phones and mp3 players** and **place them in your book bag in front of the class**. Also put away ANY **disallowed** calculators. **Calculator POLICY (allowed calculators)**

- **Casio:** All fx-115 and fx-991 models (Any Casio calculator must have "fx-115" or "fx-991" in its model name.)
- **Hewlett Packard:** The HP 33s and HP 35s models, but no others
- **Texas Instruments:** All TI-30X and TI-36X models (Any Texas Instruments calculator must have "TI-30X" or "TI-36X" in its model name.)

- 1) All cellphones/smartwatches **MUST** be placed in your book bag during exams and turned off. Book bags **MUST** be placed in front of the classroom and away from students. Students without a book bag must place cellphone/smartwatch (turned off) on Instructor's desk.
- 2) Any student possessing a cellphone/smartwatch or any other unauthorized device **WILL** receive an automatic zero for the test/assignment. Such action will be cheating.
- 3) **CLOTHING:** Hoodies are **NOT** Allowed during exams. No headphones (corded or wireless) are **ALLOWED**.
- 4) **Calculator covers are DISALLOWED** during tests and must be placed in students' book bags during exams.
- 5) There shall be **NO SHARING** of resources during the exam. Writing space will be provided in the test.
- 6) **RESTROOM VISIT:** if you need to use the restroom, **do so before opening the exam**. Once the exam begins, you must submit your work to the instructor if you leave the classroom to visit the rest room (your exam terminates).
- 7) You have **70 minutes** to complete the exam. Please turn in your work on time.
- 8) Provide enough detail for each problem you solve. You earn points based on the details you provide.
- 9) Please work independently.
- 10) You are required to solve **ALL** problems.

Dishonesty or failure to adhere to instructions will result in a grade of ZERO (0 . 0)

I pledge to abide by all the rules stated for this Exam

Signature: *[Signature]*

Date: 3/10/2022

NAME [PRINT, Lastname, firstname]: Reynolds, Alyssa

REFERENCE VALUES AND FORMULAS [Unless otherwise stated or implied, assume the following]

Density of water = 1000 kg/m^3 ($= 1.94 \text{ slugs/ft}^3$) [at 4°C]
 Specific weight of water = 9810 N/m^3 ($= 62.4 \text{ lb/ft}^3$) and at 4°C
 Gravitational Acceleration, $g = 9.81 \text{ m/s}^2$ ($= 32.2 \text{ ft/s}^2$)
 Standard atmospheric pressure = 101.3 kPa ($= 2117 \text{ psf} = 14.7 \text{ psi}$)
 Gas constant for air, $R = 287 \text{ J/kg}\cdot\text{K} = 1716 \text{ ft}\cdot\text{lb/slug}\cdot^\circ\text{R}$
 $T [\text{K}] = t [^\circ\text{C}] + 273.15$
 $T [^\circ\text{R}] = t [^\circ\text{F}] + 459.67$
 $1 \text{ Btu} = 778 \text{ ft}\cdot\text{lb}$
 $1 \text{ hp} = 745.7 \text{ W} = 550 \text{ ft}\cdot\text{lb}$
 $1 \text{ m} = 100 \text{ cm}$

$1 \text{ mile} = 5280 \text{ feet}$
 $1 \text{ mile} = 1760 \text{ yards}$
 $1 \text{ acre} = 43560 \text{ ft}^2$
 $1 \text{ mi}^2 = 640 \text{ acres}$
 $1 \text{ ft} = 0.3048 \text{ m}$
 $1 \text{ slug} = 14.59 \text{ kg}$
 $1 \text{ lb} = 4.448 \text{ N}$
 $1 \text{ Pa} = 1.0 \text{ N/m}^2$
 $1 \text{ ft}^3 = 7.481 \text{ gal}$
 $25.4 \text{ mm} = 1.0 \text{ in}$
 $1 \text{ liter} = 1000 \text{ cm}^3$
 $1 \text{ m}^3 = 1000 \text{ liter}$

Forces on submerged surfaces:

$$F = \gamma \bar{h} A$$

vertical distance

Location of Center of pressure, $y_p = \bar{y} + \frac{I_{xx}}{\bar{y} A}$

Moment of Inertia for a rectangular shape:

$$I_{xx} = \frac{b l^3}{12}$$

$$\bar{y} = \frac{h}{\sin \theta}$$

Buoyant Force:

$$F_B = \gamma (\text{displaced volume})$$

Metacentric Height:

$$GM = \frac{I_{xx}}{V} - CG$$

Reynolds Number:

$$Re = \frac{VD}{\nu} = \frac{\rho V D}{\mu}$$

Swamee & Jain and other f Equations:

Swamee & Jain (1976) [error about 1% from Colebrook equation]

$$f = \frac{1.325}{\left\{ \ln \left[0.27 \frac{\epsilon}{D} + \frac{5.74}{Re^{0.9}} \right] \right\}^2} \text{ for } 10^{-6} \leq \frac{\epsilon}{D} \leq 10^{-2} \text{ and } 5000 \leq Re \leq 10^8$$

Haaland (1983) [error about 1.5% from Colebrook equation]

$$f = \frac{1}{\left\{ -1.8 \log \left[\left(\frac{0.27\epsilon}{D} \right)^{11} + \frac{6.9}{Re} \right] \right\}^2} \text{ for } 4000 \leq Re \leq 10^8$$

Fully Rough/turbulent Flow:

$$f = \frac{1}{\left[2 \log \left(\frac{3.7D}{\epsilon} \right) \right]^2}$$

Smooth Pipe flow for Hydraulically smooth pipes:

Blasius Equation: $f = \frac{0.316}{Re^{0.25}} \text{ for } 4000 \leq Re \leq 10^5$

Colebrook's Approximation: $f = \frac{1}{\left[1.8 \log \left(\frac{Re}{6.9} \right) \right]^2} \text{ for } 4000 \leq Re \leq 10^8$

$$h_L = h_m + h_f$$

Darcy-Weisbach Equation for friction headloss:

$$h_f = \frac{fL}{D} \frac{V^2}{2g}$$

Minor headloss Equation:

$$h_m = \sum K \frac{V^2}{2g}; \text{ Where } K = \text{loss coefficient}$$

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2$$

Bernoulli

$$H_1 + \frac{V_1^2}{2g} + \frac{P_1}{\gamma} + z_1 = H_2 + \frac{V_2^2}{2g} + \frac{P_2}{\gamma} + z_2 + h_L$$

Energy

Table 15.1 Roughness Values for Pipes

Pipe Material	Equivalent Roughness, ϵ (ft)	Hazen-Williams Coefficient, C
PVC, plastic	Smooth	140
Brass, copper, aluminum, glass	Smooth	140
Dawn tubing	5×10^{-6}	—
Cast iron		
new	8.0×10^{-4}	130
old		100
Galvanized iron/ductile pipe	5.0×10^{-4}	120
Asphalted iron	4.0×10^{-4}	—
Wrought iron	1.5×10^{-4}	—
Commercial and welded steel	1.5×10^{-4}	120
Wood stave	20.0×10^{-4}	120
Concrete	40.0×10^{-4}	130
Riveted steel	60.0×10^{-4}	110
Brick sewer	—	100

Table 15.3 Minor Head Loss Coefficients

Item	Loss Coefficient, K_m
Entrance from tank to pipe	
Flush connection	0.5
Projecting connection	0.8
Exit from pipe to tank	1.0
Sudden contraction ($h_m = K_m V_2^2 / 2g$)	
$d_2/d_1 = 0.2$	0.48
$d_2/d_1 = 0.4$	0.42
$d_2/d_1 = 0.6$	0.32
$d_2/d_1 = 0.8$	0.20
$d_2/d_1 = 0.9$	0.05
Sudden enlargement ($h_m = K_m V_1^2 / 2g$)	
$d_1/d_2 = 0.9$	0.04
$d_1/d_2 = 0.8$	0.13
$d_1/d_2 = 0.6$	0.41
$d_1/d_2 = 0.4$	0.71
$d_1/d_2 = 0.2$	0.92

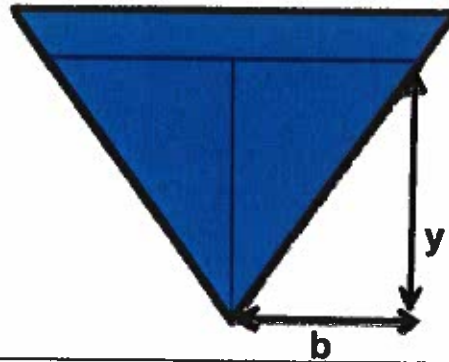
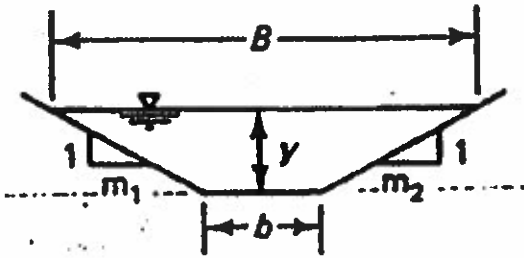
Note: Subscript 1 refers to upstream and 2 refers to downstream section.

Table 15.3 Minor Head Loss Coefficients

Item	Loss Coefficient, K_m
90° bend and 180° return—threaded	1.5
45° bend—threaded	0.4
90° bend and 180° return—flanged	0.3
45° bend—flanged	0.3
Tee—threaded	
through flow	0.9
branched flow	2.0
Tee—flanged	
through flow	0.2
branched flow	1.0
Gate valve (open)	0.19
Check valve (open)	2.0
Globe valve (open)	10.0
Angle valve (open)	2.0
Butterfly valve (open)	0.3

Note: Subscript 1 refers to upstream and 2 refers to downstream section.

Trapezoidal Channel



$$\text{Area, } A = by + \frac{1}{2}y^2(m_1 + m_2)$$

$$\text{Wetted Perimeter, } P = b + y(\sqrt{1 + m_1^2} + \sqrt{1 + m_2^2})$$

$$\text{Top Width, } T \text{ or } B = b + y(m_1 + m_2)$$

$$\text{Hydraulic Radius, } R = \frac{A}{P} = \frac{by + \frac{1}{2}y^2(m_1 + m_2)}{b + y(\sqrt{1 + m_1^2} + \sqrt{1 + m_2^2})}$$

$$\text{Area, } A = by$$

$$\text{Wetted Perimeter, } P = 2\sqrt{b^2 + y^2}$$

$$\text{Top Width, } T \text{ or } B = 2b$$

$$\text{Hydraulic Radius, } R = \frac{A}{P} = \frac{by}{2\sqrt{b^2 + y^2}}$$

$$\text{Hydraulic Depth, } D = \frac{A}{T} = \frac{by}{2b} = \frac{y}{2}$$

Manning's Equations:

$$\text{Velocity, } V \text{ [m/s]} = \frac{1}{n} R^{2/3} \sqrt{S} \quad \text{-(SI Units)}$$

$$\text{Velocity, } V \text{ [ft/s]} = \frac{1.486}{n} R^{2/3} \sqrt{S} \quad \text{-(English Units)}$$

Hazen-Williams Equations [Circular Pipes]:

English Units: Q [cfs], L [ft], D [ft], H_L [ft]

$$S = \frac{h_L}{L} = \frac{4.731}{C^{1.85} D^{4.87}} Q^{1.85}$$

$$Q = 0.432 C D^{2.63} S^{0.54}$$

Manning's Equations:

$$\text{Discharge, } Q \text{ [m}^3\text{/s]} = \frac{1}{n} A R^{2/3} \sqrt{S} \quad \text{-(SI Units)}$$

$$\text{Discharge, } Q \text{ [ft}^3\text{/s]} = \frac{1.486}{n} A R^{2/3} \sqrt{S} \quad \text{-(English Units)}$$

Hazen-Williams Equations [Circular Pipes]:

SI Units: Q [m³/s], L [m], D [m], H_L [m]

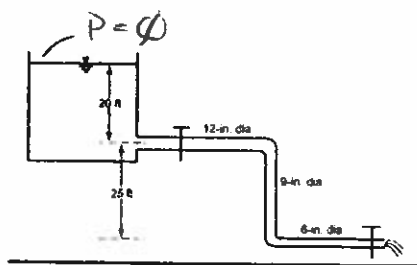
$$Q = 0.278 C D^{2.63} S^{0.54}$$

$$S = \frac{h_L}{L} = \frac{10.704}{C^{1.85} D^{4.87}} Q^{1.85}$$

1 [100]

a) [50] Water (at 100 °F) flows from the reservoir shown below at a rate of 2.00 cfs. The water is discharged into the atmosphere through a 6-inch concrete pipe, as shown in the figure. Answer the questions below. Please note that it is not necessary to separately determine the minor losses in the system in order to answer these questions.

$Q = 2 \text{ cfs}$
 $Q = V(A)$
 $2 = V(\pi/16)$
 $V = 10.19 \text{ ft/s}$
 $A = \pi/16$



I) [15] Calculate the Reynolds Number (Re) for the flow in the 6-inch pipe. State whether the flow is turbulent or laminar and why.

$Re = \frac{Vd}{\nu} = \frac{10.19(6/12)}{0.739 \times 10^{-5}} = 8.19 \times 10^5$
 Reynolds Number = 8.19×10^5
 Flow is turbulent regime in Moody diagram. (Circle one) Also, $Re > 4000$

II) [25] Determine the friction factor for the flow in the 6-inch pipe (using the friction factor equation provided or MOODY diagram).

$f = \frac{fL}{D} \left(\frac{V^2}{2g} \right)$
 Friction Factor = 0.026 (from Moody diagram)

III) [25] Determine the friction HEADLOSS [ft] for the flow in the 6-inch pipe ONLY if it is 150 ft long.

$h_f = \frac{fLQ^2}{D^5} = \frac{0.026(150)(10.19^2)}{0.5} = 17.413 \text{ ft}$
 Friction headloss = 17.413 ft

[b] [50]

Three (3) pipes, a 12-in (1500 ft) new cast iron pipe ($C=120$), a 18-in (1000 ft) new cast iron pipe ($C=120$) and a 3000 ft 24-in ductile iron pipe ($C=130$), are arranged in series in a water distribution system. The total headloss in the piping system is limited to 60 ft. Using the Hazen-Williams equation, determine the equivalent length of the 18-in new cast iron pipe to replace the pipes in series. Assume that specific weight of water = 62.4 lb/ft³.

Perform the necessary calculations (by completing the table below) to determine the length of the equivalent 18-in pipe for the system. Assume a flow of 1.50 cfs in your calculations for the equivalent pipe as provided in the table below.

Pipe	C	Diameter [in]	Dia [ft]	Q [cfs]	S = HL/L []	Pipe Len, L [ft]	HL = S*L [ft]
1	120	12.0	1	1.500	0.0014	1500	2.1
2	120	18.0	1.5	1.500	0.0002	1000	0.2
3	130	24.0	2	1.500	0.00004	3000	0.12
EQV	120	18.0	1.5	1.500	0.0002	12,100	2.42

EQV = Equivalent pipe; HL = Headloss; S = Slope of Energy grade line; Q = flowrate

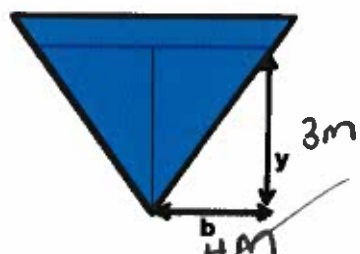
Calculate the equivalent length of a 18-in pipe.

Length of 18-in new cast iron pipe [ft] = $12,100$

2 [100]

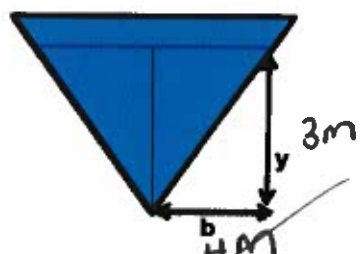
[a] [50]

Consider the channel shown here, with a rough concrete lining ($n = 0.015$). The dimensions are: $b = 4.00$ m and the depth of flow, y is 3.00 m. The channel slope, S is 3 m per 500 m.

I) [10] What is the Area of flow, A [m^2]? 

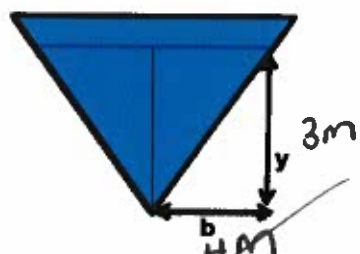
$$A = b(y) = (4m)(3m) = 12m^2$$

Area of flow, A , [m^2] = 12

II) [15] What is the Wetted perimeter, P [m]? 

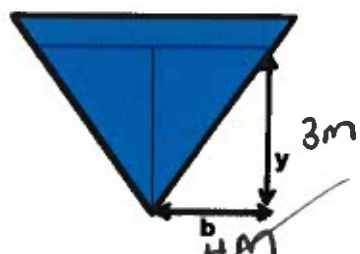
$$P = 2\sqrt{b^2 + y^2} = 2\sqrt{(4)^2 + (3)^2} = 2\sqrt{25} = 2(5) = 10m$$

Wetted Perimeter, P [m] = 10

III) [10] What is the Hydraulic Radius, R [m]? 

$$R = \frac{A}{P} = \frac{12}{10} = 1.2m$$

Hydraulic Radius, R [m] = 1.2

IV) [15] What is the Discharge, Q [m^3/s]? 

$$Q = \frac{1}{n} A R^{2/3} \sqrt{S}$$

$$= \frac{1}{0.015} (12) (1.2)^{2/3} \sqrt{3/500} = 69.98 m^3/s$$

Discharge, Q [m^3/s] = 69.98

(b) [50]

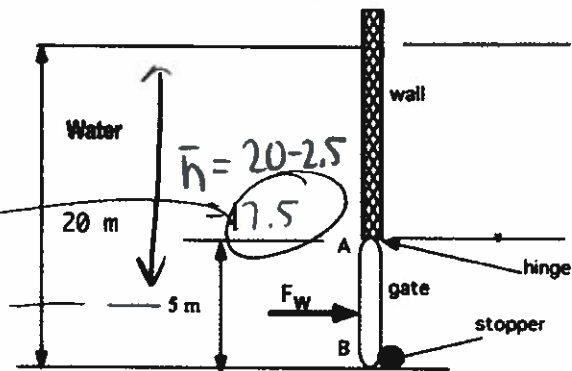
A rectangular gate is hinged as shown. The gate is 5 m high and 6 m wide.

The specific weight of the water is 10000.0 N/ m^3

(i) [20] Calculate the force, F_w [kN] on the gate due to the water

$$F_w = \gamma \cdot \bar{h} \cdot A$$

$$(10,000)(7.5)(5 \times 6) = 2250$$



Force on the gate, F_w = 2250 [kN]

(ii) [30] Calculate the force, S [kN] due to the stopper (shown) on the gate to keep the gate in the closed position.

$$\sum M_{HINGE} = 0$$

$$S(5) - F_w(2.5) = 0$$

$$S(5) = 2250(2.5)$$

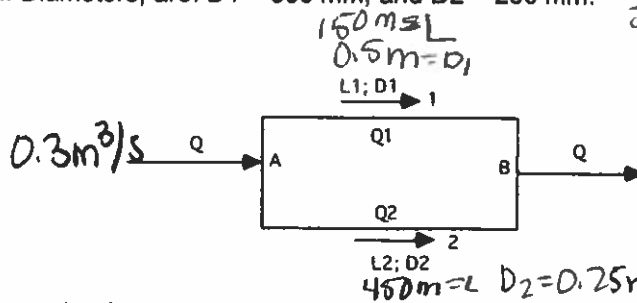
$$S = \frac{2250(2.5)}{5} = 2812.5$$

Force on stopper to keep the gate closed, S = 2812.5 [kN]

3 [100]

$$1000L = 1m^3$$

The total discharge (flowrate) from A to B in the figure below is 300 liters/s. Pipe lengths are: $L_1 = 150$ m, and $L_2 = 450$ m. Diameters, are: $D_1 = 500$ mm, and $D_2 = 250$ mm.



$$\frac{300L}{S} = 0.3m^3/s$$

$$1ft = 0.3048m$$

$$1m = \frac{1}{0.3048} ft$$

$$1.64ft$$

Determine [Using Darcy's equation] the headloss [m] and the flowrates [l/s] across A-B in pipes 1 and 2 if riveted steel iron pipes are used in the system and flow is FULLY TURBULENT.

$$Q = Q_1 + Q_2$$

$$0.3 = Q_1 + Q_2$$

$$\frac{f_1 V_1^2 L_1}{2D_1 g} = \frac{f_2 V_2^2 L_2}{2D_2 g}$$

$$R_{f1} = \frac{e}{D} = \frac{60 \times 10^{-4}}{1.64} = 0.0037 \quad 3.7 \times 10^{-3} \quad C_{f1} = 0.028$$

$$R_{f2} = \frac{60 \times 10^{-4}}{0.820} = 0.0073 \quad 7.3 \times 10^{-3} \quad C_{f2} = 0.034$$

$$\frac{0.028(V_1)^2(150)}{2(0.5)(9.81)} = \frac{0.034(V_2)^2(450)}{2(0.25)(9.81)} \quad \text{Flowrate pipe \#1 [l/s]} = \frac{0.27m^3/s \times 1000}{1} = 270m^3/s$$

$$Q_1 = V_1(A)$$

$$= 1.3975(0.25^2\pi) = 0.04m^3/s$$

$$Q_2 = V_2(A)$$

$$= 0.52(0.125^2\pi) = 0.0255m^3/s$$

$$\text{Flowrate pipe \#2 [l/s]} = \frac{0.03m^3/s \times 1000}{1} = 30m^3/s$$

$$Q = \frac{\pi}{4} (D_1^2(V_1) + D_2^2(V_2))$$

$$0.3 = \frac{\pi}{4} (0.5^2(V_1) + 0.25^2(V_2))$$

$$\frac{\pi}{4} (0.67V_2 + 0.0625V_2)$$

$$0.3(4) = 0.7325V_2$$

$$V_2 = 0.526m/s$$

$$V_1 = 2.68(0.52) = 1.3975m/s$$

$$h_L = h_f + h_m$$

$$h_f = \frac{fLV^2}{2Dg} = \frac{0.028(1.3975)^2(150)}{2(0.5)(9.81)} = 0.836m$$

$$h_m = \sum K \frac{V^2}{2g} \approx \text{neg}^?$$

$$\text{Headloss pipe \#1 [m]} = 0.836$$

$$h_f = \frac{0.034(0.52)^2(450)}{2(0.25)(9.81)} = 0.843$$

$$\text{Headloss pipe \#2 [m]} = 0.843 \checkmark$$

Same
DON'T WASTE
TIME
CALCULATING
PIPS

Problem 4 [100]

$$200 \frac{\text{L}}{\text{s}} = 0.2 \frac{\text{m}^3}{\text{s}}$$

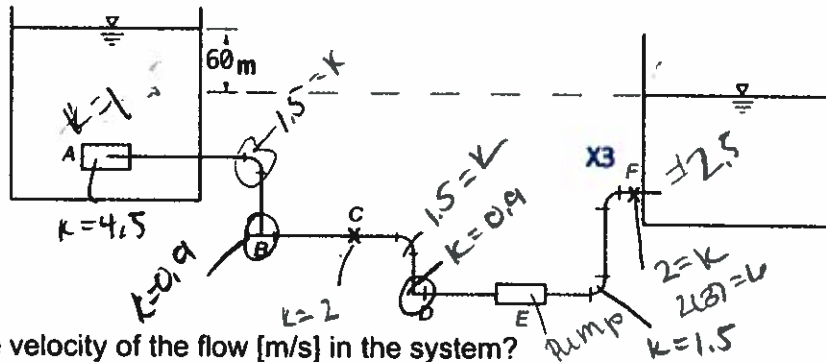
$$\text{diam.} = 0.4 \text{ m}$$

+15

Water (at 50 °C) with a discharge of 200 L/s flows through a 400-mm, 100 m galvanized iron pipe ($\epsilon = 0.16 \text{ mm}$) in the system shown below from **right to left** and there is a pump (E) in the system. In order to calculate the minor losses, assume the following in the figure, A is a diffuser ($K = 4.5$), C is a Check valve (open); E is the Pump; F represents three (3 – for redundancy) **ANGLE** valves (open). The elbows in the system are 90° threaded elbows and the tees (B and D) are threaded (through flow). For the entrance minor loss from the RIGHT tank, assume $K = 2.5$. [Hint: see appropriate table values provided in Exam for K values not provided]

The flow is fully turbulent. The elevation difference is 60 m as shown. Answer the questions below.

$$\sum K = 1 + 4.5 + 1.5 + 0.9 + 2 + 1.5 + 0.9 + 1.5 + 6 + 2.5 = 22.3$$



$$1 \text{ ft} = 0.3048 \text{ m}$$

$$\frac{1}{0.3048} \text{ ft} = 1 \text{ m}$$

$$= 1.31$$

- a) [10] What is the velocity of the flow [m/s] in the system?

$$Q = VA$$

$$0.2 = V(\pi/25) \quad V = 1.59 \text{ m/s}$$

Velocity of flow in the Pipe = 1.59 [m/s]

- b) [15] Determine the friction factor for the flow in the system

$$Re = \frac{VD}{\nu} = \frac{1.59(0.4)}{0.556 \times 10^{-4}} = 1.14 \times 10^4$$

$$Re = \frac{VD}{\nu} = \frac{1.59(0.4)}{0.556 \times 10^{-4}} = 1.14 \times 10^4$$

$$Re = \frac{VD}{\nu} = \frac{1.59(0.4)}{0.556 \times 10^{-4}} = 1.14 \times 10^4$$

Friction factor for the flow in the Pipe = 0.0165 rough estimate from Moody

- c) [15] Determine the minor headloss [m] for the flow in the system

$$h_m = \sum K \frac{V^2}{2g} = \frac{22.3(1.59)^2}{2(9.81)} = 2.87 \text{ m}$$

Minor headloss Pipe = 2.87 [m]

- d) [20] Determine the friction headloss [m] for the flow in the system

$$h_f = \frac{fLV^2}{2Dg} = \frac{0.0165(100)(1.59)^2}{2(0.4)(9.81)} = 0.532 \text{ m}$$

Friction headloss Pipe = 0.532 [m]

- e) [20] Determine the head supplied by the pump, E [m] to the flow

$$H_p = \Delta z + h_{loss}$$

$$= (60) + h_m + h_f$$

$$= 60 + 2.87 + 0.532 = 63.042 \text{ m}$$

Head of Pump = 63.042 [m]

- f) [15] If the pump in the system has an efficiency of 78%, determine the power [kW] supplied to the pump?

$$\frac{Q \times H_p \times \gamma}{\eta} = \frac{0.2(63.042)(9.81)}{\left(\frac{78}{100}\right)} = 156.7 \text{ kW}$$

Power Supplied to Pump = 156.7 [kW]

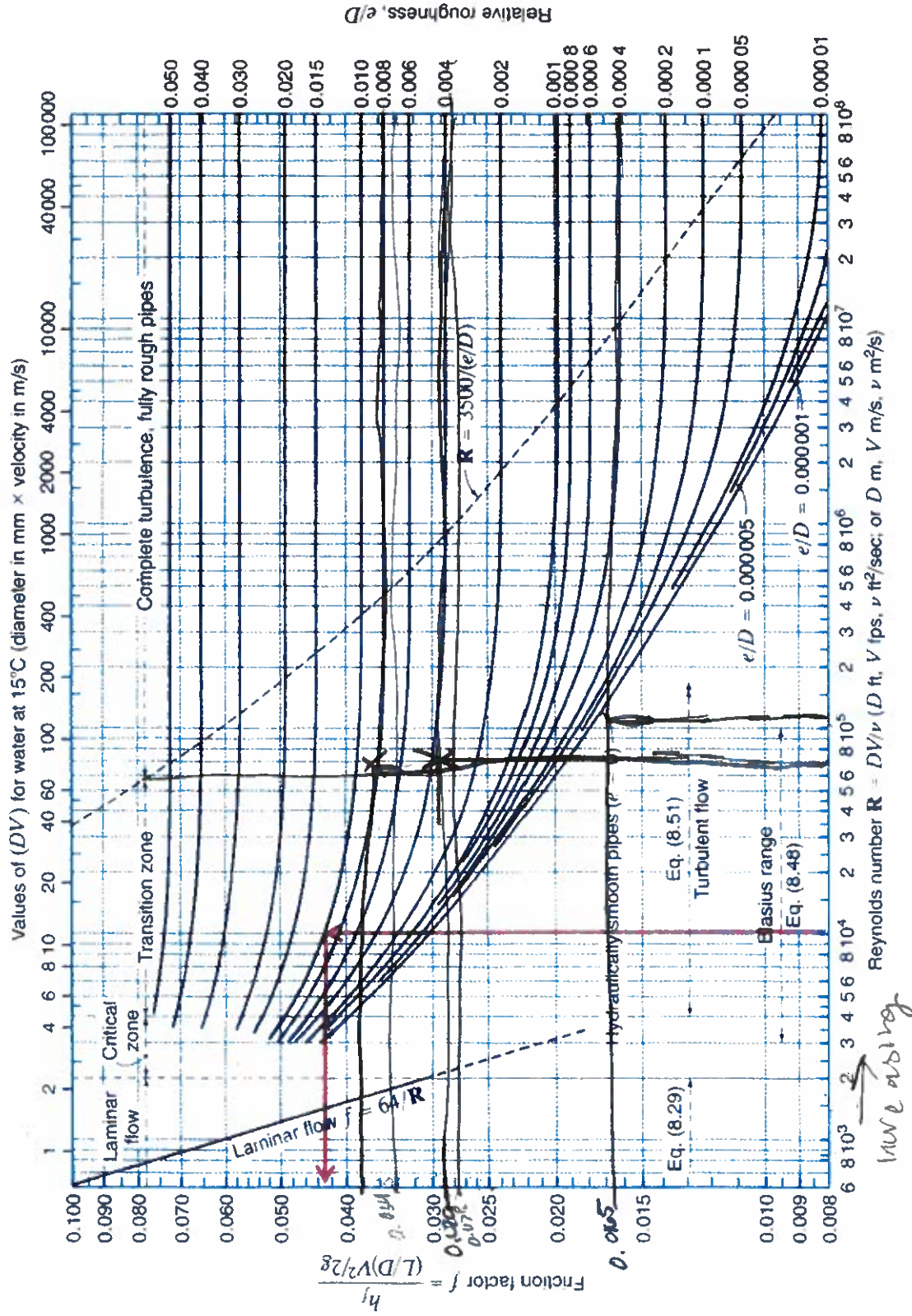
Properties of Water

Temperature (°C)	Density ρ (kg/m ³)	Specific Weight γ (N/m ³)	Viscosity μ (N·s/m ²)	Kinematic viscosity ν (m ² /s)	Bulk modulus B (Pa)	Surface Tension σ (N/m)	Vapor Pressure (kPa)
0	999.9	9809	1.792×10^{-3}	1.792×10^{-6}	204×10^7	7.62×10^{-2}	0.610
5	1000.0	9810	1.519	1.519	206	7.54	0.872
10	999.7	9807	1.308	1.308	211	7.48	1.13
15	999.1	9801	1.140	1.141	214	7.41	1.60
20	998.2	9792	1.005	1.007	220	7.36	2.34
30	995.7	9768	0.801	0.804	223	7.18	4.24
40	992.2	9733	0.656	0.661	227	7.01	7.38
50	988.1	9693	0.549	0.556	230	6.82	12.3
60	983.2	9645	0.469	0.477	228	6.68	19.9
70	977.8	9592	0.406	0.415	225	6.50	31.2
80	971.8	9533	0.357	0.367	221	6.30	47.3
90	965.3	9470	0.317	0.328	216	6.12	70.1
100	958.4	9402	0.284×10^{-3}	0.296×10^{-6}	207×10^7	5.94×10^{-2}	101.3

PROPERTIES OF WATER (ENGLISH UNITS)

Temperature (°F)	Specific Weight γ (lb/ft ³)	Mass Density ρ (lb • sec ² /ft ⁴)	Absolute Dynamic Viscosity μ ($\times 10^{-5}$ lb • sec/ft ²)	Kinematic Viscosity ν ($\times 10^{-5}$ ft ² /sec)	Vapor Pressure P_v (psi)
32	62.42	1.940	3.746	1.931	0.09
40	62.43	1.940	3.229	1.664	0.12
50	62.41	1.940	2.735	1.410	0.18
60	62.37	1.938	2.359	1.217	0.26
70	62.30	1.936	2.050	1.059	0.36
80	62.22	1.934	1.799	0.930	0.51
90	62.11	1.931	1.595	0.826	0.70
100	62.00	1.927	1.424	0.739	0.95
110	61.86	1.923	1.284	0.667	1.24
120	61.71	1.918	1.168	0.609	1.69
130	61.55	1.913	1.069	0.558	2.22
140	61.38	1.908	0.981	0.514	2.89
150	61.20	1.902	0.905	0.476	3.72
160	61.00	1.896	0.838	0.442	4.74
170	60.80	1.890	0.780	0.413	5.99
180	60.58	1.883	0.726	0.385	7.51
190	60.36	1.876	0.678	0.362	9.34
200	60.12	1.868	0.637	0.341	11.52
212	59.83	1.860	0.593	0.319	14.70

Moody Diagram – friction factor, f



(Note: If $e/D = 0.01$ and $Re = 10^4$, the left arrow locates $f = 0.043$.)

AVERAGE

**Submit the entire exam the order given**

Name (PRINT)

Ahmed Ghouse

In all the problems you must provide enough details and description of the solution method to demonstrate your knowledge of the solution method. A substantial portion of the grade will be based on your methods.

400

All necessary equations are provided except for elementary relationships you are expected to master. This is a **CLOSED** book exam. Please **turn off all cell phones and mp3 players** and **place them in your book bag in front of the class**. Also put away ANY **disallowed** calculators. **Calculator POLICY (allowed calculators)**

- **Casio:** All fx-115 and fx-991 models (Any Casio calculator must have "fx-115" or "fx-991" in its model name.)
- **Hewlett Packard:** The HP 33s and HP 35s models, but no others
- **Texas Instruments:** All TI-30X and TI-36X models (Any Texas Instruments calculator must have "TI-30X" or "TI-36X" in its model name.)

- 1) All cellphones/smartwatches **MUST** be placed in your book bag during exams and turned off. Book bags **MUST** be placed in front of the classroom and away from students. Students without a book bag must place cellphone/smartwatch (turned off) on Instructor's desk.
- 2) Any student possessing a cellphone/smartwatch or any other unauthorized device **WILL** receive an automatic zero for the test/assignment. Such action will be cheating.
- 3) **CLOTHING:** Hoodies are **NOT** Allowed during exams. No headphones (corded or wireless) are **ALLOWED**.
- 4) **Calculator covers are DISALLOWED** during tests and must be placed in students' book bags during exams.
- 5) There shall be **NO SHARING** of resources during the exam. Writing space will be provided in the test.
- 6) **RESTROOM VISIT:** if you need to use the restroom, **do so before opening the exam**. Once the exam begins, you must submit your work to the instructor if you leave the classroom to visit the rest room (your exam terminates).
- 7) You have **70 minutes** to complete the exam. Please turn in your work on time.
- 8) Provide enough detail for each problem you solve. You earn points based on the details you provide.
- 9) Please work independently.
- 10) You are required to solve **ALL** problems.

Dishonesty or failure to adhere to instructions will result in a grade of ZERO (0.0)

I pledge to abide by all the rules stated for this Exam

Signature:

Ahmed Ghouse

Date:

3/10/22

NAME [PRINT, Lastname, firstname]:

REFERENCE VALUES AND FORMULAS [Unless otherwise stated or implied, assume the following]

Density of water = 1000 kg/m^3 ($= 1.94 \text{ slugs/ft}^3$) [at 4°C]
 Specific weight of water = 9810 N/m^3 ($= 62.4 \text{ lb/ft}^3$) and at 4°C
 Gravitational Acceleration, $g = 9.81 \text{ m/s}^2$ ($= 32.2 \text{ ft/s}^2$)
 Standard atmospheric pressure = 101.3 kPa ($= 2117 \text{ psf} = 14.7 \text{ psi}$)
 Gas constant for air, $R = 287 \text{ J/kg}\cdot\text{K} = 1716 \text{ ft}\cdot\text{lb/slug}\cdot^\circ\text{R}$
 $T [\text{K}] = t [^\circ\text{C}] + 273.15$
 $T [^\circ\text{R}] = t [^\circ\text{F}] + 459.67$
 $1 \text{ Btu} = 778 \text{ ft}\cdot\text{lb}$
 $1 \text{ hp} = 745.7 \text{ W} = 550 \text{ ft}\cdot\text{lb/s}$
 $1 \text{ m} = 100 \text{ cm}$

$1 \text{ mile} = 5280 \text{ feet}$
 $1 \text{ mile} = 1760 \text{ yards}$
 $1 \text{ acre} = 43560 \text{ ft}^2$
 $1 \text{ mi}^2 = 640 \text{ acres}$
 $1 \text{ ft} = 0.3048 \text{ m}$
 $1 \text{ slug} = 14.59 \text{ kg}$
 $1 \text{ lb} = 4.448 \text{ N}$
 $1 \text{ Pa} = 1.0 \text{ N/m}^2$
 $1 \text{ ft}^3 = 7.481 \text{ gal}$
 $25.4 \text{ mm} = 1.0 \text{ in}$
 $1 \text{ liter} = 1000 \text{ cm}^3$
 $1 \text{ m}^3 = 1000 \text{ liter}$

Forces on submerged surfaces:

$$F = \gamma \bar{h} A$$

Location of Center of pressure, $y_p = \bar{y} + \frac{I_{xx}}{A \bar{y}}$

Moment of Inertia for a rectangular shape:

$$I_{xx} = \frac{b l^3}{12}$$

Buoyant Force:

$$F_B = \gamma(\text{displaced volume})$$

Metacentric Height:

$$GM = \frac{I_{xx}}{V} - CG$$

Reynolds Number:

$$Re = \frac{VD}{\nu} = \frac{\rho V D}{\mu}$$

Swamee & Jain and other f Equations:

Swamee & Jain (1976) [error about 1% from Colebrook equation]

$$f = \frac{1.325}{\left[\ln \left[0.27 \frac{\epsilon}{D} + \frac{5.74}{Re^{0.9}} \right] \right]^2} \text{ for } 10^{-6} \leq \frac{\epsilon}{D} \leq 10^{-2} \text{ and } 5000 \leq Re \leq 10^8$$

Haaland (1983) [error about 1.5% from Colebrook equation]

$$f = \left[\frac{1}{-1.8 \log \left[\left(\frac{0.27 \epsilon}{D} \right)^{11} + \frac{6.9}{Re} \right]} \right]^2 \text{ for } 4000 \leq Re \leq 10^8$$

Fully Rough/turbulent Flow:

$$f = \left[\frac{1}{2 \log \left(\frac{3.7 D}{\epsilon} \right)} \right]^2$$

Smooth Pipe flow for Hydraulically smooth pipes:

Blasius Equation: $f = \frac{0.316}{Re^{0.25}} \text{ for } 4000 \leq Re \leq 10^5$

Colebrook's Approximation: $f = \left[\frac{1}{1.8 \log \left(\frac{Re}{6.9} \right)} \right]^2 \text{ for } 4000 \leq Re \leq 10^8$

Darcy-Weisbach Equation for friction headloss:

$$h_f = \frac{fL}{D} \frac{V^2}{2g}$$

Minor headloss Equation:

$$h_m = \sum K \frac{V^2}{2g}; \text{ Where } K = \text{loss coefficient}$$

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2$$

$$H_P + \frac{V_1^2}{2g} + \frac{P_1}{\gamma} + z_1 = H_P + \frac{V_2^2}{2g} + \frac{P_2}{\gamma} + z_2 + h_L$$

Table 15.1 Roughness Values for Pipes

Pipe Material	Equivalent Roughness, ϵ (ft)	Hazen-Williams Coefficient, C
PVC, plastic	Smooth	140
Brass, copper, aluminum, glass	Smooth	140
Dawn tubing	5×10^{-6}	—
Cast iron		
new	8.0×10^{-4}	130
old		100
Galvanized iron/ductile pipe	5.0×10^{-4}	120
Asphalted iron	4.0×10^{-4}	—
Wrought iron	1.5×10^{-4}	—
Commercial and welded steel	1.5×10^{-4}	120
Wood stave	20.0×10^{-4}	120
Concrete	40.0×10^{-4}	130
Riveted steel	60.0×10^{-4}	110
Brick sewer	—	100

Table 15.3 Minor Head Loss Coefficients

Item	Loss Coefficient, K_m
Entrance from tank to pipe	
Flush connection	0.5
Projecting connection	0.8
Exit from pipe to tank	1.0
Sudden contraction ($h_m = K_m V_2^2 / 2g$)	
$d_2/d_1 = 0.2$	0.48
$d_2/d_1 = 0.4$	0.42
$d_2/d_1 = 0.6$	0.32
$d_2/d_1 = 0.8$	0.20
$d_2/d_1 = 0.9$	0.05
Sudden enlargement ($h_m = K_m V_1^2 / 2g$)	
$d_1/d_2 = 0.9$	0.04
$d_1/d_2 = 0.8$	0.13
$d_1/d_2 = 0.6$	0.41
$d_1/d_2 = 0.4$	0.71
$d_1/d_2 = 0.2$	0.92

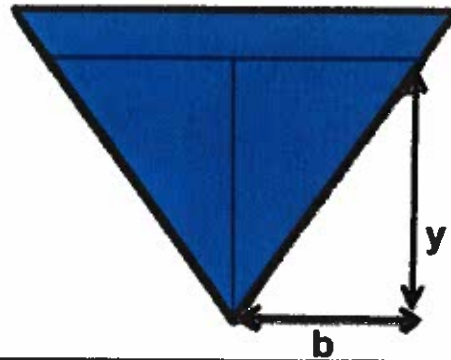
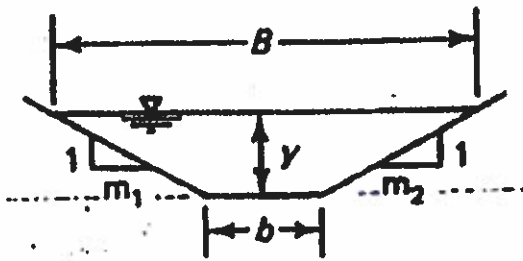
Note: Subscript 1 refers to upstream and 2 refers to downstream section.

Table 15.3 Minor Head Loss Coefficients

Item	Loss Coefficient, K_m
90° bend and 180° return—threaded	1.5
45° bend—threaded	0.4
90° bend and 180° return—flanged	0.3
45° bend—flanged	0.3
Tee—threaded	
through flow	0.9
branched flow	2.0
Tee—flanged	
through flow	0.2
branched flow	1.0
Gate valve (open)	0.19
Check valve (open)	2.0
Globe valve (open)	10.0
Angle valve (open)	2.0
Butterfly valve (open)	0.3

Note: Subscript 1 refers to upstream and 2 refers to downstream section.

Trapezoidal Channel



$$\text{Area, } A = by + \frac{1}{2}y^2(m_1 + m_2)$$

$$\text{Wetted Perimeter, } P = b + y(\sqrt{1 + m_1^2} + \sqrt{1 + m_2^2})$$

$$\text{Top Width, } T \text{ or } B = b + y(m_1 + m_2)$$

$$\text{Hydraulic Radius, } R = \frac{A}{P} = \frac{by + \frac{1}{2}y^2(m_1 + m_2)}{b + y(\sqrt{1 + m_1^2} + \sqrt{1 + m_2^2})}$$

$$\text{Area, } A = by$$

$$\text{Wetted Perimeter, } P = 2\sqrt{b^2 + y^2}$$

$$\text{Top Width, } T \text{ or } B = 2b$$

$$\text{Hydraulic Radius, } R = \frac{A}{P} = \frac{by}{2\sqrt{b^2 + y^2}}$$

$$\text{Hydraulic Depth, } D = \frac{A}{T} = \frac{by}{2b} = \frac{y}{2}$$

Manning's Equations:

$$\text{Velocity, } V \text{ [m/s]} = \frac{1}{n} R^{2/3} \sqrt{S} \quad \text{-(SI Units)}$$

$$\text{Velocity, } V \text{ [ft/s]} = \frac{1.486}{n} R^{2/3} \sqrt{S} \quad \text{-(English Units)}$$

Hazen-Williams Equations [Circular Pipes]:

English Units: Q [cfs], L [ft], D [ft], H_L [ft]

$$S = \frac{h_L}{L} = \frac{4.731}{C^{1.85} D^{4.87}} Q^{1.85}$$

$$Q = 0.432 C D^{2.63} S^{0.54}$$

Manning's Equations:

$$\text{Discharge, } Q \text{ [m}^3\text{/s]} = \frac{1}{n} A R^{2/3} \sqrt{S} \quad \text{-(SI Units)}$$

$$\text{Discharge, } Q \text{ [ft}^3\text{/s]} = \frac{1.486}{n} A R^{2/3} \sqrt{S} \quad \text{-(English Units)}$$

Hazen-Williams Equations [Circular Pipes]:

SI Units: Q [m³/s], L [m], D [m], H_L [m]

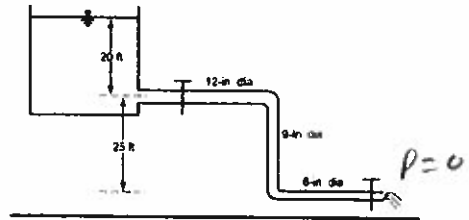
$$Q = 0.278 C D^{2.63} S^{0.54}$$

$$S = \frac{h_L}{L} = \frac{10.704}{C^{1.85} D^{4.87}} Q^{1.85}$$

1 [100]

a) [50] Water (at 100 °F) flows from the reservoir shown below at a rate of 2.00 cfs. The water is discharged into the atmosphere through a 6-inch concrete pipe, as shown in the figure. Answer the questions below. Please note that it is not necessary to separately determine the minor losses in the system in order to answer these questions.

$$V = \frac{Q}{A} \Rightarrow \frac{2.00}{\frac{\pi (6)^2}{4}} = 10.2 \text{ ft/s}$$



I) [15] Calculate the Reynolds Number (Re) for the flow in the 6-inch pipe. State whether the flow is turbulent or laminar and why.

$$Re = \frac{(10.2)(6.5)}{2.4 \times 10^{-6}} =$$

Reynolds Number =

$$1.2 \times 10^7$$

Laminar

or

Turbulent

[Circle one]

II) [25] Determine the friction factor for the flow in the 6-inch pipe (using the friction factor equation provided or MOODY diagram).

$$\frac{\epsilon}{D} = \frac{40 \times 10^{-4} \text{ ft}}{6 \text{ ft}}$$

What is the relative roughness of the pipe =

$$.008$$

Friction Factor =

$$.036$$

how?

III) [25] Determine the friction HEADLOSS [ft] for the flow in the 6-inch pipe ONLY if it is 150 ft long.

$$h_f = \frac{f L V^2}{D 2g} = \frac{(0.036)(150)(10.2)^2}{(6)(2)(32.2)}$$

Friction headloss =

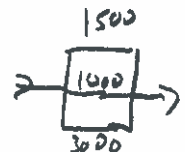
$$17.45$$

[ft]

[b] [50]

Three (3) pipes, a 12-in (1500 ft) new cast iron pipe (C=120), a 18-in (1000 ft) new cast iron pipe (C=120) and a 3000 ft 24-in ductile iron pipe (C=130), are arranged in series in a water distribution system. The total headloss in the piping system is limited to 60 ft. Using the Hazen-Williams equation, determine the equivalent length of the 18-in new cast iron pipe to replace the pipes in series. Assume that specific weight of water = 62.4 lb/ft³.

Perform the necessary calculations (by completing the table below) to determine the length of the equivalent 18-in pipe for the system. Assume a flow of 1.50 cfs in your calculations for the equivalent pipe as provided in the table below.



Pipe	C	Diameter [in]	Dia [ft]	Q [cfs]	S = HL/L []	Pipe Len, L [ft]	HL = S*L [ft]
1	120	12.0	1	1.500	.004	1500	6
2	120	18.0	1.5	1.500	.006	1000	6
3	130	24.0	2	1.500	.02	3000	60
EQV	120	18.0	1.5	1.500	.003		72

EQV = Equivalent pipe; HL = Headloss; S = Slope of Energy grade line; Q = flowrate

Calculate the equivalent length of a 18-in pipe.

$$L_e = \frac{H_e}{S} = \frac{72}{.003}$$

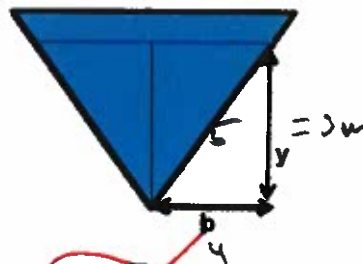
Length of 18-in new cast iron pipe [ft] =

$$2400 \text{ ft}$$

2 [100]

[a] [50]

Consider the channel shown here, with a rough concrete lining ($n = 0.015$). The dimensions are: $b = 4.00$ m and the depth of flow, y is 3.00 m. The channel slope, S is 3 m per 500 m.



I) [10] What is the Area of flow, A [m^2]? $A = \frac{1}{2}(4)(3) = 6 m^2$

Area of flow, A , [m^2] = ~~6 m^2~~

II) [15] What is the Wetted perimeter, P [m]? $h = 4^2 + 3^2 = \sqrt{25} = 5$

Wetted Perimeter, P [m] = ~~10 m~~

III) [10] What is the Hydraulic Radius, R [m]? $R = \frac{b \cdot y}{2 \sqrt{b^2 + y^2}} = \frac{(4)(3)}{2 \sqrt{4^2 + 3^2}} = 1.2$

Hydraulic Radius, R [m] = ~~1.2 m~~

IV) [15] What is the Discharge, Q [m^3/s]? $Q = \frac{1}{10.5} (6) (1.2)^{2/3} \sqrt{3/500}$

Discharge, Q [m^3/s] = ~~34.58 m^3/s~~

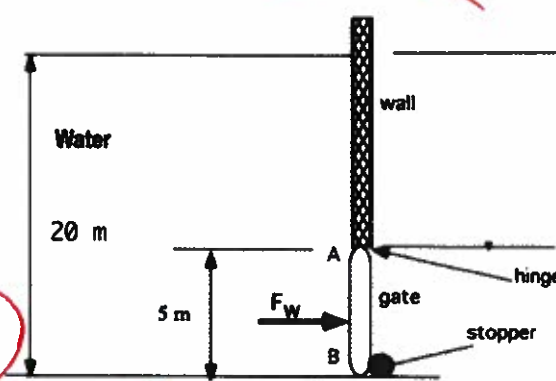
(b) [50]

A rectangular gate is hinged as shown. The gate is 5 m high and 6 m wide.

The specific weight of the water is 10000.0 N/ m^3

(i) [20] Calculate the force, F_w [kN] on the gate due to the water

$$F = (10000)(5)(5 \times 6) = 1,500 \text{ kN}$$



Force on the gate, F_w = ~~1,500~~ [kN]

(ii) [30] Calculate the force, S [kN] due to the stopper (shown) on the gate to keep the gate in the closed position.

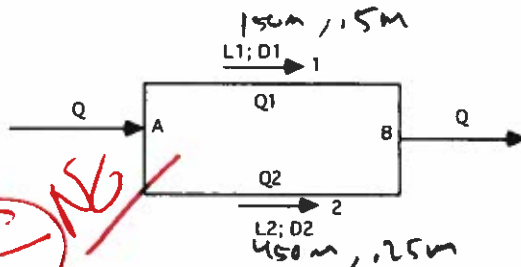
$$(10,000)(20)(5 \times 6) = 60,000 \text{ kN}$$

Take moments
25

Force on stopper to keep the gate closed, S = ~~60,000~~ [kN]

3 [100]

The total discharge (flowrate) from A to B in the figure below is 300 liters/s. Pipe lengths are: $L_1 = 150$ m, and $L_2 = 450$ m. Diameters, are: $D_1 = 500$ mm, and $D_2 = 250$ mm.



$$Q = 300$$

$$\epsilon = 60.6 \times 10^{-4}$$

$$A_1 = \frac{\pi}{4} (1.5)^2 = 0.1767 \text{ m}^2$$

$$A_2 = \frac{\pi}{4} (0.25)^2 = 0.0491 \text{ m}^2$$

$$\frac{60 \times 10^{-4}}{1.5} = 0.04$$

$$\frac{60 \times 10^{-4}}{0.25} = 0.024$$

$$f_2 = 0.052$$

$$300 = Q_1 + Q_2 \Rightarrow V_1 A_1 + V_2 A_2$$

$$300 = V_1 (0.1767) + V_2 (0.0491)$$

$$73 = 2.74 V_2 + (0.0491) V_2$$

$$h_L = h_{L1} = h_{L2}$$

$$\sqrt{f_1} = \sqrt{\frac{2 D_1 f_2 L_2}{f_1 L_1 D_2^5}} V_2^2$$

$$= \sqrt{\frac{(1.5)(0.052)(450)}{(0.04)(150)(0.25)^5}}$$

$$V_1 = 2.74 V_2$$

$$h_L = h_{L1} = h_{L2}$$

$$\frac{f_1 L_1 V_1^2}{2 D_1} = \frac{f_2 L_2 V_2^2}{2 D_2} \Rightarrow V_1 = \sqrt{\frac{f_2 L_2 V_2^2 2 D_1}{f_1 L_1 2 D_2}} = \sqrt{\frac{(0.052)(450)(V_2^2)(2)(1.5)}{(0.04)(150)(2)(0.25)}} = V_1 = 2.8 V_2$$

$$13 = (0.1767)(2.8 V_2) + (0.0491) V_2$$

$$= (0.5978) V_2$$

$$V_2 = 0.5$$

$$h_F = \frac{f L V^2}{D 2g}$$

$$h_F = \frac{f L V^2}{D 2g}$$

$$13 = (0.1767) V_1 + (0.0491) V_2$$

$$V_1 = 1.4$$

$$h_F = \frac{f L V^2}{D 2g}$$

$$h_F = \frac{f L V^2}{D 2g}$$

Flowrate pipe #1 [l/s] = 274.4 l/s

$$0.3 = (1.4)(0.1767) + (0.5)(0.0491)$$

$$(1.4)(0.1767) =$$

Flowrate pipe #2 [l/s] = 251.6 l/s

Headloss pipe #1 [m] = 11.76

Headloss pipe #2 [m] = 11.76

-25

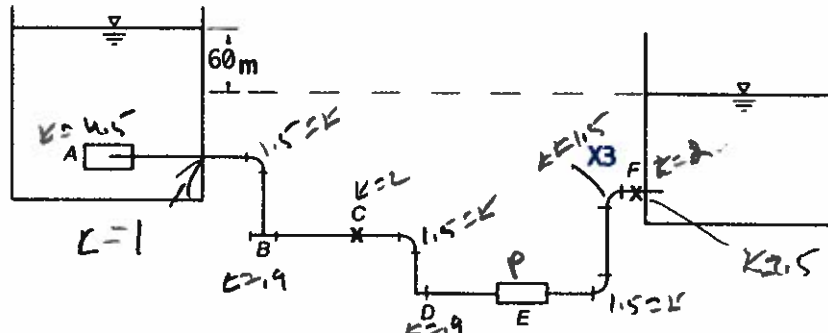
-25

$$\epsilon = 0.16 \text{ mm} = 0.16 \times 10^{-3}$$

Problem 4 [100]

Water (at 50 °C) with a discharge of 200 l/s flows through a 400-mm, 100 m galvanized iron pipe ($\epsilon = 0.16 \text{ mm}$) in the system shown below from right to left and there is a pump (E) in the system. In order to calculate the minor losses, assume the following in the figure, A is a diffuser ($K = 4.5$), C is a Check valve (open); E is the Pump; F represents three (3 – for redundancy) **ANGLE** valves (open). The elbows in the system are 90° threaded elbows and the tees (B and D) are threaded (through flow). For the entrance minor loss from the RIGHT tank, assume $K = 2.5$. [Hint: see appropriate table values provided in Exam for K values not provided]

The flow is fully turbulent. The elevation difference is 60 m as shown. Answer the questions below.



a) [10] What is the velocity of the flow [m/s] in the system?

Velocity of flow in the Pipe = 1.6 [m/s]

b) [15] Determine the friction factor for the flow in the system

$$h_f = \frac{f L V^2}{2D}$$

Friction factor for the flow in the Pipe = 0.01

c) [15] Determine the minor headloss [m] for the flow in the system

$$h_m = \frac{(1.0)(100)(1.6)^2}{(2)(4)(1.01)} = 10$$

Minor headloss Pipe = 10 [m]

d) [20] Determine the friction headloss [m] for the flow in the system

$$h_m = \sum K \frac{V^2}{2g} = \frac{(23.8)(1.6)^2}{2(9.81)} = 1.5$$

Friction headloss Pipe = 1.5 [m]

e) [20] Determine the head supplied by the pump, E [m] to the flow

H_p

Head of Pump = 20 [m]

f) [15] If the pump in the system has an efficiency of 78%, determine the power [kW] supplied to the pump?

Power Supplied to Pump = 15 [kW]

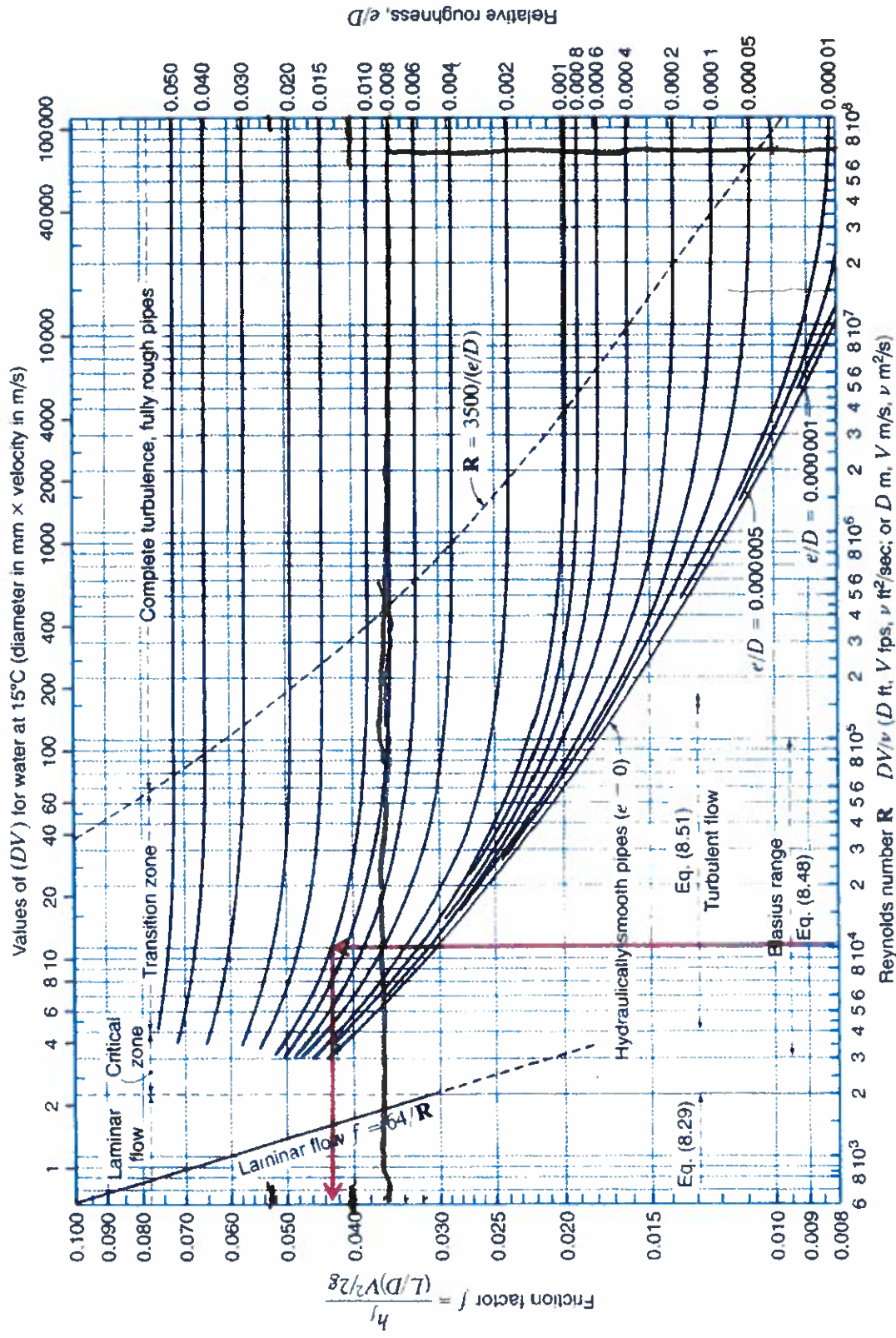
Properties of Water

Temperature (°C)	Density ρ (kg/m ³)	Specific Weight γ (N/m ³)	Viscosity μ (N·s/m ²)	Kinematic viscosity ν (m ² /s)	Bulk modulus B (Pa)	Surface Tension σ (N/m)	Vapor Pressure (kPa)
0	999.9	9809	1.792×10^{-3}	1.792×10^{-6}	204×10^7	7.62×10^{-2}	0.610
5	1000.0	9810	1.519	1.519	206	7.54	0.872
10	999.7	9807	1.308	1.308	211	7.48	1.13
15	999.1	9801	1.140	1.141	214	7.41	1.60
20	998.2	9792	1.005	1.007	220	7.36	2.34
30	995.7	9768	0.801	0.804	223	7.18	4.24
40	992.2	9733	0.656	0.661	227	7.01	7.38
50	988.1	9693	0.549	0.556	230	6.82	12.3
60	983.2	9645	0.469	0.477	228	6.68	19.9
70	977.8	9592	0.406	0.415	225	6.50	31.2
80	971.8	9533	0.357	0.367	221	6.30	47.3
90	965.3	9470	0.317	0.328	216	6.12	70.1
100	958.4	9402	0.284×10^{-3}	0.296×10^{-6}	207×10^7	5.94×10^{-2}	101.3

PROPERTIES OF WATER (ENGLISH UNITS)

Temperature (°F)	Specific Weight γ (lb/ft ³)	Mass Density ρ (lb • sec ² /ft ⁴)	Absolute Dynamic Viscosity μ ($\times 10^{-5}$ lb • sec/ft ²)	Kinematic Viscosity ν ($\times 10^{-5}$ ft ² /sec)	Vapor Pressure p_v (psi)
32	62.42	1.940	3.746	1.931	0.09
40	62.43	1.940	3.229	1.664	0.12
50	62.41	1.940	2.735	1.410	0.18
60	62.37	1.938	2.359	1.217	0.26
70	62.30	1.936	2.050	1.059	0.36
80	62.22	1.934	1.799	0.930	0.51
90	62.11	1.931	1.595	0.826	0.70
100	62.00	1.927	1.424	0.739	0.95
110	61.86	1.923	1.284	0.667	1.24
120	61.71	1.918	1.168	0.609	1.69
130	61.55	1.913	1.069	0.558	2.22
140	61.38	1.908	0.981	0.514	2.89
150	61.20	1.902	0.905	0.476	3.72
160	61.00	1.896	0.838	0.442	4.74
170	60.80	1.890	0.780	0.413	5.99
180	60.58	1.883	0.726	0.385	7.51
190	60.36	1.876	0.678	0.362	9.34
200	60.12	1.868	0.637	0.341	11.52
212	59.83	1.860	0.593	0.319	14.70

Moody Diagram – friction factor, f



(Note: If $e/D = 0.01$ and $Re = 10^4$, the left arrow locates $f = 0.043$.)

BELOW
AVERAGE



Thurs. Mar 10, 2022, 01:00 PM, SR Collins 205

Submit the entire exam the order given

Name (PRINT)

MOUNI YAMBA

In all the problems you must provide enough details and description of the solution method to demonstrate your knowledge of the solution method. A substantial portion of the grade will be based on your methods.

400

All necessary equations are provided except for elementary relationships you are expected to master. This is a **CLOSED** book exam. Please **turn off all cell phones and mp3 players** and **place them in your book bag in front of the class**. Also put away ANY **disallowed** calculators. **Calculator POLICY (allowed calculators)**

- **Casio:** All fx-115 and fx-991 models (Any Casio calculator must have "fx-115" or "fx-991" in its model name.)
- **Hewlett Packard:** The HP 33s and HP 35s models, but no others
- **Texas Instruments:** All TI-30X and TI-36X models (Any Texas Instruments calculator must have "TI-30X" or "TI-36X" in its model name.)

- 1) All cellphones/smartwatches **MUST** be placed in your book bag during exams and turned off. Book bags **MUST** be placed **in front of the classroom** and away from students. Students without a book bag must place cellphone/smartwatch (turned off) on Instructor's desk.
- 2) Any student possessing a cellphone/smartwatch or any other unauthorized device **WILL** receive an automatic zero for the test/assignment. Such action will be cheating.
- 3) **CLOTHING:** Hoodies are **NOT** Allowed during exams. No headphones (corded or wireless) are **ALLOWED**.
- 4) **Calculator covers are DISALLOWED** during tests and must be placed in students' book bags during exams.
- 5) There shall be **NO SHARING** of resources during the exam. Writing space will be provided in the test.
- 6) **RESTROOM VISIT:** if you need to use the restroom, **do so before opening the exam**. Once the exam begins, you must submit your work to the instructor if you leave the classroom to visit the rest room (your exam terminates).
- 7) You have **70 minutes** to complete the exam. Please turn in your work on time.
- 8) Provide enough detail for each problem you solve. You earn points based on the details you provide.
- 9) Please work independently.
- 10) You are required to solve **ALL** problems.

Dishonesty or failure to adhere to instructions will result in a grade of ZERO (0.0)

I pledge to abide by all the rules stated for this Exam

Signature:

Date:

03/10/2022

NAME [PRINT, Lastname, firstname]:

YAMBA, MOUNI

REFERENCE VALUES AND FORMULAS [Unless otherwise stated or implied, assume the following]

Density of water = 1000 kg/m^3 ($= 1.94 \text{ slugs/ft}^3$) [at 4°C]
 Specific weight of water = 9810 N/m^3 ($= 62.4 \text{ lb/ft}^3$) and at 4°C
 Gravitational Acceleration, $g = 9.81 \text{ m/s}^2$ ($= 32.2 \text{ ft/s}^2$)
 Standard atmospheric pressure = 101.3 kPa ($= 2117 \text{ psf} = 14.7 \text{ psi}$)
 Gas constant for air, $R = 287 \text{ J/kg}\cdot\text{K} = 1716 \text{ ft}\cdot\text{lb/slug}\cdot^\circ\text{R}$
 $T [\text{K}] = t [^\circ\text{C}] + 273.15$
 $T [^\circ\text{R}] = t [^\circ\text{F}] + 459.67$
 $1 \text{ Btu} = 778 \text{ ft}\cdot\text{lb}$
 $1 \text{ hp} = 745.7 \text{ W} = 550 \text{ ft}\cdot\text{lb/s}$
 $1 \text{ m} = 100 \text{ cm}$

$1 \text{ mile} = 5280 \text{ feet}$
 $1 \text{ mile} = 1760 \text{ yards}$
 $1 \text{ acre} = 43560 \text{ ft}^2$
 $1 \text{ mi}^2 = 640 \text{ acres}$
 $1 \text{ ft} = 0.3048 \text{ m}$
 $1 \text{ slug} = 14.59 \text{ kg}$
 $1 \text{ lb} = 4.448 \text{ N}$
 $1 \text{ Pa} = 1.0 \text{ N/m}^2$
 $1 \text{ ft}^3 = 7.481 \text{ gal}$
 $25.4 \text{ mm} = 1.0 \text{ in}$
 $1 \text{ liter} = 1000 \text{ cm}^3$
 $1 \text{ m}^3 = 1000 \text{ liter}$

Forces on submerged surfaces:

$$F = \gamma h A$$

$$\text{Location of Center of pressure, } y_p = \bar{y} + \frac{I_{xx}}{A \bar{y}}$$

Moment of Inertia for a rectangular shape:

$$I_{xx} = \frac{b l^3}{12}$$

Buoyant Force:

$$F_B = \gamma (\text{displaced volume})$$

Metacentric Height:

$$GM = \frac{I_{xx}}{V} - CG$$

Reynolds Number:

$$Re = \frac{VD}{\nu} = \frac{\rho VD}{\mu}$$

Swamee & Jain and other f Equations:

Swamee & Jain (1976) [error about 1% from Colebrook equation]

$$f = \frac{1.325}{\left[\ln \left(0.27 \frac{\epsilon}{D} + \frac{5.74}{Re^{0.9}} \right) \right]^2} \text{ for } 10^{-6} \leq \frac{\epsilon}{D} \leq 10^{-2} \text{ and } 5000 \leq Re \leq 10^8$$

Haaland (1983) [error about 1.5% from Colebrook equation]

$$f = \frac{1}{\left[-1.8 \log \left(\left(\frac{0.27\epsilon}{D} \right)^{11} + \frac{6.9}{Re} \right) \right]^2} \text{ for } 4000 \leq Re \leq 10^8$$

Fully Rough/turbulent Flow:

$$f = \frac{1}{\left[2 \log \left(\frac{3.7D}{\epsilon} \right) \right]^2}$$

Smooth Pipe flow for Hydraulically smooth pipes:

$$\text{Blasius Equation: } f = \frac{0.316}{Re^{0.25}} \text{ for } 4000 \leq Re \leq 10^5$$

$$\text{Colebrook's Approximation: } f \approx \frac{1}{\left[1.8 \log \left(\frac{Re}{6.9} \right) \right]^2} \text{ for } 4000 \leq Re \leq 10^8$$

Darcy-Weisbach Equation for friction headloss:

$$h_f = \frac{fL}{D} \frac{V^2}{2g}$$

Minor headloss Equation:

$$h_m = \sum K \frac{V^2}{2g}; \text{ Where } K = \text{loss coefficient}$$

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2$$

$$H_1 + \frac{V_1^2}{2g} + \frac{P_1}{\gamma} + z_1 = H_2 + \frac{V_2^2}{2g} + \frac{P_2}{\gamma} + z_2 + h_L$$

Table 15.1 Roughness Values for Pipes

Pipe Material	Equivalent Roughness, ϵ (ft)	Hazen-Williams Coefficient, C
PVC, plastic	Smooth	140
Brass, copper, aluminum, glass	Smooth	140
Dawn tubing	5×10^{-6}	—
Cast iron		
new	8.0×10^{-4}	130
old		100
Galvanized iron/ductile pipe	5.0×10^{-4}	120
Asphalted iron	4.0×10^{-4}	—
Wrought iron	1.5×10^{-4}	—
Commercial and welded steel	1.5×10^{-4}	120
Wood stave	20.0×10^{-4}	120
Concrete	40.0×10^{-4}	130
Riveted steel	60.0×10^{-4}	110
Brick sewer	—	100

Table 15.3 Minor Head Loss Coefficients

Item	Loss Coefficient, K_m
Entrance from tank to pipe	
Flush connection	0.5
Projecting connection	0.8
Exit from pipe to tank	1.0
Sudden contraction ($h_m = K_m V_2^2 / 2g$)	
$d_2/d_1 = 0.2$	0.48
$d_2/d_1 = 0.4$	0.42
$d_2/d_1 = 0.6$	0.32
$d_2/d_1 = 0.8$	0.20
$d_2/d_1 = 0.9$	0.05
Sudden enlargement ($h_m = K_m V_1^2 / 2g$)	
$d_1/d_2 = 0.9$	0.04
$d_1/d_2 = 0.8$	0.13
$d_1/d_2 = 0.6$	0.41
$d_1/d_2 = 0.4$	0.71
$d_1/d_2 = 0.2$	0.92

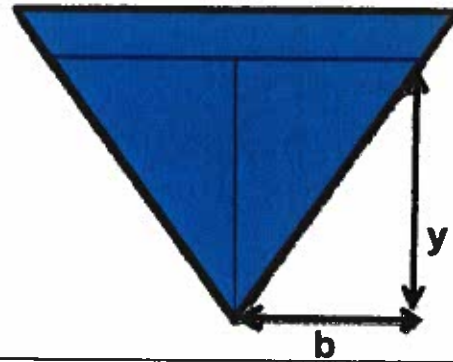
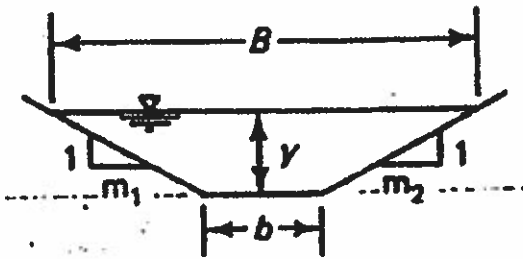
Note: Subscript 1 refers to upstream and 2 refers to downstream section.

Table 15.3 Minor Head Loss Coefficients

Item	Loss Coefficient, K_m
90° bend and 180° return—threaded	1.5
45° bend—threaded	0.4
90° bend and 180° return—flanged	0.3
45° bend—flanged	0.3
Tee—threaded	
through flow	0.9
branched flow	2.0
Tee—flanged	
through flow	0.2
branched flow	1.0
Gate valve (open)	0.19
Check valve (open)	2.0
Globe valve (open)	10.0
Angle valve (open)	2.0
Butterfly valve (open)	0.3

Note: Subscript 1 refers to upstream and 2 refers to downstream section.

Trapezoidal Channel



$$\text{Area, } A = by + \frac{1}{2}y^2(m_1 + m_2)$$

$$\text{Wetted Perimeter, } P = b + y(\sqrt{1 + m_1^2} + \sqrt{1 + m_2^2})$$

$$\text{Top Width, T or B} = b + y(m_1 + m_2)$$

$$\text{Hydraulic Radius, } R = \frac{A}{P} = \frac{by + \frac{1}{2}y^2(m_1 + m_2)}{b + y(\sqrt{1 + m_1^2} + \sqrt{1 + m_2^2})}$$

$$\text{Area, } A = by$$

$$\text{Wetted Perimeter, } P = 2\sqrt{b^2 + y^2}$$

$$\text{Top Width, T or B} = 2b$$

$$\text{Hydraulic Radius, } R = \frac{A}{P} = \frac{by}{2\sqrt{b^2 + y^2}}$$

$$\text{Hydraulic Depth, } D = \frac{A}{T} = \frac{by}{2b} = \frac{y}{2}$$

Manning's Equations:

$$\text{Velocity, } V \text{ [m/s]} = \frac{1}{n} R^{2/3} \sqrt{S} \quad \text{-(SI Units)}$$

$$\text{Velocity, } V \text{ [ft/s]} = \frac{1.486}{n} R^{2/3} \sqrt{S} \quad \text{-(English Units)}$$

Hazen-Williams Equations [Circular Pipes]:

English Units: Q [cfs], L [ft], D [ft], H_L [ft]

$$S = \frac{h_L}{L} = \frac{4.731}{C^{1.85} D^{4.87}} Q^{1.85}$$

$$Q = 0.432 C D^{2.63} S^{0.54}$$

Manning's Equations:

$$\text{Discharge, } Q \text{ [m}^3\text{/s]} = \frac{1}{n} A R^{2/3} \sqrt{S} \quad \text{-(SI Units)}$$

$$\text{Discharge, } Q \text{ [ft}^3\text{/s]} = \frac{1.486}{n} A R^{2/3} \sqrt{S} \quad \text{-(English Units)}$$

Hazen-Williams Equations [Circular Pipes]:

SI Units: Q [m³/s], L [m], D [m], H_L [m]

$$Q = 0.278 C D^{2.63} S^{0.54}$$

$$S = \frac{h_L}{L} = \frac{10.704}{C^{1.85} D^{4.87}} Q^{1.85}$$

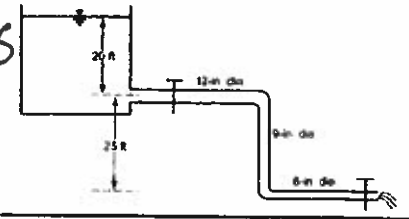
$$S = \frac{4.731}{C^{1.85} D^{4.87}} Q^{1.85}$$

1 [100]

a) [50] Water (at 100 °F) flows from the reservoir shown below at a rate of 2.00 cfs. The water is discharged into the atmosphere through a 6-inch concrete pipe, as shown in the figure. Answer the questions below. Please note that it is not necessary to separately determine the minor losses in the system in order to answer these questions.

$$Q = VA \Rightarrow V = \frac{Q}{A} = \frac{2.00 \text{ cfs}}{\frac{\pi}{4} \left(\frac{6}{12}\right)^2} = 10.19 \text{ ft/s}$$

$$\text{at } 100^\circ \text{F}, \nu = 0.739 \text{ ft}^2/\text{s}$$



I) [15] Calculate the Reynolds Number (Re) for the flow in the 6-inch pipe. State whether the flow is turbulent or laminar and why.

$$Re = \frac{VD}{\nu} = \frac{10.19 \times \frac{6}{12}}{0.739 \text{ ft}^2/\text{s}} = 6.89$$

Reynolds Number = 6.89

Laminar or Turbulent [Circle one]

II) [25] Determine the friction factor for the flow in the 6-inch pipe (using the friction factor equation provided or MOODY diagram).

$$f = \frac{\epsilon}{Re} =$$

What is the relative roughness of the pipe =

Friction Factor =

III) [25] Determine the friction HEADLOSS [ft] for the flow in the 6-inch pipe ONLY if it is 150 ft long.

Friction headloss =

[b] [50]

Three (3) pipes, a 12-in (1500 ft) new cast iron pipe (C=120), a 18-in (1000 ft) new cast iron pipe (C=120) and a 3000 ft 24-in ductile iron pipe (C=130), are arranged in series in a water distribution system. The total headloss in the piping system is limited to 60 ft. Using the Hazen-Williams equation, determine the equivalent length of the 18-in new cast iron pipe to replace the pipes in series. Assume that specific weight of water = 62.4 lb/ft³.

Perform the necessary calculations (by completing the table below) to determine the length of the equivalent 18-in pipe for the system. Assume a flow of 1.50 cfs in your calculations for the equivalent pipe as provided in the table below.

Pipe	C	Diameter [in]	Dia [ft]	Q [cfs]	S = HL/L []	Pipe Len, L [ft]	HL = S*L [ft]
1	120	12.0	1	1.500	0.00143	1500	2.145
2	120	18.0	1.5	1.500	0.000198	1000	0.198
3	130	24.0	2	1.500	0.00042	3000	0.126
EQV	120	18.0	1.5	1.500			

EQV = Equivalent pipe; HL = Headloss; S = Slope of Energy grade line; Q = flowrate

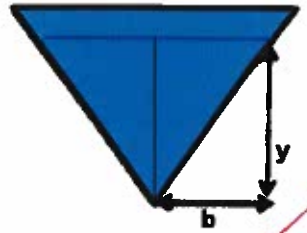
Calculate the equivalent length of a 18-in pipe.

Length of 18-in new cast iron pipe [ft] =

2 [100]

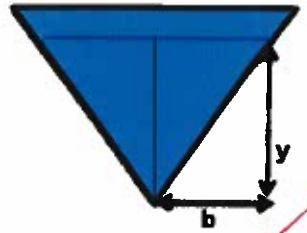
[a] [50]

Consider the channel shown here, with a rough concrete lining ($n = 0.015$). The dimensions are: $b = 4.00$ m and the depth of flow, y is 3.00 m. The channel slope, S is 3 m per 500 m.

I) [10] What is the Area of flow, A [m^2]? 

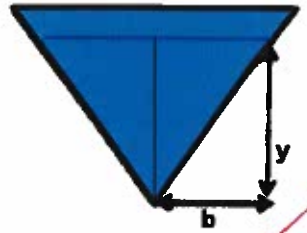
$$A = by = 4.00 \text{ m} \times 3.00 = 12.00 \text{ m}^2$$

Area of flow, A , [m^2] = 12 m²

II) [15] What is the Wetted perimeter, P [m]? 

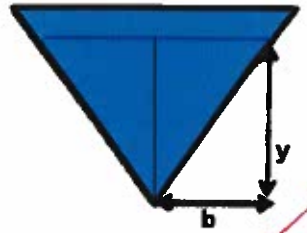
$$P = 2\sqrt{b^2 + y^2} = 2\sqrt{4^2 + 3^2} = 10$$

Wetted Perimeter, P [m] = 10 m

III) [10] What is the Hydraulic Radius, R [m]? 

$$R = \frac{A}{P} = \frac{12}{10} = 1.2$$

Hydraulic Radius, R [m] = 1.2 m

IV) [15] What is the Discharge, Q [m^3/s]? 

$$Q = \frac{1.486}{n} A R^{2/3} \sqrt{S} \Rightarrow Q = \frac{1.486}{0.015} \times 12 \times 1.2^{2/3} \sqrt{3/500} = 2325.18 \text{ m}^3/\text{s}$$

Discharge, Q [m^3/s] = 2325.18 -10

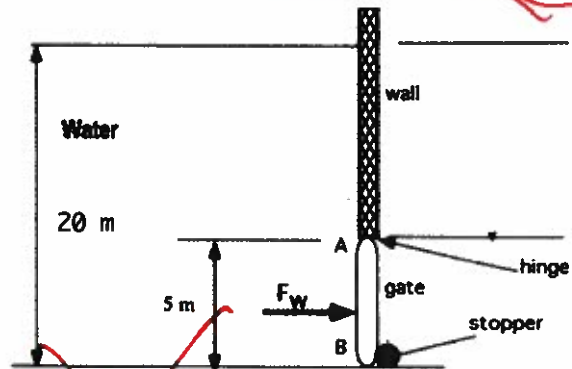
(b) [50]

A rectangular gate is hinged as shown. The gate is 5 m high and 6 m wide. The specific weight of the water is 10000.0 N/ m^3

(i) [20] Calculate the force, F_w [kN] on the gate due to the water

$$A = 30 \text{ m}^2$$

$$F_w = 300 \text{ kN}$$



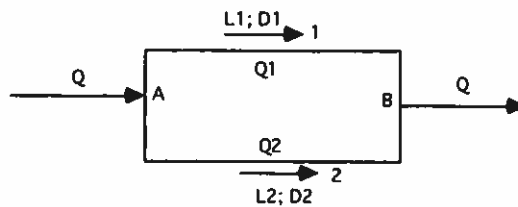
Force on the gate, F_w = 300 [kN]

(ii) [30] Calculate the force, S [kN] due to the stopper (shown) on the gate to keep the gate in the closed position.

Force on stopper to keep the gate closed, S = 30 [kN]

3 [100]

The total discharge (flowrate) from A to B in the figure below is 300 liters/s. Pipe lengths are: $L_1 = 150$ m, and $L_2 = 450$ m. Diameters, are: $D_1 = 500$ mm, and $D_2 = 250$ mm.



$$Q = 0.3 \text{ m}^3/\text{s}$$

$$V_1 = \frac{Q}{\frac{\pi}{4}(0.5)^2} = \frac{0.3}{\frac{\pi}{4}(0.5)^2} = 1.53 \text{ m/s}$$

$$V_2 = \frac{0.3}{\frac{\pi}{4}(0.25)^2} = 6.11 \text{ m/s}$$

Determine [Using Darcy's equation] the headloss [m] and the flowrates [l/s] across A-B in pipes 1 and 2 if riveted steel iron pipes are used in the system and flow is **FULLY TURBULENT**.

$$f_1 = ?$$

$$f_2 = ?$$

$$Q_1 = V_1 A_1 = 1.53 \times \frac{\pi}{4}(0.5)^2$$

$$= 0.3 \text{ m}^3/\text{s}$$

$$\text{Flowrate pipe \#1 [l/s]} = 300 \text{ l/s}$$

$$Q_2 = V_2 A_2 = 6.11 \times \frac{\pi}{4}(0.25)^2$$

$$= 300 \text{ l/s}$$

$$\text{Flowrate pipe \#2 [l/s]} = 300 \text{ l/s}$$

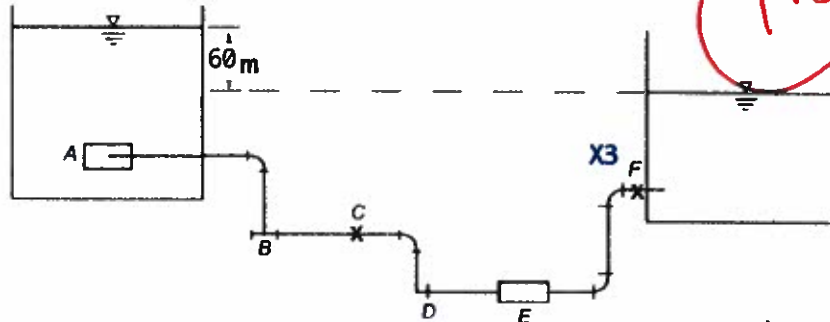
$$\text{Headloss pipe \#1 [m]} =$$

$$\text{Headloss pipe \#2 [m]} =$$

Problem 4 [100]

Water (at 50 °C) with a discharge of 200 l/s flows through a 400-mm, 100 m galvanized iron pipe ($\epsilon = 0.16$ mm) in the system shown below from **right to left** and there is a pump (E) in the system. In other to calculate the minor losses, assume the following in the figure, A is a diffuser ($K = 4.5$), C is a Check valve (open); E is the Pump; F represents three (3 – for redundancy) **ANGLE** valves (open). The elbows in the system are 90° threaded elbows and the tees (B and D) are threaded (through flow). For the entrance minor loss from the RIGHT tank, assume $K = 2.5$. [Hint: see appropriate table values provided in Exam for K values not provided]

The flow is fully turbulent. The elevation difference is 60 m as shown.
Answer the questions below.



- a) [10] What is the velocity of the flow [m/s] in the system?

$Q = 200 \text{ l/s}$
 $Q = 0.2 \text{ m}^3/\text{s}$
 $V = \frac{Q}{\frac{\pi}{4}(0.4)^2}$
 $V = \frac{0.2}{\frac{\pi}{4}(0.4)^2} = 1.59 \text{ m/s}$

Velocity of flow in the Pipe = 1.59 [m/s]

- b) [15] Determine the friction factor for the flow in the system

$f = \left[\frac{1}{2.5 \log(3.7 \times 0.4)} \right]^2 \Rightarrow f = \left[\frac{1}{2.5 \log(3.7 \times 0.4)} \right]^2 = 0.16$

Friction factor for the flow in the Pipe = 0.16

- c) [15] Determine the minor headloss [m] for the flow in the system

$f = \frac{1}{2.5 \log(3.7 \times 0.4)} = 0.16$

Minor headloss Pipe = 0.16 [m]

- d) [20] Determine the friction headloss [m] for the flow in the system

Friction headloss Pipe = 0.16 [m]

- e) [20] Determine the head supplied by the pump, E [m] to the flow

Head of Pump = 0.16 [m]

- f) [15] If the pump in the system has an efficiency of 78%, determine the power [kW] supplied to the pump?

Power Supplied to Pump = 0.16 [kW]

-70

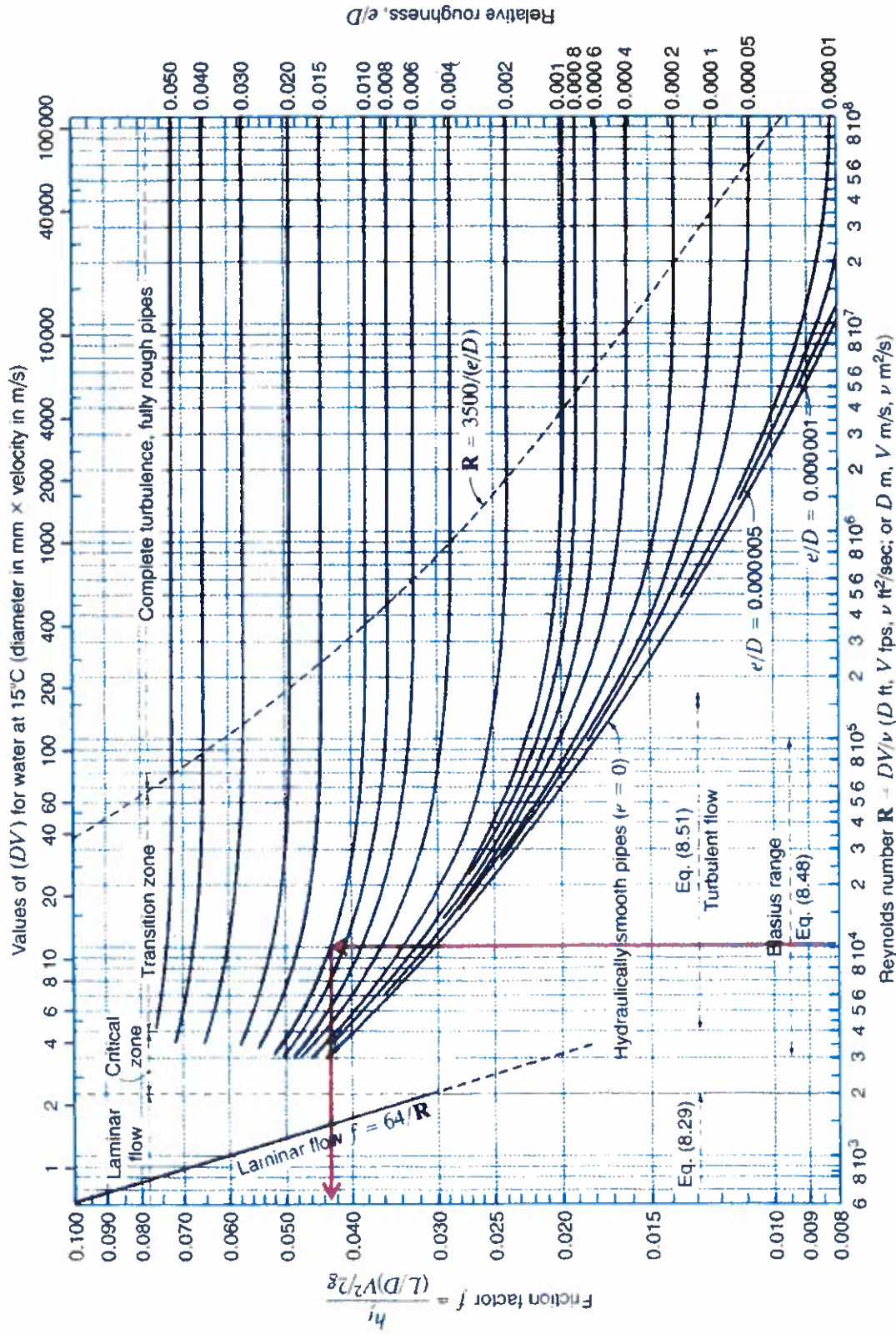
Properties of Water

Temperature (°C)	Density ρ (kg/m ³)	Specific Weight γ (N/m ³)	Viscosity μ (N·s/m ²)	Kinematic viscosity ν (m ² /s)	Bulk modulus B (Pa)	Surface Tension σ (N/m)	Vapor Pressure (kPa)
0	999.9	9809	1.792×10^{-3}	1.792×10^{-6}	204×10^7	7.62×10^{-2}	0.610
5	1000.0	9810	1.519	1.519	206	7.54	0.872
10	999.7	9807	1.308	1.308	211	7.48	1.13
15	999.1	9801	1.140	1.141	214	7.41	1.60
20	998.2	9792	1.005	1.007	220	7.36	2.34
30	995.7	9768	0.801	0.804	223	7.18	4.24
40	992.2	9733	0.656	0.661	227	7.01	7.38
50	988.1	9693	0.549	0.556	230	6.82	12.3
60	983.2	9645	0.469	0.477	228	6.68	19.9
70	977.8	9592	0.406	0.415	225	6.50	31.2
80	971.8	9533	0.357	0.367	221	6.30	47.3
90	965.3	9470	0.317	0.328	216	6.12	70.1
100	958.4	9402	0.284×10^{-3}	0.296×10^{-6}	207×10^7	5.94×10^{-2}	101.3

PROPERTIES OF WATER (ENGLISH UNITS)

Temperature (°F)	Specific Weight γ (lb/ft ³)	Mass Density ρ (lb • sec ² /ft ⁴)	Absolute Dynamic Viscosity μ ($\times 10^{-5}$ lb • sec/ft ²)	Kinematic Viscosity ν ($\times 10^{-5}$ ft ² /sec)	Vapor Pressure p_v (psi)
32	62.42	1.940	3.746	1.931	0.09
40	62.43	1.940	3.229	1.664	0.12
50	62.41	1.940	2.735	1.410	0.18
60	62.37	1.938	2.359	1.217	0.26
70	62.30	1.936	2.050	1.059	0.36
80	62.22	1.934	1.799	0.930	0.51
90	62.11	1.931	1.595	0.826	0.70
100	62.00	1.927	1.424	0.739	0.95
110	61.86	1.923	1.284	0.667	1.24
120	61.71	1.918	1.168	0.609	1.69
130	61.55	1.913	1.069	0.558	2.22
140	61.38	1.908	0.981	0.514	2.89
150	61.20	1.902	0.905	0.476	3.72
160	61.00	1.896	0.838	0.442	4.74
170	60.80	1.890	0.780	0.413	5.99
180	60.58	1.883	0.726	0.385	7.51
190	60.36	1.876	0.678	0.362	9.34
200	60.12	1.868	0.637	0.341	11.52
212	59.83	1.860	0.593	0.319	14.70

Moody Diagram – friction factor, f



(Note: If $e/D = 0.01$ and $Re = 10^4$, the left arrow locates $f = 0.043$.)

**CVEG 4303
WATER RESOURCES ENGINEERING
SPRING 2022**

Title of Assignment: Exam 02

TOPICS COVERED in Exam 02

Exam 02 covered the following topics:

1. Application of Hardy Cross method in a looped water distribution system
2. Selection of a pump given System Head curve and Characteristic curve: operating point, pump efficiency, power/head supplied, flowrate
3. Application of hydraulic elements of circular pipes table to determine flow parameters in a circular open channel
4. Implementation of Rational Method: determination of time of concentration, average Runoff Coefficient (non-homogeneous watershed), design Rainfall Intensity and peak flowrate

ABOVE
AVERAGE

Submit the entire exam the order given

Name (PRINT)

OGLE TREE

In all the problems you must provide enough details and description of the solution method to demonstrate your knowledge of the solution method. A substantial portion of the grade will be based on your methods.

400

All necessary equations are provided except for elementary relationships you are expected to master. This is a **CLOSED book exam. Please **turn off all cell phones and mp3 players** and **place them in your book bag in front of the class**. Also put away ANY **disallowed** calculators.**

Calculator POLICY (allowed calculators)

- **Casio:** All fx-115 and fx-991 models (Any Casio calculator must have "fx-115" or "fx-991" in its model name.)
- **Hewlett Packard:** The HP 33s and HP 35s models, but no others
- **Texas Instruments:** All TI-30X and TI-36X models (Any Texas Instruments calculator must have "TI-30X" or "TI-36X" in its model name.)

- 1) All cellphones/smartwatches **MUST** be placed in your book bag during exams and turned off. Book bags **MUST** be placed in front of the classroom and away from students. Students without a book bag must place cellphone/smartwatch (turned off) on Instructor's desk.
- 2) Any student possessing a cellphone/smartwatch or any other unauthorized device **WILL** receive an automatic zero for the test/assignment. Such action will be cheating.
- 3) **CLOTHING:** Hoodies are **NOT** Allowed during exams. No headphones (corded or wireless) are **ALLOWED**.
- 4) **Calculator covers are DISALLOWED** during tests and must be placed in students' book bags during exams.
- 5) There shall be **NO SHARING** of resources during the exam. Writing space will be provided in the test.
- 6) **RESTROOM VISIT:** if you need to use the restroom, **do so before opening the exam**. Once the exam begins, you must submit your work to the instructor if you leave the classroom to visit the rest room (your exam terminates).
- 7) You have **70 minutes** to complete the exam. Please turn in your work on time.
- 8) Provide enough detail for each problem you solve. You earn points based on the details you provide.
- 9) Please work independently.
- 10) You are required to solve **ALL** problems.

Dishonesty or failure to adhere to instructions will result in a grade of ZERO (0.0)

I pledge to abide by all the rules stated for this Exam

Signature:

[Signature]

Date:

04-21-22

NAME [PRINT, Lastname, firstname]:

Layla Ogletree

REFERENCE VALUES AND FORMULAS [Unless otherwise stated or implied, assume the following]

Density of water = 1000 kg/m^3 ($= 1.94 \text{ slugs/ft}^3$) [at 4°C]
 Specific weight of water = 9810 N/m^3 ($= 62.4 \text{ lb/ft}^3$) and at 4°C
 Gravitational Acceleration, $g = 9.81 \text{ m/s}^2$ ($= 32.2 \text{ ft/s}^2$)
 Standard atmospheric pressure = 101.3 kPa ($= 2117 \text{ psf} = 14.7 \text{ psi}$)
 Gas constant for air, $R = 287 \text{ J/kg}\cdot\text{K} = 1716 \text{ ft}\cdot\text{lb/slug}\cdot^\circ\text{R}$
 $T [\text{K}] = t [^\circ\text{C}] + 273.15$
 $T [^\circ\text{R}] = t [^\circ\text{F}] + 459.67$
 $1 \text{ Btu} = 778 \text{ ft}\cdot\text{lb}$
 $1 \text{ hp} = 745.7 \text{ W} = 550 \text{ ft}\cdot\text{lb/s}$
 $1 \text{ m} = 100 \text{ cm}$

$1 \text{ mile} = 5280 \text{ feet}$
 $1 \text{ mile} = 1760 \text{ yards}$
 $1 \text{ acre} = 43560 \text{ ft}^2$
 $1 \text{ mi}^2 = 640 \text{ acres}$
 $1 \text{ ft} = 0.3048 \text{ m}$
 $1 \text{ slug} = 14.59 \text{ kg}$
 $1 \text{ lb} = 4.448 \text{ N}$
 $1 \text{ Pa} = 1.0 \text{ N/m}^2$
 $1 \text{ ft}^3 = 7.481 \text{ gal}$
 $25.4 \text{ mm} = 1.0 \text{ in}$
 $1 \text{ liter} = 1000 \text{ cm}^3$
 $1 \text{ m}^3 = 1000 \text{ liter}$

Forces on submerged surfaces:

$$F = \gamma h A$$

$$\text{Location of Center of pressure, } y_p = \bar{y} + \frac{I_{xx}}{A \bar{y}}$$

Moment of Inertia for a rectangular shape:

$$I_{xx} = \frac{b l^3}{12}$$

Buoyant Force:

$$F_B = \gamma (\text{displaced volume})$$

Metacentric Height:

$$GM = \frac{I_{xx}}{V} - CG$$

Reynolds Number:

$$Re = \frac{VD}{\nu} = \frac{\rho VD}{\mu}$$

Swamee & Jain and other f Equations:

Swamee & Jain (1976) [error about 1% from Colebrook equation]

$$f = \frac{1.325}{\left\{ \ln \left[0.27 \frac{\epsilon}{D} + \frac{5.74}{Re^{0.9}} \right] \right\}^2} \text{ for } 10^{-6} \leq \frac{\epsilon}{D} \leq 10^{-2} \text{ and } 5000 \leq Re \leq 10^8$$

Haaland (1983) [error about 1.5% from Colebrook equation]

$$f = \left[\frac{1}{-1.8 \log \left[\left(\frac{0.27\epsilon}{D} \right)^{1.1} + \frac{6.9}{Re} \right]} \right]^2 \text{ for } 4000 \leq Re \leq 10^8$$

Fully Rough/turbulent Flow:

$$f = \left[\frac{1}{2 \log \left(\frac{3.7D}{\epsilon} \right)} \right]^2$$

Smooth Pipe flow for Hydraulically smooth pipes:

$$\text{Blasius Equation: } f = \frac{0.316}{Re^{0.25}} \text{ for } 4000 \leq Re \leq 10^5$$

$$\text{Colebrook's Approximation: } f \approx \left[\frac{1}{1.8 \log \left(\frac{Re}{6.9} \right)} \right]^2 \text{ for } 4000 \leq Re \leq 10^8$$

Darcy-Weisbach Equation for friction headloss:

$$h_f = \frac{fL}{D} \frac{V^2}{2g}$$

Minor headloss Equation:

$$h_m = \sum K \frac{V^2}{2g}; \text{ Where } K = \text{loss coefficient}$$

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2$$

$$H_P + \frac{V_1^2}{2g} + \frac{P_1}{\gamma} + z_1 = H_T + \frac{V_2^2}{2g} + \frac{P_2}{\gamma} + z_2 + h_L$$

Power supplied TO pump:

$$\text{BHP} = \frac{\gamma Q H_p}{550 \eta} \quad [\text{FLT}^{-1}] \quad (\text{English units}) \quad [\text{hp}]$$

$$\text{BHP} = \frac{\gamma Q H_p}{\eta} \quad [\text{FLT}^{-1}] \quad (\text{metric units}) \quad [\text{Watts}]$$

Power supplied by pump:

$$\text{Power, } H_{\text{pump}} = \frac{\gamma Q H_p}{550} \quad \text{horsepower [hp] English Units}$$

$$\text{Power, } H_{\text{pump}} = \gamma Q H_p \quad \text{Watts [W] SI Units}$$

Pumps in Parallel

$$\text{Combined efficiency, } \eta = \frac{Q_A + Q_B}{\frac{Q_A}{\eta_A} + \frac{Q_B}{\eta_B}}$$

Pumps in series

$$\text{Combined efficiency, } \eta = \frac{H_A + H_B}{\frac{H_A}{\eta_A} + \frac{H_B}{\eta_B}}$$

Table 15.1 Roughness Values for Pipes

Pipe Material	Equivalent Roughness, ϵ (ft)	Hazen-Williams Coefficient, C
PVC, plastic	Smooth	140
Brass, copper, aluminum, glass	Smooth	140
Dawn tubing	5×10^{-6}	—
Cast iron		
new	8.0×10^{-4}	130
old		100
Galvanized iron/ductile pipe	5.0×10^{-4}	120
Asphalted iron	4.0×10^{-4}	—
Wrought iron	1.5×10^{-4}	—
Commercial and welded steel	1.5×10^{-4}	120
Wood stave	20.0×10^{-4}	120
Concrete	40.0×10^{-4}	130
Riveted steel	60.0×10^{-4}	110
Brick sewer	—	100

Table 15.3 Minor Head Loss Coefficients

Item	Loss Coefficient, K_m
Entrance from tank to pipe	
Flush connection	0.5
Projecting connection	0.8
Exit from pipe to tank	1.0
Sudden contraction ($h_m = K_m V_2^2 / 2g$)	
$d_2/d_1 = 0.2$	0.48
$d_2/d_1 = 0.4$	0.42
$d_2/d_1 = 0.6$	0.32
$d_2/d_1 = 0.8$	0.20
$d_2/d_1 = 0.9$	0.05
Sudden enlargement ($h_m = K_m V_1^2 / 2g$)	
$d_1/d_2 = 0.9$	0.04
$d_1/d_2 = 0.8$	0.13
$d_1/d_2 = 0.6$	0.41
$d_1/d_2 = 0.4$	0.71
$d_1/d_2 = 0.2$	0.92

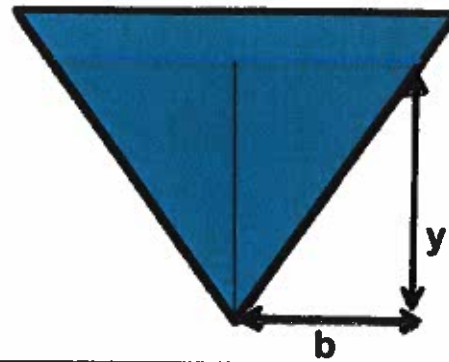
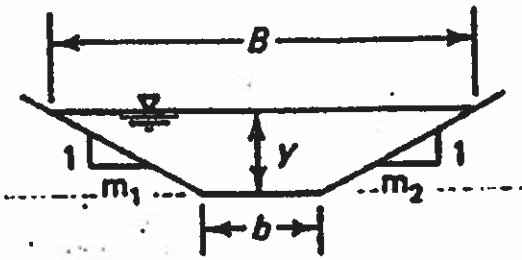
Note: Subscript 1 refers to upstream and 2 refers to downstream section.

Table 15.3 Minor Head Loss Coefficients

Item	Loss Coefficient, K_m
90° bend and 180° return—threaded	1.5
45° bend—threaded	0.4
90° bend and 180° return—flanged	0.3
45° bend—flanged	0.3
Tee—threaded	
through flow	0.9
branched flow	2.0
Tee—flanged	
through flow	0.2
branched flow	1.0
Gate valve (open)	0.19
Check valve (open)	2.0
Globe valve (open)	10.0
Angle valve (open)	2.0
Butterfly valve (open)	0.3

Note: Subscript 1 refers to upstream and 2 refers to downstream section.

Trapezoidal Channel



$$\text{Area, } A = by + \frac{1}{2}y^2(m_1 + m_2)$$

$$\text{Wetted Perimeter, } P = b + y(\sqrt{1 + m_1^2} + \sqrt{1 + m_2^2})$$

$$\text{Top Width, } T \text{ or } B = b + y(m_1 + m_2)$$

$$\text{Hydraulic Radius, } R = \frac{A}{P} = \frac{by + \frac{1}{2}y^2(m_1 + m_2)}{b + y(\sqrt{1 + m_1^2} + \sqrt{1 + m_2^2})}$$

$$\text{Area, } A = by$$

$$\text{Wetted Perimeter, } P = 2\sqrt{b^2 + y^2}$$

$$\text{Top Width, } T \text{ or } B = 2b$$

$$\text{Hydraulic Radius, } R = \frac{A}{P} = \frac{by}{2\sqrt{b^2 + y^2}}$$

$$\text{Hydraulic Depth, } D = \frac{A}{T} = \frac{by}{2b} = \frac{y}{2}$$

Manning's Equations:

$$\text{Velocity, } V \text{ [m/s]} = \frac{1}{n} R^{2/3} \sqrt{S} \quad \text{-(SI Units)}$$

$$\text{Velocity, } V \text{ [ft/s]} = \frac{1.486}{n} R^{2/3} \sqrt{S} \quad \text{-(English Units)}$$

Hazen-Williams Equations [Circular Pipes]:

English Units: Q [cfs], L [ft], D [ft], H_L [ft]

$$S = \frac{h_L}{L} = \frac{4.731}{C^{1.85} D^{4.87}} Q^{1.85}$$

$$Q = 0.432 C D^{2.63} S^{0.54}$$

Manning's Equations:

$$\text{Discharge, } Q \text{ [m}^3\text{/s]} = \frac{1}{n} A R^{2/3} \sqrt{S} \quad \text{-(SI Units)}$$

$$\text{Discharge, } Q \text{ [ft}^3\text{/s]} = \frac{1.486}{n} A R^{2/3} \sqrt{S} \quad \text{-(English Units)}$$

Hazen-Williams Equations [Circular Pipes]:

SI Units: Q [m³/s], L [m], D [m], H_L [m]

$$Q = 0.278 C D^{2.63} S^{0.54}$$

$$S = \frac{h_L}{L} = \frac{10.704}{C^{1.85} D^{4.87}} Q^{1.85}$$

$$\text{For critical flow, } Fr = \frac{V}{\sqrt{gD}}$$

$$\text{For critical flow, } V = \sqrt{gD}$$

$$\text{For critical flow, } Q = V \cdot A = A \sqrt{gD}$$

$$\text{For normal flow, } Z_n = AR^{2/3}$$

$$\text{For critical flow, } Z_c = A \sqrt{D}$$

Table 14.1 Geometric Elements for a Circular Section

$\frac{y}{d_0}$	$\frac{A}{d_0^2}$	$\frac{P_w}{d_0}$	$\frac{R}{d_0}$	$\frac{T}{d_0}$	$\frac{D}{d_0}$	$\frac{A\sqrt{D}}{d_0^{5/2}}$	$\frac{AR^{2/3}}{d_0^{8/3}}$
0.01	0.0013	0.2003	0.0066	0.1990	0.0066	0.0001	0.0000
0.05	0.0147	0.4510	0.0326	0.4359	0.0336	0.0027	0.0015
0.10	0.0409	0.6435	0.0635	0.6000	0.0682	0.0107	0.0065
0.15	0.0739	0.7954	0.0929	0.7141	0.1034	0.0238	0.0152
0.20	0.1118	0.9273	0.1206	0.8000	0.1398	0.0418	0.0273
0.25	0.1535	1.0472	0.1466	0.8660	0.1774	0.0646	0.0427
0.30	0.1982	1.1593	0.1709	0.9165	0.2162	0.0921	0.0610
0.35	0.2450	1.2661	0.1935	0.9539	0.2568	0.1241	0.0820
0.40	0.2934	1.3694	0.2142	0.9798	0.2994	0.1603	0.1050
0.45	0.3428	1.4706	0.2331	0.9950	0.3446	0.2011	0.1298
0.50	0.3927	1.5708	0.2500	1.0000	0.3928	0.2459	0.1558
0.55	0.4426	1.6710	0.2649	0.9950	0.4448	0.2949	0.1825
0.60	0.4920	1.7722	0.2776	0.9798	0.5022	0.3438	0.2092
0.65	0.5404	1.8755	0.2881	0.9539	0.5666	0.4066	0.2358
0.67	0.5594	1.9177	0.2917	0.9404	0.5948	0.4309	0.2460
0.70	0.5872	1.9823	0.2962	0.9165	0.6408	0.4694	0.2608
0.75	0.6318	2.0944	0.3017	0.8660	0.7296	0.5392	0.2840
0.80	0.6736	2.2143	0.3042	0.8000	0.8420	0.6177	0.3045
0.85	0.7115	2.3462	0.3033	0.7141	0.9964	0.7098	0.3212
0.90	0.7445	2.4981	0.2980	0.6000	1.2408	0.8285	0.3324
0.94 ^a	0.7662	2.6467	0.2896	0.4750	1.6130	0.9725	0.3353
0.95	0.7707	2.6906	0.2864	0.4359	1.7682	1.0242	0.3349
1.00	0.7854	3.1416	0.2500	0.0000	∞	∞	0.3117

^a Maximum flow occurs at 0.94 full depth.

Kirpich Formula [time of concentration]:

$$t_c [\text{minutes}] = \frac{0.0078L^{0.77}}{S^{0.385}}; L [\text{ft}] \text{ and } S [\text{ft/ft}]$$

Intensity-Duration-Frequency equation:

$$\text{Rainfall Intensity, } i [\text{in/hr}] = a(D + b)^c$$

Where: D = duration [hrs]

Where,

a, b and c are local parameters for a given return period, T in years;
D = rainfall duration in hours.

Rational Formula:

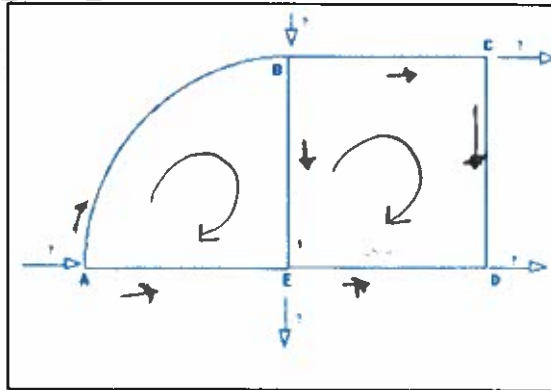
$$Q = CIA$$

C = Runoff coefficient

I = Rainfall Intensity (in/hr)

A = Area in Acres

1 [100]



Clockwise flows are POSITIVE

The table below provides data for the application of the Hardy Cross Method.

PROVIDE THE FLOWS FOR THE GRAY FIELDS ONLY (see problem b, below)
Final Flows after 9 iterations [Clockwise Flows are Positive]

Iteration	Loop	Pipeline	Len [ft]	diam [in]	K	Qa [cfs]	headloss, hf = kQa ² [ft]	hf/Q	Correction, δ [cfs]	Final Q [cfs]
1		AB	4000	12	1.8136	2.215	8.9145	4.0207	-0.002	2.217
		BE	2000	6	29.017	0.960	26.7617	27.8668	0.002	0.962
		EA	1500	6	21.763	-1.285	-35.8213	27.9213	0.002	-1.283
9	Corrections		Loop 1		δ1 [cfs] =	0.002	Loop 2		δ2 [cfs] =	-0.004

2		BC	3000	8	10.329	1.757	31.8757	18.1451	-0.004	1.753
		CD	2000	8	6.886	0.257	0.4538	1.7677	-0.004	0.253
		DE	3000	8	10.329	-0.743	-5.7066	7.6775	-0.004	-0.747
		EB	2000	6	29.018					

a) [40] Complete the CORRECTION and Final Q (flows) columns for the table given (GRAY fields ONLY)

$$\delta = \frac{\sum hf}{\sum n \left| \frac{hf}{Q} \right|} = \frac{-0.1431}{(2)(59.808)} = -0.0012$$

$$\delta = \frac{27.8668}{2 \cdot 26.7617} = 0.52$$

b) [20] Complete the highlighted fields in columns for headloss and hf/Q in the table given (light blue fields ONLY)

c) [40] With reference to the FINAL flows values:

Fill in ALL the flow values on the figure (AND please fill in the appropriate fields below):

Inflow at A = 3.5 [cfs]

Inflow at B = 0.498 [cfs]

Outflow (withdrawal) at C = 1.5 [cfs]

Outflow (withdrawal) at D = 1 [cfs]

Outflow (withdrawal) at E = 1.498 [cfs]

$$AB + B = BE + BC$$

$$E = BE + AE - ED$$

$$A = AB + AE = 2.217 + (-1.283)$$

$$B = BE + BC - AB = 0.962 + 1.753 - 2.217$$

$$BE + AE = E + ED$$

$$C = BC - CD = 1.5$$

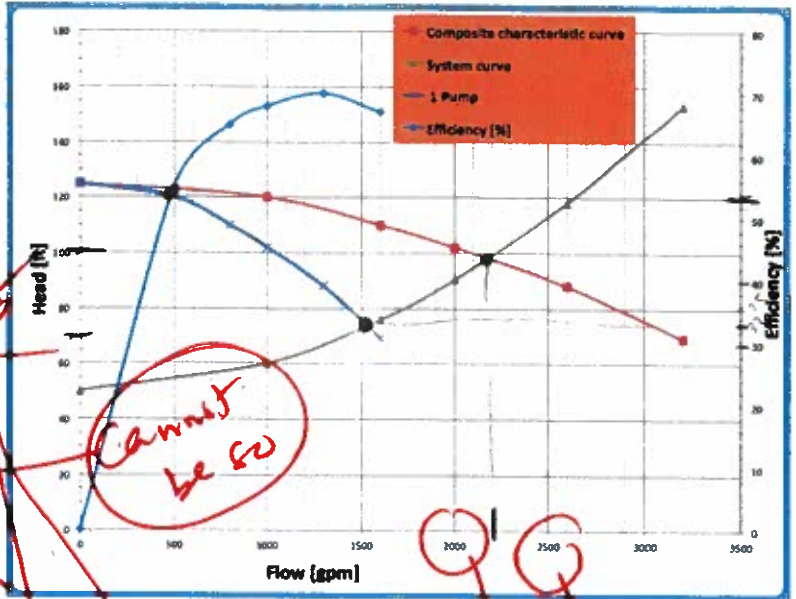
$$D = ED + CD =$$

2 [100] Consider a pumping system in a pressurized flow.

For the given system, the specific weight of the liquid being pumped, $\gamma = 67.0 \text{ lb/ft}^3$. The graph shown provides the system and pump characteristics (performance) curves. There are multiple identical pumps (2) in the system. The right Y-axis is for the efficiency [%] of the pump.

Determine:

(a) [50] The operating point data for the combined system [complete]:



I) System Operating Head [ft] = 100 *NOT Quite*
(Show how you obtained it on the graph)

II) Operating system flowrate [gpm] = 2400
(Show how you obtained it on the graph)

III) Operating efficiency for 1 pump [%] = 55%
(Show how you obtained it on the graph)

IV) Operating Head for 1 pump [ft] = 70
(Show how you obtained it on the graph)

V) Operating flowrate for 1 pump [gpm] = 1500
(show how you obtained it on the graph)

(b) [15] What type of pump arrangement is in this system?

the system is in parallel
Serial or parallel [circle] arrangement and WHY? = b/c of the efficiency curve

(c) [35] Calculate the power supplied by the pumping system [hp] to the flow

HINT: calculate the combined system efficiency first

$$BHP = \frac{H_{pump} \cdot Q}{\eta} = \frac{100 \cdot 2400}{0.48} = 60426$$

$$P = \frac{\gamma \cdot Q \cdot H_p}{550} = \frac{67 \cdot 2400 \cdot 100}{550} = 29236$$

$$\eta = 0.48 \quad \eta = \frac{Q_A + Q_B}{\frac{Q_A}{\eta_A} + \frac{Q_B}{\eta_B}} = \frac{1500 + 2400}{\frac{1500}{.55} + \frac{2400}{.45}} = \frac{3900}{8060} = 0.48$$

$$\eta = \frac{H_A + H_B}{\frac{H_A}{\eta_A} + \frac{H_B}{\eta_B}} = \frac{70 + 100}{\frac{70}{.55} + \frac{100}{.45}} = \frac{170}{272.7 + 222.2} = \frac{170}{494.9} = 0.34$$

Power supplied by pumping system [hp] = 29236

3 [100]

Suppose a circular channel with a diameter of 1.00 m is used to convey stormwater, at a depth of 0.45 m and Manning's roughness, $n = 0.013$ for the lining of the channel. Provide answers for the following questions.

[Hint: You may use Table 14.1 which has been provided. Do not interpolate, use the closest value - if appropriate]

(a) [20] What is the hydraulic radius [m] for the flow condition [m]?

Show all work.

$$y = 0.45 \quad d_0 = 1 \text{ m} \quad 0.2331 = R/d_0$$

$$\frac{0.45}{1} = 0.45 \quad R = 0.2331$$

Hydraulic Radius [m] = 0.2331

(b) [25] What is the discharge [m^3/s] if the channel slope is 5%

$$Q = 0.278 \text{ (crossed out)} \quad C = ? \quad \text{assume } 140$$

$$0.3428 = A/d_0^2 \quad A = 0.3428$$

$$Q = \frac{1}{n} A R^{2/3} \sqrt{S}$$

$$= \frac{1}{0.013} (0.3428) (0.2331)^{2/3} \sqrt{0.05}$$

Discharge of flow [m^3/s] = 2.23 m^3/s

(c) [25] What is the hydraulic depth [m] for the flow?

$$\frac{D}{d_0^{5/2}} = 0.3446$$

NO

Hydraulic Depth of flow [m] = 0.3446 m

(d) [30] What is the Froude Number [] for the flow?

$$Fr = \frac{V}{\sqrt{gD}} = \frac{6.514}{\sqrt{9.81 \cdot 0.3446}} = 3.54$$

$$Q = VA$$

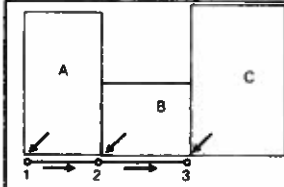
$$V = \frac{Q}{A} = \frac{2.23}{0.3428} = 6.514 \text{ m/s}$$

$$V = \frac{1}{n} R^{2/3} \sqrt{S}$$

Froude Number of flow [] = 3.54

Problem 4 [100]

You have been hired by local H&H firm, **AIHydrologicsMax**, to design the drainage system for the area below in Watershed, TX. The IDF (Intensity Duration Frequency) curve parameters are: **A = 212 and B = 20 for a return period of 15 years.**



$$\text{Rainfall intensity, } i \text{ [in/hr]} = \frac{A}{t+B}$$

$$Q = C I A$$

Where t is the rainfall duration in minutes. The minimum time of concentration (due to Watershed, TX ordinance) is 15 minutes,

The velocity of flow in the pipes (manhole to manhole in the sewer system) is given in the second table below and the other data for watershed are given in the first table. Your primary goal is to calculate the peak flowrate [cfs] from sections A, B, and C for the 15-year design rainfall. Use the Rational Method.

Data for the watershed

SECTION	C Value	Length [ft]	Slope [%]	Area [ac]	Inlet Travel time [min]	% of total area [%]
A	0.5	2000	4	400	1.378	28.6%
B	0.4	1200	6	250	0.417	17.9%
C	0.7	4500	2	750	2.068	53.5%
Total Area				1400		100%

Provide sample calculations for the first row at the right of above table

Data for the sewer system

Manhole Segment	Length [ft]	Velocity [ft/s]	Travel time [min]
1-2	250	2.5	1.6 min
2-3	350	3.5	1.6 min

Provide sample calculations for the first row at the right of above table

- a) [45] Calculate the time of concentration (using manhole 3 as the reference point or outlet) by completing the table below and portions of the 2 tables above.

Complete the table below

Travel Path [Inlet-Man#1-Man#2-...Outlet]	Time of travel [min]
A->1->2->3	9.378 + 1.6 + 1.6 = 12.711 min
B->2->3	0.417 + 1.6 = 2.017 min
C->2->3	2.068 + 1.6 = 3.678 min
	22.865 min

Provide sample calculation for the first row below and complete the rest of the table

$$\text{Time of concentration, } t_c \text{ [minutes]} = 22.865$$

- b) [20] Design Rainfall intensity, i (Use IDF formula provided)

$$I = \frac{A}{t+B} = \frac{212}{0.38 + 20}$$

$$\text{Design Rainfall Intensity, } i \text{ [in/hr]} = 10.4 \text{ in/hr}$$

- c) [15] Composite Runoff Coefficient, C

$$C = \frac{\sum C_i A_i}{\sum A_i} = \frac{(0.5 \cdot 400) + (0.4 \cdot 250) + (0.7 \cdot 750)}{400 + 250 + 750} = \frac{825}{1400}$$

$$\text{Runoff Coefficient [2 decimal places], } C = 0.59$$

- d) [20] The peak runoff for ABC (Using Rational Formula)

$$Q = (0.59)(10.4)(1400)$$

$$\text{Watershed ABCD Peak runoff [cfs]} = 8581.49$$

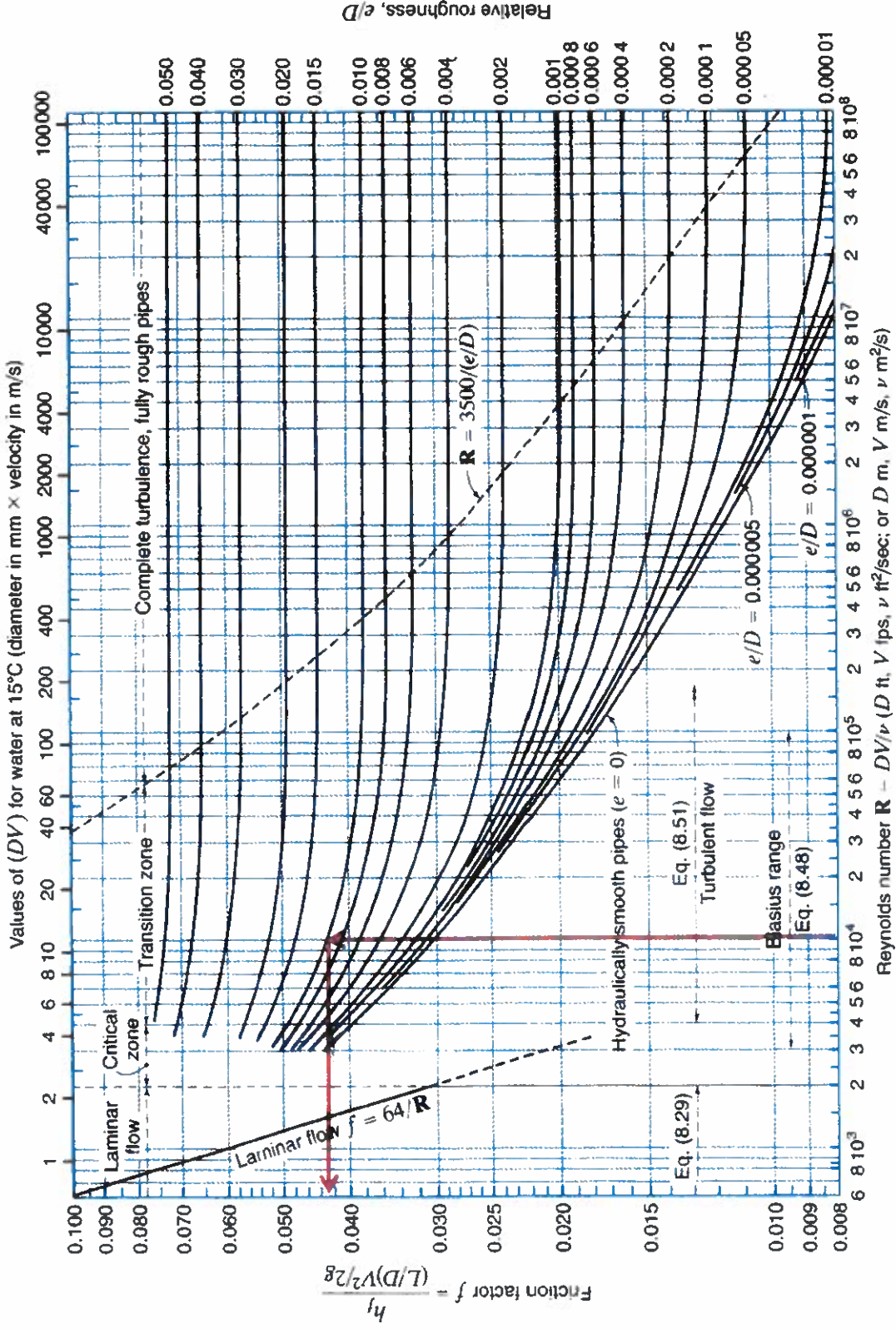
Properties of Water

Temperature (°C)	Density ρ (kg/m ³)	Specific Weight γ (N/m ³)	Viscosity μ (N·s/m ²)	Kinematic viscosity ν (m ² /s)	Bulk modulus B (Pa)	Surface Tension σ (N/m)	Vapor Pressure (kPa)
0	999.9	9809	1.792×10^{-3}	1.792×10^{-6}	204×10^7	7.62×10^{-2}	0.610
5	1000.0	9810	1.519	1.519	206	7.54	0.872
10	999.7	9807	1.308	1.308	211	7.48	1.13
15	999.1	9801	1.140	1.141	214	7.41	1.60
20	998.2	9792	1.005	1.007	220	7.36	2.34
30	995.7	9768	0.801	0.804	223	7.18	4.24
40	992.2	9733	0.656	0.661	227	7.01	7.38
50	988.1	9693	0.549	0.556	230	6.82	12.3
60	983.2	9645	0.469	0.477	228	6.68	19.9
70	977.8	9592	0.406	0.415	225	6.50	31.2
80	971.8	9533	0.357	0.367	221	6.30	47.3
90	965.3	9470	0.317	0.328	216	6.12	70.1
100	958.4	9402	0.284×10^{-3}	0.296×10^{-6}	207×10^7	5.94×10^{-2}	101.3

PROPERTIES OF WATER (ENGLISH UNITS)

Temperature (°F)	Specific Weight γ (lb/ft ³)	Mass Density ρ (lb • sec ² /ft ⁴)	Absolute Dynamic Viscosity μ ($\times 10^{-5}$ lb • sec/ft ²)	Kinematic Viscosity ν ($\times 10^{-5}$ ft ² /sec)	Vapor Pressure p_v (psi)
32	62.42	1.940	3.746	1.931	0.09
40	62.43	1.940	3.229	1.664	0.12
50	62.41	1.940	2.735	1.410	0.18
60	62.37	1.938	2.359	1.217	0.26
70	62.30	1.936	2.050	1.059	0.36
80	62.22	1.934	1.799	0.930	0.51
90	62.11	1.931	1.595	0.826	0.70
100	62.00	1.927	1.424	0.739	0.95
110	61.86	1.923	1.284	0.667	1.24
120	61.71	1.918	1.168	0.609	1.69
130	61.55	1.913	1.069	0.558	2.22
140	61.38	1.908	0.981	0.514	2.89
150	61.20	1.902	0.905	0.476	3.72
160	61.00	1.896	0.838	0.442	4.74
170	60.80	1.890	0.780	0.413	5.99
180	60.58	1.883	0.726	0.385	7.51
190	60.36	1.876	0.678	0.362	9.34
200	60.12	1.868	0.637	0.341	11.52
212	59.83	1.860	0.593	0.319	14.70

Moody Diagram – friction factor, f



(Note: If $e/D = 0.01$ and $Re = 10^4$, the left arrow locates $f = 0.043$.)

AVERAGE



CVEG 4303-P01

Dr. Nzewi

Department of Civil & Environmental Engineering
Water Resources Engineering

Spring 2022

EXAM 02

Thurs. April 21, 2022, 01:00 – 2:20 PM; SR Collins 205

Submit the entire exam the order given

Name [PRINT] Nathaniel Smith

In all the problems you must provide enough details and description of the solution method to demonstrate your knowledge of the solution method. A substantial portion of the grade will be based on your methods.

400

All necessary equations are provided except for elementary relationships you are expected to master. This is a **CLOSED** book exam. Please **turn off all cell phones and mp3 players and place them in your book bag in front of the class.** Also put away ANY disallowed calculators.

Calculator POLICY (allowed calculators)

- **Casio:** All fx-115 and fx-991 models (Any Casio calculator must have "fx-115" or "fx-991" in its model name)
- **Hewlett Packard:** The HP 33s and HP 35s models, but no others
- **Texas Instruments:** All TI-30X and TI-36X models (Any Texas Instruments calculator must have "TI-30X" or "TI-36X" in its model name)

- 1) All cellphones/smartwatches **MUST** be placed in your book bag during exams and turned off. Book bags **MUST** be placed in front of the classroom and away from students. Students without a book bag must place cellphone/smartwatch (turned off) on Instructor's desk.
- 2) Any student possessing a cellphone/smartwatch or any other unauthorized device **WILL** receive an automatic zero for the test/assignment. Such action will be cheating.
- 3) **CLOTHING:** Hoodies are **NOT** Allowed during exams. No headphones (corded or wireless) are **ALLOWED**.
- 4) **Calculator covers are DISALLOWED** during tests and must be placed in students' book bags during exams.
- 5) There shall be **NO SHARING** of resources during the exam. Writing space will be provided in the test.
- 6) **RESTROOM VISIT:** if you need to use the restroom, **do so before opening the exam**. Once the exam begins, you must submit your work to the instructor if you leave the classroom to visit the rest room (your exam terminates).
- 7) You have **70 minutes** to complete the exam. Please turn in your work on time.
- 8) Provide enough detail for each problem you solve. You earn points based on the details you provide.
- 9) Please work independently.
- 10) You are required to solve **ALL** problems.

Dishonesty or failure to adhere to instructions will result in a grade of ZERO (0.0)

I pledge to abide by all the rules stated for this Exam

Signature: Nathaniel Smith

Date: 4/21/2022

NAME [PRINT, Lastname, firstname]: Smith, Nathaniel

REFERENCE VALUES AND FORMULAS [Unless otherwise stated or implied, assume the following]

Density of water = 1000 kg/m^3 ($= 1.94 \text{ slugs/ft}^3$) [at 4°C]
 Specific weight of water = 9810 N/m^3 ($= 62.4 \text{ lb/ft}^3$) and at 4°C
 Gravitational Acceleration, $g = 9.81 \text{ m/s}^2$ ($= 32.2 \text{ ft/s}^2$)
 Standard atmospheric pressure = 101.3 kPa ($= 2117 \text{ psf} = 14.7 \text{ psi}$)
 Gas constant for air, $R = 287 \text{ J/kg}\cdot\text{K} = 1716 \text{ ft}\cdot\text{lb/slug}\cdot^\circ\text{R}$
 $T [\text{K}] = t [^\circ\text{C}] + 273.15$
 $T [^\circ\text{R}] = t [^\circ\text{F}] + 459.67$
 $1 \text{ Btu} = 778 \text{ ft}\cdot\text{lb}$
 $1 \text{ hp} = 745.7 \text{ W} = 550 \text{ ft}\cdot\text{lb}$
 $1 \text{ m} = 100 \text{ cm}$

$1 \text{ mile} = 5280 \text{ feet}$
 $1 \text{ mile} = 1760 \text{ yards}$
 $1 \text{ acre} = 43560 \text{ ft}^2$
 $1 \text{ mi}^2 = 640 \text{ acres}$
 $1 \text{ ft} = 0.3048 \text{ m}$
 $1 \text{ slug} = 14.59 \text{ kg}$
 $1 \text{ lb} = 4.448 \text{ N}$
 $1 \text{ Pa} = 1.0 \text{ N/m}^2$
 $1 \text{ ft}^3 = 7.481 \text{ gal}$
 $25.4 \text{ mm} = 1.0 \text{ in}$
 $1 \text{ liter} = 1000 \text{ cm}^3$
 $1 \text{ m}^3 = 1000 \text{ liter}$

Forces on submerged surfaces:

$$F = \gamma h A$$

Location of Center of pressure, $y_p = \bar{y} + \frac{I_{xx}}{A \bar{y}}$

Moment of Inertia for a rectangular shape:

$$I_{xx} = \frac{b l^3}{12}$$

Buoyant Force:

$$F_B = \gamma(\text{displaced volume})$$

Metacentric Height:

$$GM = \frac{I_{xx}}{V} - CG$$

Reynolds Number:

$$Re = \frac{VD}{\nu} = \frac{\rho V D}{\mu}$$

Swamee & Jain and other f Equations:

Swamee & Jain (1976) [error about 1% from Colebrook equation]

$$f = \frac{1.325}{\left\{ \ln \left[0.27 \frac{\epsilon}{D} + \frac{5.74}{Re^{0.9}} \right] \right\}^2} \text{ for } 10^{-6} \leq \frac{\epsilon}{D} \leq 10^{-2} \text{ and } 5000 \leq Re \leq 10^8$$

Haaland (1983) [error about 1.5% from Colebrook equation]

$$f = \left[\frac{1}{-1.8 \log \left[\left(\frac{0.27 \epsilon}{D} \right)^{1.1} + \frac{6.9}{Re} \right]} \right]^2 \text{ for } 4000 \leq Re \leq 10^8$$

Fully Rough/turbulent Flow:

$$f = \left[\frac{1}{2 \log \left(\frac{3.7 D}{\epsilon} \right)} \right]^2$$

Smooth Pipe flow for Hydraulically smooth pipes:

$$\text{Blasius Equation: } f = \frac{0.316}{Re^{0.25}} \text{ for } 4000 \leq Re \leq 10^5$$

$$\text{Colebrook's Approximation: } f \approx \left[\frac{1}{1.8 \log \left(\frac{Re}{6.9} \right)} \right]^2 \text{ for } 4000 \leq Re \leq 10^8$$

Darcy-Weisbach Equation for friction headloss:

$$h_f = \frac{fL}{D} \frac{V^2}{2g}$$

Minor headloss Equation:

$$h_m = \sum K \frac{V^2}{2g}; \text{ Where } K = \text{loss coefficient}$$

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2$$

$$H_p + \frac{V_1^2}{2g} + \frac{P_1}{\gamma} + z_1 = H_T + \frac{V_2^2}{2g} + \frac{P_2}{\gamma} + z_2 + h_L$$

Power supplied TO pump:

$$\text{BHP} = \frac{\gamma Q H_p}{550 \eta} \quad [\text{FLT}^{-1}] \quad (\text{English units}) \quad [\text{hp}]$$

$$\text{BHP} = \frac{\gamma Q H_p}{\eta} \quad [\text{FLT}^{-1}] \quad (\text{metric units}) \quad [\text{Watts}]$$

Power supplied by pump:

$$\text{Power, } H_{\text{hydraulic}} = \frac{\gamma Q H_p}{550} \text{ horsepower [hp] English Units}$$

$$\text{Power, } H_{\text{pump}} = \gamma Q H_p \text{ Watts [W] SI Units}$$

Pumps in Parallel

$$\text{Combined efficiency, } \eta = \frac{Q_A + Q_B}{\frac{Q_A}{\eta_A} + \frac{Q_B}{\eta_B}}$$

Pumps in series

$$\text{Combined efficiency, } \eta = \frac{H_A + H_B}{\frac{H_A}{\eta_A} + \frac{H_B}{\eta_B}}$$

Table 15.1 Roughness Values for Pipes

Pipe Material	Equivalent Roughness, ϵ (ft)	Hazen-Williams Coefficient, C
PVC, plastic	Smooth	140
Brass, copper, aluminum, glass	Smooth	140
Dawn tubing	5×10^{-6}	—
Cast iron		
new	8.0×10^{-4}	130
old		100
Galvanized iron/ductile pipe	5.0×10^{-4}	120
Asphalted iron	4.0×10^{-4}	—
Wrought iron	1.5×10^{-4}	—
Commercial and welded steel	1.5×10^{-4}	120
Wood stave	20.0×10^{-4}	120
Concrete	40.0×10^{-4}	130
Riveted steel	60.0×10^{-4}	110
Brick sewer	—	100

Table 15.3 Minor Head Loss Coefficients

Item	Loss Coefficient, K_m
Entrance from tank to pipe	
Flush connection	0.5
Projecting connection	0.8
Exit from pipe to tank	1.0
Sudden contraction ($h_m = K_m V_2^2 / 2g$)	
$d_2/d_1 = 0.2$	0.48
$d_2/d_1 = 0.4$	0.42
$d_2/d_1 = 0.6$	0.32
$d_2/d_1 = 0.8$	0.20
$d_2/d_1 = 0.9$	0.05
Sudden enlargement ($h_m = K_m V_1^2 / 2g$)	
$d_1/d_2 = 0.9$	0.04
$d_1/d_2 = 0.8$	0.13
$d_1/d_2 = 0.6$	0.41
$d_1/d_2 = 0.4$	0.71
$d_1/d_2 = 0.2$	0.92

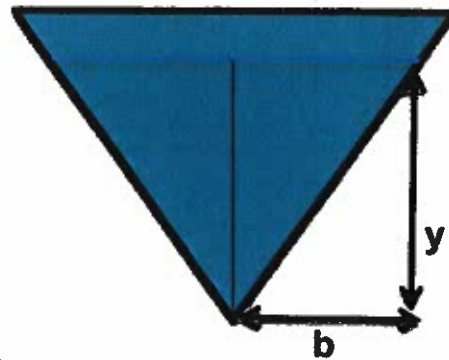
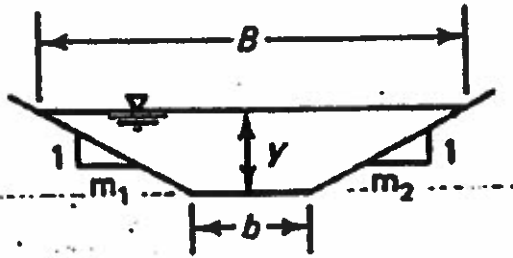
Note: Subscript 1 refers to upstream and 2 refers to downstream section.

Table 15.3 Minor Head Loss Coefficients

Item	Loss Coefficient, K_m
90° bend and 180° return—threaded	1.5
45° bend—threaded	0.4
90° bend and 180° return—flanged	0.3
45° bend—flanged	0.3
Tee—threaded	
through flow	0.9
branched flow	2.0
Tee—flanged	
through flow	0.2
branched flow	1.0
Gate valve (open)	0.19
Check valve (open)	2.0
Globe valve (open)	10.0
Angle valve (open)	2.0
Butterfly valve (open)	0.3

Note: Subscript 1 refers to upstream and 2 refers to downstream section.

Trapezoidal Channel



Area, $A = by + \frac{1}{2}y^2(m_1 + m_2)$

Wetted Perimeter, $P = b + y(\sqrt{1 + m_1^2} + \sqrt{1 + m_2^2})$

Top Width, T or B = $b + y(m_1 + m_2)$

Hydraulic Radius, $R = \frac{A}{P} = \frac{by + \frac{1}{2}y^2(m_1 + m_2)}{b + y(\sqrt{1 + m_1^2} + \sqrt{1 + m_2^2})}$

Area, $A = by$

Wetted Perimeter, $P = 2\sqrt{b^2 + y^2}$

Top Width, T or B = $2b$

Hydraulic Radius, $R = \frac{A}{P} = \frac{by}{2\sqrt{b^2 + y^2}}$

Hydraulic Depth, $D = \frac{A}{T} = \frac{by}{2b} = \frac{y}{2}$

Manning's Equations:

Velocity, $V \text{ [m/s]} = \frac{1}{n} R^{2/3} \sqrt{S}$ - (SI Units)

Velocity, $V \text{ [ft/s]} = \frac{1.486}{n} R^{2/3} \sqrt{S}$ - (English Units)

Hazen-Williams Equations [Circular Pipes]:

English Units: $Q \text{ [cfs]}, L \text{ [ft]}, D \text{ [ft]}, H_L \text{ [ft]}$

$$S = \frac{h_L}{L} = \frac{4.731}{C^{1.85} D^{4.87}} Q^{1.85}$$

$$Q = 0.432 C D^{2.63} S^{0.54}$$

Manning's Equations:

Discharge, $Q \text{ [m}^3\text{/s]} = \frac{1}{n} A R^{2/3} \sqrt{S}$ - (SI Units)

Discharge, $Q \text{ [ft}^3\text{/s]} = \frac{1.486}{n} A R^{2/3} \sqrt{S}$ - (English Units)

Hazen-Williams Equations [Circular Pipes]:

SI Units: $Q \text{ [m}^3\text{/s]}, L \text{ [m]}, D \text{ [m]}, H_L \text{ [m]}$

$$Q = 0.278 C D^{2.63} S^{0.54}$$

$$S = \frac{h_L}{L} = \frac{10.704}{C^{1.85} D^{4.87}} Q^{1.85}$$

For critical flow, $Fr = \frac{V}{\sqrt{gD}}$

For critical flow, $V = \sqrt{gD}$

For critical flow, $Q = V \cdot A = A \sqrt{gD}$

For normal flow, $Z_n = AR^{2/3}$

For critical flow, $Z_c = A \sqrt{D}$

Table 14.1 Geometric Elements for a Circular Section

$\frac{y}{d_0}$	$\frac{A}{d_0^2}$	$\frac{P_{wet}}{d_0}$	$\frac{R}{d_0}$	$\frac{T}{d_0}$	$\frac{D}{d_0}$	$\frac{A\sqrt{D}}{d_0^{5/2}}$	$\frac{AR^{2/3}}{d_0^{8/3}}$
0.01	0.0013	0.2003	0.0066	0.1990	0.0066	0.0001	0.0000
0.05	0.0147	0.4510	0.0326	0.4359	0.0336	0.0027	0.0015
0.10	0.0409	0.6435	0.0635	0.6000	0.0682	0.0107	0.0065
0.15	0.0739	0.7954	0.0929	0.7141	0.1034	0.0238	0.0152
0.20	0.1118	0.9273	0.1206	0.8000	0.1398	0.0418	0.0273
0.25	0.1535	1.0472	0.1466	0.8660	0.1774	0.0646	0.0427
0.30	0.1982	1.1593	0.1709	0.9165	0.2162	0.0921	0.0610
0.35	0.2450	1.2661	0.1935	0.9539	0.2568	0.1241	0.0820
0.40	0.2934	1.3694	0.2142	0.9798	0.2994	0.1603	0.1050
0.45	0.3428	1.4706	0.2331	0.9950	0.3446	0.2011	0.1298
0.50	0.3927	1.5708	0.2500	1.0000	0.3928	0.2459	0.1558
0.55	0.4426	1.6710	0.2649	0.9950	0.4448	0.2949	0.1825
0.60	0.4920	1.7722	0.2776	0.9798	0.5022	0.3438	0.2092
0.65	0.5404	1.8755	0.2881	0.9539	0.5666	0.4066	0.2358
0.67	0.5594	1.9177	0.2917	0.9404	0.5948	0.4309	0.2460
0.70	0.5872	1.9823	0.2962	0.9165	0.6408	0.4694	0.2608
0.75	0.6318	2.0944	0.3017	0.8660	0.7296	0.5392	0.2840
0.80	0.6736	2.2143	0.3042	0.8000	0.8420	0.6177	0.3045
0.85	0.7115	2.3462	0.3033	0.7141	0.9964	0.7098	0.3212
0.90	0.7445	2.4981	0.2980	0.6000	1.2408	0.8285	0.3324
0.94 ^a	0.7662	2.6467	0.2896	0.4750	1.6130	0.9725	0.3353
0.95	0.7707	2.6906	0.2864	0.4359	1.7682	1.0242	0.3349
1.00	0.7854	3.1416	0.2500	0.0000	∞	∞	0.3117

^a Maximum flow occurs at 0.94 full depth.

Kirpich Formula [time of concentration]:

$$t_c [\text{minutes}] = \frac{0.0078L^{0.77}}{S^{0.385}}; L [\text{ft}] \text{ and } S [\text{ft/ft}]$$

Intensity-Duration-Frequency equation:

$$\text{Rainfall Intensity, } i [\text{in/hr}] = a(D + b)^c$$

Where: D = duration [hrs]

Where,

a, b and c are local parameters for a given return period, T in years;
D = rainfall duration in hours.

Rational Formula:

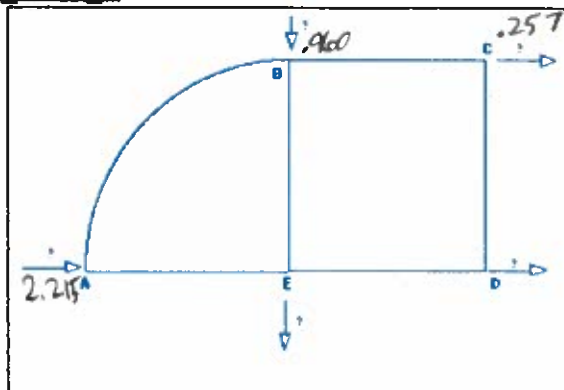
$$Q = CIA$$

C = Runoff coefficient

I = Rainfall Intensity (in/hr)

A = Area in Acres

1 [100]



Clockwise flows are POSITIVE

The table below provides data for the application of the Hardy Cross Method.

PROVIDE THE FLOWS FOR THE GRAY FIELDS ONLY (see problem b, below)

Final Flows after 9 iterations [Clockwise Flows are Positive]

Iteration	Loop	Pipeline	Len [ft]	diam [in]	K	Qa [cfs]	headloss, hf = kQa^2 [ft]	hf/Q	Correction, δ [cfs]	Final Q [cfs]
1		AB	4000	12	1.8136	2.215	8.9145	4.0207	.004	2.219
		BE	2000	6	29.017	0.960	26.7617	27.6668	.002	.962
		EA	1500	6	21.763	-1.285	-35.8213	27.9213	-.003	-1.288
							-1.451	59.8213		
9	Corrections	Loop 1	δ_1 [cfs] =		0.002	Loop 2	δ_2 [cfs] =		-0.004	
2		BC	3000	8	10.329	1.757	31.8757	18.1451	-.007	1.750
		CD	2000	8	6.886	0.257	0.4538	1.7677	-.001	.256
		DE	3000	8	10.329	-0.743	-5.7066	7.6775	.003	-.740
		EB	2000	6	29.018				-.002	-.962

a) [40] Complete the CORRECTION and Final Q (flows) columns for the table given (GRAY fields ONLY)

b) [20] Complete the highlighted fields in columns for headloss and |hf/Q| in the table given (light blue fields ONLY)

c) [40] With reference to the FINAL flows values:

Fill in ALL the flow values on the figure (AND please fill in the appropriate fields below):

Inflow at A = 2.219 [cfs]

Inflow at B = .962 [cfs]

Outflow (withdrawal) at C = -1.152 [cfs]

Outflow (withdrawal) at D = -.152 [cfs]

Outflow (withdrawal) at E = -1.893 [cfs]

found taken the sum of final Q in loop then halving & inverting the sign of determined number

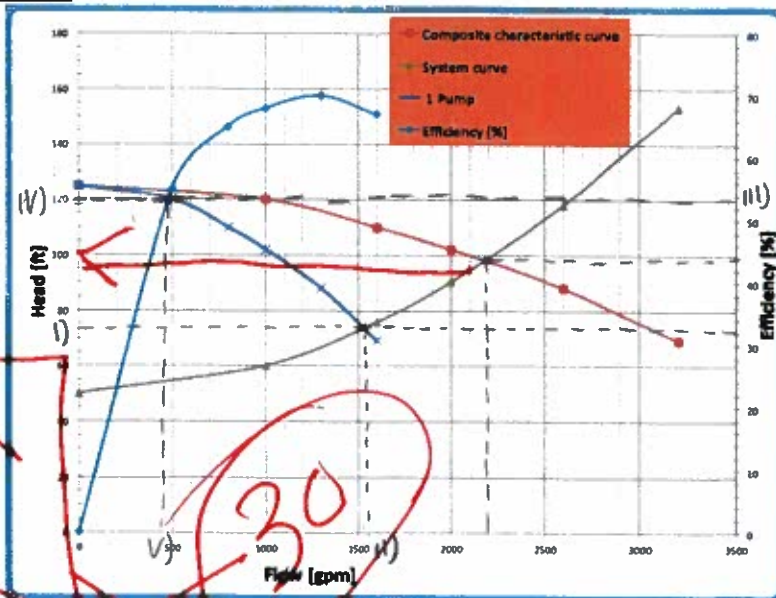
found taken the sum of final Q in loop 1 then inverting the sign of determined number

2 [100] Consider a pumping system in a pressurized flow.

For the given system, the specific weight of the liquid being pumped, $\gamma = 67.0 \text{ lb/ft}^3$. The graph shown provides the system and pump characteristics (performance) curves. There are multiple identical pumps (2) in the system. The right Y-axis is for the efficiency [%] of the pump.

Determine:

(a) [50] The operating point data for the combined system [complete]:



I) System Operating Head [ft] = 73 ft
(Show how you obtained it on the graph)

II) Operating system flowrate [gpm] = 1550 gpm
(Show how you obtained it on the graph)

III) Operating efficiency for 1 pump [%] = 51%
(Show how you obtained it on the graph)

IV) Operating Head for 1 pump [ft] = 120 ft
(Show how you obtained it on the graph)

V) Operating flowrate for 1 pump [gpm] = 775 gpm
(show how you obtained it on the graph)

(b) [15] What type of pump arrangement is in this system?

Serial or parallel [circle] arrangement and WHY? = system + composite curve have same initial head

Pump Composite curve is developed by add Q values

(c) [35] Calculate the power supplied by the pumping system [hp] to the flow
HINT: calculate the combined system efficiency first

$$BHP = \frac{\gamma Q H_P}{550 \eta} = \frac{(67 \text{ lb/ft}^3)(1550 \text{ gpm})(73 \text{ ft})}{550 \left(\frac{1550}{1550 + 2200} \cdot \frac{.32}{.44} \right)}$$

head is same
Pumps are identical

$$BHP = \frac{(67 \text{ lb/ft}^3)(1550 \text{ gpm})(73 \text{ ft})}{550} = 1378.73 \text{ hp}$$

efficiency?

25

Power supplied by pumping system [hp] = 1378.73 hp

3 [100]

Suppose a circular channel with a diameter of 1.00 m is used to convey stormwater, at a depth of 0.45 m and Manning's roughness, $n = 0.013$ for the lining of the channel. Provide answers for the following questions.

[Hint: You may use Table 14.1 which has been provided. Do not interpolate, use the closest value – if appropriate]

- (a) [20] What is the hydraulic radius [m] for the flow condition [m]?
Show all work.

$$y = .45 \text{ m}$$

$$d_o = 1.00 \text{ m}$$

$$\frac{y}{d_o} = \frac{.45 \text{ m}}{1 \text{ m}} = .45$$

$$\frac{R}{d_o} = .2331 \rightarrow R = .2331 d_o$$

$$= .2331 (1 \text{ m})$$

$$= .2331 \text{ m}$$

$$\text{Hydraulic Radius [m]} = .2331 \text{ m}$$

- (b) [25] What is the discharge [m^3/s] if the channel slope is $5\% = .05$

$$Q = \frac{1.486}{n} A R^{2/3} S^{1/2}$$

$$Q = \frac{1}{.013} (.1298) (.05)^{1/2} = 2.23 \text{ m}^3/\text{s}$$

$$\frac{A R^{2/3}}{d_o^{8/3}} = .1298 \rightarrow \frac{A R^{2/3}}{(1 \text{ m})} = .1298 \rightarrow A R^{2/3} = .1298$$

$$\text{Discharge of flow [m}^3/\text{s]} = 2.23 \text{ m}^3/\text{s}$$

- (c) [25] What is the hydraulic depth [m] for the flow?

$$\frac{D}{d_o} = .3446 \rightarrow \frac{D}{1 \text{ m}} = .3446 \rightarrow D = .3446 \text{ m}$$

$$\text{Hydraulic Depth of flow [m]} = .3446 \text{ m}$$

- (d) [30] What is the Froude Number [] for the flow?

$$Fr = \frac{V}{\sqrt{gD}} = \frac{6.51 \text{ m/s}}{\sqrt{9.81 \text{ m/s}^2 (.3446 \text{ m})}} = 3.54$$

good!

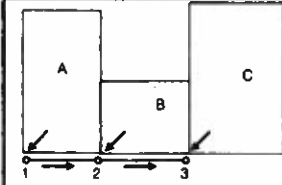
$$\frac{A}{d_o^2} = .3428 \rightarrow \frac{A}{(1 \text{ m})^2} = .3428 \rightarrow A = .3428 \text{ m}^2$$

$$V = \frac{Q}{A} = \frac{2.23 \text{ m}^3/\text{s}}{.3428 \text{ m}^2} = 6.51 \text{ m/s}$$

$$\text{Froude Number of flow []} = 3.54$$

Problem 4 [100]

You have been hired by local H&H firm, **AlHydrologicsMax**, to design the drainage system for the area below in Watershed, TX. The IDF (Intensity Duration Frequency) curve parameters are: **A = 212 and B = 20 for a return period of 15 years.**



$$\text{Rainfall intensity, } i \text{ [in/hr]} = \frac{A}{t+B};$$

Where t is the rainfall duration in minutes. The minimum time of concentration (due to Watershed, TX ordinance) is 15 minutes.

The velocity of flow in the pipes (manhole to manhole in the sewer system) is given in the second table below and the other data for watershed are given in the first table. Your primary goal is to calculate the peak flowrate [cfs] from sections A, B, and C for the 15-year design rainfall. **Use the Rational Method.**

Data for the watershed

SECTION	C Value	Length [ft]	Slope [%]	Area [ac]	Inlet Travel time [min]	% of total area [%]
A	0.5	2000	4	400	3.60	33.3%
B	0.4	1200	6	250	5.02	17.9%
C	0.7	4500	2	750	20.57	53.7%
Total Area				1400		100%

Provide sample calculations for the first row at the right of above table

Data for the sewer system

Manhole Segment	Length [ft]	Velocity	Travel time [min]
1-2	250	2.5	1.67 min
2-3	350	3.5	1.67 min

Provide sample calculations for the first row at the right of above table

- a) [45] Calculate the time of concentration (using manhole 3 as the reference point or outlet) by completing the table below and portions of the 2 tables above.

Complete the table below

Travel Path [Inlet-Man#1-Man#2-...Outlet]	Time of travel [min]
A→1→2→3 $8.6 + 1.67 + 1.67 = 11.94 \text{ min}$	11.94
B→2→3 $5.02 + 1.67 = 6.69 \text{ min}$	6.69
C→3 20.57 min	20.57
A→B→2→3 $8.6 + 5.02 + 1.67 + 1.67 = 16.96 \text{ min}$	16.96

Provide sample calculation for the first row below and complete the rest of the table

$$\text{Time of concentration, } t_c \text{ [minutes]} = 20.57 \text{ min}$$

- b) [20] Design Rainfall intensity, i (Use IDF formula provided)

$$i = \frac{A}{t+B} = \frac{212}{(20.57+20)} = 5.23 \text{ in/hr}$$

$$\text{Design Rainfall intensity, } i \text{ [in/hr]} = 5.23 \text{ in/hr}$$

- c) [15] Composite Runoff Coefficient, C

$$\bar{C} = \frac{\sum a_i C_i}{\sum a_i} = \frac{400(.5) + 250(.4) + 750(.7)}{400 + 250 + 750} = .59$$

$$\text{Runoff Coefficient [2 decimal places], } C = .59$$

- d) [20] The peak runoff for ABC (Using Rational Formula) $Q = CIA$

$$Q = .59 (5.23 \text{ in/hr}) (1400 \text{ ac}) = 4319.98 \text{ cfs}$$

$$\text{Watershed ABCD Peak runoff [cfs]} = 4319.98 \text{ cfs}$$

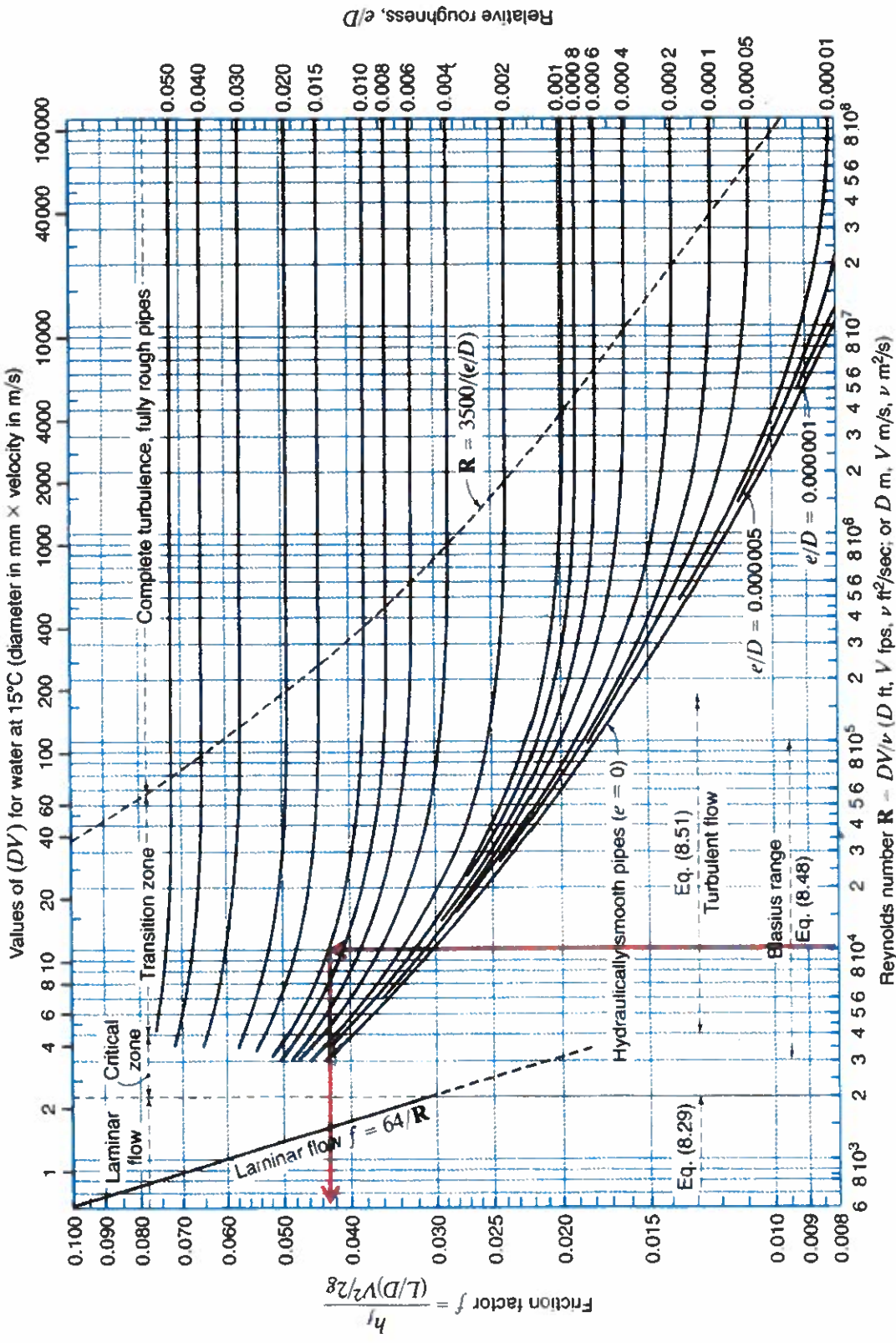
Properties of Water

Temperature (°C)	Density ρ (kg/m ³)	Specific Weight γ (N/m ³)	Viscosity μ (N·s/m ²)	Kinematic viscosity ν (m ² /s)	Bulk modulus B (Pa)	Surface Tension σ (N/m)	Vapor Pressure (kPa)
0	999.9	9809	1.792×10^{-3}	1.792×10^{-6}	204×10^7	7.62×10^{-2}	0.610
5	1000.0	9810	1.519	1.519	206	7.54	0.872
10	999.7	9807	1.308	1.308	211	7.48	1.13
15	999.1	9801	1.140	1.141	214	7.41	1.60
20	998.2	9792	1.005	1.007	220	7.36	2.34
30	995.7	9768	0.801	0.804	223	7.18	4.24
40	992.2	9733	0.656	0.661	227	7.01	7.38
50	988.1	9693	0.549	0.556	230	6.82	12.3
60	983.2	9645	0.469	0.477	228	6.68	19.9
70	977.8	9592	0.406	0.415	225	6.50	31.2
80	971.8	9533	0.357	0.367	221	6.30	47.3
90	965.3	9470	0.317	0.328	216	6.12	70.1
100	958.4	9402	0.284×10^{-3}	0.296×10^{-6}	207×10^7	5.94×10^{-2}	101.3

PROPERTIES OF WATER (ENGLISH UNITS)

Temperature (°F)	Specific Weight γ (lb/ft ³)	Mass Density ρ (lb • sec ² /ft ⁴)	Absolute Dynamic Viscosity μ ($\times 10^{-5}$ lb • sec/ft ²)	Kinematic Viscosity ν ($\times 10^{-5}$ ft ² /sec)	Vapor Pressure p_v (psi)
32	62.42	1.940	3.746	1.931	0.09
40	62.43	1.940	3.229	1.664	0.12
50	62.41	1.940	2.735	1.410	0.18
60	62.37	1.938	2.359	1.217	0.26
70	62.30	1.936	2.050	1.059	0.36
80	62.22	1.934	1.799	0.930	0.51
90	62.11	1.931	1.595	0.826	0.70
100	62.00	1.927	1.424	0.739	0.95
110	61.86	1.923	1.284	0.667	1.24
120	61.71	1.918	1.168	0.609	1.69
130	61.55	1.913	1.069	0.558	2.22
140	61.38	1.908	0.981	0.514	2.89
150	61.20	1.902	0.905	0.476	3.72
160	61.00	1.896	0.838	0.442	4.74
170	60.80	1.890	0.780	0.413	5.99
180	60.58	1.883	0.726	0.385	7.51
190	60.36	1.876	0.678	0.362	9.34
200	60.12	1.868	0.637	0.341	11.52
212	59.83	1.860	0.593	0.319	14.70

Moody Diagram – friction factor, f



(Note: If $e/D = 0.01$ and $Re = 10^4$, the left arrow locates $f = 0.043$.)

BELOW
AVERAGE



Department of Civil & Environmental Engineering

CVEG 4303-P01

Water Resources Engineering

Spring 2022

Dr. Azewi

EXAM 02

Thurs. April 21, 2022, 01:00 – 2:20 PM; SR Collins 205

Submit the entire exam the order given

Name [PRINT] YAMBA, MOUNI

In all the problems you must provide enough details and description of the solution method to demonstrate your knowledge of the solution method. A substantial portion of the grade will be based on your methods.

400

All necessary equations are provided except for elementary relationships you are expected to master. This is a **CLOSED book exam. Please **turn off all cell phones and mp3 players** and **place them in your book bag in front of the class**. Also put away ANY disallowed calculators.**
Calculator POLICY (allowed calculators)

- **Casio:** All fx-115 and fx-991 models (Any Casio calculator must have "fx-115" or "fx-991" in its model name.)
- **Hewlett Packard:** The HP 33s and HP 35s models, but no others
- **Texas Instruments:** All TI-30X and TI-36X models (Any Texas Instruments calculator must have "TI-30X" or "TI-36X" in its model name.)

- 1) All cellphones/smartwatches **MUST** be placed in your book bag during exams and turned off. Book bags **MUST** be placed in front of the classroom and away from students. Students without a book bag must place cellphone/smartwatch (turned off) on Instructor's desk.
- 2) Any student possessing a cellphone/smartwatch or any other unauthorized device **WILL** receive an automatic zero for the test/assignment. Such action will be cheating.
- 3) **CLOTHING:** Hoodies are **NOT** Allowed during exams. No headphones (corded or wireless) are **ALLOWED**.
- 4) **Calculator covers are DISALLOWED** during tests and must be placed in students' book bags during exams.
- 5) There shall be **NO SHARING** of resources during the exam. Writing space will be provided in the test.
- 6) **RESTROOM VISIT:** if you need to use the restroom, **do so before opening the exam**. Once the exam begins, you must submit your work to the instructor if you leave the classroom to visit the rest room (your exam terminates).
- 7) You have **70 minutes** to complete the exam. Please turn in your work on time.
- 8) Provide enough detail for each problem you solve. You earn points based on the details you provide.
- 9) Please work independently.
- 10) You are required to solve **ALL** problems.

Dishonesty or failure to adhere to instructions will result in a grade of ZERO (0.0)

I pledge to abide by all the rules stated for this Exam

Signature: *[Signature]*

Date: 04/21/2022

NAME [PRINT, Lastname, firstname]: YAMBA, MOUNI

REFERENCE VALUES AND FORMULAS [Unless otherwise stated or implied, assume the following]

Density of water = 1000 kg/m^3 ($= 1.94 \text{ slugs/ft}^3$) [at 4°C]
 Specific weight of water = 9810 N/m^3 ($= 62.4 \text{ lb/ft}^3$) and at 4°C
 Gravitational Acceleration, $g = 9.81 \text{ m/s}^2$ ($= 32.2 \text{ ft/s}^2$)
 Standard atmospheric pressure = 101.3 kPa ($= 2117 \text{ psf} = 14.7 \text{ psi}$)
 Gas constant for air, $R = 287 \text{ J/kg}\cdot\text{K} = 1716 \text{ ft}\cdot\text{lb/slug}\cdot^\circ\text{R}$
 $T [\text{K}] = t [^\circ\text{C}] + 273.15$
 $T [^\circ\text{R}] = t [^\circ\text{F}] + 459.67$
 $1 \text{ Btu} = 778 \text{ ft}\cdot\text{lb}$
 $1 \text{ hp} = 745.7 \text{ W} = 550 \text{ ft}\cdot\text{lb}$
 $1 \text{ m} = 100 \text{ cm}$

$1 \text{ mile} = 5280 \text{ feet}$
 $1 \text{ mile} = 1760 \text{ yards}$
 $1 \text{ acre} = 43560 \text{ ft}^2$
 $1 \text{ mi}^2 = 640 \text{ acres}$
 $1 \text{ ft} = 0.3048 \text{ m}$
 $1 \text{ slug} = 14.59 \text{ kg}$
 $1 \text{ lb} = 4.448 \text{ N}$
 $1 \text{ Pa} = 1.0 \text{ N/m}^2$
 $1 \text{ ft}^3 = 7.481 \text{ gal}$
 $25.4 \text{ mm} = 1.0 \text{ in}$
 $1 \text{ liter} = 1000 \text{ cm}^3$
 $1 \text{ m}^3 = 1000 \text{ liter}$

Forces on submerged surfaces:

$$F = \gamma \bar{h} A$$

Location of Center of pressure, $y_p = \bar{y} + \frac{I_{xx}}{A \bar{y}}$

Moment of Inertia for a rectangular shape:

$$I_{xx} = \frac{b l^3}{12}$$

Buoyant Force:

$$F_B = \gamma (\text{displaced volume})$$

Metacentric Height:

$$GM = \frac{I_{xx}}{V} - CG$$

Reynolds Number:

$$Re = \frac{VD}{\nu} = \frac{\rho VD}{\mu}$$

Swamee & Jain and other f Equations:

Swamee & Jain (1976) [error about 1% from Colebrook equation]

$$f = \frac{1.325}{\left\{ \ln \left[0.27 \frac{\epsilon}{D} + \frac{5.74}{Re^{0.9}} \right] \right\}^2} \text{ for } 10^{-6} \leq \frac{\epsilon}{D} \leq 10^{-2} \text{ and } 5000 \leq Re \leq 10^8$$

Haaland (1983) [error about 1.5% from Colebrook equation]

$$f = \frac{1}{\left\{ -1.8 \log \left[\left(\frac{0.27\epsilon}{D} \right)^{1.1} + \frac{6.9}{Re} \right] \right\}^2} \text{ for } 4000 \leq Re \leq 10^8$$

Fully Rough/turbulent Flow:

$$f = \frac{1}{\left[2 \log \left(\frac{3.7D}{\epsilon} \right) \right]^2}$$

Smooth Pipe flow for Hydraulically smooth pipes:

Blasius Equation: $f = \frac{0.316}{Re^{0.25}}$ for $4000 \leq Re \leq 10^5$

Colebrook's Approximation: $f \approx \frac{1}{\left[1.8 \log \left(\frac{Re}{6.9} \right) \right]^2} \text{ for } 4000 \leq Re \leq 10^8$

Darcy-Weisbach Equation for friction headloss:

$$h_f = \frac{fL}{D} \frac{V^2}{2g}$$

Minor headloss Equation:

$$h_m = \sum K \frac{V^2}{2g}; \text{ Where } K = \text{loss coefficient}$$

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2$$

$$H_P + \frac{V_1^2}{2g} + \frac{P_1}{\gamma} + z_1 = H_T + \frac{V_2^2}{2g} + \frac{P_2}{\gamma} + z_2 + h_L$$

Power supplied TO pump:

$$\text{BHP} = \frac{\gamma Q H_p}{550 \eta} \quad [\text{FLT}^{-1}] \quad (\text{English units}) \quad [\text{hp}]$$

$$\text{BHP} = \frac{\gamma Q H_p}{\eta} \quad [\text{FLT}^{-1}] \quad (\text{metric units}) \quad [\text{Watts}]$$

Power supplied by pump:

$$\text{Power, } H_{\text{pump}} = \frac{\gamma Q H_p}{550} \quad \text{horsepower [hp] English Units}$$

$$\text{Power, } H_{\text{pump}} = \gamma Q H_p \quad \text{Watts [W] SI Units}$$

Pumps in Parallel

$$\text{Combined efficiency, } \eta = \frac{\frac{Q_A + Q_B}{\eta_A + \eta_B}}$$

Pumps in series

$$\text{Combined efficiency, } \eta = \frac{\frac{H_A + H_B}{\eta_A + \eta_B}}$$

Table 15.1 Roughness Values for Pipes

Pipe Material	Equivalent Roughness, ϵ (ft)	Hazen-Williams Coefficient, C
PVC, plastic	Smooth	140
Brass, copper, aluminum, glass	Smooth	140
Dawn tubing	5×10^{-6}	—
Cast iron		
new	8.0×10^{-4}	130
old		100
Galvanized iron/ductile pipe	5.0×10^{-4}	120
Asphalted iron	4.0×10^{-4}	—
Wrought iron	1.5×10^{-4}	—
Commercial and welded steel	1.5×10^{-4}	120
Wood stave	20.0×10^{-4}	120
Concrete	40.0×10^{-4}	130
Riveted steel	60.0×10^{-4}	110
Brick sewer	—	100

Table 15.3 Minor Head Loss Coefficients

Item	Loss Coefficient, K_m
Entrance from tank to pipe	
Flush connection	0.5
Projecting connection	0.8
Exit from pipe to tank	1.0
Sudden contraction ($h_m = K_m V_2^2 / 2g$)	
$d_2/d_1 = 0.2$	0.48
$d_2/d_1 = 0.4$	0.42
$d_2/d_1 = 0.6$	0.32
$d_2/d_1 = 0.8$	0.20
$d_2/d_1 = 0.9$	0.05
Sudden enlargement ($h_m = K_m V_1^2 / 2g$)	
$d_1/d_2 = 0.9$	0.04
$d_1/d_2 = 0.8$	0.13
$d_1/d_2 = 0.6$	0.41
$d_1/d_2 = 0.4$	0.71
$d_1/d_2 = 0.2$	0.92

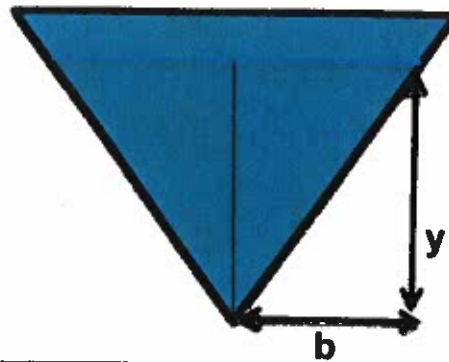
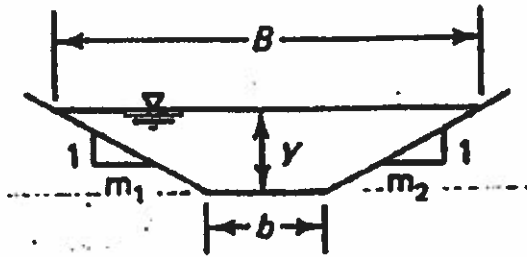
Note: Subscript 1 refers to upstream and 2 refers to downstream section.

Table 15.3 Minor Head Loss Coefficients

Item	Loss Coefficient, K_m
90° bend and 180° return—threaded	1.5
45° bend—threaded	0.4
90° bend and 180° return—flanged	0.3
45° bend—flanged	0.3
Tee—threaded	
through flow	0.9
branched flow	2.0
Tee—flanged	
through flow	0.2
branched flow	1.0
Gate valve (open)	0.19
Check valve (open)	2.0
Globe valve (open)	10.0
Angle valve (open)	2.0
Butterfly valve (open)	0.3

Note: Subscript 1 refers to upstream and 2 refers to downstream section.

Trapezoidal Channel



$$\text{Area, } A = by + \frac{1}{2}y^2(m_1 + m_2)$$

$$\text{Wetted Perimeter, } P = b + y(\sqrt{1 + m_1^2} + \sqrt{1 + m_2^2})$$

$$\text{Top Width, T or B} = b + y(m_1 + m_2)$$

$$\text{Hydraulic Radius, } R = \frac{A}{P} = \frac{by + \frac{1}{2}y^2(m_1 + m_2)}{b + y(\sqrt{1 + m_1^2} + \sqrt{1 + m_2^2})}$$

$$\text{Area, } A = by$$

$$\text{Wetted Perimeter, } P = 2\sqrt{b^2 + y^2}$$

$$\text{Top Width, T or B} = 2b$$

$$\text{Hydraulic Radius, } R = \frac{A}{P} = \frac{by}{2\sqrt{b^2 + y^2}}$$

$$\text{Hydraulic Depth, } D = \frac{A}{T} = \frac{by}{2b} = \frac{y}{2}$$

Manning's Equations:

$$\text{Velocity, } V \text{ [m/s]} = \frac{1}{n} R^{2/3} \sqrt{S} \quad \text{-(SI Units)}$$

$$\text{Velocity, } V \text{ [ft/s]} = \frac{1.486}{n} R^{2/3} \sqrt{S} \quad \text{-(English Units)}$$

Hazen-Williams Equations [Circular Pipes]:

English Units: Q [cfs], L [ft], D [ft], H_L [ft]

$$S = \frac{h_L}{L} = \frac{4.731}{C^{1.85} D^{4.87}} Q^{1.85}$$

$$Q = 0.432 C D^{2.63} S^{0.54}$$

Manning's Equations:

$$\text{Discharge, } Q \text{ [m}^3\text{/s]} = \frac{1}{n} A R^{2/3} \sqrt{S} \quad \text{-(SI Units)}$$

$$\text{Discharge, } Q \text{ [ft}^3\text{/s]} = \frac{1.486}{n} A R^{2/3} \sqrt{S} \quad \text{-(English Units)}$$

Hazen-Williams Equations [Circular Pipes]:

SI Units: Q [m³/s], L [m], D [m], H_L [m]

$$Q = 0.278 C D^{2.63} S^{0.54}$$

$$S = \frac{h_L}{L} = \frac{10.704}{C^{1.85} D^{4.87}} Q^{1.85}$$

$$\text{For critical flow, } Fr = \frac{V}{\sqrt{gD}}$$

$$\text{For critical flow, } V = \sqrt{gD}$$

$$\text{For critical flow, } Q = V \cdot A = A \sqrt{gD}$$

$$\text{For normal flow, } Z_n = AR^{2/3}$$

$$\text{For critical flow, } Z_c = A \sqrt{D}$$

Table 14.1 Geometric Elements for a Circular Section

$\frac{y}{d_0}$	$\frac{A}{d_0^2}$	$\frac{P_w}{d_0}$	$\frac{R}{d_0}$	$\frac{T}{d_0}$	$\frac{D}{d_0}$	$\frac{A\sqrt{D}}{d_0^{5/2}}$	$\frac{AR^{2/3}}{d_0^{8/3}}$
0.01	0.0013	0.2003	0.0066	0.1990	0.0066	0.0001	0.0000
0.05	0.0147	0.4510	0.0326	0.4359	0.0336	0.0027	0.0015
0.10	0.0409	0.6435	0.0635	0.6000	0.0682	0.0107	0.0065
0.15	0.0739	0.7954	0.0929	0.7141	0.1034	0.0238	0.0152
0.20	0.1118	0.9273	0.1206	0.8000	0.1398	0.0418	0.0273
0.25	0.1535	1.0472	0.1466	0.8660	0.1774	0.0646	0.0427
0.30	0.1982	1.1593	0.1709	0.9165	0.2162	0.0921	0.0610
0.35	0.2450	1.2661	0.1935	0.9539	0.2568	0.1241	0.0820
0.40	0.2934	1.3694	0.2142	0.9798	0.2994	0.1603	0.1050
0.45	0.3428	1.4706	0.2331	0.9950	0.3446	0.2011	0.1298
0.50	0.3927	1.5708	0.2500	1.0000	0.3928	0.2459	0.1558
0.55	0.4426	1.6710	0.2649	0.9950	0.4448	0.2949	0.1825
0.60	0.4920	1.7722	0.2776	0.9798	0.5022	0.3438	0.2092
0.65	0.5404	1.8755	0.2881	0.9539	0.5666	0.4066	0.2358
0.67	0.5594	1.9177	0.2917	0.9404	0.5948	0.4309	0.2460
0.70	0.5872	1.9823	0.2962	0.9165	0.6408	0.4694	0.2608
0.75	0.6318	2.0944	0.3017	0.8660	0.7296	0.5392	0.2840
0.80	0.6736	2.2143	0.3042	0.8000	0.8420	0.6177	0.3045
0.85	0.7115	2.3462	0.3033	0.7141	0.9964	0.7098	0.3212
0.90	0.7445	2.4981	0.2980	0.6000	1.2408	0.8285	0.3324
0.94 ^a	0.7662	2.6467	0.2896	0.4750	1.6130	0.9725	0.3353
0.95	0.7707	2.6906	0.2864	0.4359	1.7682	1.0242	0.3349
1.00	0.7854	3.1416	0.2500	0.0000	∞	∞	0.3117

^a Maximum flow occurs at 0.94 full depth.**Kirpich Formula [time of concentration]:**

$$t_c \text{ [minutes]} = \frac{0.0078L^{0.77}}{S^{0.385}}; L \text{ [ft] and } S \text{ [ft/ft]}$$

Intensity-Duration-Frequency equation:

$$\text{Rainfall Intensity, } i \text{ [in/hr]} = a(D + b)^c$$

Where: D = duration [hrs]

Where,

a, b and c are local parameters for a given return period, T in years;
D = rainfall duration in hours.

Rational Formula:

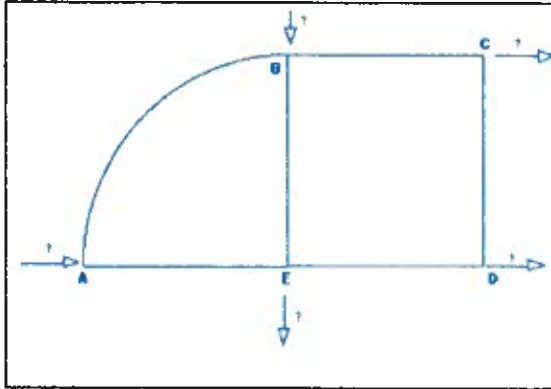
$$Q = CIA$$

C = Runoff coefficient

I = Rainfall Intensity (in/hr)

A = Area in Acres

1 [100]



Clockwise flows are POSITIVE

The table below provides data for the application of the Hardy Cross Method.

PROVIDE THE FLOWS FOR THE GRAY FIELDS ONLY (see problem b, below)

Final Flows after 9 iterations [Clockwise Flows are Positive]

Iteration	Loop	Pipeline	Len [ft]	diam [in]	K	Qa [cfs]	headloss, hf = kQa ² [ft]	hf/Q	Correction, δ [cfs]	Final Q [cfs]
1		AB	4000	12	1.8136	2.215	8.9145	4.0207	0.002	4018.7
		BE	2000	6	29.017	0.960	26.7617	27.8668	0.002	27.8668
		EA	1500	6	21.763	-1.285	-35.8213	27.9213	0.002	27.9213
							-0.145	59.8088		
9	Corrections		Loop 1		δ1 [cfs] =	0.002	Loop 2		δ2 [cfs] =	-0.004
2		BC	3000	8	10.329	1.757	31.8757	18.1451	-0.004	18.1451
		CD	2000	8	6.886	0.257	0.4538	1.7677	-0.004	1.7637
		DE	3000	8	10.329	-0.743	-5.7066	7.6775	-0.004	7.6735
		EB	2000	6	29.018					

a) [40] Complete the CORRECTION and Final Q (flows) columns for the table given (GRAY fields ONLY)

b) [20] Complete the highlighted fields in columns for headloss and |hf/Q| in the table given (light blue fields ONLY)

c) [40] With reference to the FINAL flows values:

Fill in ALL the flow values on the figure (AND please fill in the appropriate fields below).

Inflow at A = 59.8088 [cfs]

Inflow at B = 59.8088 [cfs]

Outflow (withdrawal) at C = [cfs]

Outflow (withdrawal) at D = [cfs]

Outflow (withdrawal) at E = [cfs]

These values are OUT OF RANGE

38

2 [100] Consider a pumping system in a pressurized flow.

For the given system, the specific weight of the liquid being pumped, $\gamma = 67.0 \text{ lb/ft}^3$. The graph shown provides the system and pump characteristics (performance) curves. There are multiple identical pumps (2) in the system. The right Y-axis is for the efficiency [%] of the pump.

Determine:

(a) [50] The operating point data for the combined system [complete]:

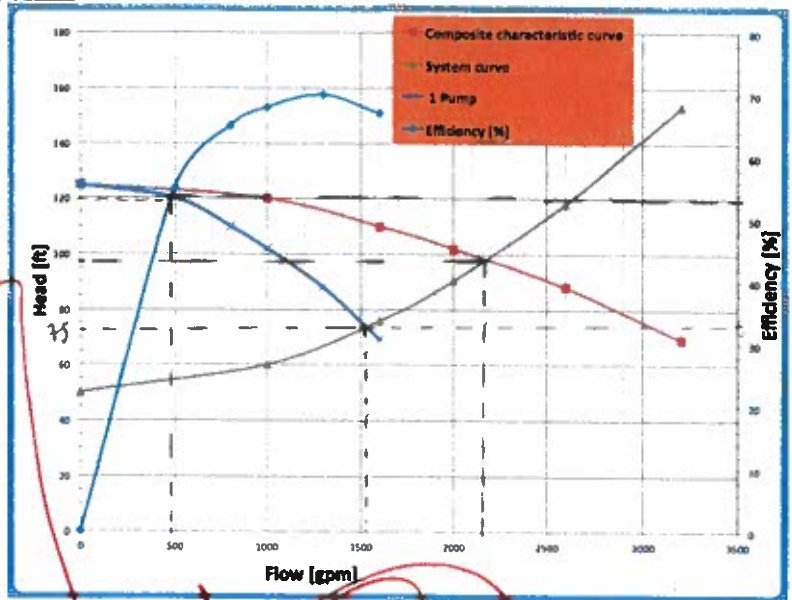
I) System Operating Head [ft] = 75 ft
(Show how you obtained it on the graph)

II) Operating system flowrate [gpm] = 1510 gpm
(Show how you obtained it on the graph)

III) Operating efficiency for 1 pump [%] = 53%
(Show how you obtained it on the graph)

IV) Operating Head for 1 pump [ft] = 120 ft
(Show how you obtained it on the graph)

V) Operating flowrate for 1 pump [gpm] = 490 gpm
(show how you obtained it on the graph)



(b) [15] What type of pump arrangement is in this system?

(Serial or parallel) [circle] arrangement and WHY? = parallel because

(c) [35] Calculate the power supplied by the pumping system [hp] to the flow
HINT: calculate the combined system efficiency first

$$\text{combined efficiency, } \eta = \frac{Q_A + Q_B}{\frac{Q_A}{\eta_A} + \frac{Q_B}{\eta_B}} = \frac{1510/449 + 490/449}{\frac{1510/449}{0.325} + \frac{490/449}{0.53}} = \frac{4.4}{12.1}$$

$$\eta = 0.359 \Rightarrow 35.9\%$$

$$\text{BHP} = \frac{\gamma Q H_P}{550 \eta} = \frac{67 \times 1510/449 \times 75}{550 \times 0.359}$$

$$\text{BHP} = 85.6 \text{ hp}$$

Power supplied by pumping system [hp] = 85.6 hp

Pumps are identical efficiency = overall efficiency

3 [100]

Suppose a circular channel with a diameter of 1.00 m is used to convey stormwater, at a depth of 0.45 m and Manning's roughness, $n = 0.013$ for the lining of the channel. Provide answers for the following questions.

[Hint: You may use Table 14.1 which has been provided. Do not interpolate, use the closest value - if appropriate]

(a) [20] What is the hydraulic radius [m] for the flow condition [m]?

Show all work.

$$d_o = 1 \text{ m}, y = 0.45 \text{ m} \quad \frac{y}{d_o} = 0.45 \Rightarrow \frac{R}{d_o} = 0.2331 \Rightarrow R = 0.2331 \times 1$$

$$R = 0.2331 \text{ m}$$

$$\text{Hydraulic Radius [m]} = 0.2331 \text{ m}$$

(b) [25] What is the discharge [m^3/s] if the channel slope is 5%

$$S = 5\% = 0.05$$

$$Q = \frac{1}{n} A R^{2/3} \sqrt{S}$$

$$\frac{A}{d_o^2} = 0.3428 \Rightarrow A = d_o^2 \times 0.3428 \Rightarrow A = 1^2 \times 0.3428 = 0.3428 \text{ m}^2$$

$$Q = \frac{1}{0.013} \times 0.3428 \times 0.2331^{2/3} \sqrt{0.05}$$

$$\text{Discharge of flow [m}^3/\text{s]} = 2.23 \text{ m}^3/\text{s}$$

(c) [25] What is the hydraulic depth [m] for the flow?

$$D = \frac{A}{T} \quad \frac{y}{d_o} = 0.45 \Rightarrow \frac{T}{d_o} = 0.9950 \Rightarrow T = 0.9950 \times 1$$

$$D = \frac{0.3428 \text{ m}^2}{0.9950 \text{ m}} = 0.3445 \text{ m}$$

$$\text{Hydraulic Depth of flow [m]} = D = 0.3445 \text{ m}$$

(d) [30] What is the Froude Number [] for the flow?

$$Fr = \frac{V}{\sqrt{gD}} \quad V = \sqrt{gD} \Rightarrow V = \sqrt{9.81 \times 0.3445}$$

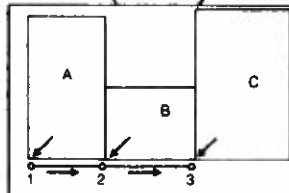
$$V = 1.84 \text{ m/s}$$

$$Fr = \frac{1.84 \text{ m/s}}{\sqrt{9.81 \times 0.3445}} = 1$$

$$\text{Froude Number of flow []} = 1$$

Problem 4 [100]

You have been hired by local H&H firm, **AlHydrologicsMax**, to design the drainage system for the area below in Watershed, TX. The IDF (Intensity Duration Frequency) curve parameters are: **A = 212** and **B = 20** for a return period of 15 years.



$$\text{Rainfall intensity, } i \text{ [in/hr]} = \frac{A}{t+B}$$

Where t is the rainfall duration in minutes. The minimum time of concentration (due to Watershed, TX ordinance) is 15 minutes.

The velocity of flow in the pipes (manhole to manhole in the sewer system) is given in the second table below and the other data for watershed are given in the first table. Your primary goal is to calculate the peak flowrate [cfs] from sections A, B, and C for the 15-year design rainfall. Use the Rational Method.

Data for the watershed

SECTION	C Value	Length [ft]	Slope [%]	Area [ac]	Inlet Travel time [min]	% of total area [%]
A	0.5	2000	4	400	2.4	28.57
B	0.4	1200	6	250	1.5	17.86
C	0.7	4500	2	750	4.78	53.57
Total Area				1400		

$$T_c = \frac{0.0078L^{0.77}}{S^{0.085}}$$

Provide sample calculations for the first row at the right of above table

Data for the sewer system

Manhole Segment	Length [ft]	Velocity	Travel time [min]
1-2	250	2.5	
2-3	350	3.5	

Provide sample calculations for the first row at the right of above table

- a) [45] Calculate the time of concentration (using manhole 3 as the reference point or outlet) by completing the table below and portions of the 2 tables above.

Complete the table below

Travel Path [Inlet-Man#1-Man#2...Outlet]	Time of travel [min]
A-1-2-3	

Provide sample calculation for the first row below and complete the rest of the table

Time of concentration, t_c [minutes] =

- b) [20] Design Rainfall intensity, i (Use IDF formula provided)

$$i = \frac{A}{(t+B)^C} = \frac{212}{(20+20)^{0.77}}$$

Design Rainfall intensity, i [in/hr] =

- c) [15] Composite Runoff Coefficient, C

Runoff Coefficient [2 decimal places], $C =$

- d) [20] The peak runoff for ABC (Using Rational Formula)

Watershed ABCD Peak runoff [cfs] =

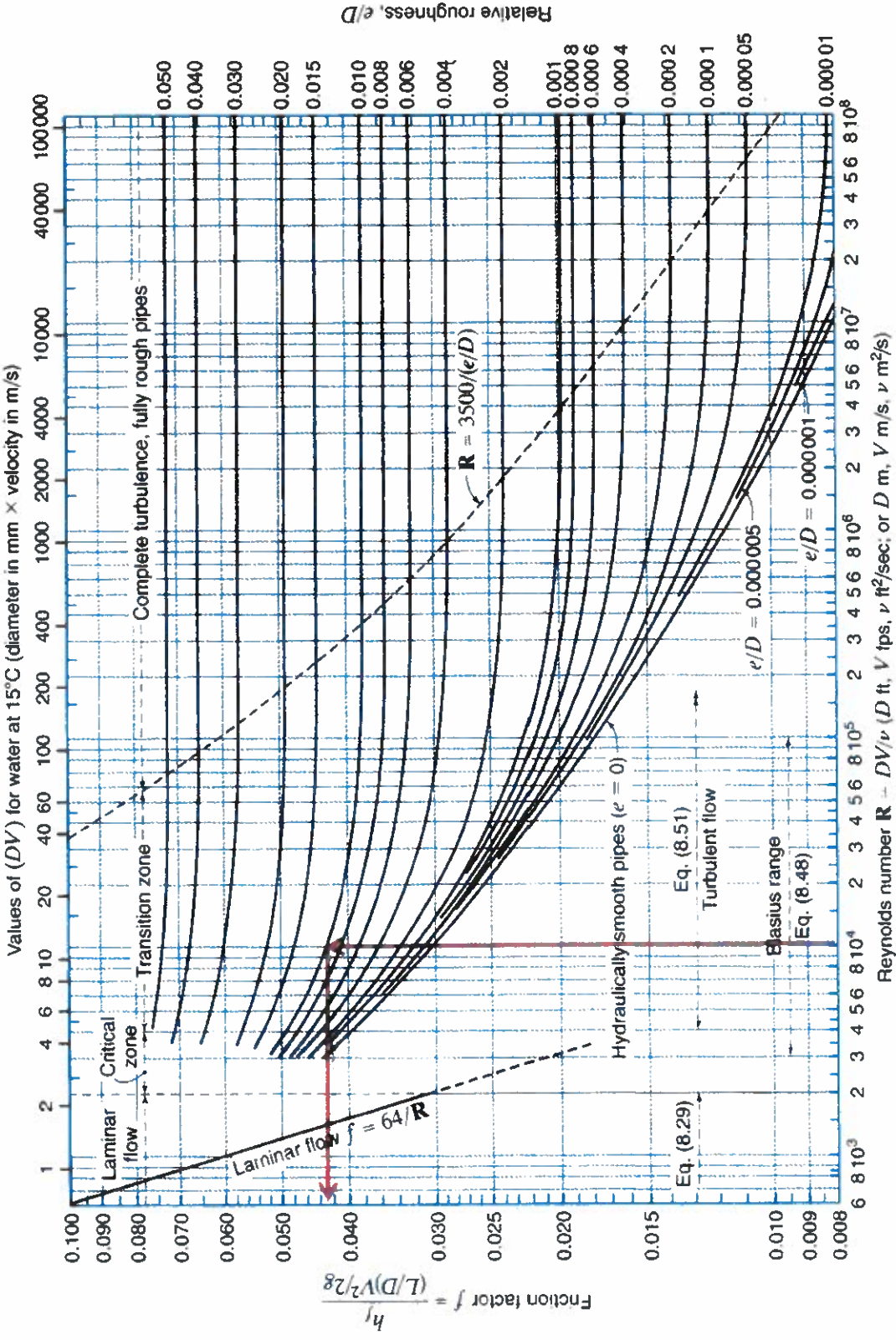
Properties of Water

Temperature (°C)	Density ρ (kg/m ³)	Specific Weight γ (N/m ³)	Viscosity μ (N·s/m ²)	Kinematic viscosity ν (m ² /s)	Bulk modulus B (Pa)	Surface Tension σ (N/m)	Vapor Pressure (kPa)
0	999.9	9809	1.792×10^{-3}	1.792×10^{-6}	204×10^7	7.62×10^{-2}	0.610
5	1000.0	9810	1.519	1.519	206	7.54	0.872
10	999.7	9807	1.308	1.308	211	7.48	1.13
15	999.1	9801	1.140	1.141	214	7.41	1.60
20	998.2	9792	1.005	1.007	220	7.36	2.34
30	995.7	9768	0.801	0.804	223	7.18	4.24
40	992.2	9733	0.656	0.661	227	7.01	7.38
50	988.1	9693	0.549	0.556	230	6.82	12.3
60	983.2	9645	0.469	0.477	228	6.68	19.9
70	977.8	9592	0.406	0.415	225	6.50	31.2
80	971.8	9533	0.357	0.367	221	6.30	47.3
90	965.3	9470	0.317	0.328	216	6.12	70.1
100	958.4	9402	0.284×10^{-3}	0.296×10^{-6}	207×10^7	5.94×10^{-2}	101.3

PROPERTIES OF WATER (ENGLISH UNITS)

Temperature (°F)	Specific Weight γ (lb/ft ³)	Mass Density ρ (lb • sec ² /ft ⁴)	Absolute Dynamic Viscosity μ ($\times 10^{-5}$ lb • sec/ft ²)	Kinematic Viscosity ν ($\times 10^{-5}$ ft ² /sec)	Vapor Pressure p_v (psi)
32	62.42	1.940	3.746	1.931	0.09
40	62.43	1.940	3.229	1.664	0.12
50	62.41	1.940	2.735	1.410	0.18
60	62.37	1.938	2.359	1.217	0.26
70	62.30	1.936	2.050	1.059	0.36
80	62.22	1.934	1.799	0.930	0.51
90	62.11	1.931	1.595	0.826	0.70
100	62.00	1.927	1.424	0.739	0.95
110	61.86	1.923	1.284	0.667	1.24
120	61.71	1.918	1.168	0.609	1.69
130	61.55	1.913	1.069	0.558	2.22
140	61.38	1.908	0.981	0.514	2.89
150	61.20	1.902	0.905	0.476	3.72
160	61.00	1.896	0.838	0.442	4.74
170	60.80	1.890	0.780	0.413	5.99
180	60.58	1.883	0.726	0.385	7.51
190	60.36	1.876	0.678	0.362	9.34
200	60.12	1.868	0.637	0.341	11.52
212	59.83	1.860	0.593	0.319	14.70

Moody Diagram – friction factor, f



(Note: If $e/D = 0.01$ and $Re = 10^4$, the left arrow locates $f = 0.043$.)

CVEG 4303
WATER RESOURCES ENGINEERING
SPRING 2022

Title of Assignment: Final Exam

TOPICS COVERED in Final Exam

Final Exam covered the following topics:

1. Detention/retention ponds: purposes and function
2. Determination of equivalent pipe length for pipes arranged in series
3. Determination of system head curve **equation** for a pumping system
4. Application of hydraulic elements of circular pipes table to determine flow parameters in a circular open channel: depth of flow and hydraulic depth, etc
5. Implementation of Rational Method: determination of time of concentration, average Runoff Coefficient (non-homogeneous watershed), design Rainfall Intensity and peak flowrate
6. Basic open channel flow computations: flowrate, velocity
7. Forces and moments of a concrete dam section
8. Application of Hardy Cross method to determine flow correction in one iteration
9. Simple looped pipe systems: application of continuity and energy conservation
10. Determination of head provided by a pump in a piping system: Energy equation

ABOVE
AVERAGE



CVEG 4303-P01

Dr. Nzewi

Department of Civil & Environmental Engineering

Water Resources Engineering

Spring 2022

FINAL EXAM

Tuesday, May 10, 2022, 01:30 – 3:20 PM: SR Collins 205

Submit the entire exam the order given

Name [PRINT] Alyssa Reynolds

In all the problems you must provide enough details and description of the solution method to demonstrate your knowledge of the solution method. A substantial portion of the grade will be based on your methods.

525

600

All necessary equations are provided except for elementary relationships you are expected to master. This is a **CLOSED** book exam. Please **turn off all cell phones and mp3 players** and **place them in your book bag in front of the class**. Also put away ANY **disallowed** calculators.

Calculator POLICY (allowed calculators)

- **Casio:** All fx-115 and fx-991 models (Any Casio calculator must have "fx-115" or "fx-991" in its model name.)
- **Hewlett Packard:** The HP 33s and HP 35s models, but no others
- **Texas Instruments:** All TI-30X and TI-36X models (Any Texas Instruments calculator must have "TI-30X" or "TI-36X" in its model name.)

- 1) All cellphones/smartwatches **MUST** be placed in your book bag during exams and turned off. Book bags **MUST** be placed in front of the classroom and away from students. Students without a book bag must place cellphone/smartwatch (turned off) on Instructor's desk.
- 2) Any student possessing a cellphone/smartwatch or any other unauthorized device **WILL** receive an automatic zero for the test/assignment. Such action will be cheating.
- 3) **CLOTHING:** Hoodies are **NOT** Allowed during exams. No headphones (corded or wireless) are **ALLOWED**.
- 4) **Calculator covers are DISALLOWED** during tests and must be placed in students' book bags during exams.
- 5) There shall be **NO SHARING** of resources during the exam. Writing space will be provided in the test.
- 6) **RESTROOM VISIT:** if you need to use the restroom, **do so before opening the exam**. Once the exam begins, you must submit your work to the instructor if you leave the classroom to visit the rest room (your exam terminates).
- 7) You have **110 minutes** to complete the exam. Please turn in your work on time.
- 8) Provide enough detail for each problem you solve. You earn points based on the details you provide.
- 9) Please work independently.
- 10) You are required to solve **ALL** problems.

Dishonesty or failure to adhere to instructions will result in a grade of ZERO (0.0)

I pledge to abide by all the rules stated for this Exam

Signature: *Alyssa Reynolds*

Date: 05/10/2022

NAME [PRINT, Lastname, firstname]: Reynolds, Alyssa

REFERENCE VALUES AND FORMULAS [Unless otherwise stated or implied, assume the following]

Density of water = 1000 kg/m^3 ($= 1.94 \text{ slugs/ft}^3$) [at 4°C]
 Specific weight of water = 9810 N/m^3 ($= 62.4 \text{ lb/ft}^3$) and at 4°C
 Gravitational Acceleration, $g = 9.81 \text{ m/s}^2$ ($= 32.2 \text{ ft/s}^2$)
 Standard atmospheric pressure = 101.3 kPa ($= 2117 \text{ psf} = 14.7 \text{ psi}$)
 Gas constant for air, $R = 287 \text{ J/kg}\cdot\text{K} = 1716 \text{ ft}\cdot\text{lb/slug}\cdot^\circ\text{R}$
 $T [\text{K}] = t [^\circ\text{C}] + 273.15$
 $T [^\circ\text{R}] = t [^\circ\text{F}] + 459.67$
 $1 \text{ Btu} = 778 \text{ ft}\cdot\text{lb}$
 $1 \text{ hp} = 745.7 \text{ W} = 550 \text{ ft}\cdot\text{lb/s}$
 $1 \text{ m} = 100 \text{ cm}$

$1 \text{ mile} = 5280 \text{ feet}$
 $1 \text{ mile} = 1760 \text{ yards}$
 $1 \text{ acre} = 43560 \text{ ft}^2$
 $1 \text{ mi}^2 = 640 \text{ acres}$
 $1 \text{ ft} = 0.3048 \text{ m}$
 $1 \text{ slug} = 14.59 \text{ kg}$
 $1 \text{ lb} = 4.448 \text{ N}$
 $1 \text{ Pa} = 1.0 \text{ N/m}^2$
 $1 \text{ ft}^3 = 7.481 \text{ gal}$
 $25.4 \text{ mm} = 1.0 \text{ in}$
 $1 \text{ liter} = 1000 \text{ cm}^3$
 $1 \text{ m}^3 = 1000 \text{ liter}$

Forces on submerged surfaces:

$$F = \gamma \bar{h} A$$

Location of Center of pressure, $y_p = \bar{y} + \frac{I_{xx}}{A \bar{y}}$

Moment of Inertia for a rectangular shape:

$$I_{xx} = \frac{b l^3}{12}$$

Buoyant Force:

$$F_B = \gamma (\text{displaced volume})$$

Metacentric Height:

$$GM = \frac{I_{xx}}{V} - CG$$

Reynolds Number:

$$Re = \frac{VD}{\nu} = \frac{\rho V D}{\mu}$$

Swamee & Jain and other f Equations:

Swamee & Jain (1976) [error about 1% from Colebrook equation]

$$f = \frac{1.325}{\left\{ \ln \left[0.27 \frac{\epsilon}{D} + \frac{5.74}{Re^{0.9}} \right] \right\}^2} \text{ for } 10^{-6} \leq \frac{\epsilon}{D} \leq 10^{-2} \text{ and } 5000 \leq Re \leq 10^8$$

Haaland (1983) [error about 1.5% from Colebrook equation]

$$f = \frac{1}{\left\{ -1.8 \log \left[\left(\frac{0.27\epsilon}{D} \right)^{1.1} + \frac{6.9}{Re} \right] \right\}^2} \text{ for } 4000 \leq Re \leq 10^8$$

Fully Rough/turbulent Flow:

$$f = \frac{1}{\left[2 \log \left(\frac{3.7D}{\epsilon} \right) \right]^2}$$

Smooth Pipe flow for Hydraulically smooth pipes:

Blasius Equation: $f = \frac{0.316}{Re^{0.25}}$ for $4000 \leq Re \leq 10^5$

Colebrook's Approximation: $f \approx \frac{1}{\left[1.8 \log \left(\frac{Re}{6.9} \right) \right]^2}$ for $4000 \leq Re \leq 10^5$

Darcy-Weisbach Equation for friction headloss:

$$h_f = \frac{fL}{D} \frac{V^2}{2g}$$

Minor headloss Equation:

$$h_m = \sum K \frac{V^2}{2g}; \text{ Where } K = \text{loss coefficient}$$

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2$$

$$H_P + \frac{V_1^2}{2g} + \frac{P_1}{\gamma} + z_1 = H_T + \frac{V_2^2}{2g} + \frac{P_2}{\gamma} + z_2 + h_L$$

Power supplied TO pump:

$$\text{BHP} = \frac{\gamma Q H_p}{550 \eta} \quad [\text{FLT}^{-1}] \quad (\text{English units}) \quad [\text{hp}]$$

$$\text{BHP} = \frac{\gamma Q H_p}{\eta} \quad [\text{FLT}^{-1}] \quad (\text{metric units}) \quad [\text{Watts}]$$

Power supplied by pump:

$$\text{Power}, H_{\text{pump}} = \frac{\gamma Q H_p}{550} \text{ horsepower [hp] English Units}$$

$$\text{Power}, H_{\text{pump}} = \gamma Q H_p \text{ Watts [W] SI Units}$$

Pumps in Parallel

$$\text{Combined efficiency, } \eta = \frac{\frac{Q_A + Q_B}{\frac{Q_A}{\eta_A} + \frac{Q_B}{\eta_B}}}$$

Pumps in series

$$\text{Combined efficiency, } \eta = \frac{\frac{H_A + H_B}{\frac{H_A}{\eta_A} + \frac{H_B}{\eta_B}}}$$

Hardy Cross Method: flow correction for EACH loop in an iteration:

$$\delta = \frac{-\sum K Q_a^n}{n \sum |K Q_a^{n-1}|} = \frac{-\sum h_f}{n \sum \left| \frac{h_f}{Q} \right|}$$

Table 15.1 Roughness Values for Pipes

Pipe Material	Equivalent Roughness, ϵ (ft)	Hazen-Williams Coefficient, C
PVC, plastic	Smooth	140
Brass, copper, aluminum, glass	Smooth	140
Dawn tubing	5×10^{-6}	—
Cast iron		
new	8.0×10^{-4}	130
old		100
Galvanized iron/ductile pipe	5.0×10^{-4}	120
Asphalted iron	4.0×10^{-4}	—
Wrought iron	1.5×10^{-4}	—
Commercial and welded steel	1.5×10^{-4}	120
Wood stave	20.0×10^{-4}	120
Concrete	40.0×10^{-4}	130
Riveted steel	60.0×10^{-4}	110
Brick sewer	—	100

Table 15.3 Minor Head Loss Coefficients

Item	Loss Coefficient, K_m
Entrance from tank to pipe	
Flush connection	0.5
Projecting connection	0.8
Exit from pipe to tank	1.0
Sudden contraction ($h_m = K_m V_2^2 / 2g$)	
$d_2/d_1 = 0.2$	0.48
$d_2/d_1 = 0.4$	0.42
$d_2/d_1 = 0.6$	0.32
$d_2/d_1 = 0.8$	0.20
$d_2/d_1 = 0.9$	0.05
Sudden enlargement ($h_m = K_m V_1^2 / 2g$)	
$d_1/d_2 = 0.9$	0.04
$d_1/d_2 = 0.8$	0.13
$d_1/d_2 = 0.6$	0.41
$d_1/d_2 = 0.4$	0.71
$d_1/d_2 = 0.2$	0.92

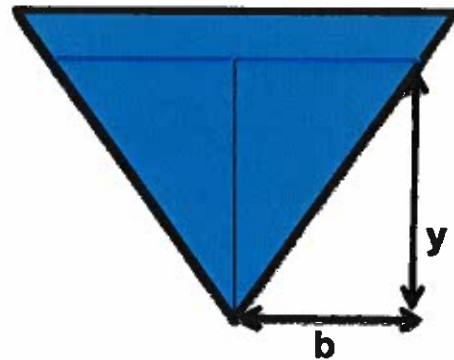
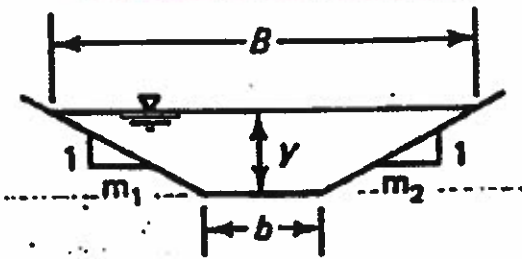
Note: Subscript 1 refers to upstream and 2 refers to downstream section.

Table 15.3 Minor Head Loss Coefficients

Item	Loss Coefficient, K_m
90° bend and 180° return—threaded	1.5
45° bend—threaded	0.4
90° bend and 180° return—flanged	0.3
45° bend—flanged	0.3
Tee—threaded	
through flow	0.9
branched flow	2.0
Tee—flanged	
through flow	0.2
branched flow	1.0
Gate valve (open)	0.19
Check valve (open)	2.0
Globe valve (open)	10.0
Angle valve (open)	2.0
Butterfly valve (open)	0.3

Note: Subscript 1 refers to upstream and 2 refers to downstream section.

Trapezoidal Channel



$$\text{Area, } A = by + \frac{1}{2}y^2(m_1 + m_2)$$

$$\text{Wetted Perimeter, } P = b + y(\sqrt{1+m_1^2} + \sqrt{1+m_2^2})$$

$$\text{Top Width, } T \text{ or } B = b + y(m_1 + m_2)$$

$$\text{Hydraulic Radius, } R = \frac{A}{P} = \frac{by + \frac{1}{2}y^2(m_1 + m_2)}{b + y(\sqrt{1+m_1^2} + \sqrt{1+m_2^2})}$$

$$\text{Area, } A = by$$

$$\text{Wetted Perimeter, } P = 2\sqrt{b^2 + y^2}$$

$$\text{Top Width, } T \text{ or } B = 2b$$

$$\text{Hydraulic Radius, } R = \frac{A}{P} = \frac{by}{2\sqrt{b^2 + y^2}}$$

$$\text{Hydraulic Depth, } D = \frac{A}{T} = \frac{by}{2b} = \frac{y}{2}$$

Manning's Equations:

$$\text{Velocity, } V \text{ [m/s]} = \frac{1}{n} R^{2/3} \sqrt{S} \quad \text{-(SI Units)}$$

$$\text{Velocity, } V \text{ [ft/s]} = \frac{1.486}{n} R^{2/3} \sqrt{S} \quad \text{-(English Units)}$$

Hazen-Williams Equations [Circular Pipes]:

English Units: Q [cfs], L [ft], D [ft], H_L [ft]

$$S = \frac{h_L}{L} = \frac{4.731}{C^{1.85} D^{4.87}} Q^{1.85}$$

$$Q = 0.432 C D^{2.63} S^{0.54}$$

Manning's Equations:

$$\text{Discharge, } Q \text{ [m}^3\text{/s]} = \frac{1}{n} A R^{2/3} \sqrt{S} \quad \text{-(SI Units)}$$

$$\text{Discharge, } Q \text{ [ft}^3\text{/s]} = \frac{1.486}{n} A R^{2/3} \sqrt{S} \quad \text{-(English Units)}$$

Hazen-Williams Equations [Circular Pipes]:

SI Units: Q [m³/s], L [m], D [m], H_L [m]

$$Q = 0.278 C D^{2.63} S^{0.54}$$

$$S = \frac{h_L}{L} = \frac{10.704}{C^{1.85} D^{4.87}} Q^{1.85}$$

$$\text{For critical flow, } Fr = \frac{V}{\sqrt{gD}}$$

$$\text{For critical flow, } V = \sqrt{gD}$$

$$\text{For critical flow, } Q = V \cdot A = A \sqrt{gD}$$

$$\text{For normal flow, } Z_n = AR^{2/3}$$

$$\text{For critical flow, } Z_c = A \sqrt{D}$$

$$\text{Froude Number} = \frac{V}{\sqrt{gD}}$$

$$Z_c = A \sqrt{D} = \frac{Q}{\sqrt{g}}$$

Table 14.1 Geometric Elements for a Circular Section

$\frac{y}{d_0}$	$\frac{A}{d_0^2}$	$\frac{P_w}{d_0}$	$\frac{R}{d_0}$	$\frac{T}{d_0}$	$\frac{D}{d_0}$	$\frac{A\sqrt{D}}{d_0^{5/2}}$	$\frac{AR^{2/3}}{d_0^{8/3}}$
0.01	0.0013	0.2003	0.0066	0.1990	0.0066	0.0001	0.0000
0.05	0.0147	0.4510	0.0326	0.4359	0.0336	0.0027	0.0015
0.10	0.0409	0.6435	0.0635	0.6000	0.0682	0.0107	0.0065
0.15	0.0739	0.7954	0.0929	0.7141	0.1034	0.0238	0.0152
0.20	0.1118	0.9273	0.1206	0.8000	0.1398	0.0418	0.0273
0.25	0.1535	1.0472	0.1466	0.8660	0.1774	0.0646	0.0427
0.30	0.1982	1.1593	0.1709	0.9165	0.2162	0.0921	0.0610
0.35	0.2450	1.2661	0.1935	0.9539	0.2568	0.1241	0.0820
0.40	0.2934	1.3694	0.2142	0.9798	0.2994	0.1603	0.1050
0.45	0.3428	1.4706	0.2331	0.9950	0.3446	0.2011	0.1298
0.50	0.3927	1.5708	0.2500	1.0000	0.3928	0.2459	0.1558
0.55	0.4426	1.6710	0.2649	0.9950	0.4448	0.2949	0.1825
0.60	0.4920	1.7722	0.2776	0.9798	0.5022	0.3438	0.2092
0.65	0.5404	1.8755	0.2881	0.9539	0.5666	0.4066	0.2358
0.67	0.5594	1.9177	0.2917	0.9404	0.5948	0.4309	0.2460
0.70	0.5872	1.9823	0.2962	0.9165	0.6408	0.4694	0.2608
0.75	0.6318	2.0944	0.3017	0.8660	0.7296	0.5392	0.2840
0.80	0.6736	2.2143	0.3042	0.8000	0.8420	0.6177	0.3045
0.85	0.7115	2.3462	0.3033	0.7141	0.9964	0.7098	0.3212
0.90	0.7445	2.4981	0.2980	0.6000	1.2408	0.8285	0.3324
0.94 ^a	0.7662	2.6467	0.2896	0.4750	1.6130	0.9725	0.3353
0.95	0.7707	2.6906	0.2864	0.4359	1.7682	1.0242	0.3349
1.00	0.7854	3.1416	0.2500	0.0000	∞	∞	0.3117

^a Maximum flow occurs at 0.94 full depth.

Kirpich Formula [time of concentration]:

$$t_c [\text{minutes}] = \frac{0.0078L^{0.77}}{S^{0.385}}; L [\text{ft}] \text{ and } S [\text{ft/ft}]$$

Intensity-Duration-Frequency equation:

$$\text{Rainfall Intensity, } i [\text{in/hr}] = a(D + b)^c$$

Where: D = duration [hrs]

Where,

a, b and c are local parameters for a given return period, T in years;
D = rainfall duration in hours.

Rational Formula:

$$Q = CIA$$

C = Runoff coefficient

I = Rainfall Intensity (in/hr)

A = Area in Acres

1 [100]

Two pipes, a 220 mm (300 m long) cast iron pipe and a 600 mm (1000 m long) new cast iron pipe ($C=120$), are arranged in series in a water distribution system and the total headloss is limited to 30 m. Using the Hazen-Williams equation, determine the discharge [m^3/s] through the system. Assume that specific weight of water = 9810 N/m^3 .

Perform the necessary calculations to determine the length of the **equivalent 300 mm older cast iron pipe ($C=105$)** for the system.

Assume a flow of $0.10 \text{ m}^3/\text{s}$ in your calculations for the equivalent pipe as provided in the table below.

Pipe	C	Dia [mm]	Dia [m]	Q [m^3/s]	$S = H_L/L$ []	Pipe Length [m]	Headloss, $H_L = S \cdot L$ [m]
1	120	220	0.22	0.100	0.0343	300	10.29
2	120	600	0.60	0.100	0.0003	600	0.18
EQV	105	300	0.30	0.100	0.0097	1079.4	10.47
						$\uparrow$ LE	

(a) [40] Determine the equivalent length of 300 mm pipe, older cast iron ($C=105$). -NO ADDING

$$\frac{10.47}{0.0097} = \frac{0.0097 L}{0.0097}$$

$$L = 1079.4 \text{ m}$$

(b) [35] Discharge in the system [m^3/s]; Length of 300 mm pipe [m] = 1079.4

$$Q = 0.278 C D^{2.63} S^{0.54} = 0.278 (105) (0.3)^{2.63} (0.028)^{0.54} = 0.034$$

$$S = \frac{30}{L_E} = \frac{30}{1079.4} = 0.028$$

$$\text{Discharge } [\text{m}^3/\text{s}] = 0.034$$

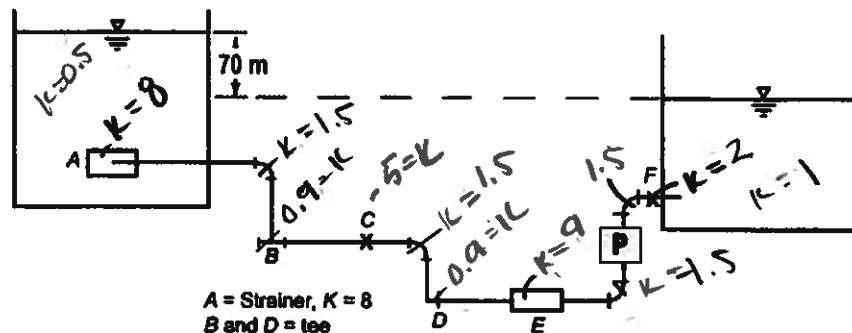
(c) [25]

What are the primary purposes of detention/retention basins. Provide at least 2. Be specific in your answer.

Detention/Retention basins have various purposes: the first is to prevent flooding in an area by diverting path water travels. The second is to store water in a collection area where it can be better controlled such as controlling how much water travels into a particular area.

2. [100] For fully rough turbulent flow.

Water is pumped by a pump (P) from right to left in the system shown below through a 400-mm, 100 m galvanized iron pipe ($\epsilon = 0.16$ mm), as shown in the figure. In order to calculate the minor losses, assume the following in the figure below: C is a gate valve, $K=5$; E is a meter, $K=9$; F is a check valve (open). The elbows in the system are 90° threaded elbows and the tees are threaded (through flow). The water surface elevation difference is 70 m. The water surface elevation difference is 70 m.



$$\begin{aligned} \sum K &= 0.5 + 8 + 1.5 \\ &+ 0.9 + 5 + 0.9 + 1.5 \\ &+ 9 + 1.5 + 1.5 + 2 \\ &+ 1 \\ &= 33.3 \end{aligned}$$

(a) [25] Assuming the flow is fully rough turbulent flow, determine the friction factor for the flow using an appropriate Friction Factor equation. Provide your answer to 4 decimal places.

$$f = \left[\frac{1}{2.1 \log \left(\frac{3.7(400)}{0.16} \right)} \right]^2 = 0.01589$$

Friction factor for the pipe flow [] = 0.01589

(b) [25] Determine the total (sum) of the minor headloss coefficients for the system. Show all work and justify your answer fully.

$$\begin{aligned} \sum K &= 0.5 + 8 + 1.5 + 0.9 + 5 + 1.5 + 0.9 + 9 + 1.5 + 2 + 1 = 33.3 \\ &\text{(entrance) + strainer + bend + tee + valve + bend + tee + meter + bend} \\ &+ \text{bend + check valve + exit.} \end{aligned}$$

Total (sum) of minor headloss coefficients [] = 33.3

(c) [35] Develop the relationship between the head [m] of the pump (H_p) and the flowrate (Q) in the system. This is the equation of the system head curve. [Hints: $V = Q/A$; the equation is based on the Energy Equation]

$$\begin{aligned} H_p + \frac{V_1^2}{2g} + \frac{P_1}{\gamma} + z_1 &= \frac{V_2^2}{2g} + \frac{P_2}{\gamma} + z_2 + h_L \\ H_p &= \Delta z + h_L + \frac{Q^2}{0.1962} \\ &= 70 + \frac{Q^2}{0.1962} (1.778 + 0.051) \\ h_L &= h_f + h_m \\ h_f &= \frac{0.01589(100\text{ m})}{19.62} \times \left(\frac{Q}{A} \right)^2 \\ h_m &= \frac{33.3(Q)^2}{19.62 A^2} \\ h_L &= \left(\frac{Q}{A} \right)^2 (1.778) \end{aligned}$$

System head curve equation, $H_p = 70 + 7.23Q^2$

(d) [15] If the flowrate (Q) is 1250 liters per second, what is the HEAD ON THE PUMP [m]? Justify your answer fully.

$$\begin{aligned} \frac{1250 \text{ L}}{\text{s}} \times \frac{1 \text{ m}^3}{1000 \text{ L}} &= 1.25 \text{ m}^3/\text{s} \\ H_p &= 70 + (7.23)(1.25)^2 = 81.29 \text{ m} \end{aligned}$$

H_p [m] = 81.29

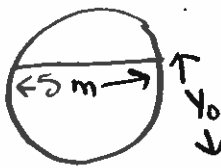
3 [100]

$$Q = VLA$$

$$V = 4.89 \text{ m/s}$$

- (a) [40] A circular channel ($n = 0.014$) with a diameter of 5.00 m is used to convey a discharge of 96 m³/s, determine the **normal depth of flow** if the channel slope is 5%.

[Hint: You may use Table 14.1 which has been provided. Do not interpolate, use the closest value – as appropriate]



$$S = 5/100 = 0.05$$

$$n = 0.014$$

$$\frac{y}{d_0} = \frac{y}{5} = 0.3$$

$$5(0.3) = 1.5$$

find $\frac{zn}{Q_0^{8/3}}$

$$Q = 96 \text{ m}^3/\text{s}$$

$$V = \frac{1}{n} R^{2/3} \sqrt{S}$$

$$4.89 = \frac{1}{0.014} (R^{2/3}) \sqrt{0.05}$$

$$R = 0.169$$

R is not known

Normal Depth of flow [m] =

- (b) [20] What is the area of flow for the flow condition in part (a) [m²]? Show all work.

[Hint: Again, Table 14.1 may be useful.]

$$\frac{A}{d_0^2} = 0.1982$$

$$25(0.1982) = 4.96$$

Area of flow [m²] =

- (c) [20] What is the hydraulic depth [m] for the flow?

$$D = \frac{A}{T} = \frac{4.96}{4.58} = 1.08$$

$$D = \frac{P}{d_0} = 0.2162(5) = 1.081$$

$$\frac{T}{d_0} = 0.9165 \quad T = 4.58$$

Hydraulic Depth of flow [m] =

- (d) [20] What is the Froude Number [] for the flow?

$$Fr = \frac{V}{\sqrt{gD}} = \frac{4.89}{\sqrt{9.81 \times 1.08}} = 1.5$$

Froude Number of flow [] =

1.5 : flow is supercritical since $Fr > 1$.

4 [100]

A channel with a right triangular section as shown carries a flow of $20 \text{ m}^3/\text{s}$. The velocity of flow = 2 m/s .

(a) [20] Determine the depth of flow, y .

$Q = V(A)$
 $\frac{20}{2} = 10 \text{ m}^2 = A$
 $\text{Depth} = \frac{A}{T} = \frac{y}{2}$
 $T = 2b = 4y$
 $A = b(y) = 2y^2 = 10 \text{ m}^2 \rightarrow \sqrt{\frac{10}{2}} = y = 2.24$
 $\frac{10}{8.96} = 1.116$
 $\frac{y}{2} = \frac{2.24}{2} = 1.12$
 Depth of flow, y [m] 2.24

(b) [25] What is the Froude number, Fr , for this flow?

$D = \frac{A}{T} = \frac{10}{8.96} = 1.116$
 $Fr = \frac{V}{\sqrt{gD}} = \frac{2}{\sqrt{9.81 \times 1.116}} = 0.604$
 Froude Number, Fr [] 0.604
 - Sub critical since $Fr < 0.604$
 one #5

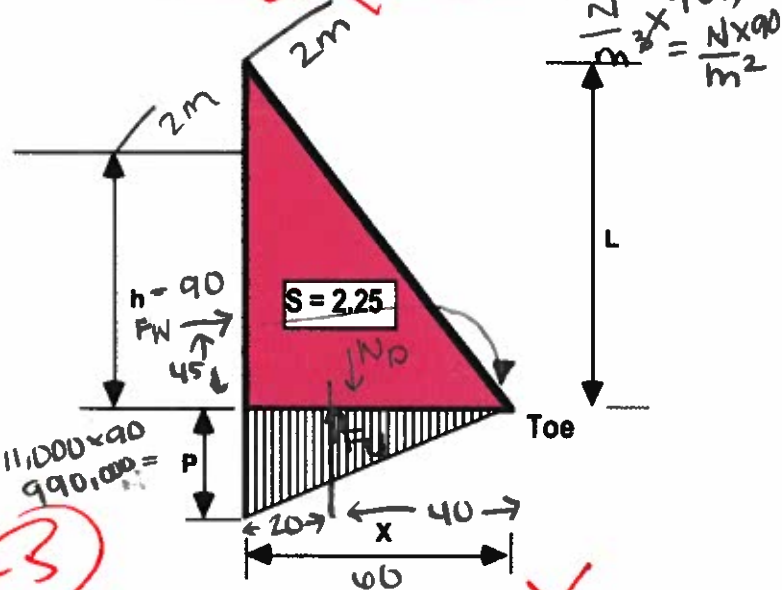
For the construction of the dam shown, a new material is used (Specific Gravity, $S = 2.25$). The depth of muddy water behind the dam ($\gamma = 11,000 \text{ N/m}^3$), $h = 90 \text{ m}$.

The dam is ($L = 100 \text{ m}$) high and $X = 60 \text{ m}$. $P = \gamma h$.

Analyze 2 m section of the dam as follows.

(c) [20] Determine the force of the muddy water behind dam, F [kN] and its moment M [kN-m] about the toe of the dam

$F = \gamma \times h \times A = 11,000 (45) (90 \times 2) = 89,100 \text{ kN}$
 $\frac{\text{kN}}{\text{m}^3} \times \text{m} \times \text{m}^2$



F (for a 2 m section) [kN] = 89,100 Moment of force, F about the toe [kN-m] = 4,004,500
 $\frac{89,100 (45)}$

(d) [20] Determine the weight of the 2-m dam section, W [kN]

$W = \gamma \times V$
 $= 11,000 (2.25) (\frac{1}{2} \times 100 \times 60 \times 2) = 148,500$
 $\frac{\text{kN}}{\text{m}^3} \times \text{m}^3$

W [kN] = 148,500

(e) [15] Determine the uplift force (for the 2-m section) under the dam, U [kN]

$F_u = (990 \frac{\text{kN}}{\text{m}^2}) \times (60 \text{ m} \times \frac{1}{2} \times 2 \text{ m}) = 59,400$

$\gamma \times h \times A$
 $= \frac{11,000}{1000} (990 \frac{\text{kN}}{\text{m}^2}) (60 \times \frac{1}{2} \times 2) \text{ [kN]} = 59,400$

$\frac{11 \text{ kN}}{\text{m}^3} \times 990 \frac{\text{kN}}{\text{m}^2} \times 30 \text{ m}^2$

-20

5 [100]

(a) [50]

HARDY-CROSS Method: Piping System using Darcy-Weisbach Equation ($n = 2$); friction factor, $f = 0.018$.

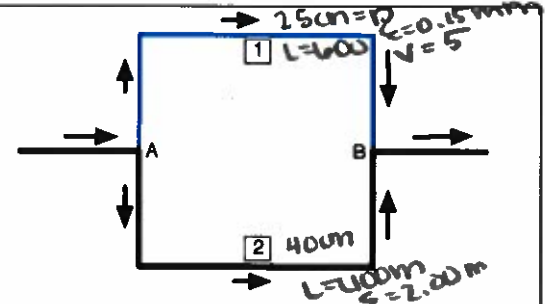
PROVIDE THE VALUES for highlighted (BLUE) FIELDS. ALL necessary information has been provided.

Iteration	Loop	Pipeline	Len [ft]	diam [in]	K	Qa [cfs]	headloss, hf = kQa^2 [ft]	h _f /Q [ft/cfs]	Correction, δ [cfs]	New Q = $Q + \delta$
1	1	AB	4000	12	1.8136	1.500	4.0806	2.7204	0.358	1.858
		BF	2000	6	29.017	1.000	29.017	29.017	-0.016	0.984
		FA	1500	6	21.763	-2.000	-87.05	43.526		
							-53.95	75.264		
6	Corrections		Loop 1		δ_1 [cfs] =		0.358	Loop 2		δ_2 [cfs] =
2	2	BC	3000	8	10.329	1.000	10.329	10.329	0.374	1.374
		CD	2000	8	6.886	-0.500	-1.722	3.443		
		DF	3000	8	10.329	-1.500	-23.240	15.494		
		FB	2000	6	29.018	-1.000	-29.018	29.018	0.016	0.984
							-43.650	58.283		

(b) [50]

Consider the piping system shown. Pipe 1 is a 25-cm (diameter), 600 m long ductile iron pipe ($\epsilon = 0.15$ mm) in which the flow velocity is 5 m/s. Pipe 2 is a 40-cm (diameter), 400 m long riveted steel pipe ($\epsilon = 2.00$ mm). The flow is fully rough turbulent and minor losses are negligible.

(i) [20] Determine the friction factors (to 4 decimal places) in each pipe using the equation (not the Moody diagram) for friction factor. Show your calculations.



$$f_1 = \left[\frac{1}{2.109 \log \left(\frac{3.7 \times 0.15 \text{ mm}}{0.15 \text{ mm}} \right)} \right]^2 = 0.0174$$

Friction factor in Pipe 1 = 0.0174

$$f_2 = \left[\frac{1}{2.109 \log \left(\frac{3.7 \times 2.00 \text{ mm}}{2.00 \text{ mm}} \right)} \right]^2 = 0.03036$$

Friction factor in Pipe 2 = 0.0304

(ii) [30] Determine the velocity in Pipe 2 [m/s]

$$Q = Q_1 + Q_2 \quad Q_1 = V_1 A_1 = 5 \left(\pi (0.25)^2 \right) = 0.245 \text{ m}^3/\text{s}$$

$$Q_2 = Q - 0.245 \text{ m}^3/\text{s}$$

$$h_{f1} = h_{f2} \quad (0.0174)(600)(5)^2 = 53.21$$

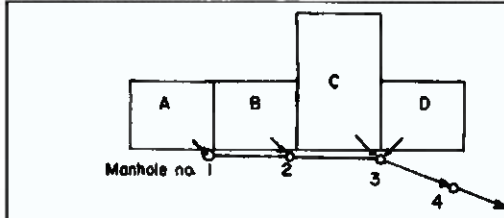
Velocity in Pipe 2 [m/s] = 5.80

$$53.21 = \frac{0.0304(400)(V_2)^2}{2(9.81)(0.40)} \quad \sqrt{34.34} = \sqrt{V_2^2} \quad V_2 = 5.86$$

6 [100]

The IDF (Intensity Duration Frequency) curve parameters for the area (called StationP) below are:

$a = 3.592$ and $b = 0.238$ and $c = -0.809$ for a return period of 25 years.



Rainfall Intensity, i [in/hr] = $a(D + b)^c$

Where: D = duration [hrs]

The minimum time of concentration (due to local ordinance) is 12 minutes.

The velocity of flow in the pipes (manhole to manhole in the sewer system) is given in the second table below and the other data for StationP are given in the first table. Your primary goal is to calculate the peak flowrate [cfs] from sections A, B, C and D for the 25-year design rainfall at the point where the discharge enters manhole 4 using the Rational Method.

Data for the watershed [TABLE 1]

SECTION	Runoff Coefficient	Length of overland travel path [ft]	Slope [%]	Area [ac]	Overland flow travel time [min]
A	0.7	1000	2.5	200	6.59
B	0.5	1200	4.0	150	6.33
C	0.8	2500	5.0	400	10.22
D	0.4	1000	3.0	250	6.14
Total Area				1000	

Provide sample calculation for the first row at the right of above table

Data for the sewer system [Table 2]

Manhole Segment	Length [ft]	Velocity [ft/s]	Travel time [min]
1-2	1200	2.0	10
2-3	1500	3.0	8.33
3-4	2500	2.5	16.67

Provide sample calculation for the first row at the right of above table

- (a) [30] Calculate the time of concentration (using manhole 4 as the reference point or outlet). Complete the table below and appropriate portions of Tables 1 and 2.

Travel Path [Inlet-Man#1-Man#2...Outlet]	Time of travel [min]
A-1-2-3-4 (6.59+10+8.33+16.67)	41.59
B-2-3-4 (6.33+8.33+16.67)	31.33
C+D-3-4 (10.22+6.14+16.67)	33.03
D-3-4 (6.14+16.67)	22.81
C-3-4 (10.22+16.67)	26.89

Provide sample calculation for the first row below and complete the rest of the table

Time of concentration, t_c [minutes] = 41.59

- (b) [20] Design Rainfall intensity, i (using IDF formula provided) for StationP

$$i = a(D+b)^c$$

$$= 3.592(41.59 \text{ min} + 0.238)^{-0.809} =$$

Design Rainfall intensity, i [in/hr] = 3.810

- (c) [25] Determine the composite Runoff Coefficient, C for StationP

$$\bar{C} = \frac{\sum C_i A_i}{\sum A_i} = \frac{(0.7 \times 200) + (0.5 \times 150) + (0.8 \times 400) + (0.4 \times 250)}{1000}$$

Composite Runoff Coefficient, C [=] 0.635

- (d) [25] Determine the Peak runoff for StationP (using Rational Formula)

$$Q = \bar{C} \times i \times A = 0.635(3.8)(1000)$$

StationP peak runoff (with MANHOLE 4 as the OUTLET) [cfs] = 2413

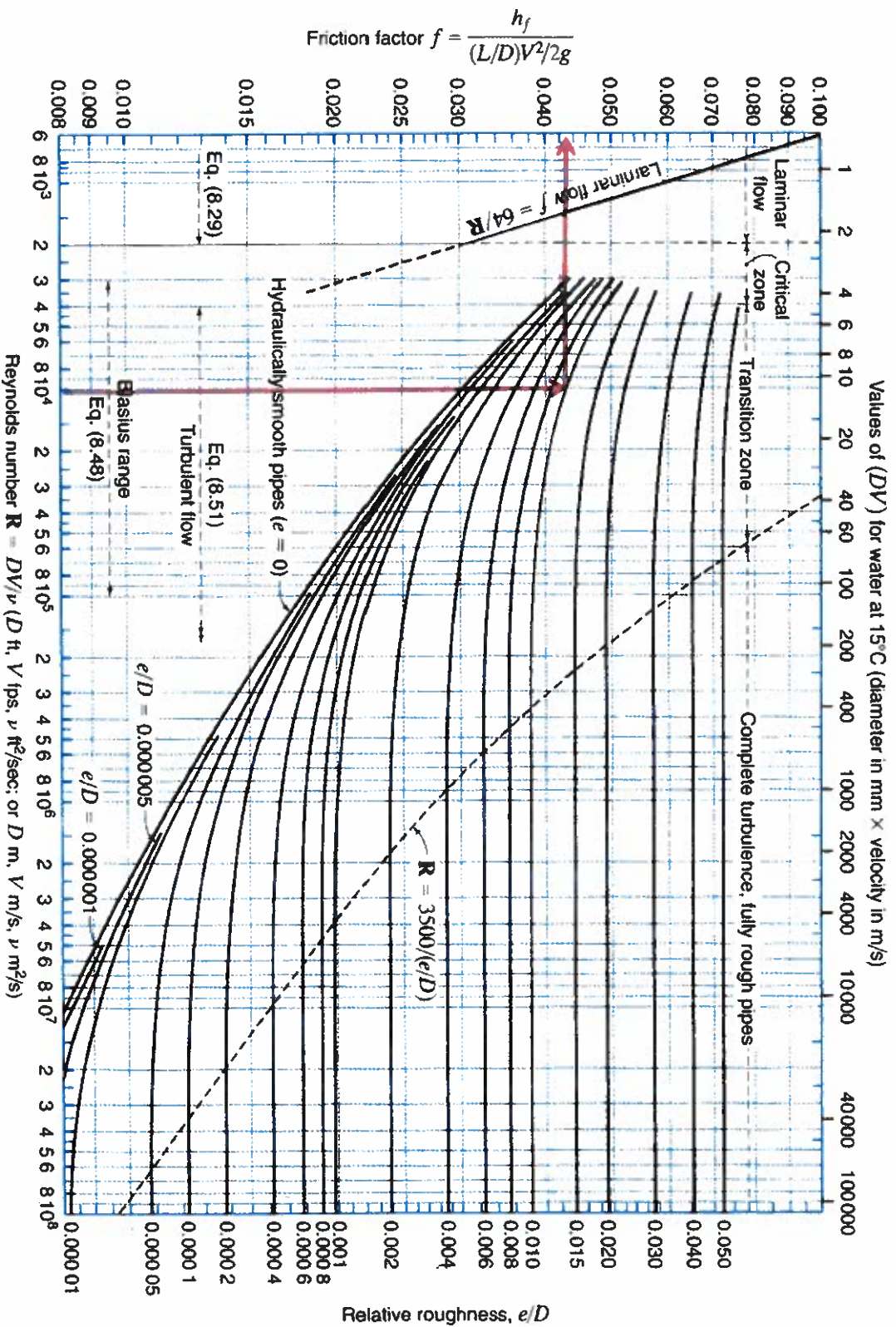
Properties of Water

Temperature (°C)	Density ρ (kg/m ³)	Specific Weight γ (N/m ³)	Viscosity μ (N·s/m ²)	Kinematic viscosity ν (m ² /s)	Bulk modulus B (Pa)	Surface Tension σ (N/m)	Vapor Pressure (kPa)
0	999.9	9809	1.792×10^{-3}	1.792×10^{-6}	204×10^7	7.62×10^{-2}	0.610
5	1000.0	9810	1.519	1.519	206	7.54	0.872
10	999.7	9807	1.308	1.308	211	7.48	1.13
15	999.1	9801	1.140	1.141	214	7.41	1.60
20	998.2	9792	1.005	1.007	220	7.36	2.34
30	995.7	9768	0.801	0.804	223	7.18	4.24
40	992.2	9733	0.656	0.661	227	7.01	7.38
50	988.1	9693	0.549	0.556	230	6.82	12.3
60	983.2	9645	0.469	0.477	228	6.68	19.9
70	977.8	9592	0.406	0.415	225	6.50	31.2
80	971.8	9533	0.357	0.367	221	6.30	47.3
90	965.3	9470	0.317	0.328	216	6.12	70.1
100	958.4	9402	0.284×10^{-3}	0.296×10^{-6}	207×10^7	5.94×10^{-2}	101.3

PROPERTIES OF WATER (ENGLISH UNITS)

Temperature (°F)	Specific Weight γ (lb/ft ³)	Mass Density ρ (lb • sec ² /ft ⁴)	Absolute Dynamic Viscosity μ ($\times 10^{-5}$ lb • sec/ft ²)	Kinematic Viscosity ν ($\times 10^{-5}$ ft ² /sec)	Vapor Pressure p_v (psi)
32	62.42	1.940	3.746	1.931	0.09
40	62.43	1.940	3.229	1.664	0.12
50	62.41	1.940	2.735	1.410	0.18
60	62.37	1.938	2.359	1.217	0.26
70	62.30	1.936	2.050	1.059	0.36
80	62.22	1.934	1.799	0.930	0.51
90	62.11	1.931	1.595	0.826	0.70
100	62.00	1.927	1.424	0.739	0.95
110	61.86	1.923	1.284	0.667	1.24
120	61.71	1.918	1.168	0.609	1.69
130	61.55	1.913	1.069	0.558	2.22
140	61.38	1.908	0.981	0.514	2.89
150	61.20	1.902	0.905	0.476	3.72
160	61.00	1.896	0.838	0.442	4.74
170	60.80	1.890	0.780	0.413	5.99
180	60.58	1.883	0.726	0.385	7.51
190	60.36	1.876	0.678	0.362	9.34
200	60.12	1.868	0.637	0.341	11.52
212	59.83	1.860	0.593	0.319	14.70

Moody Diagram – friction factor, f



(Note: If $e/D = 0.01$ and $Re = 10^4$, the left arrow locates $f = 0.043$.)

AVERAGE



Department of Civil & Environmental Engineering

CVEG 4303-P01

Water Resources Engineering

Spring 2022

Dr. Nzewi

FINAL EXAM

Tuesday, May 10, 2022, 01:30 - 3:20 PM, SR Collins 205

Submit the entire exam the order given

Name [PRINT]

Sydney Jones

In all the problems you must provide enough details and description of the solution method to demonstrate your knowledge of the solution method. A substantial portion of the grade will be based on your methods.

380

600

All necessary equations are provided except for elementary relationships you are expected to master. This is a **CLOSED** book exam. Please **turn off all cell phones and mp3 players** and **place them in your book bag in front of the class**. Also put away ANY **disallowed** calculators.

Calculator POLICY (allowed calculators)

- **Casio:** All fx-115 and fx-991 models (Any Casio calculator must have "fx-115" or "fx-991" in its model name.)
- **Hewlett Packard:** The HP 33s and HP 35s models, but no others
- **Texas Instruments:** All TI-30X and TI-36X models (Any Texas Instruments calculator must have "TI-30X" or "TI-36X" in its model name.)

- 1) All cellphones/smartwatches **MUST** be placed in your book bag during exams and turned off. Book bags **MUST** be placed in front of the classroom and away from students. Students without a book bag must place cellphone/smartwatch (turned off) on Instructor's desk.
- 2) Any student possessing a cellphone/smartwatch or any other unauthorized device **WILL** receive an automatic zero for the test/assignment. Such action will be cheating.
- 3) **CLOTHING:** Hoodies are **NOT** Allowed during exams. No headphones (corded or wireless) are **ALLOWED**.
- 4) **Calculator covers are DISALLOWED** during tests and must be placed in students' book bags during exams.
- 5) There shall be **NO SHARING** of resources during the exam. Writing space will be provided in the test.
- 6) **RESTROOM VISIT:** if you need to use the restroom, **do so before opening the exam**. Once the exam begins, you must submit your work to the instructor if you leave the classroom to visit the rest room (your exam terminates).
- 7) You have **110 minutes** to complete the exam. Please turn in your work on time.
- 8) Provide enough detail for each problem you solve. You earn points based on the details you provide.
- 9) Please work independently.
- 10) You are required to solve **ALL** problems.

Dishonesty or failure to adhere to instructions will result in a grade of ZERO (0.0)

I pledge to abide by all the rules stated for this Exam

Signature: _____

Date: _____

NAME [PRINT, Lastname, firstname]: _____

Sydney Jones

REFERENCE VALUES AND FORMULAS [Unless otherwise stated or implied, assume the following]

Density of water = 1000 kg/m^3 ($= 1.94 \text{ slugs/ft}^3$) [at 4°C]
 Specific weight of water = 9810 N/m^3 ($= 62.4 \text{ lb/ft}^3$) and at 4°C
 Gravitational Acceleration, $g = 9.81 \text{ m/s}^2$ ($= 32.2 \text{ ft/s}^2$)
 Standard atmospheric pressure = 101.3 kPa ($= 2117 \text{ psf} = 14.7 \text{ psi}$)
 Gas constant for air, $R = 287 \text{ J/kg}\cdot\text{K} = 1716 \text{ ft}\cdot\text{lb/slug}\cdot^\circ\text{R}$
 $T [\text{K}] = t [^\circ\text{C}] + 273.15$
 $T [^\circ\text{R}] = t [^\circ\text{F}] + 459.67$
 $1 \text{ Btu} = 778 \text{ ft}\cdot\text{lb}$
 $1 \text{ hp} = 745.7 \text{ W} = 550 \text{ ft}\cdot\text{lb/s}$
 $1 \text{ m} = 100 \text{ cm}$

$1 \text{ mile} = 5280 \text{ feet}$
 $1 \text{ mile} = 1760 \text{ yards}$
 $1 \text{ acre} = 43560 \text{ ft}^2$
 $1 \text{ mi}^2 = 640 \text{ acres}$
 $1 \text{ ft} = 0.3048 \text{ m}$
 $1 \text{ slug} = 14.59 \text{ kg}$
 $1 \text{ lb} = 4.448 \text{ N}$
 $1 \text{ Pa} = 1.0 \text{ N/m}^2$
 $1 \text{ ft}^3 = 7.481 \text{ gal}$
 $25.4 \text{ mm} = 1.0 \text{ in}$
 $1 \text{ liter} = 1000 \text{ cm}^3$
 $1 \text{ m}^3 = 1000 \text{ liter}$

Forces on submerged surfaces:

$$F = \gamma h A$$

Location of Center of pressure, $y_p = \bar{y} + \frac{I_{xx}}{A \bar{y}}$

Moment of Inertia for a rectangular shape:

$$I_{xx} = \frac{b l^3}{12}$$

Buoyant Force:

$$F_B = \gamma (\text{displaced volume})$$

Metacentric Height:

$$GM = \frac{I_{xx}}{V} - CG$$

Reynolds Number:

$$Re = \frac{VD}{\nu} = \frac{\rho V D}{\mu}$$

Swamee & Jain and other f Equations:

Swamee & Jain (1976) [error about 1% from Colebrook equation]

$$f = \frac{1.325}{\left\{ \ln \left[0.27 \frac{\epsilon}{D} + \frac{5.74}{Re^{0.9}} \right] \right\}^2} \text{ for } 10^{-6} \leq \frac{\epsilon}{D} \leq 10^{-2} \text{ and } 5000 \leq Re \leq 10^8$$

Haaland (1983) [error about 1.5% from Colebrook equation]

$$f = \left[\frac{1}{-1.8 \log \left[\left(\frac{0.27 \epsilon}{D} \right)^{1.1} + \frac{6.9}{Re} \right]} \right]^2 \text{ for } 4000 \leq Re \leq 10^8$$

Fully Rough/turbulent Flow:

$$f = \left[\frac{1}{2 \log \left(\frac{3.7 D}{\epsilon} \right)} \right]^2$$

Smooth Pipe flow for Hydraulically smooth pipes:

Blasius Equation: $f = \frac{0.316}{Re^{0.25}} \text{ for } 4000 \leq Re \leq 10^5$

Colebrook's Approximation: $f \approx \left[\frac{1}{1.8 \log \left(\frac{Re}{6.9} \right)} \right]^2 \text{ for } 4000 \leq Re \leq 10^8$

Darcy-Weisbach Equation for friction headloss:

$$h_f = \frac{fL}{D} \frac{V^2}{2g}$$

Minor headloss Equation:

$$h_m = \sum K \frac{V^2}{2g}; \text{ Where } K = \text{loss coefficient}$$

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2$$

$$H_P + \frac{V_1^2}{2g} + \frac{P_1}{\gamma} + z_1 = H_T + \frac{V_2^2}{2g} + \frac{P_2}{\gamma} + z_2 + h_L$$

Power supplied TO pump:

$$\text{BHP} = \frac{\gamma Q H_p}{550 \eta} \quad [\text{FLT}^{-1}] \quad (\text{English units}) \quad [\text{hp}]$$

$$\text{BHP} = \frac{\gamma Q H_p}{\eta} \quad [\text{FLT}^{-1}] \quad (\text{metric units}) \quad [\text{Watts}]$$

Power supplied by pump:

$$\text{Power}, H_{\text{pump}} = \frac{\gamma Q H_p}{550} \text{ horsepower [hp] English Units}$$

$$\text{Power}, H_{\text{pump}} = \gamma Q H_p \text{ Watts [W] SI Units}$$

Pumps in Parallel

$$\text{Combined efficiency, } \eta = \frac{\frac{Q_A + Q_B}{\frac{Q_A}{\eta_A} + \frac{Q_B}{\eta_B}}}$$

Pumps in series

$$\text{Combined efficiency, } \eta = \frac{\frac{H_A + H_B}{\frac{H_A}{\eta_A} + \frac{H_B}{\eta_B}}}$$

Hardy Cross Method: flow correction for EACH loop in an iteration:

$$\delta = \frac{-\sum K Q_a^n}{n \sum |K Q_a^{n-1}|} = \frac{-\sum h_f}{n \sum \left| \frac{h_f}{Q} \right|}$$

Table 15.1 Roughness Values for Pipes

Pipe Material	Equivalent Roughness, ϵ (ft)	Hazen-Williams Coefficient, C
PVC, plastic	Smooth	140
Brass, copper, aluminum, glass	Smooth	140
Dawn tubing	5×10^{-6}	—
Cast iron		
new	8.0×10^{-4}	130
old		100
Galvanized iron/ductile pipe	5.0×10^{-4}	120
Asphalted iron	4.0×10^{-4}	—
Wrought iron	1.5×10^{-4}	—
Commercial and welded steel	1.5×10^{-4}	120
Wood stave	20.0×10^{-4}	120
Concrete	40.0×10^{-4}	130
Riveted steel	60.0×10^{-4}	110
Brick sewer	—	100

Table 15.3 Minor Head Loss Coefficients

Item	Loss Coefficient, K_m
Entrance from tank to pipe	
Flush connection	0.5
Projecting connection	0.8
Exit from pipe to tank	1.0
Sudden contraction ($h_m = K_m V_2^2 / 2g$)	
$d_2/d_1 = 0.2$	0.48
$d_2/d_1 = 0.4$	0.42
$d_2/d_1 = 0.6$	0.32
$d_2/d_1 = 0.8$	0.20
$d_2/d_1 = 0.9$	0.05
Sudden enlargement ($h_m = K_m V_1^2 / 2g$)	
$d_1/d_2 = 0.9$	0.04
$d_1/d_2 = 0.8$	0.13
$d_1/d_2 = 0.6$	0.41
$d_1/d_2 = 0.4$	0.71
$d_1/d_2 = 0.2$	0.92

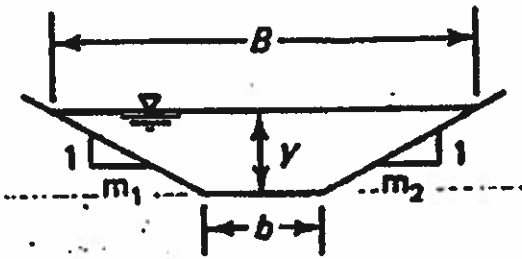
Note: Subscript 1 refers to upstream and 2 refers to downstream section.

Table 15.3 Minor Head Loss Coefficients

Item	Loss Coefficient, K_m
90° bend and 180° return—threaded	1.5
45° bend—threaded	0.4
90° bend and 180° return—flanged	0.3
45° bend—flanged	0.3
Tee—threaded	
through flow	0.9
branched flow	2.0
Tee—flanged	
through flow	0.2
branched flow	1.0
Gate valve (open)	0.19
Check valve (open)	2.0
Globe valve (open)	10.0
Angle valve (open)	2.0
Butterfly valve (open)	0.3

Note: Subscript 1 refers to upstream and 2 refers to downstream section.

Trapezoidal Channel

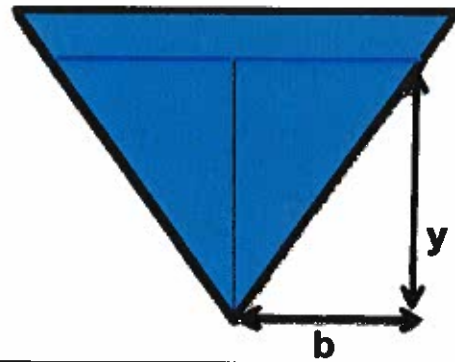


$$\text{Area, } A = by + \frac{1}{2}y^2(m_1 + m_2)$$

$$\text{Wetted Perimeter, } P = b + y(\sqrt{1+m_1^2} + \sqrt{1+m_2^2})$$

$$\text{Top Width, } T \text{ or } B = b + y(m_1 + m_2)$$

$$\text{Hydraulic Radius, } R = \frac{A}{P} = \frac{by + \frac{1}{2}y^2(m_1 + m_2)}{b + y(\sqrt{1+m_1^2} + \sqrt{1+m_2^2})}$$



$$\text{Area, } A = by$$

$$\text{Wetted Perimeter, } P = 2\sqrt{b^2 + y^2}$$

$$\text{Top Width, } T \text{ or } B = 2b$$

$$\text{Hydraulic Radius, } R = \frac{A}{P} = \frac{by}{2\sqrt{b^2 + y^2}}$$

$$\text{Hydraulic Depth, } D = \frac{A}{T} = \frac{by}{2b} = \frac{y}{2}$$

Manning's Equations:

$$\text{Velocity, } V \text{ [m/s]} = \frac{1}{n} R^{2/3} \sqrt{S} \quad \text{-(SI Units)}$$

$$\text{Velocity, } V \text{ [ft/s]} = \frac{1.486}{n} R^{2/3} \sqrt{S} \quad \text{-(English Units)}$$

Hazen-Williams Equations [Circular Pipes]:

English Units: Q [cfs], L [ft], D [ft], H_L [ft]

$$S = \frac{h_L}{L} = \frac{4.731}{C^{1.85} D^{4.87}} Q^{1.85}$$

$$Q = 0.432 C D^{2.63} S^{0.54}$$

Manning's Equations:

$$\text{Discharge, } Q \text{ [m}^3\text{/s]} = \frac{1}{n} A R^{2/3} \sqrt{S} \quad \text{-(SI Units)}$$

$$\text{Discharge, } Q \text{ [ft}^3\text{/s]} = \frac{1.486}{n} A R^{2/3} \sqrt{S} \quad \text{-(English Units)}$$

Hazen-Williams Equations [Circular Pipes]:

SI Units: Q [m³/s], L [m], D [m], H_L [m]

$$Q = 0.278 C D^{2.63} S^{0.54}$$

$$S = \frac{h_L}{L} = \frac{10.704}{C^{1.85} D^{4.87}} Q^{1.85}$$

$$\text{For critical flow, } Fr = \frac{V}{\sqrt{gD}}$$

$$\text{For critical flow, } V = \sqrt{gD}$$

$$\text{For critical flow, } Q = V \cdot A = A \sqrt{gD}$$

$$\text{For normal flow, } Z_n = AR^{2/3}$$

$$\text{For critical flow, } Z_c = A \sqrt{D}$$

$$\text{Froude Number} = \frac{V}{\sqrt{gD}}$$

$$Z_c = A \sqrt{D} = \frac{Q}{\sqrt{g}}$$

Table 14.1 Geometric Elements for a Circular Section

$\frac{y}{d_0}$	$\frac{A}{d_0^2}$	$\frac{P_w}{d_0}$	$\frac{R}{d_0}$	$\frac{T}{d_0}$	$\frac{D}{d_0}$	$\frac{A\sqrt{D}}{d_0^{5/2}}$	$\frac{AR^{2/3}}{d_0^{8/3}}$
0.01	0.0013	0.2003	0.0066	0.1990	0.0066	0.0001	0.0000
0.05	0.0147	0.4510	0.0326	0.4359	0.0336	0.0027	0.0015
0.10	0.0409	0.6435	0.0635	0.6000	0.0682	0.0107	0.0065
0.15	0.0739	0.7954	0.0929	0.7141	0.1034	0.0238	0.0152
0.20	0.1118	0.9273	0.1206	0.8000	0.1398	0.0418	0.0273
0.25	0.1535	1.0472	0.1466	0.8660	0.1774	0.0646	0.0427
0.30	0.1982	1.1593	0.1709	0.9165	0.2162	0.0921	0.0610
0.35	0.2450	1.2661	0.1935	0.9539	0.2568	0.1241	0.0820
0.40	0.2934	1.3694	0.2142	0.9798	0.2994	0.1603	0.1050
0.45	0.3428	1.4706	0.2331	0.9950	0.3446	0.2011	0.1298
0.50	0.3927	1.5708	0.2500	1.0000	0.3928	0.2459	0.1558
0.55	0.4426	1.6710	0.2649	0.9950	0.4448	0.2949	0.1825
0.60	0.4920	1.7722	0.2776	0.9798	0.5022	0.3438	0.2092
0.65	0.5404	1.8755	0.2881	0.9539	0.5666	0.4066	0.2358
0.67	0.5594	1.9177	0.2917	0.9404	0.5948	0.4309	0.2460
0.70	0.5872	1.9823	0.2962	0.9165	0.6408	0.4694	0.2608
0.75	0.6318	2.0944	0.3017	0.8660	0.7296	0.5392	0.2840
0.80	0.6736	2.2143	0.3042	0.8000	0.8420	0.6177	0.3045
0.85	0.7115	2.3462	0.3033	0.7141	0.9964	0.7098	0.3212
0.90	0.7445	2.4981	0.2980	0.6000	1.2408	0.8285	0.3324
0.94 ^a	0.7662	2.6467	0.2896	0.4750	1.6130	0.9725	0.3353
0.95	0.7707	2.6906	0.2864	0.4359	1.7682	1.0242	0.3349
1.00	0.7854	3.1416	0.2500	0.0000	∞	∞	0.3117

^a Maximum flow occurs at 0.94 full depth.

Kirpich Formula [time of concentration]:

$$t_c \text{ [minutes]} = \frac{0.0078L^{0.77}}{S^{0.385}}; L \text{ [ft]} \text{ and } S \text{ [ft/ft]}$$

Intensity-Duration-Frequency equation:

$$\text{Rainfall Intensity, } i \text{ [in/hr]} = a(D + b)^c$$

Where: D = duration [hrs]

Where,

a, b and c are local parameters for a given return period, T in years;
D = rainfall duration in hours.

Rational Formula:

$$Q = CIA$$

C = Runoff coefficient

I = Rainfall Intensity (in/hr)

A = Area in Acres

1 [100]

Two pipes, a 220 mm (300 m long) cast iron pipe and a 600 mm (1000 m long) new cast iron pipe ($C=120$), are arranged in **series** in a water distribution system and the total headloss is limited to 30 m. Using the **Hazen-Williams equation**, determine the discharge [m^3/s] through the system. Assume that specific weight of water = 9810 N/m^3 .

Perform the necessary calculations to determine the length of the **equivalent 300 mm older cast iron pipe ($C=105$)** for the system.

Assume a flow of $0.10 \text{ m}^3/\text{s}$ in your calculations for the equivalent pipe as provided in the table below.

Pipe	C	Dia [mm]	Dia [m]	Q [m^3/s]	$S = HL/L$ []	Pipe Length [m]	Headloss, $H_L = S \cdot L$ [m]
1	120	220	.22	0.100	.034	300m	10.2
2	120	600	.6	0.100	2.59×10^{-4}	1000m	.259
EQV	105	300	.3	0.100	9.7×10^{-3}	1078.25	$\Sigma 10.459$

(a) [40] Determine the equivalent length of 300 mm pipe, older cast iron ($C=105$).

$$S = \frac{H_L}{L} = \frac{10.704}{L} \quad Q = 0.1$$

$$L = \frac{10.704}{C^{1.85} S^{1.85}} = \frac{10.704}{(120^{1.85})(.22^{4.87})} = \frac{10.704}{(120^{1.85})(.6^{4.87})} = \frac{10.704}{105^{1.85}(.3^{4.87})}$$

Length of 300 mm pipe [m] = 1078.25m

(b) [35] Discharge in the system [m^3/s]:

$$Q = .278 C D^{2.63} S^{.54}$$

$$.278 (105) (.3)^{2.63} (9.7 \times 10^{-3})^{.54}$$

$$.101$$

Discharge [m^3/s] = .101 m^3/s

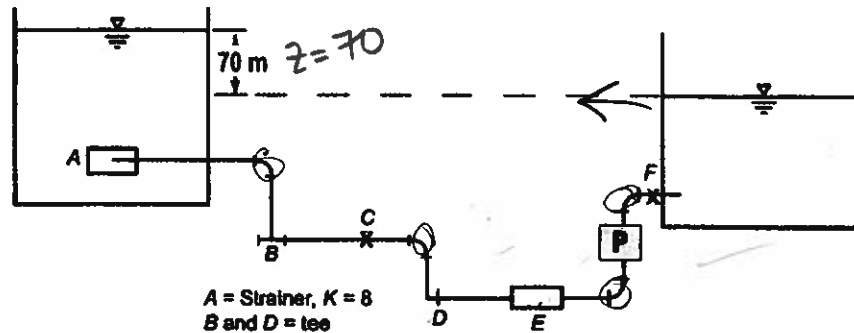
(c) [25]

What are the primary purposes of detention/retention basins. Provide at least 2. Be specific in your answer.

To not increase the amount of water flowing off property/project after development & to decrease the chances of flooding after high amounts of rainfall

2. [100] For fully rough turbulent flow.

Water is pumped by a pump (P) from right to left in the system shown below through a 400-mm, 100 m galvanized iron pipe ($\epsilon = 0.16$ mm), as shown in the figure. In order to calculate the minor losses, assume the following in the figure below: C is a gate valve, $K = 5$; E is a meter, $K = 9$; F is a check valve (open). The elbows in the system are 90° threaded elbows and the tees are threaded (through flow). The water surface elevation difference is 70 m. The water surface elevation difference is 70 m.



(a) [25] Assuming the flow is fully rough turbulent flow, determine the friction factor for the flow using an appropriate Friction Factor equation. Provide your answer to 4 decimal places.

$$f = \left[\frac{1}{2 \log \left(\frac{3.7D}{\epsilon} \right)} \right]^2 = \left[\frac{1}{2 \log \left(\frac{3.7(0.4)}{1.6 \times 10^{-4}} \right)} \right]^2 = 0.06772$$

Friction factor for the pipe flow $[f] = 0.06772$

(b) [25] Determine the total (sum) of the minor headloss coefficients for the system. Show all work and justify your answer fully.

$$\sum K \frac{V^2}{2g}$$

$$36.8 \frac{1.98^2}{2(9.81)}$$

$$2 + 5 + (1.9 \times 2) + (1.5 \times 4) + 5 + 9 + 8 = 36.8$$

$$V = \sqrt{(9.81)(0.4)} = 1.98$$

Total (sum) of minor headloss coefficients $[K] = 36.8$

(c) [35] Develop the relationship between the head [m] of the pump (H_p) and the flowrate (Q) in the system. This is the equation of the system head curve. [Hints: $V = Q/A$; the equation is based on the Energy Equation]

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + 0 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + 70$$

$$h_f = \frac{(0.06772)(100m)}{0.4} \cdot \frac{1.98^2}{2 \cdot 9.81}$$

$$H_p = \frac{7.35}{2g} - \frac{P_1}{\gamma} - 0 - 0 - \frac{7.35}{\gamma} + \frac{P_2}{\gamma} + 70 + 7.35$$

$$V = \frac{Q}{A}$$

$$1.257 \times 1.98 = \frac{Q}{\frac{\pi}{4} \cdot 0.4^2} = Q = 0.25$$

System head curve equation, $H_p =$

(d) [15] If the flowrate (Q) is 1250 liters per second, what is the HEAD ON THE PUMP [m]? Justify your answer fully.

H_p [m] =

3 [100]

(a) [40] A circular channel ($n = 0.014$) with a diameter of 5.00 m is used to convey a discharge of 96 m³/s, determine the **normal depth of flow** if the channel slope is 5%.

[Hint: You may use Table 14.1 which has been provided. Do not interpolate, use the closest value – as appropriate]

$$Q = 96 \text{ m}^3/\text{s}$$

$$S = .05$$

$$d = 5 \text{ m}$$

$$n = .014$$

$$\left[\frac{4^{5/3} Q n}{\pi \sqrt{S}} \right]^{3/8} = \left[\frac{4^{5/3} 96 \cdot .014}{\pi \sqrt{.05}} \right]^{3/8}$$



$$3.03$$

$$y =$$

Normal Depth of flow [m] =

$$3.034$$

(b) [20] What is the **area of flow** for the flow condition in part (a) [m²]? Show all work.

[Hint: Again, Table 14.1 may be useful.]

$$b = 2.5 \text{ m}$$

$$y = 3.03$$

Area of flow [m²] =

$$7.58$$

(c) [20] What is the **hydraulic depth** [m] for the flow?

$$D = \frac{A}{T} = \frac{7.58}{5}$$

Hydraulic Depth of flow [m] =

$$1.516$$

(d) [20] What is the **Froude Number** [] for the flow?

$$V = \frac{Q}{A} = \frac{96 \text{ m}^3/\text{s}}{7.58}$$

$$Fr = \frac{V}{\sqrt{gD}} = \frac{12.66}{\sqrt{9.81 \cdot 1.516}}$$

Froude Number of flow [] =

$$3.28$$

one method

4 [100]

A channel with a right triangular section as shown carries a flow of $20 \text{ m}^3/\text{s}$. The velocity of flow = 2 m/s .

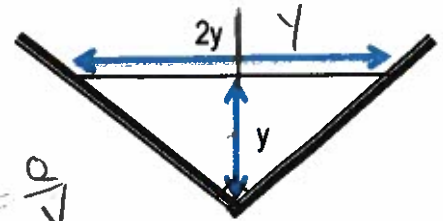
(a) [20] Determine the depth of flow, y .

$$Q = 20 \text{ m}^3/\text{s}$$

$$V = 2 \text{ m/s}$$

$$A = 10 \text{ m}^2$$

$$A = \frac{Q}{V}$$



$$A = by$$

$$10 = 2y^2$$

$$5 = y^2$$

$$y = \sqrt{5}$$

Depth of flow, y [m]

$$2.24 \text{ m}$$

(b) [25] What is the Froude number, Fr , for this flow?

$$\frac{V}{\sqrt{gD}} = \frac{2 \text{ m/s}}{\sqrt{9.81}}$$

$$D = \frac{A}{T} = \frac{by}{2b} = \frac{10 \text{ m}^2}{2(2.24)}$$

Froude Number, Fr []

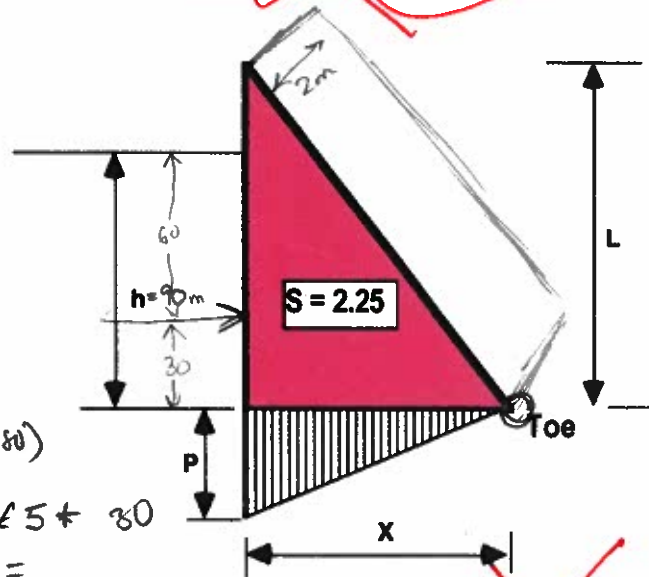
$$2.28$$

For the construction of the dam shown, a new material is used (Specific Gravity, $S = 2.25$). The depth of muddy water behind the dam ($\gamma = 11,000 \text{ N/m}^3$), $h = 90 \text{ m}$.

The dam is ($L = 100 \text{ m}$) high and $X = 60 \text{ m}$. $P = \gamma h$.

Analyze 2 m section of the dam as follows.

(c) [20] Determine the force of the muddy water behind dam, F [kN] and its moment M [kN-m] about the toe of the dam



$$\gamma h A$$

$$= (11 \text{ kN})(90)(100)$$

$$1.19 \times 10^6$$

$$F \text{ (for a 2 m section) [kN]} = 1.19 \times 10^6 \quad \text{Moment of force, } F \text{ about the toe [kN-m]} = 3.56 \times 10^6$$

(d) [20] Determine the weight of the 2-m dam section, W [kN]

$$9.81 \cdot \left(\left(\frac{1}{2} \cdot 60 \cdot 100 \right) \cdot 2 \right)$$

$$W \text{ [kN]} = 5.89 \times 10^4$$

(e) [15] Determine the uplift force (for the 2-m section) under the dam, U [kN]

$$U \text{ [kN]} =$$

5 [100]

(a) [50]

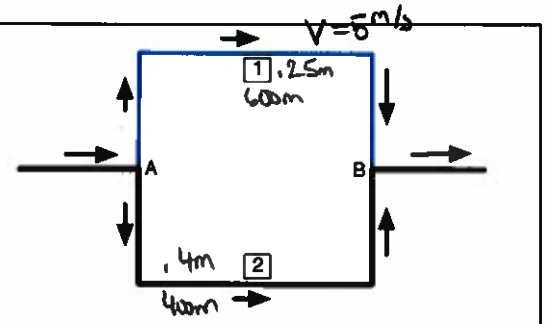
HARDY-CROSS Method: Piping System using Darcy-Weisbach Equation ($n = 2$); friction factor, $f = 0.018$.

PROVIDE THE VALUES for highlighted (BLUE) FIELDS. ALL necessary information has been provided.

Iteration	Loop	Pipeline	Len [ft]	diam [in]	K	Qa [cfs]	headloss, hf = kQa^2 [ft]	lhf/Q	Correction, δ [cfs]	New Q
1		AB	4000	12	1.8136	1.500	4.0806	2.7204	+0.358	1.858
		BF	2000	6	29.017	1.000	29.017	29.017	+0.732	1.732
		FA	1500	6	21.763	-2.000	-87.05	43.526		
							-83.95	75.264		
6	Corrections		Loop 1		δ1 [cfs] =		Loop 2		δ2 [cfs] =	
					+0.358				+0.374	
2		BC	3000	8	10.329	1.000	10.329	10.329	+0.374	1.374
		CD	2000	8	6.886	-0.500	-1.722	3.443		
		DF	3000	8	10.329	-1.500	-23.240	15.494		
		FB	2000	6	29.018	-1.000	-29.018	29.018	+0.732	-2.08
								-43.650	58.283	

(b) [50]

Consider the piping system shown. Pipe 1 is a 25-cm (diameter), 600 m long ductile iron pipe ($\epsilon = 0.15$ mm) in which the flow velocity is 5 m/s. Pipe 2 is a 40-cm (diameter), 400 m long riveted steel pipe ($\epsilon = 2.00$ mm). The flow is fully rough turbulent and minor losses are negligible.



(i) [20] Determine the friction factors (to 4 decimal places) in each pipe using the equation (not the Moody diagram) for friction factor. Show your calculations.

$$f_{\text{Pipe 1}} = \left[\frac{1}{2 \log \left(\frac{3.7D}{\epsilon} \right)} \right]^2$$

$$f_{\text{Pipe 1}} = \left[\frac{1}{2 \log \left(\frac{3.7(1.25)}{1.5 \times 10^{-4}} \right)} \right]^2$$

$$f_{\text{Pipe 2}} = \left[\frac{1}{2 \log \left(\frac{3.7D}{\epsilon} \right)} \right]^2$$

$$f_{\text{Pipe 2}} = \left[\frac{1}{2 \log \left(\frac{3.7(4)}{2 \times 10^{-3}} \right)} \right]^2$$

Friction factor in Pipe 1 = 0.019

Friction factor in Pipe 2 = 0.026

(ii) [30] Determine the velocity in Pipe 2 [m/s]

$$V = \frac{Q}{A}$$

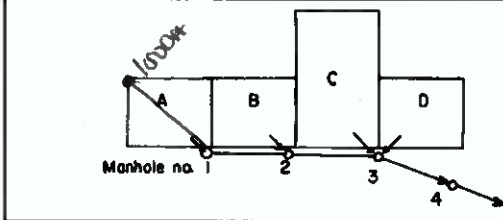
Velocity in Pipe 2 [m/s] =

-55

6 [100]

The IDF (Intensity Duration Frequency) curve parameters for the area (called **StationP**) below are:

$a = 3.592$ and $b = 0.238$ and $c = -0.809$ for a return period of 25 years.



Rainfall Intensity, i [in/hr] = $a(D + b)^c$

Where: D = duration [hrs]

The minimum time of concentration (due to local ordinance) is 12 minutes.

The velocity of flow in the pipes (manhole to manhole in the sewer system) is given in the second table below and the other data for **StationP** are given in the first table. Your primary goal is to calculate the peak flowrate [cfs] from sections A, B, C and D for the 25-year design rainfall at the point where the discharge enters manhole 4 using the Rational Method.

Data for the watershed [TABLE 1]

SECTION	Runoff Coefficient	Length of overland travel path [ft]	Slope [%]	Area [ac]	Overland flow travel time [min]
A	0.7	1000	2.5	200	6.59
B	0.5	1200	4.0	150	6.33
C	0.8	2500	5.0	400	10.22
D	0.4	1000	3.0	250	6.14
Total Area				1000	

$$t_c = \frac{.0078 L^{.77}}{S^{.385}} = \frac{.0078 (1000)^{.77}}{.025^{.385}}$$

Provide sample calculation for the first row at the right of above table

Data for the sewer system [Table 2]

Manhole Segment	Length [ft]	Velocity [ft/s]	Travel time [min]
1-2	1200	2.0	10 min
2-3	1500	3.0	8.3 min
3-4	2500	2.5	16.6 min

$$\frac{1200 \text{ ft}}{2 \text{ ft/s}} = \frac{600 \text{ s}}{60 \text{ s}} = 10 \text{ min}$$

Provide sample calculation for the first row at the right of above table

- (a) [30] Calculate the time of concentration (using manhole 4 as the reference point or outlet). Complete the table below and appropriate portions of Tables 1 and 2.

Travel Path [Inlet-Man#1-Man#2...Outlet]	Time of travel [min]
A-1-2-3-4 = 6.59 + 10 + 8.3 + 16.6	41.49
B-2-3-4 = 6.33 + 8.3 + 16.6	31.23
C-3-4 = 10.22 + 16.6	26.82
D-3-4 = 6.14 + 16.6	22.74
3-4 =	16.6

$$6.59 + 10.0 + 8.3 + 16.6 = 41.49$$

Provide sample calculation for the first row below and complete the rest of the table

Time of concentration, t_c [minutes] = 41.49 min

- (b) [20] Design Rainfall intensity, i (using IDF formula provided) for **StationP**

$$3.592 (41.49 + 0.238)^{-0.809} = 1.76$$

Design Rainfall Intensity, i [in/hr] = 1.76

- (c) [25] Determine the composite Runoff Coefficient, C for **StationP**

$$(.7 \times 200) + (.5 \times 150) + (.8 \times 400) + (.4 \times 250)$$

Composite Runoff Coefficient, C [=] 0.635

- (d) [25] Determine the Peak runoff for **StationP** (using Rational Formula)

$$Q = i \sum CA$$

StationP peak runoff (with MANHOLE 4 as the OUTLET) [cfs] = 17.6

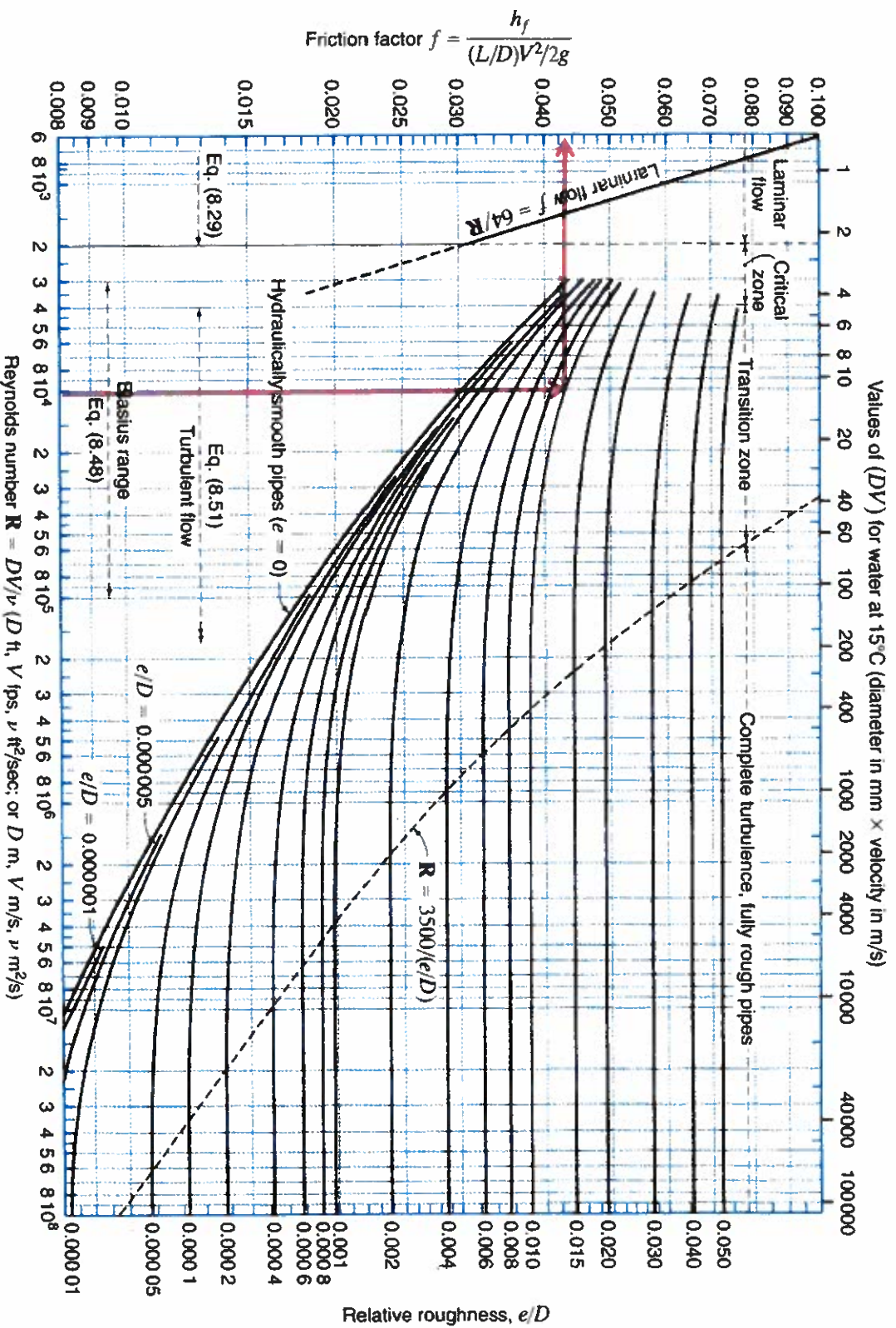
Properties of Water

Temperature (°C)	Density ρ (kg/m ³)	Specific Weight γ (N/m ³)	Viscosity μ (N·s/m ²)	Kinematic viscosity ν (m ² /s)	Bulk modulus B (Pa)	Surface Tension σ (N/m)	Vapor Pressure (kPa)
0	999.9	9809	1.792×10^{-3}	1.792×10^{-6}	204×10^7	7.62×10^{-2}	0.610
5	1000.0	9810	1.519	1.519	206	7.54	0.872
10	999.7	9807	1.308	1.308	211	7.48	1.13
15	999.1	9801	1.140	1.141	214	7.41	1.60
20	998.2	9792	1.005	1.007	220	7.36	2.34
30	995.7	9768	0.801	0.804	223	7.18	4.24
40	992.2	9733	0.656	0.661	227	7.01	7.38
50	988.1	9693	0.549	0.556	230	6.82	12.3
60	983.2	9645	0.469	0.477	228	6.68	19.9
70	977.8	9592	0.406	0.415	225	6.50	31.2
80	971.8	9533	0.357	0.367	221	6.30	47.3
90	965.3	9470	0.317	0.328	216	6.12	70.1
100	958.4	9402	0.284×10^{-3}	0.296×10^{-6}	207×10^7	5.94×10^{-2}	101.3

PROPERTIES OF WATER (ENGLISH UNITS)

Temperature (°F)	Specific Weight γ (lb/ft ³)	Mass Density ρ (lb • sec ² /ft ⁴)	Absolute Dynamic Viscosity μ ($\times 10^{-5}$ lb • sec/ft ²)	Kinematic Viscosity ν ($\times 10^{-5}$ ft ² /sec)	Vapor Pressure p_v (psi)
32	62.42	1.940	3.746	1.931	0.09
40	62.43	1.940	3.229	1.664	0.12
50	62.41	1.940	2.735	1.410	0.18
60	62.37	1.938	2.359	1.217	0.26
70	62.30	1.936	2.050	1.059	0.36
80	62.22	1.934	1.799	0.930	0.51
90	62.11	1.931	1.595	0.826	0.70
100	62.00	1.927	1.424	0.739	0.95
110	61.86	1.923	1.284	0.667	1.24
120	61.71	1.918	1.168	0.609	1.69
130	61.55	1.913	1.069	0.558	2.22
140	61.38	1.908	0.981	0.514	2.89
150	61.20	1.902	0.905	0.476	3.72
160	61.00	1.896	0.838	0.442	4.74
170	60.80	1.890	0.780	0.413	5.99
180	60.58	1.883	0.726	0.385	7.51
190	60.36	1.876	0.678	0.362	9.34
200	60.12	1.868	0.637	0.341	11.52
212	59.83	1.860	0.593	0.319	14.70

Moody Diagram – friction factor, f



(Note: If $e/D = 0.01$ and $Re = 10^4$, the left arrow locates $f = 0.043$.)

BELOW
AVERAGE



CVEG 4303-P01

Dr. Nzewi

Department of Civil & Environmental Engineering
Water Resources Engineering

Spring 2022

FINAL EXAM

Tuesday, May 10, 2022, 01:30 – 3:20 PM, SR Collins 205

Submit the entire exam the order given

Name [PRINT] Sophie Tukey

In all the problems you must provide enough details and description of the solution method to demonstrate your knowledge of the solution method. A substantial portion of the grade will be based on your methods.

255
600

All necessary equations are provided except for elementary relationships you are expected to master. This is a **CLOSED** book exam. Please **turn off all cell phones and mp3 players** and **place them in your book bag in front of the class**. Also put away ANY **disallowed** calculators.

Calculator POLICY (allowed calculators)

- **Casio:** All fx-115 and fx-991 models (Any Casio calculator must have "fx-115" or "fx-991" in its model name.)
- **Hewlett Packard:** The HP 33s and HP 35s models, but no others
- **Texas Instruments:** All TI-30X and TI-36X models (Any Texas Instruments calculator must have "TI-30X" or "TI-36X" in its model name.)

- 1) All cellphones/smartwatches **MUST** be placed in your book bag during exams and turned off. Book bags **MUST** be placed in front of the classroom and away from students. Students without a book bag must place cellphone/smartwatch (turned off) on Instructor's desk.
- 2) Any student possessing a cellphone/smartwatch or any other unauthorized device **WILL** receive an automatic zero for the test/assignment. Such action will be cheating.
- 3) **CLOTHING:** Hoodies are **NOT** Allowed during exams. No headphones (corded or wireless) are **ALLOWED**.
- 4) **Calculator covers are DISALLOWED** during tests and must be placed in students' book bags during exams.
- 5) There shall be **NO SHARING** of resources during the exam. Writing space will be provided in the test.
- 6) **RESTROOM VISIT:** if you need to use the restroom, **do so before opening the exam**. Once the exam begins, you must submit your work to the instructor if you leave the classroom to visit the rest room (your exam terminates).
- 7) You have **110 minutes** to complete the exam. Please turn in your work on time.
- 8) Provide enough detail for each problem you solve. You earn points based on the details you provide.
- 9) Please work independently.
- 10) You are required to solve **ALL** problems.

Dishonesty or failure to adhere to instructions will result in a grade of ZERO (0.0)

I pledge to abide by all the rules stated for this Exam

Signature: 

Date: 5/10/22

NAME [PRINT, Lastname, firstname]: Tukey, Sophie

REFERENCE VALUES AND FORMULAS [Unless otherwise stated or implied, assume the following]

Density of water = 1000 kg/m^3 ($= 1.94 \text{ slugs/ft}^3$) [at 4°C]
 Specific weight of water = 9810 N/m^3 ($= 62.4 \text{ lb/ft}^3$) and at 4°C
 Gravitational Acceleration, $g = 9.81 \text{ m/s}^2$ ($= 32.2 \text{ ft/s}^2$)
 Standard atmospheric pressure = 101.3 kPa ($= 2117 \text{ psf} = 14.7 \text{ psi}$)
 Gas constant for air, $R = 287 \text{ J/kg}\cdot\text{K} = 1716 \text{ ft}\cdot\text{lb/slug}\cdot^\circ\text{R}$
 $T [\text{K}] = t [^\circ\text{C}] + 273.15$
 $T [^\circ\text{R}] = t [^\circ\text{F}] + 459.67$
 $1 \text{ Btu} = 778 \text{ ft}\cdot\text{lb}$
 $1 \text{ hp} = 745.7 \text{ W} = 550 \text{ ft}\cdot\text{lb}$
 $1 \text{ m} = 100 \text{ cm}$

$1 \text{ mile} = 5280 \text{ feet}$
 $1 \text{ mile} = 1760 \text{ yards}$
 $1 \text{ acre} = 43560 \text{ ft}^2$
 $1 \text{ mi}^2 = 640 \text{ acres}$
 $1 \text{ ft} = 0.3048 \text{ m}$
 $1 \text{ slug} = 14.59 \text{ kg}$
 $1 \text{ lb} = 4.448 \text{ N}$
 $1 \text{ Pa} = 1.0 \text{ N/m}^2$
 $1 \text{ ft}^3 = 7.481 \text{ gal}$
 $25.4 \text{ mm} = 1.0 \text{ in}$
 $1 \text{ liter} = 1000 \text{ cm}^3$
 $1 \text{ m}^3 = 1000 \text{ liter}$

Forces on submerged surfaces:

$$F = \gamma \bar{h} A$$

Location of Center of pressure, $y_p = \bar{y} + \frac{I_{xx}}{A \bar{y}}$

Moment of Inertia for a rectangular shape:

$$I_{xx} = \frac{b l^3}{12}$$

Buoyant Force:

$$F_B = \gamma (\text{displaced volume})$$

Metacentric Height:

$$GM = \frac{I_{xx}}{V} - CG$$

Reynolds Number:

$$Re = \frac{VD}{\nu} = \frac{\rho VD}{\mu}$$

Swamee & Jain and other f Equations:

Swamee & Jain (1976) [error about 1% from Colebrook equation]

$$f = \frac{1.325}{\left\{ \ln \left[0.27 \frac{\epsilon}{D} + \frac{5.74}{Re^{0.9}} \right] \right\}^2} \text{ for } 10^{-6} \leq \frac{\epsilon}{D} \leq 10^{-2} \text{ and } 5000 \leq Re \leq 10^8$$

Haaland (1983) [error about 1.5% from Colebrook equation]

$$f = \left[\frac{1}{-1.8 \log \left[\left(\frac{0.27 \epsilon}{D} \right)^{1.1} + \frac{6.9}{Re} \right]} \right]^2 \text{ for } 4000 \leq Re \leq 10^8$$

Fully Rough/turbulent Flow:

$$f = \left[\frac{1}{2 \log \left(\frac{3.7D}{\epsilon} \right)} \right]^2$$

Smooth Pipe flow for Hydraulically smooth pipes:

Blasius Equation: $f = \frac{0.316}{Re^{0.25}}$ for $4000 \leq Re \leq 10^5$

Colebrook's Approximation: $f \approx \left[\frac{1}{1.8 \log \left(\frac{Re}{6.9} \right)} \right]^2$ for $4000 \leq Re \leq 10^8$

Darcy-Weisbach Equation for friction headloss:

$$h_f = \frac{fL}{D} \frac{V^2}{2g}$$

Minor headloss Equation:

$$h_m = \sum K \frac{V^2}{2g}; \text{ Where } K = \text{loss coefficient}$$

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2$$

$$H_P + \frac{V_1^2}{2g} + \frac{P_1}{\gamma} + z_1 = H_T + \frac{V_2^2}{2g} + \frac{P_2}{\gamma} + z_2 + h_L$$

Power supplied TO pump:

$$\text{BHP} = \frac{\gamma Q H_p}{550 \eta} \quad [\text{FLT}^{-1}] \quad (\text{English units}) \quad [\text{hp}]$$

$$\text{BHP} = \frac{\gamma Q H_p}{\eta} \quad [\text{FLT}^{-1}] \quad (\text{metric units}) \quad [\text{Watts}]$$

Power supplied by pump:

$$\text{Power}, H_{\text{pump}} = \frac{\gamma Q H_p}{550} \quad \text{horsepower: [hp] English Units}$$

$$\text{Power}, H_{\text{pump}} = \gamma Q H_p \quad \text{Watts [W] SI Units}$$

Pumps in Parallel

$$\text{Combined efficiency, } \eta = \frac{Q_A + Q_B}{\frac{Q_A}{\eta_A} + \frac{Q_B}{\eta_B}}$$

Pumps in series

$$\text{Combined efficiency, } \eta = \frac{H_A + H_B}{\frac{H_A}{\eta_A} + \frac{H_B}{\eta_B}}$$

Hardy Cross Method: flow correction for EACH loop in an iteration:

$$\delta = \frac{-\sum K Q_a^n}{n \sum |K Q_a^{n-1}|} = \frac{-\sum h_f}{n \sum \left| \frac{h_f}{Q} \right|}$$

Table 15.1 Roughness Values for Pipes

Pipe Material	Equivalent Roughness, ϵ (ft)	Hazen-Williams Coefficient, C
PVC, plastic	Smooth	140
Brass, copper, aluminum, glass	Smooth	140
Dawn tubing	5×10^{-6}	—
Cast iron		
new	8.0×10^{-4}	130
old		100
Galvanized iron/ductile pipe	5.0×10^{-4}	120
Asphalted iron	4.0×10^{-4}	—
Wrought iron	1.5×10^{-4}	—
Commercial and welded steel	1.5×10^{-4}	120
Wood stave	20.0×10^{-4}	120
Concrete	40.0×10^{-4}	130
Riveted steel	60.0×10^{-4}	110
Brick sewer	—	100

Table 15.3 Minor Head Loss Coefficients

Item	Loss Coefficient, K_m
Entrance from tank to pipe	
Flush connection	0.5
Projecting connection	0.8
Exit from pipe to tank	1.0
Sudden contraction ($h_m = K_m V_2^2 / 2g$)	
$d_2/d_1 = 0.2$	0.48
$d_2/d_1 = 0.4$	0.42
$d_2/d_1 = 0.6$	0.32
$d_2/d_1 = 0.8$	0.20
$d_2/d_1 = 0.9$	0.05
Sudden enlargement ($h_m = K_m V_1^2 / 2g$)	
$d_1/d_2 = 0.9$	0.04
$d_1/d_2 = 0.8$	0.13
$d_1/d_2 = 0.6$	0.41
$d_1/d_2 = 0.4$	0.71
$d_1/d_2 = 0.2$	0.92

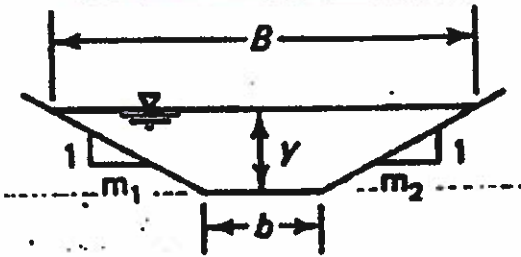
Note: Subscript 1 refers to upstream and 2 refers to downstream section.

Table 15.3 Minor Head Loss Coefficients

Item	Loss Coefficient, K_m
90° bend and 180° return—threaded	1.5
45° bend—threaded	0.4
90° bend and 180° return—flanged	0.3
45° bend—flanged	0.3
Tee—threaded	
through flow	0.9
branched flow	2.0
Tee—flanged	
through flow	0.2
branched flow	1.0
Gate valve (open)	0.19
Check valve (open)	2.0
Globe valve (open)	10.0
Angle valve (open)	2.0
Butterfly valve (open)	0.3

Note: Subscript 1 refers to upstream and 2 refers to downstream section.

Trapezoidal Channel

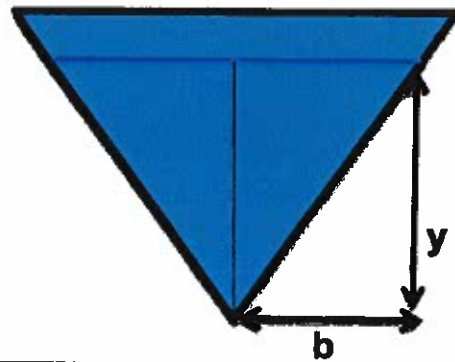


$$\text{Area, } A = by + \frac{1}{2}y^2(m_1 + m_2)$$

$$\text{Wetted Perimeter, } P = b + y(\sqrt{1+m_1^2} + \sqrt{1+m_2^2})$$

$$\text{Top Width, } T \text{ or } B = b + y(m_1 + m_2)$$

$$\text{Hydraulic Radius, } R = \frac{A}{P} = \frac{by + \frac{1}{2}y^2(m_1 + m_2)}{b + y(\sqrt{1+m_1^2} + \sqrt{1+m_2^2})}$$



$$\text{Area, } A = by$$

$$\text{Wetted Perimeter, } P = 2\sqrt{b^2 + y^2}$$

$$\text{Top Width, } T \text{ or } B = 2b$$

$$\text{Hydraulic Radius, } R = \frac{A}{P} = \frac{by}{2\sqrt{b^2 + y^2}}$$

$$\text{Hydraulic Depth, } D = \frac{A}{T} = \frac{by}{2b} = \frac{y}{2}$$

Manning's Equations:

$$\text{Velocity, } V \text{ [m/s]} = \frac{1}{n} R^{2/3} \sqrt{S} \quad \text{-(SI Units)}$$

$$\text{Velocity, } V \text{ [ft/s]} = \frac{1.486}{n} R^{2/3} \sqrt{S} \quad \text{-(English Units)}$$

Hazen-Williams Equations [Circular Pipes]:

English Units: Q [cfs], L [ft], D [ft], H_L [ft]

$$S = \frac{h_L}{L} = \frac{4.731}{C^{1.85} D^{4.87}} Q^{1.85}$$

$$Q = 0.432 C D^{2.63} S^{0.54}$$

Manning's Equations:

$$\text{Discharge, } Q \text{ [m}^3\text{/s]} = \frac{1}{n} A R^{2/3} \sqrt{S} \quad \text{-(SI Units)}$$

$$\text{Discharge, } Q \text{ [ft}^3\text{/s]} = \frac{1.486}{n} A R^{2/3} \sqrt{S} \quad \text{-(English Units)}$$

Hazen-Williams Equations [Circular Pipes]:

SI Units: Q [m³/s], L [m], D [m], H_L [m]

$$Q = 0.278 C D^{2.63} S^{0.54}$$

$$S = \frac{h_L}{L} = \frac{10.704}{C^{1.85} D^{4.87}} Q^{1.85}$$

$$\text{For critical flow, } Fr = \frac{V}{\sqrt{gD}}$$

$$\text{For critical flow, } V = \sqrt{gD}$$

$$\text{For critical flow, } Q = V \cdot A = A \sqrt{gD}$$

$$\text{For normal flow, } Z_n = AR^{2/3}$$

$$\text{For critical flow, } Z_c = A \sqrt{D}$$

$$\text{Froude Number} = \frac{V}{\sqrt{gD}}$$

$$Z_c = A \sqrt{D} = \frac{Q}{\sqrt{g}}$$

Table 14.1 Geometric Elements for a Circular Section

$\frac{y}{d_0}$	$\frac{A}{d_0^2}$	$\frac{P_w}{d_0}$	$\frac{R}{d_0}$	$\frac{T}{d_0}$	$\frac{D}{d_0}$	$\frac{A\sqrt{D}}{d_0^{5/2}}$	$\frac{AR^{2/3}}{d_0^{8/3}}$
0.01	0.0013	0.2003	0.0066	0.1990	0.0066	0.0001	0.0000
0.05	0.0147	0.4510	0.0326	0.4359	0.0336	0.0027	0.0015
0.10	0.0409	0.6435	0.0635	0.6000	0.0682	0.0107	0.0065
0.15	0.0739	0.7954	0.0929	0.7141	0.1034	0.0238	0.0152
0.20	0.1118	0.9273	0.1206	0.8000	0.1398	0.0418	0.0273
0.25	0.1535	1.0472	0.1466	0.8660	0.1774	0.0646	0.0427
0.30	0.1982	1.1593	0.1709	0.9165	0.2162	0.0921	0.0610
0.35	0.2450	1.2661	0.1935	0.9539	0.2568	0.1241	0.0820
0.40	0.2934	1.3694	0.2142	0.9798	0.2994	0.1603	0.1050
0.45	0.3428	1.4706	0.2331	0.9950	0.3446	0.2011	0.1298
0.50	0.3927	1.5708	0.2500	1.0000	0.3928	0.2459	0.1558
0.55	0.4426	1.6710	0.2649	0.9950	0.4448	0.2949	0.1825
0.60	0.4920	1.7722	0.2776	0.9798	0.5022	0.3438	0.2092
0.65	0.5404	1.8755	0.2881	0.9539	0.5666	0.4066	0.2358
0.67	0.5594	1.9177	0.2917	0.9404	0.5948	0.4309	0.2460
0.70	0.5872	1.9823	0.2962	0.9165	0.6408	0.4694	0.2608
0.75	0.6318	2.0944	0.3017	0.8660	0.7296	0.5392	0.2840
0.80	0.6736	2.2143	0.3042	0.8000	0.8420	0.6177	0.3045
0.85	0.7115	2.3462	0.3033	0.7141	0.9964	0.7098	0.3212
0.90	0.7445	2.4981	0.2980	0.6000	1.2408	0.8285	0.3324
0.94 ^a	0.7662	2.6467	0.2896	0.4750	1.6130	0.9725	0.3353
0.95	0.7707	2.6906	0.2864	0.4359	1.7682	1.0242	0.3349
1.00	0.7854	3.1416	0.2500	0.0000	∞	∞	0.3117

^a Maximum flow occurs at 0.94 full depth.

Kirpich Formula [time of concentration]:

$$t_c \text{ [minutes]} = \frac{0.0078L^{0.77}}{S^{0.385}}; L \text{ [ft] and } S \text{ [ft/ft]}$$

Intensity-Duration-Frequency equation:

$$\text{Rainfall Intensity, } i \text{ [in/hr]} = a(D + b)^c$$

Where: D = duration [hrs]

Where,

a, b and c are local parameters for a given return period, T in years;
D = rainfall duration in hours.

Rational Formula:

$$Q = CIA$$

C = Runoff coefficient

I = Rainfall Intensity (in/hr)

A = Area in Acres

1 [100]

Two pipes, a 220 mm (300 m long) cast iron pipe and a 600 mm (1000 m long) new cast iron pipe ($C=120$), are arranged in **series** in a water distribution system and the total headloss is limited to 30 m. Using the Hazen-Williams equation, determine the discharge [m^3/s] through the system. Assume that specific weight of water = 9810 N/m^3 .

Perform the necessary calculations to determine the length of the **equivalent 300 mm older cast iron pipe ($C=105$)** for the system.

Assume a flow of $0.10 \text{ m}^3/\text{s}$ in your calculations for the equivalent pipe as provided in the table below.

Pipe	C	Dia [mm]	Dia [m]	[m^3/s]	$S = HL/L$ []	Pipe Length [m]	Headloss, $H_L = S \cdot L$ [m]
1	120	220	0.22	0.100	0.1	300	30
2	120	600	0.6	0.100	0.03	1000	30
EQV	105	300	0.3	0.100	0.0097	3092.8	30

(a) [40] Determine the equivalent length of 300 mm pipe, older cast iron ($C=105$).

$$S = \frac{h_L}{L} = \frac{10.704}{C^{1.85} D^{4.87}} Q^{1.85}$$

$$= \frac{30 \text{ m}}{L} = \frac{10.704}{(105)^{1.85} (0.3)^{4.87}} (0.1 \text{ m}^3/\text{s})^{1.85}$$

$$= \frac{30 \text{ m}}{L} = 9.7 \times 10^{-3}$$

$$L = 3092.8 \text{ m}$$

$$\text{Length of 300 mm pipe [m]} = 3092.8$$

(b) [35] Discharge in the system [m^3/s]:

$$Q = 0.278 \text{ CD}^{2.63} S^{0.54}$$

$$= 0.278 (105) (0.3)^{2.63} (0.0097)^{0.54}$$

$$= 0.1 \text{ m}^3/\text{s}$$

$$\text{Discharge [m}^3/\text{s]} = 0.1$$

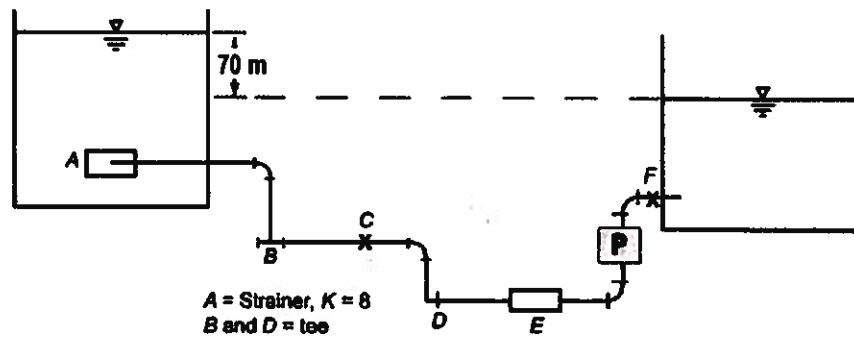
(c) [25]

What are the primary purposes of detention/retention basins. Provide at least 2. Be specific in your answer.

they hold water in specific parts of city in order to control flooding when rainfall is really high and distributes water accordingly, they are built well below the regular ground surface to control it.

2. [100] For fully rough turbulent flow.

Water is pumped by a pump (P) from right to left in the system shown below through a 400-mm, 100 m galvanized iron pipe ($\epsilon = 0.16$ mm), as shown in the figure. In order to calculate the minor losses, assume the following in the figure below: C is a gate valve, $K = 5$; E is a meter, $K = 9$; F is a check valve (open). The elbows in the system are 90° threaded elbows and the tees are threaded (through flow). The water surface elevation difference is 70 m. The water surface elevation difference is 70 m.



$$K_m = 1.5$$

$$A = 100 \times 70 = 7000 \text{ m}^2$$

(a) [25] Assuming the flow is fully rough turbulent flow, determine the friction factor for the flow using an appropriate Friction Factor equation. Provide your answer to 4 decimal places.

$$f = \frac{1}{2.109 \left(\frac{3.70}{\epsilon} \right)} = \frac{1}{2.109 \left(\frac{3.7 \times 400}{0.16} \right)} = 0.126$$

Friction factor for the pipe flow [] = 0.126

(b) [25] Determine the total (sum) of the minor headloss coefficients for the system. Show all work and justify your answer fully.

$$\sum K = 5 + 9 + 1.5$$

Total (sum) of minor headloss coefficients [] = 15.5

(c) [35] Develop the relationship between the head [m] of the pump (H_p) and the flowrate (Q) in the system. This is the equation of the system head curve. [Hints: $V = Q/A$; the equation is based on the Energy Equation]

$$V = Q/A$$

$$H_p + \frac{V_1^2}{2g} + \frac{P_1}{\gamma} + z_1 = H_1 + \frac{V_2^2}{2g} + \frac{P_2}{\gamma} + z_2 + h_L$$

$$H_p = \left(H_1 + \frac{(Q_2/A_2)^2}{2g} + \frac{P_2}{\gamma} + z_2 + h_L \right) - \left(\frac{(Q_1/A_1)^2}{2g} + \frac{P_1}{\gamma} + z_1 \right)$$

System head curve equation, $H_p = \left(\frac{(Q_2/A_2)^2}{2g} + \frac{P_2}{\gamma} + z_2 + h_L \right) - \left(\frac{(Q_1/A_1)^2}{2g} + \frac{P_1}{\gamma} + z_1 \right)$

(d) [15] If the flowrate (Q) is 1250 liters per second, what is the HEAD ON THE PUMP [m]? Justify your answer fully.

$$H_p = \frac{(1250 \text{ L/s} / 7000)^2}{2 \times 9.81}$$

$$H_p [\text{m}] = 1.63 \times 10^{-3}$$

3 [100]

(a) [40] A circular channel ($n = 0.014$) with a diameter of 5.00 m is used to convey a discharge of 96 m³/s, determine the **normal depth of flow** if the channel slope is 5%.

[Hint: You may use Table 14.1 which has been provided. Do not interpolate, use the closest value – as appropriate]

$$P = 2\sqrt{b^2 + y^2}$$

$$Q = \frac{1}{n} A R^{2/3} \sqrt{S}$$

$$R = \frac{A}{P}$$

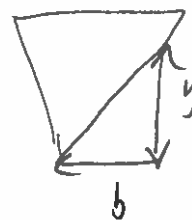
$$R = \frac{A}{P}$$

= taken from 14.1

$$96 \frac{\text{m}^3}{\text{s}} = \frac{1}{0.014} A (0.0376)^{2/3} (\sqrt{5/100})$$

$$A = 58.89$$

$$D = \frac{A}{T} =$$



Normal Depth of flow [m] =

(b) [20] What is the **area of flow** for the flow condition in part (a) [m²]? Show all work.

[Hint: Again, Table 14.1 may be useful.]

$$A = 0.0147 = \frac{1}{2} b h = \frac{1}{2}$$

Area of flow [m²] =

(c) [20] What is the **hydraulic depth** [m] for the flow?

$$D = \frac{A}{T} = \frac{0.0147}{0.4359}$$

$$T = 2b$$

=

Hydraulic Depth of flow [m] =

(d) [20] What is the **Froude Number** [] for the flow?

$$= \frac{V}{\sqrt{gD}}$$

$$V = \frac{1}{n} R^{2/3} \sqrt{S} = \frac{1}{0.014} (0.0376)^{2/3} (\sqrt{0.05})$$

$$= \frac{1.61}{\sqrt{(9.81 \times 0.37)}}$$

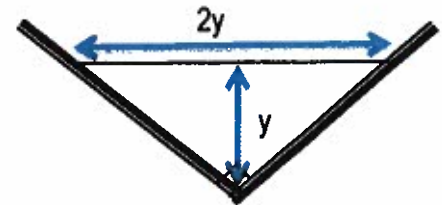
$$V = 1.61$$

Froude Number of flow [] =

4 [100]

A channel with a right triangular section as shown carries a flow of $20 \text{ m}^3/\text{s}$. The velocity of flow = 2 m/s .

(a) [20] Determine the depth of flow, y .



$$D = 20/2 ?$$

Depth of flow, y [m]

~~10 m~~

~~-15~~

(b) [25] What is the Froude number, Fr , for this flow?

$$Fr = \frac{V}{\sqrt{gD}} = \frac{2 \text{ m/s}}{\sqrt{9.81 \times 10}}$$

Froude Number, Fr []

~~0.2~~

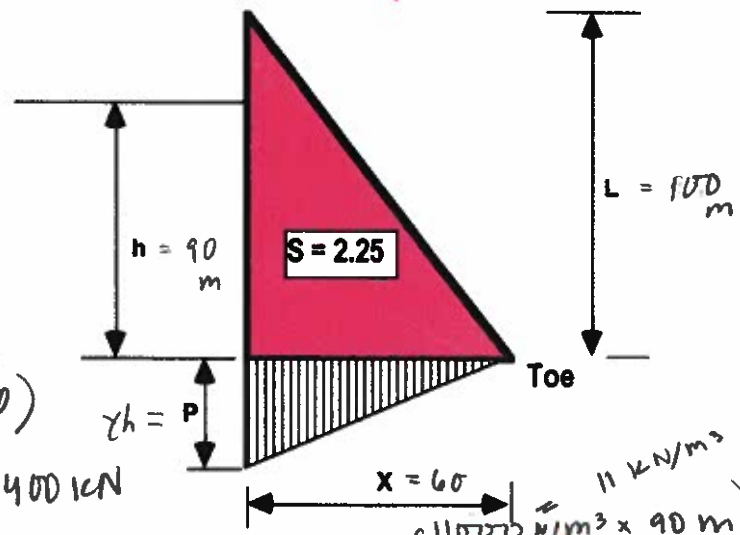
~~-15~~

For the construction of the dam shown, a new material is used (Specific Gravity, $S=2.25$). The depth of muddy water behind the dam ($\gamma = 11,000 \text{ N/m}^3$), $h = 90 \text{ m}$.

The dam is ($L = 100 \text{ m}$) high and $X = 60 \text{ m}$. $P = \gamma h$.

Analyze 2 m section of the dam as follows.

(c) [20] Determine the force of the muddy water behind dam, F [kN] and its moment M [kN-m] about the toe of the dam



$$F = \gamma h A = (11,000 \text{ N/m}^3) (2 \text{ m}) \left(\frac{1}{2} \times 60 \text{ m} \times 90 \text{ m} \right) = 59,400,000 \text{ N} = 59,400 \text{ kN}$$

F (for a 2 m section) [kN] = ~~59,400~~ Moment of force, F about the toe [kN-m] = ~~998~~

(d) [20] Determine the weight of the 2-m dam section, W [kN]

$W =$

W [kN] =

~~35~~

(e) [15] Determine the uplift force (for the 2-m section) under the dam, U [kN]

U [kN] =

~~N~~

~~-75~~

5 [100]

(a) [50]

HARDY-CROSS Method: Piping System using Darcy-Weisbach Equation ($n = 2$); friction factor, $f = 0.018$.

PROVIDE THE VALUES for highlighted (BLUE) FIELDS. ALL necessary information has been provided.

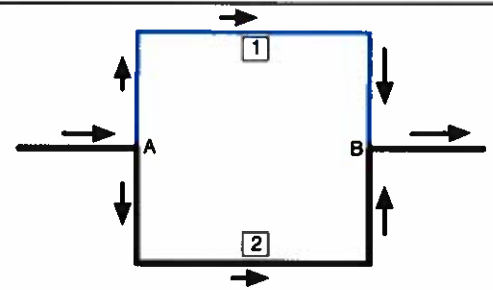
Iteration	Loop	Pipeline	Len [ft]	diam [in]	K	Qa [cfs]	headloss, hf = kQa ² [ft]	lhf/Qj	Correction, δ [cfs]	New Q
1		AB	4000	12	1.8136	1.500	4.0806	2.7204	0.358	1.142
		BF	2000	6	29.017	1.000	29.017	29.017	0.358	0.642
		FA	1500	6	21.763	-2.000	-87.05	43.526	0.358	2.358
							-53.95	75.264		
6	Corrections	Loop 1	δ_1 [cfs] =		0.358	Loop 2	δ_2 [cfs] =		0.374	

2		BC	3000	8	10.329	1.000	10.329	10.329	0.374	4.955
		CD	2000	8	6.886	-0.500	-1.722	3.443	0.374	-0.874
		DF	3000	8	10.329	-1.500	-23.240	15.494	0.374	-1.874
		FB	2000	6	29.018	-1.000	-29.018	29.018	0.374	-1.374
							-43.650	58.283		

(b) [50]

Consider the piping system shown. Pipe 1 is a 25-cm (diameter), 600 m long ductile iron pipe ($\epsilon = 0.15$ mm) in which the flow velocity is 5 m/s. Pipe 2 is a 40-cm (diameter), 400 m long riveted steel pipe ($\epsilon = 2.00$ mm). The flow is fully rough turbulent and minor losses are negligible.

(i) [20] Determine the friction factors (to 4 decimal places) in each pipe using the equation (not the Moody diagram) for friction factor. Show your calculations.



$$f_1 = \frac{1}{2.105 \left(\frac{3.7 \times D}{\epsilon} \right)} = \frac{1}{2.105 \frac{3.7 \times 25}{0.15}} = 0.179$$

Friction factor in Pipe 1 =

0.179

$$f_2 = \frac{1}{2.105 \frac{3.7 \times 40}{2}} = 0.267$$

Friction factor in Pipe 2 =

0.267

(ii) [30] Determine the velocity in Pipe 2 [m/s]

$$(25)(600)(5 \frac{m}{s}) = (40)(400)(v_2 \frac{m}{s})$$

$$v_2 = 4.69 \text{ m/s}$$

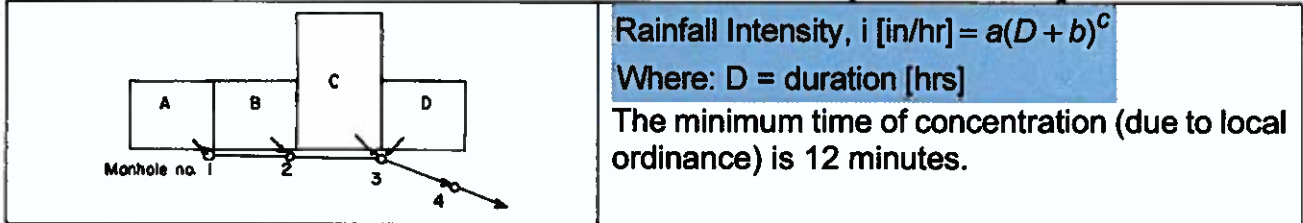
Velocity in Pipe 2 [m/s] =

4.69 m/s

6 [100]

The IDF (Intensity Duration Frequency) curve parameters for the area (called **StationP**) below are:

$a = 3.592$ and $b = 0.238$ and $c = -0.809$ for a return period of 25 years.



The velocity of flow in the pipes (manhole to manhole in the sewer system) is given in the second table below and the other data for **StationP** are given in the first table. Your primary goal is to calculate the peak flowrate [cfs] from sections A, B, C and D for the 25-year design rainfall at the point where the discharge enters **manhole 4** using the Rational Method.

Data for the watershed [TABLE 1]

SECTION	Runoff Coefficient	Length of overland travel path [ft]	Slope [%]	Area [ac]	Overland flow travel time [min]
A	0.7	1000	2.5	200	6.59
B	0.5	1200	4.0	150	6.33
C	0.8	2500	5.0	400	10.22
D	0.4	1000	3.0	250	6.14
Total Area				1000	

Provide sample calculation for the first row at the right of above table

Data for the sewer system [Table 2]

Manhole Segment	Length [ft]	Velocity [ft/s]	Travel time [min]
1-2	1200	2.0	6.33
2-3	1500	3.0	5.11
3-4	2500	2.5	10.22

Provide sample calculation for the first row at the right of above table

- (a) [30] Calculate the time of concentration (using manhole 4 as the reference point or outlet). Complete the table below and appropriate portions of Tables 1 and 2.

Travel Path [Inlet-Man#1-Man#2-...-Outlet]	Time of travel [min]
A-1-2-3	

Provide sample calculation for the first row below and complete the rest of the table

Time of concentration, t_c [minutes] = 12 mins — greatest

- (b) [20] Design Rainfall intensity, i (using IDF formula provided) for **StationP**

$i = a(D + b)^c = (3.592) \left(\frac{12}{60} + 0.238 \right)^{-0.809}$

Design Rainfall Intensity, i [in/hr] = 7.005 *ok for #5*

- (c) [25] Determine the composite Runoff Coefficient, C for **StationP**

$\Sigma C = 0.7 + 0.5 + 0.8 + 0.4$

Composite Runoff Coefficient, C [=] = 2.4 *20*

- (c) [25] Determine the Peak runoff for **StationP** (using Rational Formula)

$Q = CIA = (2.4)(7.005)(1000 \text{ acres})$

StationP peak runoff (with MANHOLE 4 as the OUTLET) [cfs] = 16,812

140

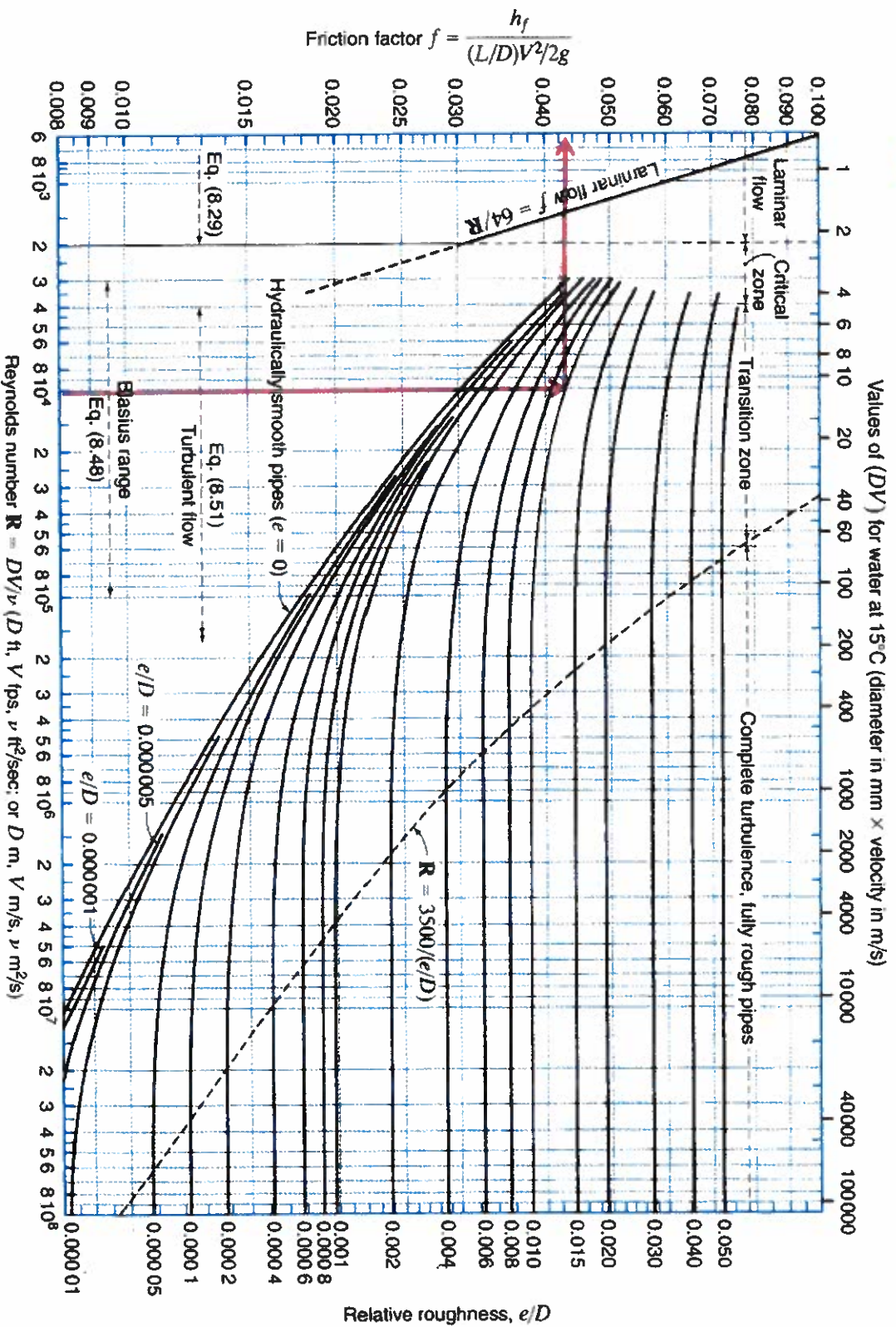
Properties of Water

Temperature (°C)	Density ρ (kg/m ³)	Specific Weight γ (N/m ³)	Viscosity μ (N·s/m ²)	Kinematic viscosity ν (m ² /s)	Bulk modulus B (Pa)	Surface Tension σ (N/m)	Vapor Pressure (kPa)
0	999.9	9809	1.792×10^{-3}	1.792×10^{-6}	204×10^7	7.62×10^{-2}	0.610
5	1000.0	9810	1.519	1.519	206	7.54	0.872
10	999.7	9807	1.308	1.308	211	7.48	1.13
15	999.1	9801	1.140	1.141	214	7.41	1.60
20	998.2	9792	1.005	1.007	220	7.36	2.34
30	995.7	9768	0.801	0.804	223	7.18	4.24
40	992.2	9733	0.656	0.661	227	7.01	7.38
50	988.1	9693	0.549	0.556	230	6.82	12.3
60	983.2	9645	0.469	0.477	228	6.68	19.9
70	977.8	9592	0.406	0.415	225	6.50	31.2
80	971.8	9533	0.357	0.367	221	6.30	47.3
90	965.3	9470	0.317	0.328	216	6.12	70.1
100	958.4	9402	0.284×10^{-3}	0.296×10^{-6}	207×10^7	5.94×10^{-2}	101.3

PROPERTIES OF WATER (ENGLISH UNITS)

Temperature (°F)	Specific Weight γ (lb/ft ³)	Mass Density ρ (lb • sec ² /ft ⁴)	Absolute Dynamic Viscosity μ ($\times 10^{-5}$ lb • sec/ft ²)	Kinematic Viscosity ν ($\times 10^{-5}$ ft ² /sec)	Vapor Pressure p_v (psi)
32	62.42	1.940	3.746	1.931	0.09
40	62.43	1.940	3.229	1.664	0.12
50	62.41	1.940	2.735	1.410	0.18
60	62.37	1.938	2.359	1.217	0.26
70	62.30	1.936	2.050	1.059	0.36
80	62.22	1.934	1.799	0.930	0.51
90	62.11	1.931	1.595	0.826	0.70
100	62.00	1.927	1.424	0.739	0.95
110	61.86	1.923	1.284	0.667	1.24
120	61.71	1.918	1.168	0.609	1.69
130	61.55	1.913	1.069	0.558	2.22
140	61.38	1.908	0.981	0.514	2.89
150	61.20	1.902	0.905	0.476	3.72
160	61.00	1.896	0.838	0.442	4.74
170	60.80	1.890	0.780	0.413	5.99
180	60.58	1.883	0.726	0.385	7.51
190	60.36	1.876	0.678	0.362	9.34
200	60.12	1.868	0.637	0.341	11.52
212	59.83	1.860	0.593	0.319	14.70

Moody Diagram – friction factor, f



(Note: If $e/D = 0.01$ and $Re = 10^4$, the left arrow locates $f = 0.043$.)

IV.

**HOMEWORK
ASSIGNMENTS**

[07]

**CVEG 4303
WATER RESOURCES ENGINEERING
SPRING 2022**

**HOMework
01**

ABOVE
AVERAGE

CVEG 4303 P01

Dr. Nzewi

Water Resources Engineering

Homework 01 Update

Due: Tuesday, Feb 01, 2022 at 1:00 PM (beginning of class)/Canvas 01/31/2022, 11:30 PM

Spring 2022

Assigned: 01/25/2022

SUBMIT THIS as cover sheet with your work

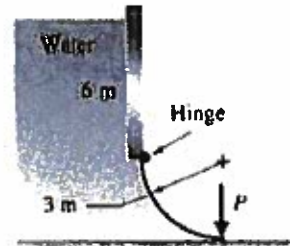
Instructions:

IN ALL THE PROBLEMS YOU MUST PROVIDE ENOUGH DETAILS AND DESCRIPTION OF THE SOLUTION METHOD TO DEMONSTRATE YOUR KNOWLEDGE OF THE SOLUTION METHOD. A SUBSTANTIAL PORTION OF THE GRADE WILL BE BASED ON YOUR METHODS.

Name [PRINT] Amyssa Reynolds

Problem 1 [200]

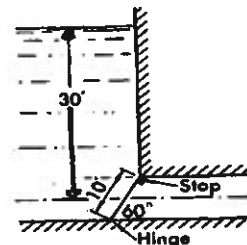
Determine the force, P [kN] needed to keep the curved gate closed if it is 4 m wide (into the paper). The water (hot) has a specific gravity of 0.90. Show your work fully.



800
900

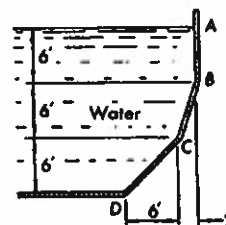
Problem 2 [200]

A 10 ft X 20 ft rectangular gate is hinged at its lower edge as shown and closes the entrance to a tunnel. The vertical distance from the water ($SG = 1.00$) surface to the centroid of the gate is 30 ft (as shown). The gate makes an angle of 60° with the horizontal plane. Determine the force [lb] on the stop along the upper edge of the gate as shown. Show your work fully.



Problem 3 [200]

Compute the magnitude [lb] and direction (angle with the horizontal plane) of the resultant hydrostatic force on the tank wall ABCD as shown in the figure to the right. Show your work fully.

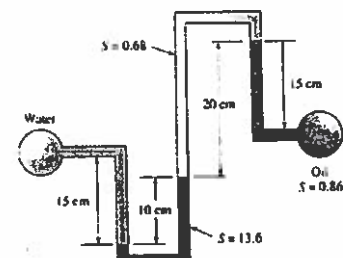


Problem 4 [150]

A barge (scow) is 12 ft wide, 24 ft long and 4 ft deep and is made of wood of specific gravity $= 0.72$. The sides and the bottom of the barge are 10 inch thick. How many cubic yards of gravel (with specific gravity of 1.762) can the barge carry with a freeboard (portion above the waterline) of 1.0 ft? Show your work fully.

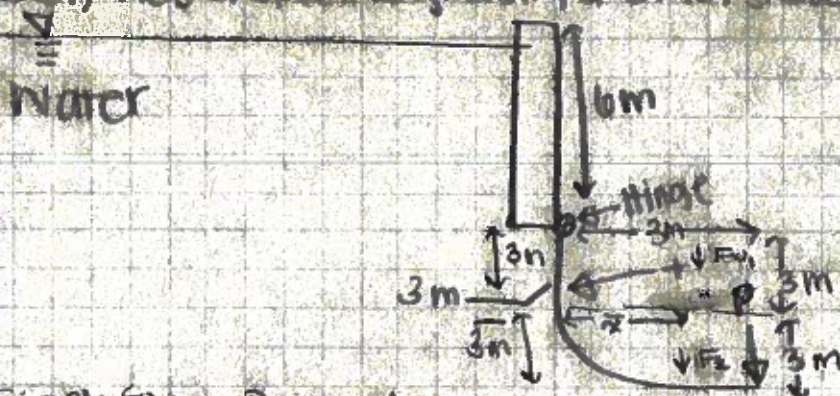
Problem 5 [150]

Determine the pressure difference [kPa] between the water pipe and the oil pipe in the figure below



Problem 01

Determine the force, P (kN) needed to keep the curved gate closed if it is 4m wide (into the paper). The water (top) has a specific gravity of 0.90. Show work fully.



Find: force, P , in kN
Given: width = 4m
SG of water = 0.90

Method: $\gamma = SG \times g = 0.90 \times 9.81 \frac{\text{m}}{\text{s}^2} = 8.829 \frac{\text{m}}{\text{s}^2}$
Solve:

$$F_H = F_{H1} + F_{H2}$$

$$W = \gamma \times V$$

$$F_{H1} = 8.829 (3)(3)(4) \leftarrow \text{KN} \times \text{m} \times \text{m} \times \text{m}$$

$$F_{H2} = 8.829 (\pi (1.5)^2 (4))$$

$$F_H = 317.844 + 249.634 = 567.478 \text{ kN}$$

$$\bar{x} = \frac{(A_1)(\bar{x}_1) + (A_2)(\bar{x}_2)}{A_1 + A_2}$$

$$A_1 = 3 \times 3 = 9 \text{ m}^2$$

$$\bar{x}_1 = 1.5 \text{ m}$$

$$A_2 = \pi (1.5)^2 = 7.069 \text{ m}^2$$

$$\bar{x}_2 = 3 - \frac{(4)(3)}{2\pi} = 1.727 \text{ m}$$

$$\bar{x} = \frac{(9)(1.5) + (7.069)(1.727)}{(9) + (7.069)} = 1.59 \approx 1.6 \text{ m}$$

F_H : hydrostatic force in horizontal direction

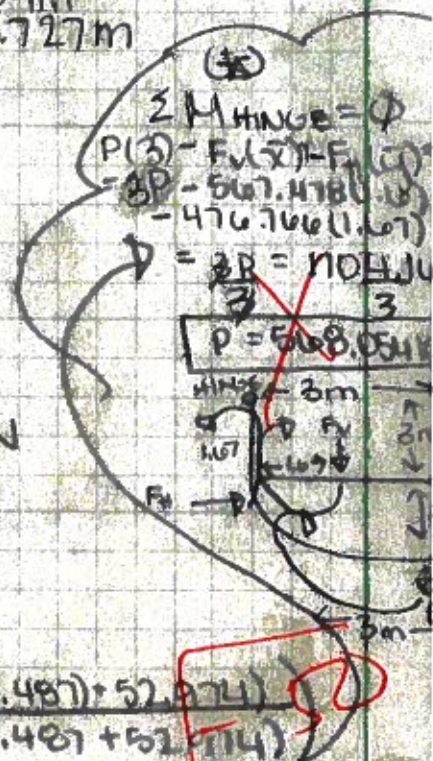
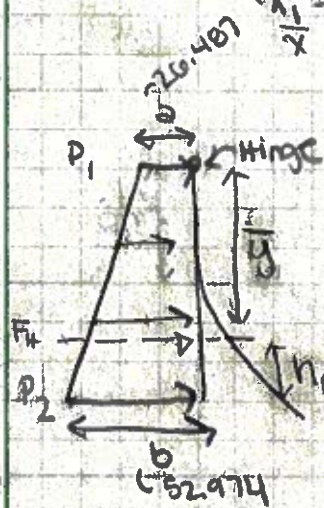
$$p_1 = \gamma \times h_1 = 8.829 (3) = 26.487 \text{ kPa}$$

$$p_2 = \gamma \times (h_1 + h_2) = 8.829 (3 + 3) = 52.974 \text{ kN}$$

$$F_H = \frac{1}{2} \times \text{width} \times (26.487 + 52.974) \times 4 = 476.766 \text{ kN}$$

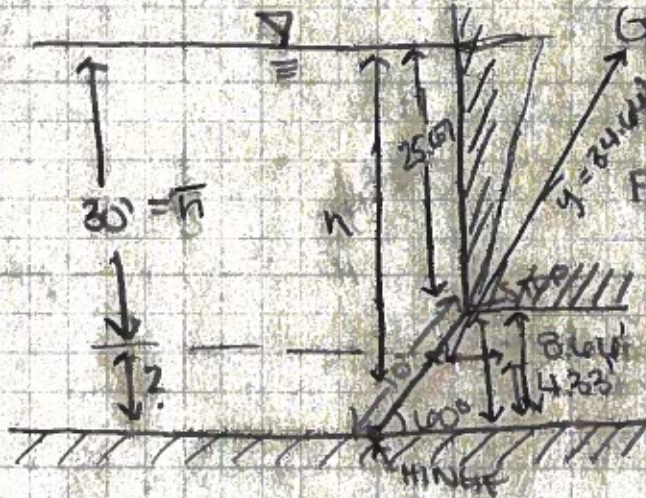
$$\bar{y} = 3 - h_p$$

$$h_p = \text{height} \left(\frac{1}{3} \right) \times \frac{(2a+b)}{(a+b)} = \frac{1}{3} \frac{(2(26.487) + 52.974)}{(26.487 + 52.974)}$$



Problem 2

A 10ft x 20ft rectangular gate is hinged at its lower edge and stops the entrance to a tunnel. The vertical distance from the water (SG = 1.00) surface to the centroid of the gate is 30ft. The gate makes an angle of 60° w/ the horizontal plane. Determine the force (lb) on the stop along the upper edge of the gate as shown.



Given: SG = 1.00

Area of gate = 10 x 20 = 200 ft²

h = 30 ft

θ = 60°

Find: Force on stop

Method/Some:



SOH CAH TOA

$\sin(60) = \frac{x}{10}$

$10(\sin 60) = 8.66$

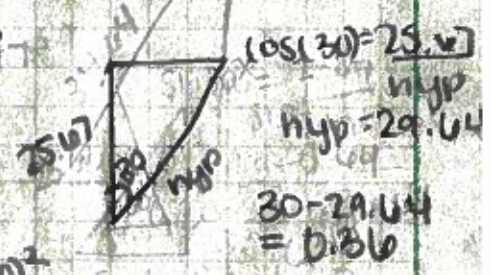
$\frac{2}{2} = 4.33$

$\bar{y} = \frac{h}{\sin \theta} = \frac{30}{\sin 60} = 34.64$

$F = \gamma \cdot A \cdot \bar{h}$
 $= (1)(62.4)(200)(30)$
 $= 374,400 \text{ lb}$

$y_p = \bar{y} + \frac{I}{A\bar{y}} = 34.64 + \frac{(20)(10)^3}{12} = 34.88$

$30 - 25.67 = 4.33$



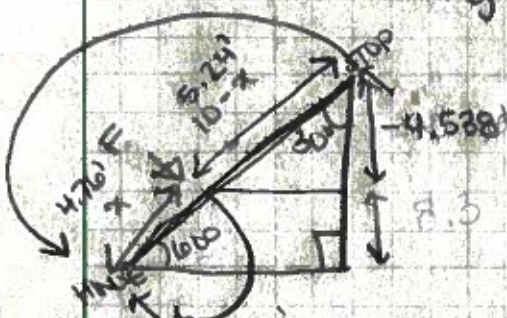
$\cos(30) = \frac{25.67}{\text{hyp}}$

$\text{hyp} = 29.64$

$30 - 29.64 = 0.36$

$h = \bar{h} + \frac{I \sin^2 \theta}{A\bar{h}}$
 $= 30 + \frac{(20)(10)^3 (\sin 60)^2}{12(200)(30)}$
 $= 30.208'$

$30.208 - 25.67 = 4.538$
 $\frac{4.538}{10} = 0.4538$
 $\frac{10}{0.4538} = 22.03$
 $x = 9.524$



$\cos(30) = \frac{4.538}{10-x}$

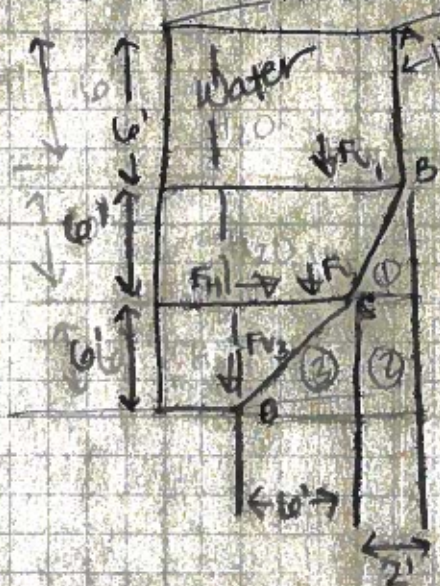
$10 \cos(30) - \cos(30)x = 4.538$
 $x = 4.76'$

$\sum M_{\text{Hinge}} = 0$
 $F_{\text{stop}}(10) - F(4.76) = 0$
 $10 F_{\text{stop}} = (374,400)(4.76)$
 $F_{\text{stop}} = 1,782,144$

$F_{\text{stop}} = 178,214 \text{ lb}$

-0

Problem 2 Compute the magnitude (b) & direction (angle w/ horizontal plane) of the resultant hydrostatic force on the tank wall ABC as shown.



Find: magnitude + direction of resultant force.

Given: $A-B = 6'$
 $B-C = 6'$
 $C-A = 2'$
 $D-C = 6'$

Method/solve:

$$F_V = \gamma \cdot h \cdot A = (120 \times 18 \times 8) (62.4) = 8985.6$$

$$F_H = \gamma \cdot h \cdot A = (120 \times 18 \times 8 - \frac{1}{2} (2 \times 6)) (62.4) = 8611.2$$

$$F_{N3} = (1) \times 18 \times 8 - \frac{1}{2} (18 \times 6) - (6 \times 2) (62.4) = 7113.6$$

$$F_R = F_{V1} + F_{V2} + F_{V3}$$

$$= 24710.4$$

$$F_H = \gamma \cdot h \cdot A = (62.4 \times \frac{18}{2}) (\pi (16)) = 28,229.116$$

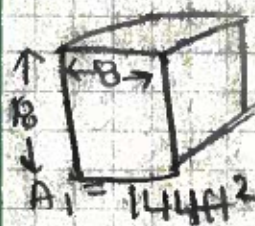
$$F_R = \sqrt{(F_H)^2 + (F_V)^2}$$

$$= \sqrt{(28,229.1)^2 + (24,710.4)^2}$$

$$F_R = 37,514.9816$$

$$\angle = \tan^{-1} \left(\frac{F_V}{F_H} \right) = \tan^{-1} \left(\frac{24,710.4}{28,229.1} \right) = 41.2^\circ$$

These are Straight as drawn Not Curved

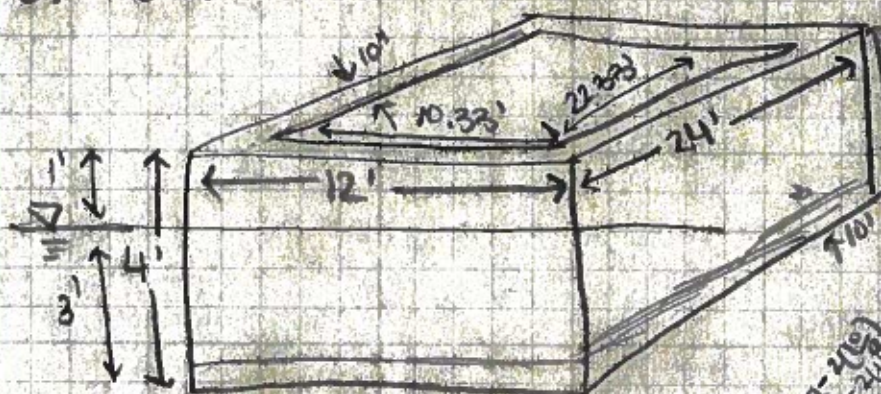


$$A_2 = \frac{1}{2} (8)^2 = 50.265 \text{ ft}^2$$

- 30

Problem 4

A barge (slab) is 12' wide, 24' long, + 4' deep. It's made of wood w/ SG = 0.72. The sides + bottom of barge are 10" thick. How many cubic yards of gravel (w/ SG of 1.762) can barge carry w/ a freeboard (portion above waterline) of 1.0'?



Find: how much
gravel can fit in
barge

Given: 12x24x4'
dimension w/ 10" thicknes

of gravel = 2
SG gravel = 1.762
SG wood = 0.72

$$V = L \times W \times H$$

Method/ Solve: $V_{\text{barge}} = (12 \times 24 \times 4) - (10.33 \times 22.33 \times 3.167)$
 $= 1152 - 730.528 = 421.4713$

$N_{\text{barge}} = V_{\text{barge}} \times \rho \times SG$
 $= 421.47 \times 62.4 (0.72)$
 $= 18,935.8816$

$V_{\text{barge}}' = 12 \times 24 \times 3 = 864 \text{ ft}^3$

$N_{\text{barge}}' = V_{\text{barge}}' \times \rho \times SG$
 $= 864 \times 62.4 (1) = 53,913.616$

$N_{\text{gravel}} + N_{\text{barge}} = N_{\text{barge}}'$
 $N_{\text{gravel}} = 53,913.6 - 18,935.88$
 $= 34,977.7216$

$N_{\text{gravel}} = \frac{N_{\text{gravel}}}{SG}$
 $= \frac{34,977.72}{1.762}$
 $= 19,851.13$

$\frac{19,851.13}{27} = 735.23$
 $\frac{1}{27} (318.13) = 11.78 \text{ yds}^3$

The barge can carry 11.78 yds of gravel.

FO

AVERAGE

CVEG 4303 P01

Water Resources Engineering

Spring 2022

Dr. Nzewi

Homework 01

Assigned: 01/25/2022

Due: Tuesday, Feb 01, 2022 at 1:00 PM (beginning of class)

SUBMIT THIS as cover sheet with your work

Instructions:

IN ALL THE PROBLEMS YOU MUST PROVIDE ENOUGH DETAILS AND DESCRIPTION OF THE SOLUTION METHOD TO DEMONSTRATE YOUR KNOWLEDGE OF THE SOLUTION METHOD. A SUBSTANTIAL PORTION OF THE GRADE WILL BE BASED ON YOUR METHODS.

Name [PRINT]

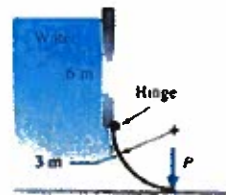
MOUALLI YAMBA

710
900

Problem 1 [200]

Determine the force, P [kN] needed to keep the curved gate closed if it is 4 m wide (into the paper). The water (hot) has a specific gravity of 0.90.

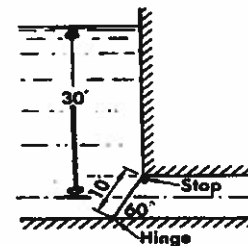
Show your work fully.



Problem 2 [200]

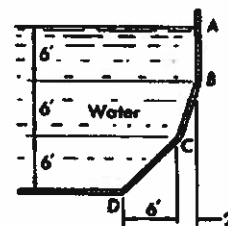
A 10 ft X 20 ft rectangular gate is hinged at its lower edge as shown and closes the entrance to a tunnel. The vertical distance from the water ($SG = 1.00$) surface to the centroid of the gate is 30 ft (as shown). The gate makes an angle of 60° with the horizontal plane. Determine the force [lb] on the stop along the upper edge of the gate as shown.

Show your work fully.



Problem 3 [200]

Compute the magnitude [lb] and direction (angle with the horizontal plane) of the resultant hydrostatic force on the tank wall ABCD as shown in the figure to the right. Show your work fully.

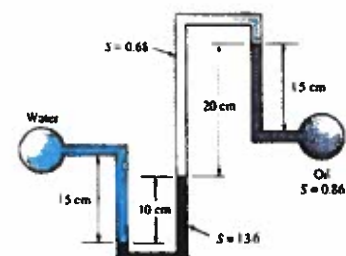


Problem 4 [150]

A barge (scow) is 12 ft wide, 24 ft long and 4 ft deep and is made of wood of specific gravity = 0.72. The sides and the bottom of the barge are 10 inch thick. How many cubic yards of gravel (with specific gravity of 1.762) can the barge carry with a freeboard (portion above the waterline) of 1.0 ft? Show your work fully.

Problem 5 [150]

Determine the pressure difference [kPa] between the water pipe and the oil pipe in the figure below

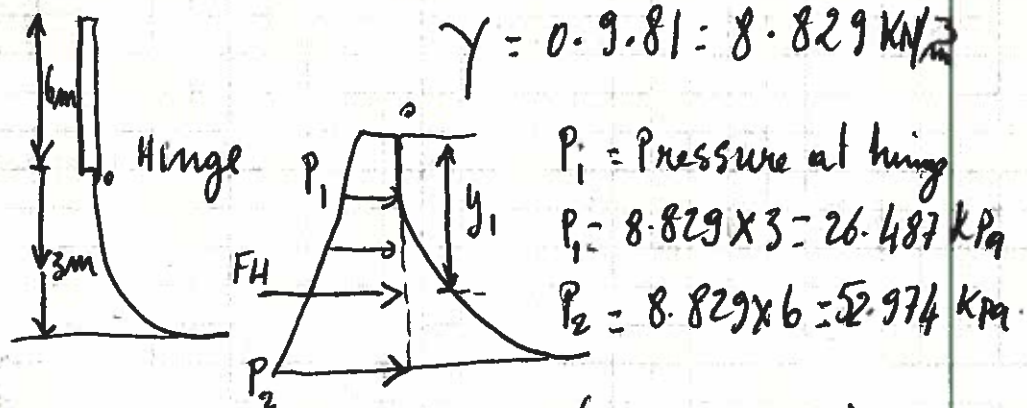


Problem 1Given:

specific gravity = 0.90.

Step 1

Calculate horizontal component of hydrostatic force acting on curved gate.



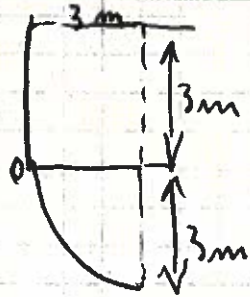
$$F_H = \text{Volume of pressure} = \frac{1}{2} \frac{(26.487 + 52.974) \times 3 \times 4}{2}$$

$$F_H = 476.766 \text{ kN}$$

Let F_H acts at a depth of y_1 from Hinge.

$$\therefore y_1 = \frac{26.487 + 2 \times 52.974}{26.487 + 52.974} \times \frac{3}{3} = \frac{5}{3}$$

Step 2:Calculate vertical component of hydrostatic force acting on the gate, F_v .



F_V = Weight of water column

(2/6)

$$\therefore F_V = W_1 + W_2$$

$$\therefore F_V = \left[\frac{\pi \times 3^2}{4} + 3 \times 3 \right] 4 \times 8.829$$

$$F_V = 567.478 \text{ kN}$$

Let F_V acts at a $\bar{x}$ distance (horizontal) from D.

$$\therefore \bar{x} = \frac{(3 \times 3) \times 1.5 + (0.25 \times \pi \times 3^2) \times (3 - \frac{4 \times 3}{3\pi})}{3 \times 3 + 0.25 \pi \times 3^2}$$

$$\bar{x} = 1.59975 \approx 1.6 \text{ m}$$

Step 3

Calculate value of force, P

→ For rotational equilibrium about hinge:

$$\sum M_{\text{hinge}} = 0 \Rightarrow P \times 3 - F_V \times \bar{x} - F_H \times y_1 = 0$$

$$\Rightarrow 3P - 567.478 \times 1.6 - 476.766 \times \frac{5}{3} = 0$$

$$P = 567.525 \text{ kN}$$

Handwritten signature or mark.

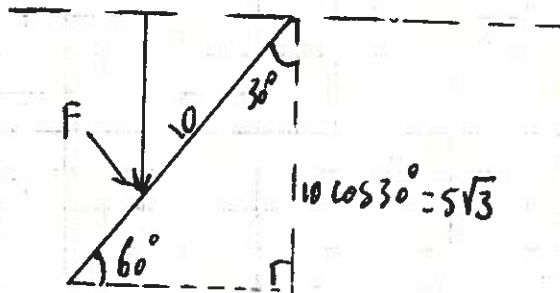
Problem 2

Force acting on the plate

$$F = \gamma A \bar{h} = (62.43)(10 \times 20) \times 30$$

$$F = 374580 \text{ lb}$$

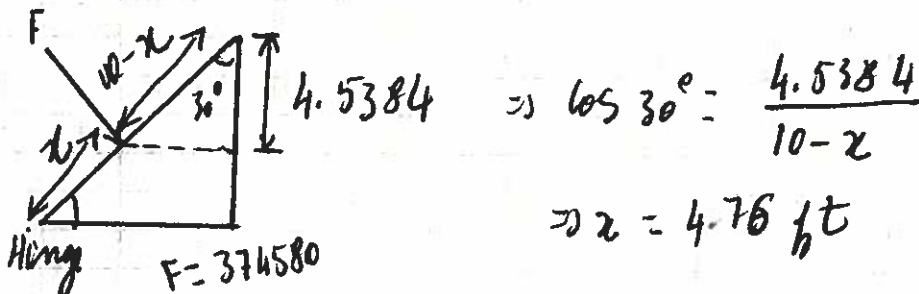
Force F acting on the plate at center of pressure (h^*)



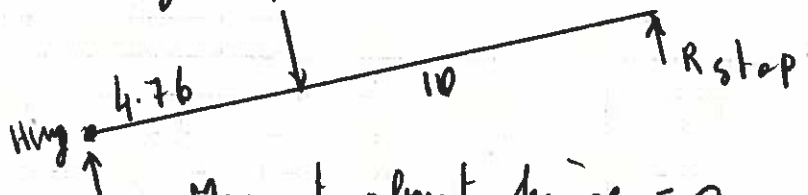
$$I_G = \frac{20 \times 10^3}{12} = 1666.67 \text{ ft}^4$$

$$h^* = \bar{h} + \frac{I_G \sin^2 \theta}{A \bar{h}} = 30 + \frac{\left(\frac{5000}{3}\right) (\sin 60^\circ)^2}{(10 \times 20) (30)}$$

$$h^* = 30.2083 \text{ ft}$$



$$\Rightarrow 2 = 4.76 \text{ ft}$$



Moment about hinge = 0

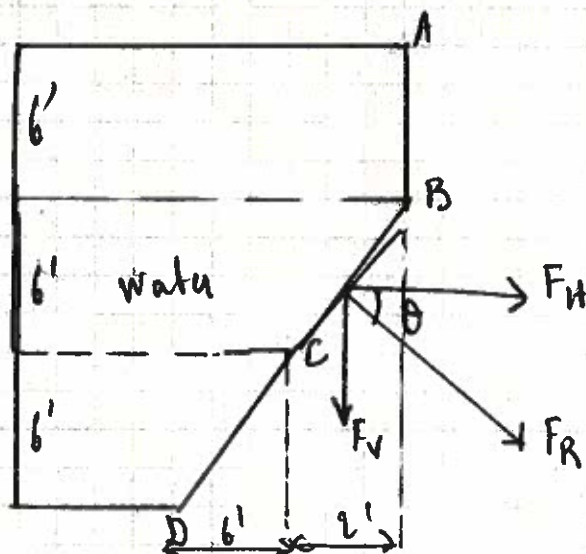
$$R_{\text{stop}} \times 10 = F \times 4.76$$

$$R_{\text{stop}} = \frac{374580 \times 4.76}{10} = 178281.351$$

$$R = 178.28 \text{ kip}$$

Problem 3

(4/6)

given

$$F_H = \rho g \bar{x} A$$

$$F_H = 1000 \times 9.81 \times 12 \times [(6 \times 1) + (2 \times 1)]$$

$$F_H = 1000 \times 9.81 \times 12 \times 8$$

$$F_H = 941.76 \text{ kN}$$

$$F_V = \rho g \times V = 1000 \times 9.81 \left[18 \times 8 - \frac{1}{2} \times 6 \times 6 - \frac{1}{2} \times 6 \times 2 \right] \times 1$$

$$F_V = 9810 \times [144 - 18 - 6] \times 1$$

$$F_V = 11772 \text{ kN}$$

$$F_R = \sqrt{F_V^2 + F_H^2} = \sqrt{(941.76)^2 + (11772)^2} = 150755 \text{ kN}$$

$$\tan \theta = \frac{F_V}{F_H} \Rightarrow \theta = \tan^{-1} \left(\frac{F_V}{F_H} \right) \Rightarrow \theta = \tan^{-1} \left(\frac{11772}{941.76} \right)$$

$$\theta = 0.89^\circ$$

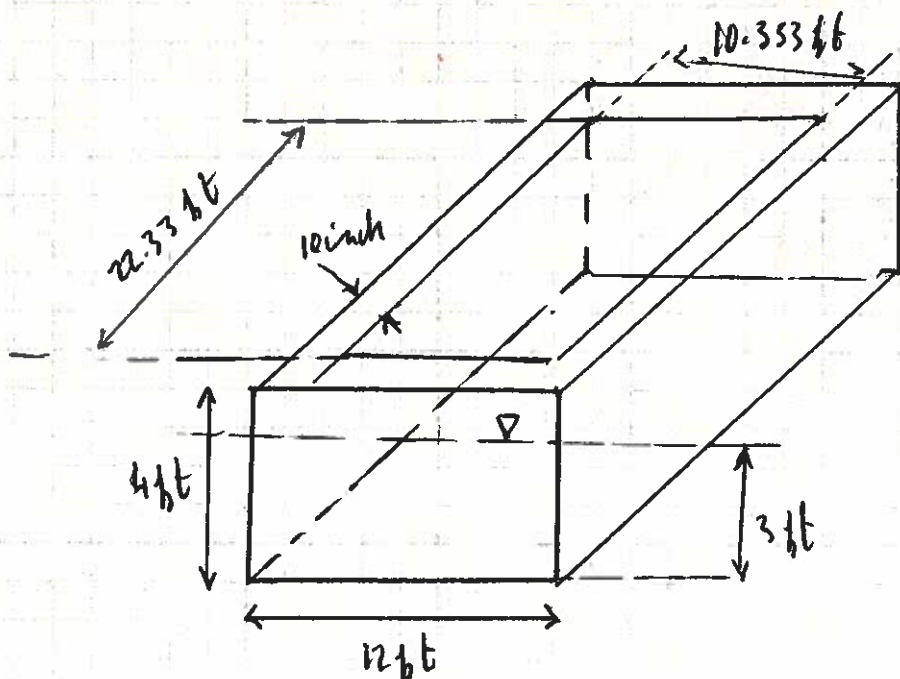
70

70

Problem 4

Given: $W = 12 \text{ ft}$, $L = 24 \text{ ft}$ $SG = 0.72$

(5/6)



As we require free board of 1 ft, so volume of water displaced by barge = $12 \times 24 \times 3 = 864 \text{ ft}^3$

Principle of buoyancy,

weight of body immersed in fluid = weight of the fluid that body displaced

(Weight of barge + weight of gravel) = weight of the fluid that body displaced

Weight of barge = (Volume of barge $\times$ density)

$$= [(12 \times 24 \times 4) - (10.333 \times 22.333 \times 3.167)] \times 62.43 \times 0.72$$

$$= 18933.04867 \text{ lb}$$

Weight of fluid displaced by barge = $864 \times 62.43 = 53939.52 \text{ lb}$

$\therefore 18933.048 + \text{Weight of gravel} = 53939.52$

$$\text{Weight of gravel} = 35006.472 \text{ lb}$$

70

Volume??

-70

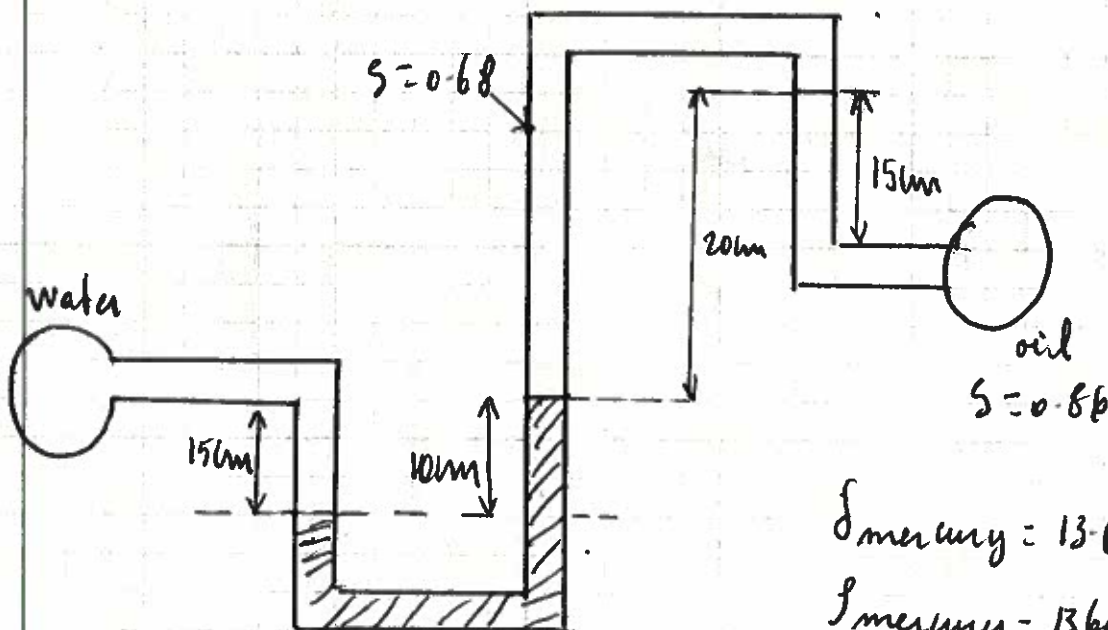
$$\text{density of gravel} = 62.43 \times 1.762 = 110.26 \text{ lb/ft}^3$$

(5/6)

$$\text{Volume of gravel} = \frac{35006.47}{110} = 318.235 \text{ ft}^3$$

$$1 \text{ ft}^3 = 0.037037 \text{ yd}^3$$

$$\Rightarrow V = 11.78 \text{ yd}^3$$

Problem 5

$$S_{\text{mercury}} = 13.6$$

$$S_{\text{mercury}} = 13600 \text{ kg/m}^3$$

$$S_{\text{oil}} = 0.86 \quad \frac{S_{\text{oil}}}{S_{\text{water}}} = 0.86 \Rightarrow S_{\text{oil}} = 860 \text{ kg/m}^3$$

Manometry Principle

$$P_{\text{water}} + \rho_w g h_w - \rho_{\text{Hg}} g h_{\text{Hg}} - \rho_{\text{gasoline}} g h_{\text{gasoline}} + \rho_{\text{oil}} g h_{\text{oil}} = P_{\text{oil}}$$

$$P_{\text{water}} - P_{\text{oil}} = 9.81 [13600 \times 0.1 - 1000 \times 0.15 - 860 \times 0.15 + 860 \times 0.2]$$

$$P_{\text{water}} - P_{\text{oil}} = 11.938 \text{ kN/m}^2$$



Fo

BELOW
AVERAGE

CVEG 4303 P01

Water Resources Engineering

Spring 2022

Dr. Nzewi

Homework 01

Assigned: 01/25/2022

Due: Tuesday, Feb 01, 2022 at 1:00 PM (beginning of class)

SUBMIT THIS as cover sheet with your work

Name (PRINT) Dmar Hunter

Instructions:

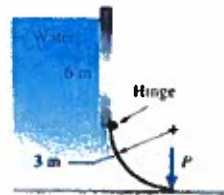
IN ALL THE PROBLEMS YOU MUST PROVIDE ENOUGH DETAILS AND DESCRIPTION OF THE SOLUTION METHOD TO DEMONSTRATE YOUR KNOWLEDGE OF THE SOLUTION METHOD. A SUBSTANTIAL PORTION OF THE GRADE WILL BE BASED ON YOUR METHODS.

380
900

Problem 1 [200]

Determine the force, P [kN] needed to keep the curved gate closed if it is 4 m wide (into the paper). The water (hot) has a specific gravity of 0.90.

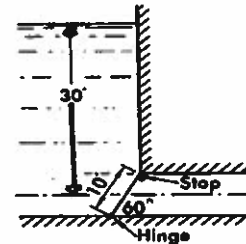
Show your work fully.



Problem 2 [200]

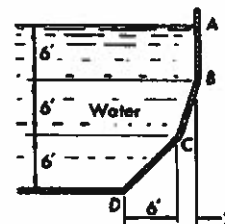
A 10 ft X 20 ft rectangular gate is hinged at its lower edge as shown and closes the entrance to a tunnel. The vertical distance from the water ($SG = 1.00$) surface to the centroid of the gate is 30 ft (as shown). The gate makes an angle of 60° with the horizontal plane. Determine the force [lb] on the stop along the upper edge of the gate as shown.

Show your work fully.



Problem 3 [200]

Compute the magnitude [lb] and direction (angle with the horizontal plane) of the resultant hydrostatic force on the tank wall ABCD as shown in the figure to the right. Show your work fully.

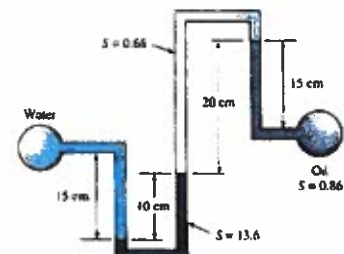


Problem 4 [150]

A barge (scow) is 12 ft wide, 24 ft long and 4 ft deep and is made of wood of specific gravity = 0.72. The sides and the bottom of the barge are 10 inch thick. How many cubic yards of gravel (with specific gravity of 1.762) can the barge carry with a freeboard (portion above the waterline) of 1.0 ft? Show your work fully.

Problem 5 [150]

Determine the pressure difference [kPa] between the water pipe and the oil pipe in the figure below



Problem 1Omar Hunter

Given:

$$W = 4\text{m}$$

$$SG = 0.9$$

$$H = 9\text{m}$$

$$P = \gamma h$$

$$F = \gamma \bar{h} A$$

$$F = 8829(4.5)(12)$$

$$F = 476766\text{N}$$

$$\bar{h} = \frac{H}{2} = \frac{9}{2} = 4.5\text{m}$$

$$\gamma = \rho g$$

$$0.9 = \frac{e}{e_w}$$

$$e = 0.9(1000)$$

$$e = 900$$

$$\gamma = 900(9.81)$$

$$\gamma = 8829$$

$$A = L \times W$$

$$= 3\text{m} \times 4\text{m}$$

$$= 12\text{m}^2$$

the rest?

1000

-120

Problem 2Omar Hunter

$$\bar{h} = 30 \text{ ft}$$

$$L = 10 \text{ ft}$$

$$W = 20 \text{ ft}$$

$$\bar{y} = 5 \text{ ft}$$

$$\theta = 60^\circ$$

$$F = \gamma \bar{h} A$$

$$= 9810 (30) (200)$$

$$=$$

$$A = 10 \times 20$$

$$A = 200 \text{ ft}^2$$

$$\bar{h} = 30 \text{ ft}$$

$$\gamma = 62.4$$

$$\gamma = 1000 (9.81)$$

$$\gamma = 9810$$

NO

62.4

180

-180

English units

Problem 5

Omar Harter

$$P_1 - P_2 = P_A = -0.86(15) + 0.68(20) + 13.6(10) - 1(15)$$

$$= 121.7 \text{ kPa}$$

~~30~~

#3

#4

~~-350~~ $\sqrt{-400}$

**CVEG 4303
WATER RESOURCES ENGINEERING
SPRING 2022**

**HOMework
02**

ABOVE
AVERAGE



Department of Civil & Environmental Engineering



CVEG 4303 P01

Water Resources Engineering

Spring 2022

Dr. Nzewi

Homework 02

Assigned: 02/10/2022

Due: Thursday, Feb 17, 2022 at 1:00 PM (beginning of class) / Canvas 02/16/2022, 11:30 PM

SUBMIT THIS as cover sheet with your work

Name [PRINT]

MAALVIKA AGGARWAL

Instructions:

IN ALL THE PROBLEMS YOU MUST PROVIDE ENOUGH DETAILS AND DESCRIPTION OF THE SOLUTION METHOD TO DEMONSTRATE YOUR KNOWLEDGE OF THE SOLUTION METHOD. A SUBSTANTIAL PORTION OF THE GRADE WILL BE BASED ON YOUR METHODS.

Problem 1 [150]

Solve Problem 15.1 in the textbook.

Show your work fully.

700
900

700

Problem 2 [150]

Solve Problem 15.3 in the textbook.

Show your work fully.

Problem 3 [150]

Solve Problem 15.5 in the textbook.

Show your work fully.

Problem 4 [250]

Solve Problem 15.21 in the textbook with the following changes:

- There are now 2 gate valves
- The water surface elevation difference between the reservoirs is 65 feet

Show your work fully.

Problem 5 [200]

Solve Problem 15.21 in the textbook. **Show your work fully.**

Problem 1

Given: $Q = 2.5 \text{ ft}^3/\text{s}$

$$\frac{P_1}{\rho} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2g} + z_2 + hf$$

$$P_1 = P_2 \Rightarrow V_1 = 0$$

$$\frac{P_1}{\rho} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2g} + z_2 + hf$$

$$z_1 = 20 + 25 = 45'$$

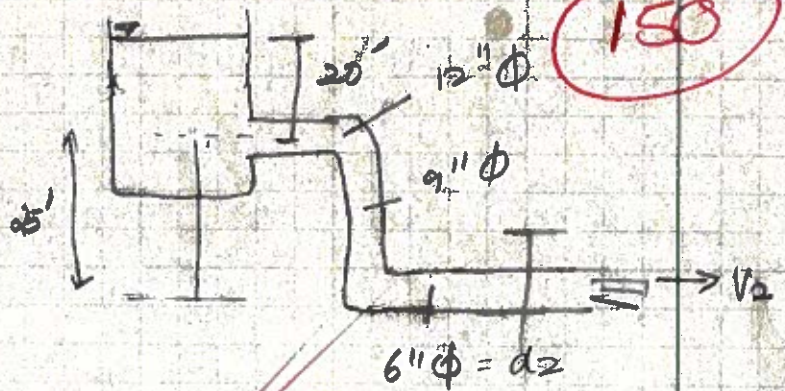
$$A_2 = \frac{\pi d_2^2}{4} = \frac{3.14 (6/12)^2}{4} = 0.1963 \text{ ft}^2$$

$$\text{So, } V_2 = \frac{Q}{A_2} = \frac{2.5}{0.1963} = 12.739 \text{ ft/s}$$

$$\text{So, } 0 + 0 + 45 = 0 + \frac{12.739^2}{2 \times 32.2} + 0 + hf$$

$$45 = 2.519 + hf$$

$$\therefore hf = 42.4801 \text{ ft}$$



150

50

20

30

50

Problem-2

Given: $d_2 = 6 \text{ in}$, $Q = 0.6$, $z_2 = 12 \text{ ft}$, $P_2 = 10 \text{ lb/in}^2$

Find: loss of energy, h_L

$$A_2 = \frac{\pi d^2}{4} = \frac{(3.14)(6/12)^2}{4} = 0.1963 \text{ ft}^2$$

$$\text{So, } V_2 = \frac{Q}{A_2} = \frac{0.6}{0.1963} = 3.057 \text{ ft/s}$$

$$\frac{P_1}{\rho} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2g} + z_2 + h_L$$

$$80 = \frac{18(12)^2}{62.4} + \frac{3.057^2}{2(32.2)} + 12 + h_L$$

$$80 = 53.68 + h_L$$

$$\therefore h_L = 26.316 \text{ ft}$$

Problem 3

150

Given: $V = 0.3 \text{ ft/s}$ $T = 40^\circ \text{F}$ Inside diameter = $d = 1 \text{ in} = \frac{1}{12} \text{ ft}$ Find: friction factor, f

Approach:

$$Re = \frac{Vd}{\nu}$$

At 40°F , $\nu = 1.664 \times 10^{-5}$

$$\text{So, } Re = \frac{(0.3)(1/12)}{1.664 \times 10^{-5}} = 1502.404$$

Flow is LAMINAR

$$\text{Relative roughness} = \frac{\epsilon}{d} = \frac{8 \times 10^{-4}}{1/12} = 0.0096$$

Roughness value is low & laminar flow, so

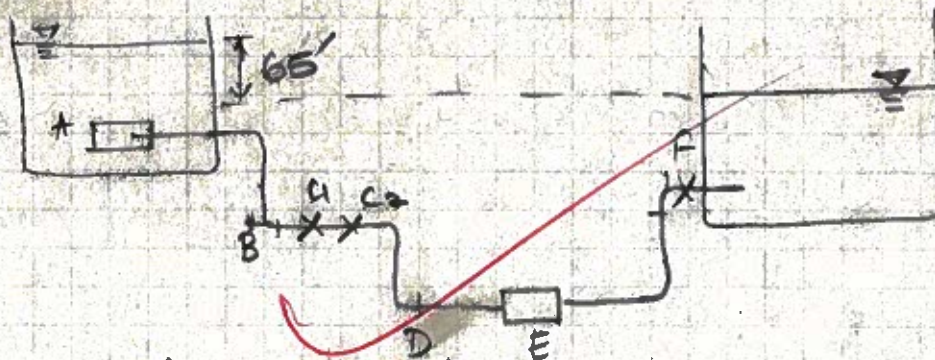
(ε from textbook table 15-1, pg 639)

$$f = \frac{64}{Re} = \frac{64}{1502.404}$$

$$f = 0.0425$$

50

Problem 4



Given: $L = 460'$
 $Q = 1 \text{ cfs}$
 $T = 70^\circ \text{F}$

A = Strainer, $K_m = 8$
 B & D = tee
 C & G = gate valves

E = meter, $K_m = 6$
 F = globe valve

$K_m \text{ tee} = 0.9$

$K_m \text{ gate valve} = 0.19$

$K_m \text{ globe valve} = 10$

$K_m \text{ 90}^\circ \text{ elbow} = 1.5$

$$\frac{P_1}{\rho} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2g} + z_2 + h_{L_{\text{loss}}}$$

$$0 + 0 + 65 = 0 + 0 + 0 + h_L$$

$$\text{So, } h_L = 65 \text{ ft}$$

$$\text{Now, } h_f = \frac{fL}{d} \frac{V^2}{2g}$$

$$h_m = \frac{V^2 K_m}{2g} = \frac{V^2}{2g} (8 + 1.5 + 0.9 + 0.19 + 0.19 + 1.5 + 0.9 + 6 + 1.5 + 10 + 1.5)$$

$$h_m = \frac{32.18 V^2}{2g}$$

$$\left(K_A + K_{\text{elbow}} + K_B + K_C + K_D + K_{\text{elbow}} + K_D + K_E + K_{\text{elbow}} + K_{\text{globe}} + K_{\text{elbow}} \right)$$

$$\text{Now, } h_L = h_f + h_m$$

$$\text{So, } 65 = \frac{fL}{d} \frac{V^2}{2g} + \frac{32.18 V^2}{2g}$$

①

$$65 = \frac{f L Q^2}{A^2 d^2 g} + \frac{32.18 Q^2}{A^2 g}$$

Assuming f as 0.06

$$65 = \frac{(0.06)(450)(1)^2}{\left(\frac{3.14 d^2}{4}\right)^2 d (2 \times 32.2)} + \frac{32.18(1)^2}{\left(\frac{3.14 d^2}{4}\right)^2 (2 \times 32.2)}$$

$$65 d^5 - 0.81 d = 0.68$$

$$\therefore d = 0.43 \text{ ft}$$

$$\text{At } 70^\circ\text{F}, \nu = 1.058 \times 10^{-5} \text{ ft}^2/\text{s}$$

$$\text{So, } Re = \frac{V d}{\nu} = \frac{Q d}{A \nu} = \frac{(1)(0.43)}{\frac{3.14(0.43)^2}{4} (1.058 \times 10^{-5})}$$

$$Re = 2800.11072 = 2.80 \times 10^3$$

$$\text{Cast Iron, } \epsilon = 8 \times 10^{-4} \text{ ft (Table 15-1, Pg 689)}$$

$$\text{So, } \frac{\epsilon}{d} = \frac{(8 \times 10^{-4})}{0.43} = 0.0019$$

from moody diagram, $f = 0.029$. So, assumption is wrong.

Again,

Assuming $f = 0.029$

$$65 = \frac{(0.029)(450)(1)^2}{\left(\frac{3.14 d^2}{4}\right)^2 d (2 \times 32.2)} + \frac{32.18(1)^2}{\left(\frac{3.14 d^2}{4}\right)^2 (2 \times 32.2)}$$

$$65 d^5 - 0.81 d = 0.328$$

$$d = 0.38 \text{ ft}$$

$$\text{So, } Re = \frac{Q d}{A \nu} = \frac{(1)(0.38)}{\frac{3.14(0.38)^2}{4} (1.058 \times 10^{-5})} = 308730.88 = 3.08 \times 10^5$$

$$\frac{\epsilon}{d} = \frac{(8 \times 10^{-4})}{0.38} = 0.002$$

from moody diagram, $f = 0.029$

So, our assumption is CORRECT.

(Diameter of pipe, $d = 0.38 \text{ ft}$)

Problem 5

Given: $L = 450$ ft, $Q = 1$ cfs, $T = 70^\circ\text{F}$

Find: diameter of pipe

$$\frac{P_1}{\rho} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2g} + z_2 + h_L$$

$$0 + 0 + 50 = 0 + 0 + 0 + h_L$$

$$\therefore h_L = 50$$

for cast iron, $E = 8 \times 10^{-4}$ ft (Table 15.1, pg 639)

At 70°F , $\nu = 1.058 \times 10^{-5}$ ft²/s

$$\text{So, } D = 0.66 \left[E^{1.25} \left(\frac{LQ^2}{gh_L} \right)^{4.75} + \nu Q^{9.4} \left(\frac{L}{gh_L} \right)^{5.2} \right]^{0.04}$$

$$D = 0.66 \left[(8 \times 10^{-4})^{1.25} \left(\frac{450(1)^2}{32.2 \times 50} \right)^{4.75} + (1.058 \times 10^{-5})^{9.4} (1)^{9.4} \left(\frac{450}{32.2 \times 50} \right)^{5.2} \right]^{0.04}$$

$$D = 0.66 \left[3.156 \times 10^{-7} + 1.398 \times 10^{-8} \right]^{0.04}$$

$$\boxed{D = 0.363} \text{ ft [Approximately]}$$

AVERAGE



Department of Civil & Environmental Engineering

m

CVEG 4303 P01

Water Resources Engineering

Spring 2022

Dr. Nzewi

Homework 02

Assigned: 02/10/2022

Due: Thursday, Feb 17, 2022 at 1:00 PM (beginning of class)/Canvas 02/16/2022, 11:30 PM

SUBMIT THIS as cover sheet with your work

Name [PRINT] Nathaniel Smith

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Problem 1 [150]

Solve Problem 15.1 in the textbook.

Show your work fully.

550
900

700

Problem 2 [150]

Solve Problem 15.3 in the textbook.

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Problem 3 [150]

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Solve Problem 15.21 in the textbook with the following changes:

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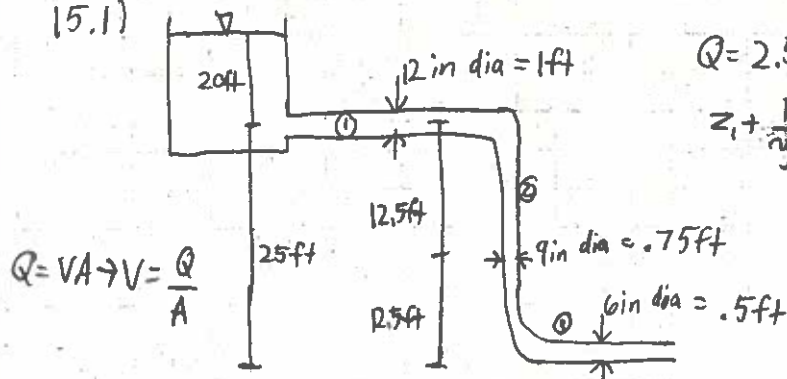
Problem 5 [200]

Solve Problem 15.21 in the textbook. Show your work fully.

150

Problem 1

15.1)



$$Q = 2.5 \text{ cfs}$$

$$z_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} = z_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + h_f \quad (50)$$

$$Q = VA \rightarrow V = \frac{Q}{A}$$

$$\textcircled{1} V_1 = \frac{2.5 \text{ cfs}}{\frac{\pi}{4}(1 \text{ ft})^2} = 3.18 \text{ ft/s}, \quad \textcircled{2} V_2 = \frac{2.5 \text{ cfs}}{\frac{\pi}{4}(0.75 \text{ ft})^2} = 5.66 \text{ ft/s}, \quad \textcircled{3} V_3 = \frac{2.5 \text{ cfs}}{\frac{\pi}{4}(0.5 \text{ ft})^2} = 12.73 \text{ ft/s}$$

$$45 \text{ ft} + 0 + 0 = 25 \text{ ft} + 0 + \frac{(3.18 \text{ ft/s})^2}{2(32.2 \text{ ft/s}^2)} + h_{f1}$$

$$45 \text{ ft} = 25 \text{ ft} + .16 \text{ ft} + h_{f1} \rightarrow h_{f1} = 19.84 \text{ ft}$$

$$25 \text{ ft} + 0 + \frac{(5.66 \text{ ft/s})^2}{2(32.2 \text{ ft/s}^2)} = 0 + 0 + \frac{(12.73 \text{ ft/s})^2}{2(32.2 \text{ ft/s}^2)} + h_{f2}$$

$$25 \text{ ft} + .49 \text{ ft} = 2.52 \text{ ft} + h_{f2} \rightarrow h_{f2} = 22.97 \text{ ft}$$

Total energy loss

$$h_{f1} + h_{f2} = 19.84 \text{ ft} + 22.97 \text{ ft} = \boxed{42.81 \text{ ft}} \quad (50)$$

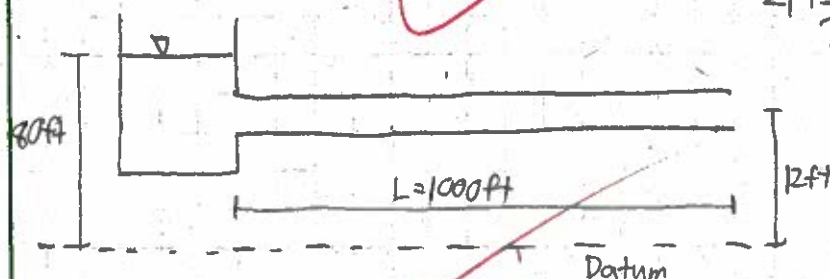
Problem 215.3) Given: $L = 1000 \text{ ft}$

dia = 6 in = .5 ft

Energy head = 80 ft from a reference datum

 $Q = .6 \text{ cfs}$ $P_2 = 18 \text{ psi}$

Elev of pipe = 12 ft from datum



$$z_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} = z_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + h_f$$

$$Q = VA \rightarrow V = \frac{Q}{A}$$

$$V = \frac{.6 \text{ cfs}}{\frac{\pi}{4} (.5 \text{ ft})^2} = 3.06 \text{ ft/s}$$

$$80 \text{ ft} + 0 + 0 = 12 \text{ ft} + \frac{18 \text{ psi} \left(\frac{144 \text{ in}^2}{144 \text{ in}^2} \right)}{62.4 \text{ pcf}} + \frac{(3.06 \text{ ft/s})^2}{2(32.2 \text{ ft/s}^2)} + h_f$$

$$80 \text{ ft} = 12 \text{ ft} + 41.54 \text{ ft} + .15 \text{ ft} + h_f$$

$$h_f = 26.31 \text{ ft}$$

150

30

50

50

Problem 3

15.5) Given: $V = .3 \text{ ft/s}$
 $\text{dia} = \text{lin} = .0833 \text{ ft}$
 400°F
Cast iron pipe

Find: friction factor, f

$$400^\circ\text{F} \rightarrow \nu = 1.664 \times 10^{-5} \text{ ft}^2/\text{s}$$

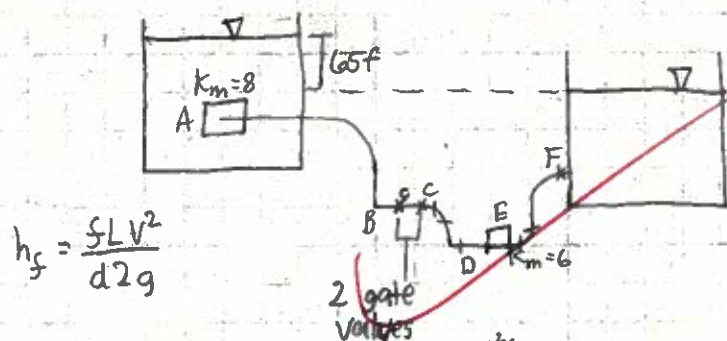
$$\text{cast iron} \rightarrow \epsilon = 8 \times 10^{-4} \text{ ft}$$

$$\text{Re} = \frac{Vd}{\nu} = \frac{.3 \text{ ft/s} (.0833 \text{ ft})}{1.664 \times 10^{-5} \text{ ft}^2/\text{s}} = 1502.4 < 2000 \rightarrow \text{Laminar}$$

$$f = \frac{64}{\text{Re}} = \frac{64}{1502.4} = .0426$$

$$f = .0426$$

Problem 4



$$h_f = \frac{fLV^2}{d2g}$$

Given: cast iron pipe

$$L = 450 \text{ ft}$$

$$Q = 1 \text{ cfs}$$

$$70^\circ \text{F}$$

Find: Diameter of pipe

$$70^\circ \text{F} \rightarrow \nu = 1.058 \times 10^{-5} \text{ ft}^2/\text{s}$$

$$\mu = 2.050 \times 10^{-5} \text{ lb} \cdot \text{s}/\text{ft}^2, \gamma = 62.301 \text{ lb}/\text{ft}^3$$

$$\text{cast iron pipe} \rightarrow \epsilon = 8 \times 10^{-4} \text{ ft}, C = 130$$

$$\text{assume } f = .03$$

$$65 \text{ ft} + 0 + 0 = 0 + 0 + \frac{\left(\frac{4(1 \text{ cfs})}{\pi d^2}\right)^2}{2(32.2 \text{ ft/s}^2)} + \frac{.03(450 \text{ ft})\left(\frac{4(1 \text{ cfs})}{\pi d^2}\right)^2}{d \cdot 2(32.2 \text{ ft/s}^2)}$$

$$65 \text{ ft} = \frac{.0252}{d^4} + \frac{.3398}{d^5}$$

$$\frac{1}{65} = \frac{d^4}{.0252} + \frac{d^5}{.3398} \rightarrow \frac{1}{65} = 39.68d^4 + 2.94d^5 \rightarrow 2.94d^5 + 39.68d^4 - .0154 = 0$$

$$\rightarrow d = .139 \text{ ft (from solver)}$$

$$Re = \frac{vd}{\nu} = \frac{\frac{4(1 \text{ cfs})}{\pi(.139 \text{ ft})}(.139 \text{ ft})}{1.058 \times 10^{-5} \text{ ft}^2/\text{s}} = 120,344 > 4000 \rightarrow \text{Turbulent}$$

$$\frac{\epsilon}{d} = \frac{8 \times 10^{-4} \text{ ft}}{.139 \text{ ft}} = 5.76 \times 10^{-3}$$

$$f = .0304 \approx f = .03 \quad \checkmark$$

(assumed)

$$\text{diameter of pipe} = 0.139 \text{ ft}$$

BELOW
AVERAGE



Department of Civil & Environmental Engineering

(L)

CVEG 4303 P01

Water Resources Engineering

Spring 2022

Dr. Nzewi

Homework 02

Assigned: 02/10/2022

Due: Thursday, Feb 17, 2022 at 1:00 PM (beginning of class) / Canvas 02/16/2022, 11:30 PM

SUBMIT THIS as cover sheet with your work

Name [PRINT] Sydney Jones

Instructions:

IN ALL THE PROBLEMS YOU MUST PROVIDE ENOUGH DETAILS AND DESCRIPTION OF THE SOLUTION METHOD TO DEMONSTRATE YOUR KNOWLEDGE OF THE SOLUTION METHOD. A SUBSTANTIAL PORTION OF THE GRADE WILL BE BASED ON YOUR METHODS.

Problem 1 [150]

Solve Problem 15.1 in the textbook.

Show your work fully.

450
900

700

Problem 2 [150]

Solve Problem 15.3 in the textbook.

Show your work fully.

Problem 3 [150]

Solve Problem 15.5 in the textbook.

Show your work fully.

Problem 4 [250]

Solve Problem 15.21 in the textbook with the following changes:

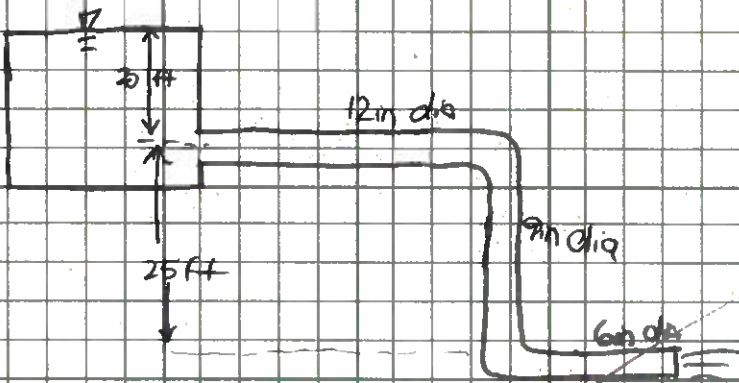
- There are now 2 gate valves
- The water surface elevation difference between the reservoirs is 65 feet

Show your work fully.

Problem 5 [200]

Solve Problem 15.21 in the textbook. Show your work fully.

Problem 1 (15.1)



16

$$\frac{P_1}{\rho} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2g} + z_2 + h_f \Rightarrow 0 + 0 + 45 = 0 + \frac{12.73^2}{2 \cdot 32.2} + 0 + h_f$$

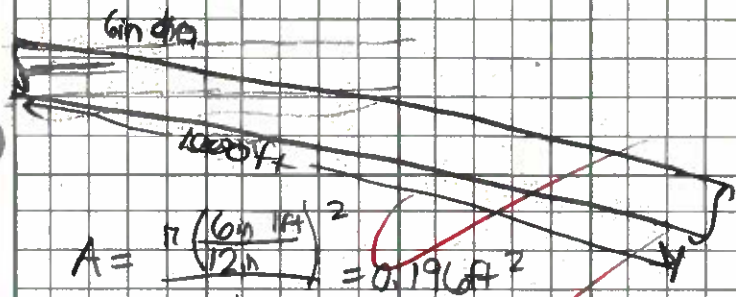
$$h_f = 42.78 \text{ ft}$$

$$V_2 = \frac{Q}{A} = \frac{2.5 \text{ cfs}}{\frac{\pi D^2}{4}} = \frac{2.5 \text{ cfs}}{\frac{(\frac{6}{12})^2 \pi}{4}} = 12.73 \text{ ft/s}$$

Please show full working

Problem 2 (15.3)

150



$$A = \frac{\pi \left(\frac{6 \text{ in}}{12 \text{ in}} \right)^2}{4} = 0.196 \text{ ft}^2$$

$$V_2 = \frac{Q}{A} = \frac{0.6}{0.196} = 3.06 \text{ ft/s}$$

$$\text{Energy}_n = z_2 + \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + h_L$$

$$80 = 12 + \frac{1816 \text{ lb/ft}^3 \cdot \left(\frac{12 \text{ in}}{12 \text{ in}} \right)^2}{62.4} + \frac{3.06^2}{2 \times 32.2} + h_L$$

$$h_L = 26.32 \text{ ft}$$

Problem 3 (15, 5)

$$\left\{ \begin{array}{l} V = 0.3 \text{ ft/sec} \\ T = 40^\circ\text{F} \end{array} \right.$$

$$Re = \frac{Vd}{\nu} = \frac{(0.3)(\frac{110}{12} \times 1 \text{ ft})}{1.66 \text{ E-}^{-5}} = 1506.02 < 2000$$

Laminar flow

$$r = \frac{E}{a} = \frac{8.0 \text{ E-}^{-4}}{.083} = .00964$$

$$f = \frac{64}{Re} = \frac{64}{1506.02} = 1.0425$$

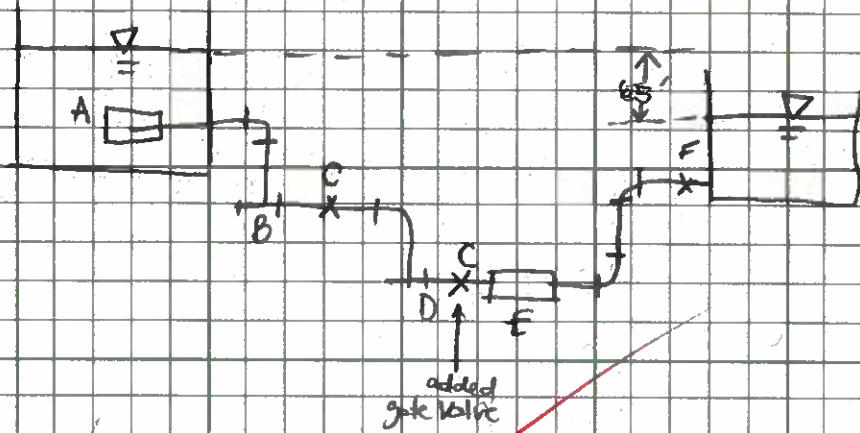
150

50

50

50

Problem 4 (15.21)



gate valve open = $k_1 = 0.15$

90° bend flanged = $k_2 = 0.2$

globe valve open = $k_3 = 10$

strainer = $k_4 = 8$

motor = $k_5 = 6$

90° bend = $k_6 = 0.2$

of 90° bends = 4

$H_1 = 65 \text{ ft}$

discharge = 1 cfs

$f = 0.004$

length, $L = 450 \text{ ft}$

$$65 = \frac{f L Q^2}{12.1 d^5} + \sum K \frac{Q^2}{A^2 2g}$$

$$65 = \frac{(0.004)(450)(1^2)}{12.1 d^5} + \sum K \frac{Q^2}{A^2 2g}$$

$$65 = \frac{18}{12.1 d^5} + \frac{Q^2}{A^2 2g} [2k_1 + 2k_2 + k_3 + k_4 + k_5 + 4k_6]$$

$$65 = \frac{18}{12.1 d^5} + \frac{1^2}{\left(\frac{\pi}{4} d^2\right)^2 2.322} [0.3 + .4 + 10 + 3 + 6 + .8]$$

$$65 = \frac{18}{12.1 d^5} + \frac{0.129}{d^4}$$

$d = 0.474 \text{ ft}$

$d = 5.69 \text{ in}$

**CVEG 4303
WATER RESOURCES ENGINEERING
SPRING 2022**

HOMework 03

ABOVE
AVERAGE



CVEG 4303 P01

Water Resources Engineering

Spring 2022

Dr. Nzewi

Homework 03

Assigned: 02/17/2022

Due: Thursday, Feb 24, 2022 at 1:00 PM (beginning of class) / Canvas 02/23/2022, 11:30 PM

SUBMIT THIS as cover sheet with your work

Name [PRINT] MAALVIKA AGARWAL

Instructions:

IN ALL THE PROBLEMS YOU MUST PROVIDE ENOUGH DETAILS AND DESCRIPTION OF THE SOLUTION METHOD TO DEMONSTRATE YOUR KNOWLEDGE OF THE SOLUTION METHOD. A SUBSTANTIAL PORTION OF THE GRADE WILL BE BASED ON YOUR METHODS.

Problem 1 [150]

Solve Problem 15.23 in the textbook.

Show your work fully.

900
900

Problem 2 [150]

Solve Problem 15.25 in the textbook. Provide your answer in tabular format using the example presented in class as a guide. Be sure to present any necessary sample calculations.

Show your work fully.

Problem 3 [150]

Solve Problem 15.27 in the textbook. Provide your answer in tabular format using the example presented in class as a guide. Be sure to present any necessary sample calculations. Furthermore, you will need to first determine (a) the flowrate BEFORE the change and, (b) the flowrate AFTER the second parallel pipe is installed.

Show your work fully.

Problem 4 [200]

Solve Problem 15.29 in the textbook. This is a 3-reservoir problem. Draw a sketch of the 3-reservoir system using Figure 15.13 in the textbook as a guide. Make the following changes to the problem data (Show your work fully):

Pipe	Length [m]	Diameter [cm]	Friction Factor, f
A	3500	150	0.017
B	800	80	0.025
C	1500	75	0.015

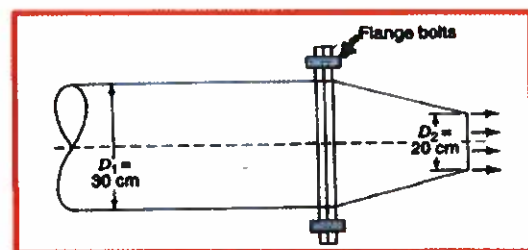
Problem 5 [150]

In the nozzle shown, the upstream pressure is 70 kPa and the discharge of the jet into the atmosphere is at rate of $0.045 \text{ m}^3/\text{s}$. [Assume no energy losses in the nozzle and a specific gravity, $SG = 1.8$, for the liquid flowing.]

Calculate:

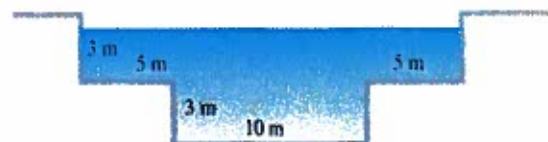
- [20] The velocities, V_1 and V_2 [m/s]
- [40] The pressure, P_2 [kPa]
- [90] Determine the force on each of the 4 flange bolts used to secure the nozzle assembly if the force is uniformly distributed

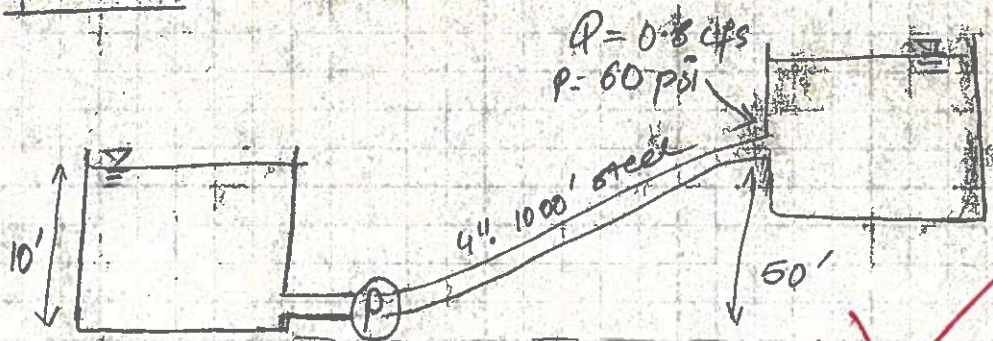
Show your work fully.



Problem 6 [100]

For the irregular channel shown, determine: (a) the area of flow, A [m^2], (b) the wetted perimeter, P [m], (c) the hydraulic radius, R [m], (d) the top width, T [m], (e) the hydraulic depth, D [m], and (f) the discharge, Q [m^3/s] if $n = 0.013$ and S (slope) = 0.003.



Problem 1

Given: $P_2 = 60 \text{ psi}$, $Q_2 = 0.8 \text{ cfs}$

Approach:

$$V_2 = \frac{Q}{A_2} = \frac{0.8}{(3.14) \left(\frac{4}{12}\right)^2} = \frac{0.8}{0.087} = 9.17 \text{ ft/sec}$$

$$Re = \frac{Vd}{\nu} = \frac{(9.17)(4/12)}{1.058 \times 10^{-5}} = 2.89 \times 10^5$$

(Turbulent flow)

(ν at 70°F from table)

$$\frac{e}{d} = \text{Relative roughness} = \frac{0.0015}{4/12} = 0.0045$$

from Moody diagram,

$$f = 0.018$$

$$h_{fL} = \frac{fLV^2}{2gd} = \frac{(0.018)(1000)(9.17)^2}{(2)(32.2)(4/12)}$$

$$h_{fL} = 70.539 \text{ ft}$$

$$h_m = \sum K \frac{V^2}{2g} =$$

$K = \text{entrance + exit loss}$

$$K = 0.5 + 1 = 1.5$$

$$= 1.5 \frac{(9.17)^2}{2 \times 32.2} = 1.959$$

Note: Δz

$$\Rightarrow 50 + P = 50 + \frac{60(144)}{62.4}$$

$$= 188.5 \text{ ft}$$

$$H_p = \Delta z + h_L$$

$$H_p = \Delta z + h_{fL} + h_m$$

$$H_p = 50 + 70.539 + 1.959$$

$$\therefore \Delta z = 188.5 - 10 = 178.5 \text{ ft}$$

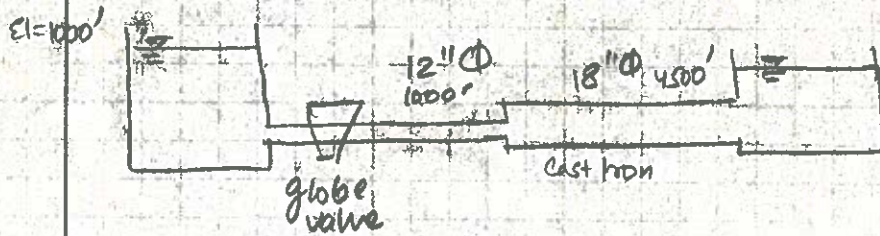
$$H_p = 122.49 \text{ f}$$

$$BHP = \frac{EQHP}{550\eta}$$

$$BHP = \frac{(62.2)(0.8)(122.49)}{550 \times 100}$$

$$BHP = 11.08 \text{ hp}$$

20

Problem 2Given: $Q = 5 \text{ cfs}$, $T = 60^\circ \text{F}$ 

$$V_1 = \frac{Q}{A_1} = \frac{5}{\frac{3.14 \cdot (12/12)^2}{4}} = 6.37 \text{ ft/sec}$$

$$Re_1 = \frac{V_1 d_1}{\nu} = \frac{(6.37)(12/12)}{1.410 \times 10^{-5}} = 4.52 \times 10^5$$

(Properties of water)

$$\frac{E}{d_1} \text{ for pipe 1} = \frac{8 \times 10^{-4}}{12/12} = 8 \times 10^{-4}$$

[Table for (15.1) roughness values for pipes]

from Moody diagram,

$$f = 0.019$$

So, Table for pipe 1 & pipe 2 calculations.

Pipe	L (ft)	Size (ft)	Q (cfs)	V (ft/s)	Re	E/d	f	f	h_f	hm
1	1000	12/12	5	6.37	4.52×10^5	8×10^{-4}	0.019		12.41	6.93
2	4500	18/12	5	2.83	3×10^5	5.3×10^{-4}	0.017		6.34	0.11

→ SAMPLE CALCULATIONS FOR PIPE 1

$$H_f \text{ for pipe 1} = \frac{f L_1 V_1^2}{2g D_1} = \frac{(0.019)(1000)(6.37)^2}{2(32.2)(12/12)}$$

$$h_{f1} = 12.41 \text{ ft}$$

$$h_{m1} = \frac{K V_1^2}{2g}$$

for pipe

$$(K_1 = \text{exit} + \text{globe valve})$$

$$K_1 = 1 + 10 = 11$$

$$h_{m1} = \frac{11 (6.37)^2}{2 \times 32.2} = 6.93$$

$$h_{m2} = \frac{K V_2^2}{2g}$$

$$(K_2 = \text{sudden enlargement} + \text{entrance})$$

($d_1/d_2 = 0.6$)

$$K_2 = 0.41 + 0.5 = 0.91$$

$$h_{m2} = \frac{(0.91) (2.83)^2}{2 \times 32.2} = 0.11$$

Now,

$$P_1 = P_2 = 0$$

using Bernoulli,

$$\frac{V_1^2}{2g} + Z_1 = \frac{V_2^2}{2g} + Z_2 + h_{f1} + h_{f2} + h_{m1} + h_{m2}$$

$$\frac{6.37^2}{2 \times 32.2} + 1000 = \frac{2.83^2}{2 \times 32.2} + Z_2 + 12.41 + 6.34 + 6.93 + 0.11$$

$$1000.63 = 25.91 + Z_2$$

$$Z_2 = 974.716 \text{ ft}$$

30

Problem 3

150

Pipe	C	Size (ft)	Assumed H_f (ft)	Pipe length (L) (ft)	Slope, h_f/L (ft/ft)	Calculated Q (cfs)
1	100 cast iron	1	50	7920	0.006313	2.802
2	100	1.5	50	2640	0.0189	14.719
Pipe EQV	100	1.5	50	1909.21 $h_e = \frac{h_f}{3}$	0.0262 $S = \frac{4.731 \cdot 0.185}{c^{1.85} D^{4.87}}$	17.522 ← Total Q

Total Equ. Pipe length, $L_e = 7920 + 1909.21 = 9829.25$ ft

PIPE EQV	C	D (ft)	Headloss, H_f (ft)	S $= (H_f/L_e)$	Total Eqv length, L_e (ft)	Q (cfs)
100	1.5	40 (given)	0.004089 H_f/L_e	9829.25	6.422	$Q = 0.432 C D^{2.63} S^{0.54}$

So, the flow in system = 6.422 cfs

Change in flow in system = $6.422 - 2.802$
= 3.619 cfs

So, there is an increase in the flow by 3.619 cfs.

SAMPLE CALCULATIONS

For Pipe 1, Assumed $h_f = 50$ ft

Pipe length = 1.5 mile = 7920 ft

Slope = $h_f/L = 50/7920 = 0.006313$ ft/ft

Calculated Q = $0.432 C D^{2.63} S^{0.54}$

= $(0.432)(100)(1)^{2.63}(0.006313)^{0.54}$

= 2.802 cfs

Then, for pipe 2 equivalent

$$\begin{aligned}\text{Total } Q &= Q_{\text{pipe 1}} + Q_{\text{pipe 2}} \\ &= 2.802 + 14.719 \\ &= \underline{17.522}\end{aligned}$$

$$\text{slope} = \frac{4.731}{C^{1.85} D^{4.87}} Q^{1.85} = \frac{4.731}{100^{1.85} 1.5^{4.87}} (17.522)^{1.85}$$

$$\text{slope} = \underline{0.0262}$$

$$\text{So, pipe length} = L_e = \frac{h_L}{S} = \frac{50}{0.0262} = \underline{1909.21 \text{ ft}}$$

$$\text{Total eqn pipe length} = L_e = (7920) + (1909.21) = \underline{9829.25 \text{ ft}}$$

So, for pipe 2, $D = 1.5 \text{ ft}$

$C = 100$ (cast iron)

$H = \text{head loss} = 40 \text{ ft}$ (given)

$$\text{So, } S = \frac{H}{L_e} = \frac{40}{9829.25} = 0.004069 \text{ ft/ft}$$

$$\text{So, } Q = 0.432 C D^{2.63} S^{0.54}$$

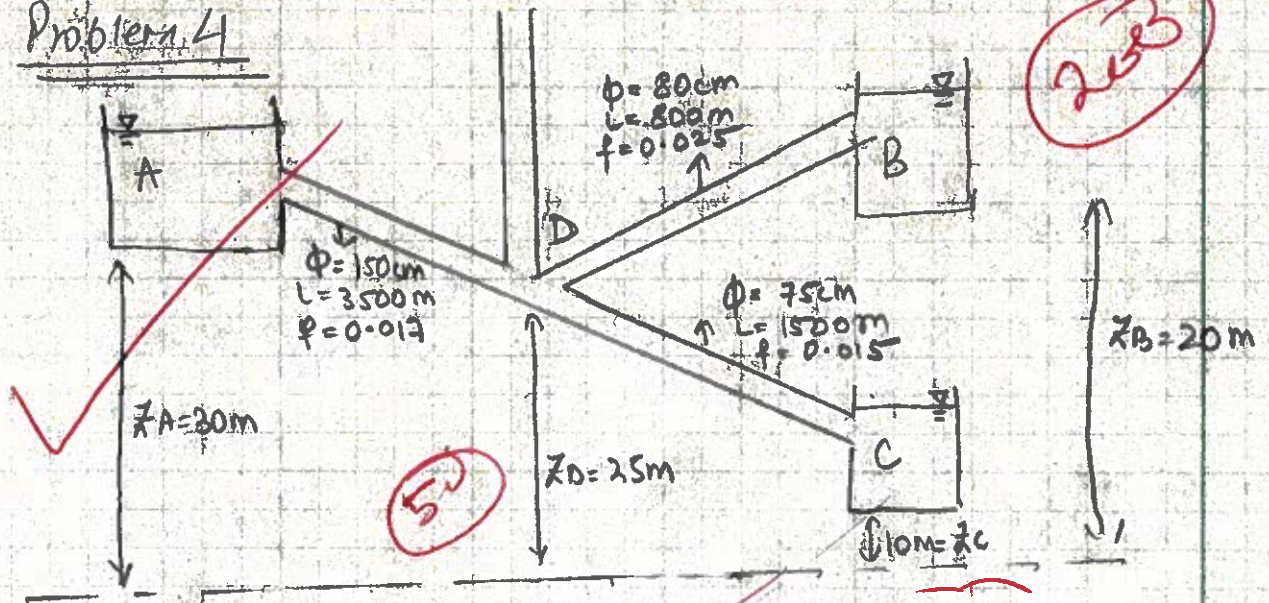
$$Q = 0.432 (100) (1.5)^{2.63} (0.004069)^{0.54}$$

$$\underline{Q = 6.422}$$

So, $Q_{\text{before}} = 2.802$

$Q_{\text{after}} = \underline{6.422}$

$$\begin{aligned}\text{So, change in } Q &= 6.422 - 2.802 \\ &= \underline{3.629 \text{ cfs}}\end{aligned}$$

Problem 4

Given: $L_{AD} = 3500 \text{ m}$, $\phi_{AD} = 150 \text{ mm}$, $f = 0.017$
 $L_{BD} = 800 \text{ m}$, $\phi_{BD} = 80 \text{ mm}$, $f = 0.025$
 $L_{CD} = 1500 \text{ m}$, $\phi_{CD} = 75 \text{ mm}$, $f = 0.015$

$z_A = 30 \text{ m}$, $z_B = 20 \text{ m}$

$z_C = 10 \text{ m}$, $z_D = 25 \text{ m}$

→ Pipe AD

$$K_{AD} = \frac{fL}{12.10 \phi^5} = \frac{(0.017)(3500)}{12.10(1.5)^5} = 0.6475$$

(Darcy)

$$Q_{AD}^2 = \frac{z_A - z_D - \frac{P_D}{\gamma}}{K_{AD}} = \frac{30 - 25 - \frac{P_D}{\gamma}}{0.6475}$$

$$Q_{AD} = \sqrt{7.72 - 1.54 P_D / \gamma} \quad \text{--- (1)}$$

→ Pipe BD

$$K_{BD} = \frac{(0.025)(800)}{12.10(0.8)^5} = 5.0442$$

$$Q_{BD}^2 = \frac{z_D - z_B + \frac{P_D}{\gamma}}{K_{BD}} = \frac{25 - 20 + \frac{P_D}{\gamma}}{5.0442}$$

$$Q_{BD} = \sqrt{0.99 + 0.198 P_D / \gamma} \quad \text{--- (2)}$$

→ Pipe CD

$$K_{CD} = \frac{(0.015)(1500)}{12.10(0.75)^5} = 7.8359$$

$$Q_{CD}^2 = \frac{z_D - z_C + \frac{P_D}{\gamma}}{K_{CD}} = \frac{25 - 10 + \frac{P_D}{\gamma}}{7.8359}$$

$$Q_{CD} = \sqrt{1.91 + 0.127 P_D / \gamma} \quad \text{--- (3)}$$

Now,

$$Q_{AD} = Q_{BD} + Q_{CD}$$

Using ① ② ③

$$\sqrt{7.72 - 1.54 P_0 / \rho} = \sqrt{0.99 + 0.198 P_0 / \rho} + \sqrt{1.91 + 0.127 P_0 / \rho}$$

Solving, through Msexcel,

$$\frac{P_0}{\rho} = 0.9296$$

So,

$$Q_{AD} = \sqrt{7.72 - 1.54 (0.9296)} = \boxed{2.507} \text{ m}^3/\text{s}$$

$$Q_{BD} = \sqrt{0.99 + 0.198 (0.9296)} = \boxed{1.0835} \text{ m}^3/\text{s}$$

$$Q_{CD} = \sqrt{1.91 + 0.127 (0.9296)} = \boxed{1.4241} \text{ m}^3/\text{s}$$

Verification

$$Q_{AD} = Q_{BD} + Q_{CD}$$

$$2.507 = 1.0835 + 1.4241$$

$$\boxed{2.507 = 2.507}$$

Problem 5

Given:

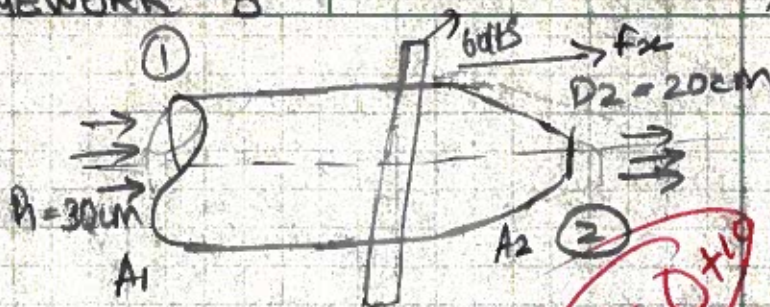
$$D_1 = 30 \text{ cm} = 0.3 \text{ m}$$

$$D_2 = 20 \text{ cm} = 0.2 \text{ m}$$

$$P_1 = 70 \text{ kPa}$$

$$Q = 0.045 \text{ m}^3/\text{s}$$

$$\rho = 1.8$$



$$a) \quad V_1 = \frac{Q}{A_1} = \frac{0.045}{\frac{3.14 (0.3)^2}{4}} = 0.637 \text{ m/s}$$

$$V_2 = \frac{Q}{A_2} = \frac{0.045}{\frac{3.14 (0.2)^2}{4}} = 1.433 \text{ m/s}$$

$$b) \quad \text{Using } \frac{P_1}{\rho} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2g} + z_2$$

$$P_2 = \left(\frac{P_1}{\rho} + \frac{V_1^2 - V_2^2}{2g} \right) \rho = \left(\frac{70000}{(9810)(1.8)} + \frac{0.637^2 - 1.433^2}{2 \times 9.81} \right) 9810$$

$$P_2 = 68517.052 \text{ Pa} = 68.517 \text{ kPa}$$

$$c) \quad P_1 A_1 + F_x = \rho Q (V_{1x} - V_{2x})$$

$$F_x = \rho Q (V_2 - V_1) - P_1 A_1$$

$$F_x = (1.8)(9810)(0.045)(1.433 - 0.637) - (70000) \left(\frac{3.14 (0.3)^2}{4} \right)$$

$$F_x = -4883.556 = 4883.556 \text{ N}$$

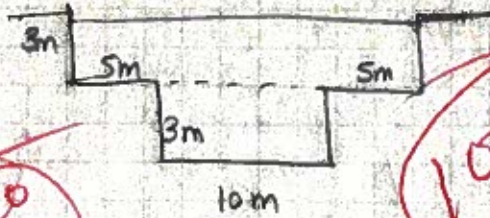
$$\text{So, on each flange} = \frac{4883.556}{4} = 1220.89 \text{ N}$$

$$= 1.22 \text{ kN}$$

Problem 6a) Area of flow, A

$$= (10)(3) + (3)(10+5+5)$$

$$= \boxed{90 \text{ m}^2}$$

b) Wetted Perimeter, P

$$P = 3 + 5 + 3 + 10 + 3 + 5 + 3$$

$$\boxed{P = 32 \text{ m}}$$

c) Hydraulic radius, R

$$R = \frac{A}{P} = \frac{90}{32} = \boxed{2.81 \text{ m}}$$

d) Top width, $T = \boxed{20 \text{ m}}$

e) Hydraulic depth, $D = \frac{A}{T} = \frac{90}{20}$

$$\boxed{D = 4.5 \text{ m}}$$

f) Flow rate, Q

$$n = 0.013, s = 0.003$$

$$Q = \frac{AR^{2/3}s^{1/2}}{n} = \frac{(90)(2.81)^{2/3}(0.003)^{1/2}}{0.013}$$

$$\boxed{Q = 755.535 \text{ m}^3/\text{s}}$$

AVERAGE



CVEG 4303 P01

Water Resources Engineering

Spring 2022

Dr. Nzewi

Homework 03

Assigned: 02/17/2022

Due: Thursday, Feb 24, 2022 at 1:00 PM (beginning of class)/Canvas 02/23/2022, 11:30 PM

SUBMIT THIS as cover sheet with your work

Name [PRINT] Nathaniel Smith

Instructions:

IN ALL THE PROBLEMS YOU MUST PROVIDE ENOUGH DETAILS AND DESCRIPTION OF THE SOLUTION METHOD TO DEMONSTRATE YOUR KNOWLEDGE OF THE SOLUTION METHOD. A SUBSTANTIAL PORTION OF THE GRADE WILL BE BASED ON YOUR METHODS.

Problem 1 [150]

Solve Problem 15.23 in the textbook.

Show your work fully.

730
900

Problem 2 [150]

Solve Problem 15.25 in the textbook. Provide your answer in tabular format using the example presented in class as a guide. Be sure to present any necessary sample calculations.

Show your work fully.

Problem 3 [150]

Solve Problem 15.27 in the textbook. Provide your answer in tabular format using the example presented in class as a guide. Be sure to present any necessary sample calculations. Furthermore, you will need to first determine (a) the **flowrate BEFORE** the change and, (b) the **flowrate AFTER** the second parallel pipe is installed.

Show your work fully.

Problem 4 [200]

Solve Problem 15.29 in the textbook. This is a 3-reservoir problem. Draw a sketch of the 3-reservoir system using Figure 15.13 in the textbook as a guide. Make the following changes to the problem data (**Show your work fully**):

Pipe	Length [m]	Diameter [cm]	Friction Factor, f
A	3500	150	0.017
B	800	80	0.025
C	1500	75	0.015

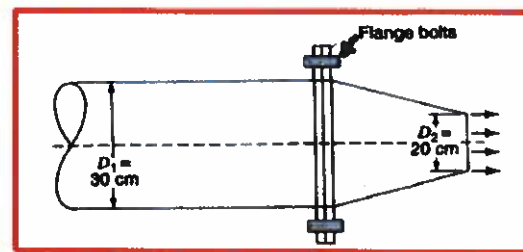
Problem 5 [150]

In the nozzle shown, the upstream pressure is 70 kPa and the discharge of the jet into the atmosphere is at rate of 0.045 m³/s. [Assume no energy losses in the nozzle and a specific gravity, SG = 1.8, for the liquid flowing.]

Calculate:

- [20] The velocities, V_1 and V_2 [m/s]
- [40] The pressure, P_2 [kPa]
- [90] Determine the force on each of the 4 flange bolts used to secure the nozzle assembly if the force is uniformly distributed

Show your work fully.



Problem 6 [100]

For the irregular channel shown, determine: (a) the area of flow, A [m²], (b) the wetted perimeter, P [m], (c) the hydraulic radius, R [m], (d) the top width, T [m], (e) the hydraulic depth, D [m], and (f) the flowrate, Q [m³] if $n = 0.013$ and S (slope) = 0.003.



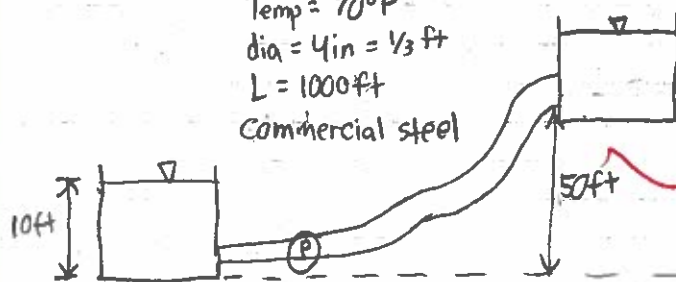
Problem 1

15.23) Given: $P_2 = 60 \text{ psi}$ $Q = 0.8 \text{ cfs}$ Temp = 70°F dia = $4 \text{ in} = \frac{1}{3} \text{ ft}$ $L = 1000 \text{ ft}$

Commercial steel

Find: a) pumping head

b) power delivered by pump



$$Z_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + H_p = Z_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + h_L$$

$$h_L = h_f + h_m, \quad h_f = f \left(\frac{L}{D} \right) \left(\frac{V^2}{2g} \right),$$

$$h_m = (\sum K) \frac{V^2}{2g}$$

$$70^\circ \text{F}: \gamma = 62.3 \text{ lb/ft}^3; \rho = 1.936 \frac{\text{lb} \cdot \text{s}}{\text{ft}^4}; \mu = 2.050 \times 10^{-5} \frac{\text{lb} \cdot \text{s}}{\text{ft}^2}; \nu = 1.059 \times 10^{-5} \frac{\text{ft}^2}{\text{s}}$$

$$V_1 = V_2 = V = \frac{Q}{A} = \frac{4Q}{\pi d^2} = \frac{4(0.8 \text{ cfs})}{\pi (1/3 \text{ ft})^2} = 9.17 \text{ ft/s}$$

$$Re = \frac{Vd}{\nu} = \frac{9.17 \text{ ft/s} (1/3 \text{ ft})}{1.059 \times 10^{-5} \text{ ft}^2/\text{s}} = 288636 \approx 2.9 \times 10^5 > 4000 \rightarrow \text{Turbulent, assume smooth pipe}$$

$$\text{Commercial steel} \rightarrow \epsilon = 1.5 \times 10^{-4} \text{ ft} \quad f = 0.0178 \text{ (from Moody Chart)}$$

$$\frac{\epsilon}{D} = \frac{1.5 \times 10^{-4} \text{ ft}}{1/3 \text{ ft}} = 4.5 \times 10^{-4}$$

$$h_f = 0.0178 \left(\frac{1000 \text{ ft}}{1/3 \text{ ft}} \right) \left(\frac{(9.17 \text{ ft/s})^2}{2(32.2 \text{ ft/s}^2)} \right) = 69.73 \text{ ft}$$

$$h_m = (1 + 5) \left(\frac{(9.17 \text{ ft/s})^2}{2(32.2 \text{ ft/s}^2)} \right) = 1.96 \text{ ft}$$

$$h_L = 69.73 + 1.96 = 71.69 \text{ ft}$$

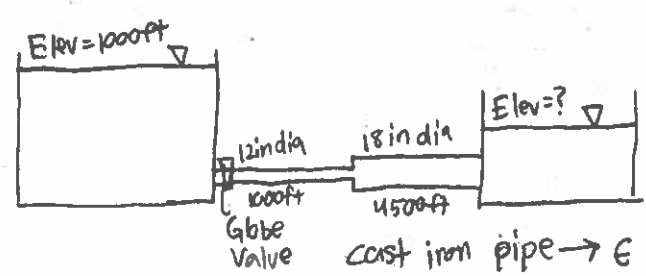
$$0 + 0 + H_p = 50 \text{ ft} + \frac{60 \text{ psi} \left(\frac{144 \text{ in}^2}{1 \text{ ft}^2} \right)}{62.3 \text{ lb/ft}^3} + 71.69 \text{ ft}$$

$$H_p = 260.37 \text{ ft}$$

$$\text{BHP} = \frac{\gamma Q H_p}{550} = \frac{62.3 (0.8) (260.37)}{550} = 23.59 \text{ hp}$$

Problem 2

15.25) Given



cast iron pipe $\rightarrow \epsilon = 8 \times 10^{-4} \text{ ft}, C = 130$

Pipe	C	size (ft)	Q_1 (cfs)	S	L (ft)	$h_L = S \cdot L$ (ft)
1	130	1 ft	5	.011	1000	1.1
2	130	1.5 ft	5	.0016	4500	7.2
Pipe eq	130	1 ft	5	.011	1654.55	18.2 $\leftarrow \text{Sum } h_L = H$

Sample work

$$\text{Pipe 1: } S = \frac{h_L}{L} = \frac{4.731 Q^{1.85}}{C^{1.85} D^{4.87}} = \frac{4.731 (5)^{1.85}}{130^{1.85} (1)^{4.87}} = .011$$

$$\text{Pipe eq: } L_E = \frac{H}{S} = \frac{18.2}{.011} = 1654.55 \text{ ft}$$

$$\text{Elev}_2 = \text{Elev}_1 - h_L$$

$$\text{Elev}_2 = 1000 \text{ ft} - 18.2 \text{ ft}$$

$$\text{Elev}_2 = 981.8 \text{ ft}$$

120

Problem 3

15.27) Given: $h_L = 40 \text{ ft}$

Pipe 1: $L_1 = 1.5 \text{ mi}$, $\text{dia} = 1 \text{ ft}$

$1 \text{ mi} = 5280 \text{ ft}$

Pipe 2: $L_2 = .5 \text{ mi}$, $\text{dia} = 1.5 \text{ ft}$

Cast iron $\rightarrow C = 130$

Pipe	C	Size (ft)	L (ft)	h_L (ft)	S	Q (cfs)
1	130	1	7920	40	.0051	3.2
2	130	1.5	2640	40	.015	16.8
Pipe eq	130	1	270.27	40	.148	20 $\leftarrow$ Sum Q

Pipe 1: $S = \frac{h_L}{L} = \frac{40}{7920} = .0051$

$Q = .432 C D^{2.63} S^{.54} = .432 (130) (1)^{2.63} (.0051)^{.54} = 3.2 \text{ cfs}$

Pipe eq: $S = \frac{4.731 Q^{1.85}}{C^{1.85} D^{4.87}} = \frac{4.731 (20)^{1.85}}{130^{1.85} (1)^{4.87}} = .148$

$L_E = \frac{h_L}{S} = \frac{40}{.148} = 270.27 \text{ ft}$

Pipe eq	C	D	h_L	S	L_E	Q cfs
	130	1	40	.148	270.27	20.02

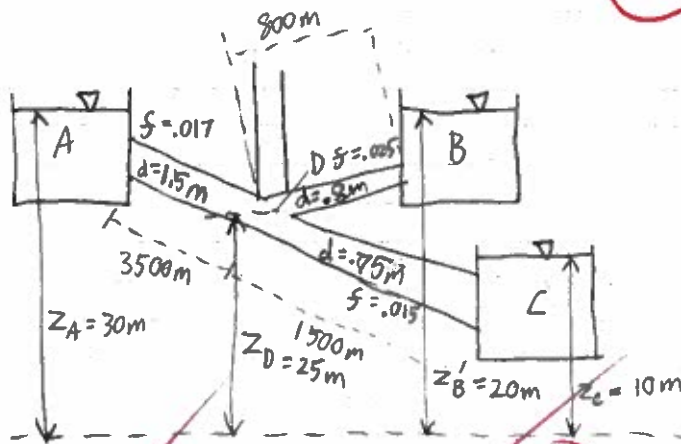
$Q = .432 (130) (1)^{2.63} (.148)^{.54} = 20.02 \text{ cfs}$

Discharge is hardly affected. Difference between the two discharges is 0.02 cfs

Problem 4

15.29)

$$K = \frac{5L}{12.1d^5}$$



$$h_f = f \left(\frac{L}{D} \right) \left(\frac{V^2}{2g} \right)$$

$$K_{AD} = \frac{0.017(3500)}{12.1(1.5)^5} = 0.65 \quad K_{DB} = \frac{0.025(800)}{12.1(0.8)^5} = 5.04 \quad K_{DC} = \frac{0.015(1500)}{12.1(0.75)^5} = 7.84$$

$$A) h_f = f \left(\frac{L}{D} \right) \left(\frac{V_A^2}{2g} \right) \rightarrow 30\text{m} - 25\text{m} = 0.017 \left(\frac{3500\text{m}}{1.5\text{m}} \right) \left(\frac{V_A^2}{2(9.81\text{m/s}^2)} \right)$$

$$V_A = 1.57\text{m/s} \rightarrow Q_A = 1.57\text{m/s} \left(\frac{\pi(1.5\text{m})^2}{4} \right) = 2.77\text{m}^3/\text{s} = Q_{AD}$$

$$B) 25\text{m} - 20\text{m} = 0.025 \left(\frac{800\text{m}}{0.8\text{m}} \right) \left(\frac{V_B^2}{2(9.81\text{m/s}^2)} \right)$$

$$V_B = 2.52\text{m/s} \rightarrow Q_B = 2.52\text{m/s} \left(\frac{\pi(0.8\text{m})^2}{4} \right) = 1.27\text{m}^3/\text{s} = Q_{DB}$$

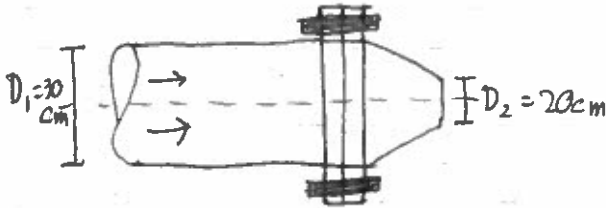
$$C) Q_{AD} = Q_{DB} + Q_{DC}$$

$$Q_{DC} = Q_{AD} - Q_{DB} = 2.77\text{m}^3/\text{s} - 1.27\text{m}^3/\text{s} = 1.50\text{m}^3/\text{s} = Q_{DC}$$

Problem 5

Given: $P_1 = 70 \text{ kPa}$
 $Q = 0.045 \text{ m}^3/\text{s}$
 $SG = 1.8$

Find: a) $V_1 + V_2$
 b) P_2
 c) Force on each of the 4 flange bolts



$$a) V_1 = \frac{4Q}{\pi D_1^2} = \frac{4(0.045 \text{ m}^3/\text{s})}{\pi (0.3 \text{ m})^2} = 0.64 \text{ m/s}, \quad V_2 = \frac{4Q}{\pi D_2^2} = \frac{4(0.045 \text{ m}^3/\text{s})}{\pi (0.2 \text{ m})^2} = 1.43 \text{ m/s}$$

$$b) SG = \frac{\gamma_s}{\gamma_w} \rightarrow \gamma_s = SG \cdot \gamma_w = 1.8(9.81 \text{ kN/m}^3) = 17.66 \text{ kN/m}^3$$

$$\cancel{z_1} + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} = \cancel{z_2} + \frac{P_2}{\gamma} + \frac{V_2^2}{2g}$$

$$\frac{70 \text{ kPa}}{17.66 \text{ kN/m}^3} + \frac{(0.64 \text{ m/s})^2}{2(9.81 \text{ m/s}^2)} = \frac{P_2}{17.66 \text{ kN/m}^3} + \frac{(1.43 \text{ m/s})^2}{2(9.81 \text{ m/s}^2)}$$

$$3.96 \text{ m} + 0.021 \text{ m} = \frac{P_2}{17.66 \text{ kN/m}^3} + 0.104 \text{ m}$$

$$\frac{P_2}{17.66 \text{ kN/m}^3} = 3.88 \text{ m} \rightarrow P_2 = 68.52 \text{ kPa}$$

$$c) -F_x + P_1 A_1 - P_2 A_2 = \rho Q (V_2 - V_1)$$

$$-F_x + 70 \text{ kPa} \left(\frac{\pi (0.3 \text{ m})^2}{4} \right) - 68.52 \text{ kPa} \left(\frac{\pi (0.2 \text{ m})^2}{4} \right) = 1.8(1000 \text{ kg/m}^3)(0.045 \text{ m}^3/\text{s})(1.43 - 0.64) \text{ m/s}$$

$$-F_x + 4.94 \text{ kN} - 2.15 \text{ kN} = 64 \text{ N}$$

$$F_x = 2.73 \text{ kN}$$

Problem 6Given: $n = .013$ $S = .003$

$$a) A = 3m(20m) + 3m(10m) = \boxed{90m^2}$$

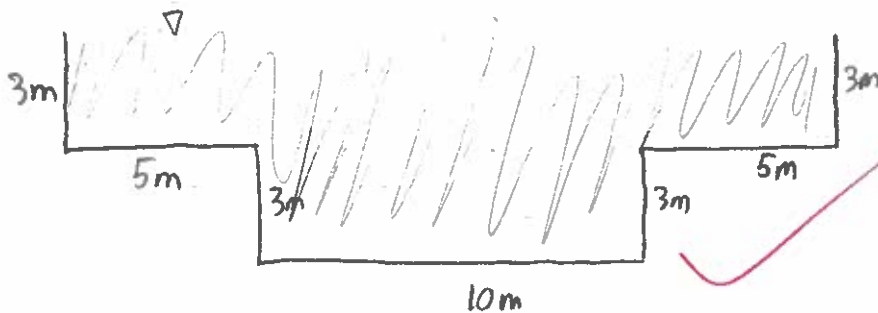
$$b) P = 4(3m) + 2(5m) + 10m = \boxed{32m}$$

$$c) R = \frac{A}{P} = \frac{90m^2}{32m} = \boxed{2.8m}$$

$$d) T = 5m + 10m + 5m = \boxed{20m}$$

$$e) D = \frac{A}{P} = \frac{90m^2}{32m} = \boxed{2.8m^2}$$

$$f) Q = \frac{1}{n} AR^{2/3} \sqrt{S} = \frac{1}{.013} (90m^2)(2.8m)^{2/3} \sqrt{.003} = \boxed{753.3 m^3/s}$$



90

10

20

10

10

10

10

20

10

BELOW
AVERAGE



CVEG 4303 P01

Water Resources Engineering

Spring 2022

Dr. Nzewi

Homework 03

Assigned: 02/17/2022

Due: Thursday, Feb 24, 2022 at 1:00 PM (beginning of class)/Canvas 02/23/2022, 11:30 PM

SUBMIT THIS as cover sheet with your work

Name [PRINT] Sophie Ivkic

Instructions:

IN ALL THE PROBLEMS YOU MUST PROVIDE ENOUGH DETAILS AND DESCRIPTION OF THE SOLUTION METHOD TO DEMONSTRATE YOUR KNOWLEDGE OF THE SOLUTION METHOD. A SUBSTANTIAL PORTION OF THE GRADE WILL BE BASED ON YOUR METHODS.

Problem 1 [150]

Solve Problem 15.23 in the textbook.

Show your work fully.

525
900

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Show your work fully.

Problem 3 [150]

Solve Problem 15.27 in the textbook. Provide your answer in tabular format using the example presented in class as a guide. Be sure to present any necessary sample calculations. Furthermore, you will need to first determine (a) the **flowrate** BEFORE the change and, (b) the **flowrate** AFTER the second parallel pipe is installed.

Show your work fully.

Problem 4 [200]

Solve Problem 15.29 in the textbook. This is a 3-reservoir problem. Draw a sketch of the 3-reservoir system using Figure 15.13 in the textbook as a guide. Make the following changes to the problem data (**Show your work fully**):

Pipe	Length [m]	Diameter [cm]	Friction Factor, f
A	3500	150	0.017
B	800	80	0.025
C	1500	75	0.015

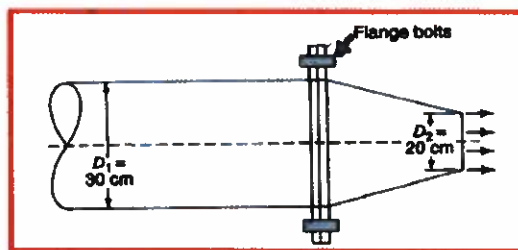
Problem 5 [150]

In the nozzle shown, the upstream pressure is 70 kPa and the discharge of the jet into the atmosphere is at rate of $0.045 \text{ m}^3/\text{s}$. [Assume no energy losses in the nozzle and a specific gravity, $SG = 1.8$, for the liquid flowing.]

Calculate:

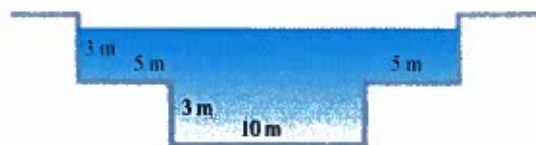
- [20] The velocities, V_1 and V_2 [m/s]
- [40] The pressure, P_2 [kPa]
- [90] Determine the force on each of the 4 flange bolts used to secure the nozzle assembly if the force is uniformly distributed

Show your work fully.



Problem 6 [100]

For the irregular channel shown, determine: (a) the area of flow, A [m^2], (b) the wetted perimeter, P [m], (c) the hydraulic radius, R [m], (d) the top width, T [m], (e) the hydraulic depth, D [m], and (f) the flowrate, Q [m^3] if $n = 0.013$ and S (slope) = 0.003.



50

Problem 1

$$A = \frac{\pi}{4} \times d^2 = \frac{\pi}{4} (0.33)^2 = 0.08 \text{ ft}^2$$

$$V = Q/A = 0.8/0.08 = 9.35 \text{ ft/s}$$

$$Re = \frac{9.35 \times 0.33}{1.058 \times 10^{-5}} = 2.91 \times 10^5 \quad \sim > 2000, \text{ turbulent flow}$$

$$\epsilon = \frac{e}{d} = \frac{0.00015}{0.33} = 0.00045 \quad \rightarrow \text{friction factor} = 0.023$$

$$h_f = \frac{fLV^2}{2g_d} = \frac{0.023 \times 1000 \times 9.35^2}{2 \times 32.2 \times 0.33} = 94.6 \text{ ft}$$

$$h_m = \sum K \frac{V^2}{2g_d} = 1.5 \times \frac{9.35^2}{2 \times 32.2} = 2.036 \text{ ft}$$

$$\Delta Z = \frac{p \times 2.31}{G_{water}} = \frac{60 \times 2.31}{1} = 138.6 \text{ ft}$$

$$H_p = \Delta Z + h_f + h_m = 138.6 + 94.6 + 2.036 = \boxed{235.24 \text{ ft}}$$

$$BHP = \frac{\gamma Q H_p}{550 \eta} = \frac{62.3 \times 0.8 \times 235.24}{550 \times 0.7} = \boxed{30.45 \text{ hp}}$$

problem 2

150

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + (h_f)_1 + (h_f)_2 + \left(\frac{KV_1^2}{2g}\right)_{\text{exit}} + \left(\frac{KV_1^2}{2g}\right)_{\text{valve}} + \left(\frac{KV_2^2}{2g}\right)_{\text{enlargement}} + \left(\frac{KV_2^2}{2g}\right)_{\text{entrance}}$$

$$V_1 = \frac{Q}{\left(\frac{\pi}{4} \times d_1^2\right)} = \frac{5}{\left(\frac{\pi}{4} \times \left(\frac{12.19}{12} \times 1\text{ft}\right)^2\right)} = 6.37 \text{ ft/s}$$

$$Re = \frac{V_1 d_1}{\nu} = \frac{6.37 \times 1}{1.21 \times 10^{-5}} = 4.52 \times 10^5 \quad \gamma = \frac{E}{d_1} = 8.0 \times 10^{-4}$$

- pipe 2: $V_2 = \frac{5}{\left(\frac{\pi}{4} \times \left(\frac{18}{12} \times 1\right)^2\right)} = 2.83 \text{ ft/s} \quad Re_2 = \frac{2.83 \times 1.5}{1.4 \times 10^{-5}} = 3.01 \times 10^5$

$$r_2 = \frac{8.0 \times 10^{-4}}{1.5} = 5.3 \times 10^{-4}$$

$$(h_f)_1 = \frac{0.0197 \times 1000 \times 6.37^2}{2 \times 32.2 \times 1} = 12.41 \text{ ft}$$

$$\left(\frac{KV_1^2}{2g}\right)_{\text{valve}} = \frac{10 \times 6.37^2}{2 \times 32.2} = 6.3$$

$$\left(\frac{KV_1^2}{2g}\right)_{\text{exit}} = \frac{1 \times 6.37^2}{2 \times 32.2} = 0.63$$

$$(h_f)_2 = \frac{0.017 \times 4500 \times 2.83^2}{2 \times 32.2 \times 1.5} = 6.34 \text{ ft}$$

$$\left(\frac{KV_2^2}{2g}\right)_{\text{enlargement}} = \left(\frac{0.41 \times 2.83^2}{2 \times 32.2}\right) = 0.005 \quad \left(\frac{KV_2^2}{2g}\right)_{\text{entrance}} = \frac{0.5 \times 2.83^2}{2 \times 32.2} = 0.002$$

$$\frac{6.37^2}{2 \times 32.2} + 1000 = \frac{2.83^2}{2 \times 32.2} + z_2 + 12.41 + 6.34 + 0.63 + 6.3 + 0.005 + 0.002$$

$$z_2 = 979.73 \text{ ft} \quad \text{elevation}$$

30

Problem 3 -

50

$$\text{pipe A: } \frac{e}{D_A} = \frac{0.00085}{1}, \quad \frac{1}{\sqrt{f_A}} = -2 \log_{10} \left(\frac{0.00085}{3.7} \right) = 0.018$$

$$\text{pipe B: } \frac{e}{D_B} = \frac{0.00085}{1.5} = 0.00056, \quad -2 \log_{10} \left(\frac{0.00056}{3.7} \right) = 0.017$$

$$h_L = f_A \frac{L_A V_A^2}{D_A 2g} + f_B \frac{L_B V_B^2}{D_B 2g} \rightarrow 40 = 0.018 \times \frac{5280}{1} \frac{V_A^2}{2 \times 32.2} + 0.017 \times \frac{2640}{1.5} \frac{V_B^2}{2 \times 32.2}$$

$$\rightarrow 40 = 1.475 V_A^2 + 0.465 V_B^2 \quad (1)$$

$$Q_A = Q_B \rightarrow A_A V_A = A_B V_B \rightarrow \frac{\pi D_A^2}{4} V_A = \frac{\pi D_B^2}{4} V_B$$

$$\frac{\pi \times 1^2}{4} \times V_A = \frac{\pi \times 1.5^2}{4} \times V_B \rightarrow V_A = 2.25 V_B$$

$$40 = (1.475) (2.25 V_B)^2 + 0.465 V_B^2 \rightarrow V_B = 2.25 \text{ ft/s}$$

$$V_A = 2.25 \times 2.25 = 5.063 \text{ ft/s}$$

$$\rightarrow \text{pipe A: } Q_A = \frac{\pi \times 1^2}{4} \times 5.063 = 3.976 \text{ cfs}$$

$$\rightarrow \text{pipe B: } Q_B = \frac{\pi \times 1.5^2}{4} \times 2.25 = \boxed{3.976 \text{ cfs}}$$

50

Problem 4 -

- pipe A to D: $Q_{AD} = A \times v$

$$L h_f = \frac{f L V^2}{2 g d} = (30-25) = \frac{0.015 \times 3000 \times V^2}{2 \times 9.81 \times 1} \quad \checkmark \quad v = 1.476 \text{ m/s}$$

$$Q_{AD} = \pi/4 \times (1)^2 \times 1.476 = \boxed{1.159 \text{ m}^3/\text{s}}$$

- pipe DB:

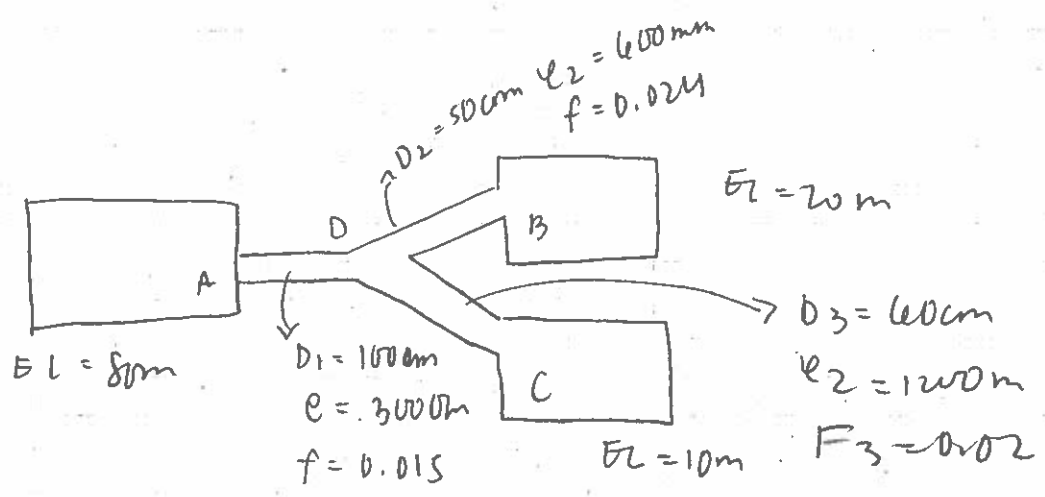
$$L h_f = \frac{f L V^2}{2 g d} = (25-20) = \frac{0.024 \times 600 \times V^2}{2 \times 9.81 \times (0.5)^2}$$

$$Q_{DB} = \frac{\pi}{4} (0.5^2) \times 1.845 = \boxed{0.356 \text{ m}^3/\text{s}}$$

- pipe DC

$$L h_f = \frac{f L V^2}{2 g d} = \frac{0.02 \times 1200 \times V^2}{2 \times 9.81 \times 0.6^2} = (25-10) \quad \checkmark \quad v_{DC} = 2.71 \text{ m/s}$$

$$Q_{DC} = 0.7669 \text{ m}^3/\text{s}$$



Problem 5 -

$$a- V_1 = \frac{Q}{A_1} = \frac{0.045}{\frac{\pi}{4} (0.3)^2} = \boxed{0.636 \text{ m/s}}$$

$$V_2 = \frac{0.045}{\frac{\pi}{4} (0.2)^2} = \boxed{1.432 \text{ m/s}}$$

$$b- \frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2$$

$$\frac{P_1}{\rho} + \frac{V_1^2}{2} = \frac{P_2}{\rho} + \frac{V_2^2}{2} \quad P_2 = P_1 + V_1^2 - V_2^2$$

$$P_2 = 70 + (0.636)^2 - (1.432)^2$$

$$\boxed{P_2 = 68.35 \text{ kPa}}$$

$$c- P_1 A_1 + F_x = m (V_{0x} - V_{1x})$$

$$F_x = 81 (1.432 - 0.636) - (70 \times 10^3 \text{ N/m}^2 \times \frac{\pi}{4} (0.3)^2)$$

$$F_x = \frac{-4883.557 \text{ N}}{4} = \boxed{1220.889 \text{ N}}$$

Problem 6 -

$$(a) \text{ Area flow} = (20 \times 3) + (3 \times 10) = \boxed{90 \text{ m}^2}$$

$$(b) P = 3 + 5 + 3 + 10 + 5 + 3 = \boxed{29 \text{ m}}$$

$$(c) R = \frac{90}{29} = \boxed{3.1 \text{ m}}$$

$$(d) T = 5 + 10 + 5 = \boxed{20 \text{ m}}$$

$$(e) \text{ Depth} = \frac{90}{20} = \boxed{4.5 \text{ m}}$$

$$(f) Q = \frac{1}{(0.013 \times (90 \times (3.1)^{2/3}) \times (10.003)^{1/2})} = \boxed{806 \text{ m}^3/\text{s}}$$

CVEG 4303
WATER RESOURCES ENGINEERING
SPRING 2022

HOMework
04

ABOVE
AVERAGE



SUBMIT THIS as cover sheet with your work Name [PRINT]

MAALVIKA AGGARWAL

Instructions: IN ALL THE PROBLEMS YOU MUST PROVIDE ENOUGH DETAILS AND DESCRIPTION OF THE SOLUTION METHOD TO DEMONSTRATE YOUR KNOWLEDGE OF THE SOLUTION METHOD. A SUBSTANTIAL PORTION OF THE GRADE WILL BE BASED ON YOUR METHODS.

Problem 1[200]

900
900 1000

2.00 cfs of water at 100 °F is entering the piping network at A and exiting at B. The pipes are: #1 - 3.0 in, 1000 ft, $C = 120$; #2 - 4.0 in, 200 ft, $C = 140$; #3 - 8.0 in, 1200 ft, $C = 110$. Using the Hazen-Williams approach presented in class, determine the following:

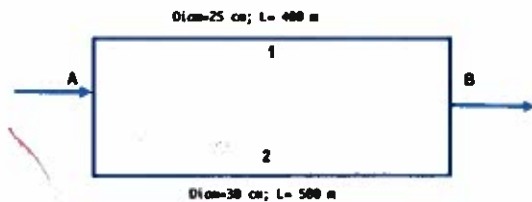


- [50] Velocities, V_1 , V_2 and V_3 [ft/s]
- [40] Corresponding flowrates, Q_1 , Q_2 and Q_3 [ft³/s]
- [50] Headloss [ft] in pipes #1, #2 and #3.
- [60] The pressure, P_B [psf] at B if the pressure at A = 20 psi (gage).

Show your work fully.

Problem 2[150] (Show your work fully)

The total discharge (flowrate) of water from into A and out of B (from left to right) in the figure below is 15 liters/s. The diameter and lengths of the pipe segments are given as shown in the diagram. Use the Darcy equation in your calculations. The flow in the pipes is fully turbulent (Hint: use this information to determine the friction factor, f in the pipes).



- [100] Determine the headloss [m] across A-B in pipes #1 and #2 if the pipes are new cast iron pipes (use data in Table 15.1) and the temperature of the water is 10° C.
- [50] Determine the flowrate in pipes #1 and #2 in liters/s.

Problem 3[550] (Show your work fully)

Water is flowing in the water distribution network shown. Pipe data are provided in the table. All pipes are ductile iron pipes ($\epsilon = 0.26$ mm). Assume that flow in the system is fully turbulent. As such, you can determine the friction factor of each pipe in the system. Use the Darcy equation to calculate headloss for the Hardy Cross method. Provide a spreadsheet solution similar to the example presented in class.

Note: $0.500 \text{ m}^3/\text{s} = 30,000 \text{ l/min}$.

On your solution:

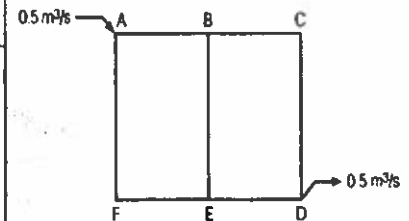
- [100] Determine the friction factor, f , for each pipe.
- [50] Provide the assumed flowrates [liter/minute] for each pipe in iteration #1.
- [400] Determine the flow in each pipe in liters/min using the Hardy Cross method. **CLOCKWISE FLOWS ARE POSITIVE**. Summarize your calculations in a table. Please use a spreadsheet to solve the problem AND provide elaborate sample calculations for each cell as appropriate. You are to perform **ONLY 2** iterations. Use the data at the **END** of iteration #2 to answer the rest of the questions.

Print and submit a hardcopy with your Hardy Cross work – but you must also submit the Spreadsheet.

Hardy Cross Requirements (Start with assumed flowrates in the table below)

Pipe Segment	AB	CD	BC
Assumed Flow [liter/min]	+18,000	+6,000	+6,000

Pipe	L (m)	D (mm)
AB	1000	300
BC	750	325
CD	800	200
DE	700	250
EF	900	300
FA	900	250
BE	950	350



- [100] If the pressure at point F is 500 kPa, and the elevation of points A, B and C is 200 m, while the elevation of points F, E and D is 170 m, determine the water pressures [kPa] at each of the intersections or nodes.

Submit your spreadsheet in CANVAS.

Problem 1

$Q = 2 \text{ cfs}$

Pipe # 1

$$d_1 = 3 \text{ in}$$

$$L_1 = 1000 \text{ ft}$$

$$C = 120$$

$$A_1 = \frac{3.14 (3/12)^2}{4} = 0.049 \text{ ft}^2$$

Pipe # 2

$$d_2 = 4 \text{ in}$$

$$L_2 = 200 \text{ ft}$$

$$C = 140$$

$$A_2 = \frac{3.14 (4/12)^2}{4}$$

$$A_2 = 0.087 \text{ ft}^2$$

Pipe # 3

$$d_3 = 8 \text{ in}$$

$$L_3 = 1200 \text{ ft}$$

$$C = 110$$

$$A_3 = \frac{3.14 (8/12)^2}{4}$$

$$A_3 = 0.349 \text{ ft}^2$$

$$h_{f1} = h_{f2} = h_{f3}$$

$$\text{So, } h_f = \frac{(3.022) V_1^{1.85} L}{C^{1.85} D^{1.165}}$$

$$\text{So, } \frac{(3.022) V_1^{1.85} (1000)}{120^{1.85} (3/12)^{1.165}} = \frac{(3.022) (V_2^{1.85}) (200)}{140^{1.85} (4/12)^{1.165}}$$

$$2.164 V_1^{1.85} = 0.233 V_2^{1.85}$$

$$1.518 V_1 = 0.455 V_2$$

$$V_2 = 3.337 V_1 \quad \text{--- (1)}$$

Similarly,

$$\frac{(3.022) V_1^{1.85} (1000)}{120^{1.85} (3/12)^{1.165}} = \frac{(3.022) V_3^{1.85} (1200)}{(110)^{1.85} (8/12)^{1.165}}$$

$$2.164 V_1^{1.85} = 0.978 V_3^{1.85}$$

$$1.518 V_1 = 0.985 V_3$$

$$V_3 = 1.540 V_1 \quad \text{--- (2)}$$

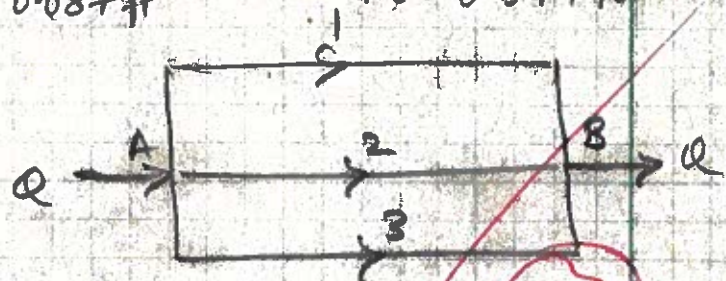
$$\text{Now, } Q = \frac{1}{4} (\pi) (D_1^2 V_1 + D_2^2 V_2 + D_3^2 V_3)$$

Substituting,

$$2 = \frac{1}{4} (3.14) \left((3/12)^2 (V_1) + (4/12)^2 (3.337 V_1) + (8/12)^2 (1.54 V_1) \right)$$

$$2 = 0.985 (0.063 V_1 + 0.37 V_1 + 0.685 V_1)$$

$$V_1 = 2.279 \text{ ft/s}$$



$$60, V_2 = 8.837(2.279)$$

$$V_2 = 7.606 \text{ ft/s}$$

$$V_3 = 1.540(2.279)$$

$$V_3 = 3.511 \text{ ft/s}$$

Since, $Q = VA$

$$Q_1 = V_1 A_1 = (2.279)(0.049)$$

$$Q_1 = 0.112 \text{ ft}^3/\text{s}$$

$$Q_2 = V_2 A_2 = (7.606)(0.087)$$

$$Q_2 = 0.663 \text{ ft}^3/\text{s}$$

$$Q_3 = V_3 A_3 = (3.511)(0.349)$$

$$Q_3 = 1.225 \text{ ft}^3/\text{s}$$

$$\text{Now, } h_{f1} = \frac{(3.022) V_1^{1.85} (L)}{C^{1.85} D^{1.65}} = \frac{(3.022)(2.279)^{1.85} (1000)}{140^{1.85} (3/12)^{1.65}}$$

$$h_{f1} = 9.931 \text{ ft}$$

$$h_{f2} = \frac{(3.022)(7.606)^{1.85} (200)}{140^{1.85} (4/12)^{1.65}} = 9.931 \text{ ft}$$

$$h_{f3} = \frac{(3.022)(3.511)^{1.85} (1200)}{110^{1.85} (8/12)^{1.65}} = 9.931 \text{ ft}$$

Hence, $h_{f1} = h_{f2} = h_{f3}$ ✓

$$\text{Now, } 1 \text{ psi} = 2.31 \text{ ft}$$

$$\text{So, } P_A = 20 \text{ psi}$$

$$\text{So, } P_B = P_A - h_f = 20 - \left(\frac{9.931}{2.31} \right) \text{ psi}$$

$$P_B = 15.701 \text{ psi}$$

$$P_B = 2260.94 \text{ PSF}$$

Problem 2

$$Q = 15 \text{ liters/sec} = 0.015 \text{ m}^3/\text{s}$$

$$D_1 = 25 \text{ cm} = 0.25 \text{ m} = 0.82 \text{ ft}$$

$$L_1 = 400 \text{ m}$$

$$D_2 = 80 \text{ cm} = 0.80 \text{ m} = 0.984 \text{ ft}$$

$$L_2 = 500 \text{ m}$$

Flow = Turbulent

New cast iron pipes, $\epsilon = 8 \times 10^{-4} \text{ ft}$

$$\text{So, } \left(\frac{\epsilon}{d}\right)_1 = \frac{8 \times 10^{-4}}{0.82} = 0.00097 \quad \text{and} \quad \left(\frac{\epsilon}{d}\right)_2 = \frac{8 \times 10^{-4}}{0.984} = 0.00081$$

So, from Moody diagrams

$$f_1 = 0.019 \quad f_2 = 0.0185$$

$$h_{f1} = h_{f2}$$

$$\frac{f_1 L_1 V_1^2}{2d_1 g} = \frac{f_2 L_2 V_2^2}{2d_2 g} \Rightarrow \frac{(0.019)(400) V_1^2}{(2)(0.25)(9.81)} = \frac{(0.0185)(500) V_2^2}{(2)(0.8)(9.81)}$$

$$1.549 V_1^2 = 1.571 V_2^2$$

$$1.2447 V_1 = 1.2536 V_2$$

$$V_1 = 1.007 V_2$$

Now,

$$Q = \frac{1}{4} \pi (D_1^2 V_1 + D_2^2 V_2)$$

$$0.015 = \frac{1}{4} (3.14) (0.25^2 (1.007 V_2) + 0.8^2 (V_2))$$

$$0.015 = 0.785 (0.1529 V_2 + 0.64 V_2)$$

$$0.015 = 0.1201 V_2$$

$$V_2 = 0.1249 \text{ m/s}$$

$$\text{So, } V_1 = 0.1258 \text{ m/s}$$

Now,
$$\frac{(0.019)(400)(0.1258)}{(2)(0.25)(9.81)} = \boxed{0.0245 \text{ m}}$$

$$h_{f2} = \frac{(0.0185)(500)(0.1249)^2}{(2)(0.30)(9.81)} = \boxed{0.0245 \text{ m}}$$

Also,
$$A_1 = \frac{3.14(0.25)^2}{4} = 0.0491 \text{ m}^2$$

$$A_2 = \frac{3.14(0.3)^2}{4} = 0.0706 \text{ m}^2$$

b) So,
$$Q_1 = A_1 V_1 = (0.0491)(0.1258) = 0.006173 \text{ m}^3/\text{s}$$

$$\boxed{Q_1 = 6.17 \text{ liters/sec}}$$

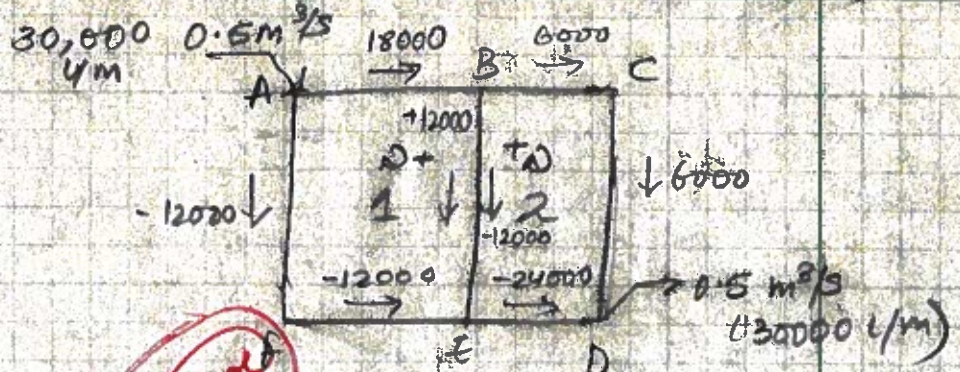
$$Q_2 = A_2 V_2 = (0.0706)(0.1249)$$

$$Q_2 = 0.008827 \text{ m}^3/\text{s}$$

$$\boxed{Q_2 = 8.83 \text{ liters/sec}}$$

Problem 3

Pipe	L (m)	D (mm)
AB	1000	300
BC	750	250
CD	200	200
DE	700	250
EF	900	300
FA	900	250
BE	950	350



$\epsilon = 0.26 \text{ mm}$ (Ductile iron)

Pipe	ϵ/d	Friction factor from Moody diagram
AB	$0.26/300 = 0.00087$	0.0195
BC	0.00080	0.0190
CD	0.00130	0.022
DE	0.00104	0.022
EF	0.00087	0.0195
FA	0.00104	0.022
BE	0.00074	0.0180

Sample Calculations

Iteration 1

Loop 1

$\epsilon = 0.26 \text{ mm}$

Pipe AB

$L = \text{Length} = 1000 \text{ m}$

Diameter $= D = 0.3 \text{ m}$

$$\text{So, } K = \frac{8.263 \times 10^{-8} f L}{D^5} = \frac{(8.263 \times 10^{-8})(0.0195)(1000)}{(0.3)^5}$$

$$K = 0.00066308$$

$$\text{Assumed } Q = Q_a = 18000 \text{ L/min} \\ = 300 \text{ L/sec}$$

So, headloss with Darcy eqⁿ = KQ^n ($n=2$)

So, $h_f = KQ^2 = (0.00066308)(300)^2$

$h_f = \underline{0.59.6772 \text{ m}}$

Now, $\left| \frac{h_f}{Q_a} \right| = \left| \frac{59.6772}{300} \right| = \underline{0.1989}$

Now, for correction, $d = \frac{-\sum h_f}{n \sum \left| \frac{h_f}{Q_a} \right|}$

For loop 1:

Here, $n=2$, $\sum h_f = h_{fAB} + h_{fBE} + h_{fEF} + h_{fFA}$

Similarly, $= \underline{130.86}$

$\sum \left| \frac{h_f}{Q_a} \right| = \underline{0.5548}$

So, $d = \frac{-130.86}{2(0.5548)} = \underline{-117.925}$ (this is for AB, BE, FA)

for BE, $d = -117.92 + 120.93 = \underline{3.007}$

So, New $Q = Q_a + d$

So, for pipe AB = $Q = 300 + (-117.925) = 182.070 \text{ l/s}$
 $= \underline{1092.44 \text{ liter/min}}$

Similarly, we repeat for loop 2 and then iteration 2 continues with the new Q values as assumed Q_a in second iteration.

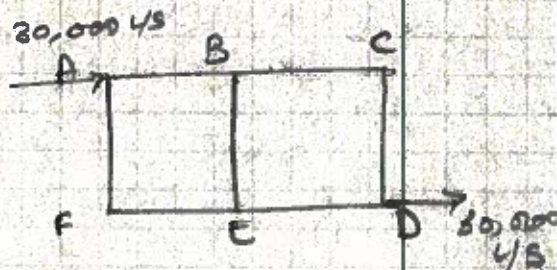
d) Pressure at F = 500 kPa

Given: Pressure head = $\frac{500}{9.81} = 50.968 \text{ m}$

Given:

$$z_A = z_B = z_C = 200 \text{ m}$$

$$z_F = z_E = z_D = 170 \text{ m}$$



$$\text{So, } \left(\frac{P}{\rho}\right)_F + z_F = \left(\frac{P}{\rho}\right)_E + z_E + h_{LFE}$$

$$(50.968) - 60.319 = \left(\frac{P}{\rho}\right)_E \quad \text{So, } \left(\frac{P}{\rho}\right)_E = -9.351$$

$$\text{So, } P_E = -91.733 \text{ kPa}$$

$$\text{Similarly, } \left(\frac{P}{\rho}\right)_F + z_F = \left(\frac{P}{\rho}\right)_A + z_A + h_{LFA}$$

$$\left(\frac{P}{\rho}\right)_A = 50.968 + 170 - 200 - 92.366 = -71.398$$

$$\text{So, } P_A = -71.398 \times 9.81 = -700.414 \text{ kPa}$$

$$\left(\frac{P}{\rho}\right)_E + z_E = \left(\frac{P}{\rho}\right)_D + z_D + h_{LDE}$$

$$\text{So, } \left(\frac{P}{\rho}\right)_D = -9.351 + 170 - 200 - 142.897 = -232.20$$

$$\text{So, } P_D = -2278.16 \text{ kPa}$$

$$\left(\frac{P}{\rho}\right)_C + z_C = \left(\frac{P}{\rho}\right)_D + z_D + h_{LCD}$$

$$\text{So, } \left(\frac{P}{\rho}\right)_C = -232.20 + 170 + 1.76 - 200 = -261.05$$

$$P_C = -2560.92 \text{ kPa}$$

$$\left(\frac{P}{\rho}\right)_A + z_A = \left(\frac{P}{\rho}\right)_B + z_B + h_{LAB}$$

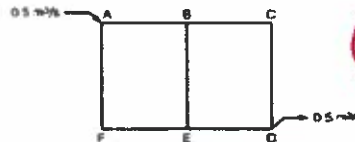
$$\left(\frac{P}{\rho}\right)_B = -71.398 + 200 - 200 - 21.48 = -93.37$$

$$\text{So, } P_B = -916.038 \text{ kPa}$$

Flow rate, Q	=	liters/sec
Length	=	m
Diameter	=	m
Headloss, hf	=	m
E	=	0.26

mm

Pipe	E/d	Friction factor
AB	0.00087	0.01950
BC	0.00080	0.01900
CD	0.00130	0.01300
DE	0.00104	0.01200
EF	0.00087	0.01950
FA	0.00104	0.01200
BE	0.00074	0.01800



250

System is fully Turbulent

$$\frac{8.263 \times 10^{-3} fL}{D^5}$$

$$h_f = KQ^2$$

$$\frac{-\sum h_f}{n \sum \frac{h_f}{Q}}$$

Review sign

Iteration	Loop	Pipeline	Length (m)	Diameter (mm)	Diameter (m)	K	Qa (L/min)	Qa (L/sec)	Headloss, hf (m)	hf/Q	Correction, d	New Q = Qa + d (liters/sec)	New Q = Qa + d (liters/min)
1	1	AB	1000	300	0.3	0.000663080	18000	300	59.677222	0.198924074	-117.9259978	182.0740022	10924.44013
		BE	950	350	0.35	0.000269026	12000	200	10.761025	0.053805124	3.007148988	203.007149	12180.42894
		EF	900	300	0.3	0.000596772	-12000	-200	23.870889	0.119354444	-117.9259978	-317.9259978	-19075.5599
		FA	900	250	0.25	0.000913822	-12000	-200	36.552868	0.182764339	-117.9259978	-317.9259978	-19075.5599
	TOTAL									130.862004	0.554847982		
	Corrections: Loop 1: d1 = -117.9259978 Loop 2: d2 = -120.9331468												
	2	BC	750	325	0.325	0.000324740	6000	100	3.247400	0.032474002	-120.9331468	-20.93314679	-1255.98881
		CD	800	200	0.2	0.002685475	6000	100	26.854750	0.2685475	-120.9331468	-20.93314679	-1255.98881
		DE	700	250	0.25	0.000710750	-24000	-400	113.720033	0.284300083	-120.9331468	-520.9331468	-31255.9888
		BE	950	350	0.35	0.000269026	-12000	-200	10.761025	0.053805124	-3.007148988	-203.007149	-12180.4289
	TOTAL									154.583208	0.639126709		
2	1	AB	1000	300	0.3	0.000663080	10924.44	182.074002	21.981735	0.120729674	-141.6677509	40.40625125	2424.375075
		BE	950	350	0.35	0.000269026	12180.43	203.007149	11.087058	0.054614124	68.71497777	271.722127	16303.32761
		EF	900	300	0.3	0.000596772	-19075.56	-317.925998	60.319910	0.189729404	-141.6677509	-459.5937488	-27575.6249
		FA	900	250	0.25	0.000913822	-19075.56	-317.925998	92.366301	0.290527675	-141.6677509	-459.5937488	-27575.6249
	TOTAL									185.755004	0.655600877		
	Corrections: Loop 1: d1 = -141.6677509 Loop 2: d2 = -210.3827287												
	2	BC	750	325	0.325	0.000324740	-1255.99	-20.933147	0.142300	0.00679783	-210.3827287	-231.3158755	-13878.9525
		CD	800	200	0.2	0.002685475	-1255.99	-20.933147	1.176766	0.056215442	-210.3827287	-231.3158755	-13878.9525
		DE	700	250	0.25	0.000710750	-31255.99	-520.933147	192.877239	0.370253342	-210.3827287	-731.3158755	-43878.9525
		BE	950	350	0.35	0.000269026	-12180.43	-203.007149	11.087058	0.054614124	-68.71497777	-271.722127	-16303.3276
	TOTAL									205.283363	0.487880739		

* headloss should have same sign (+ or -) as the flow (Qa)

* Correction (d1) for pipe (BE) in loop 1 has to be same with pipe (BE) in loop 2 with opposite signs (+ or -)

AVERAGE

SUBMIT THIS as cover sheet with your work Name (PRINT) Armando Gumbau

Instructions:

IN ALL THE PROBLEMS YOU MUST PROVIDE ENOUGH DETAILS AND DESCRIPTION OF THE SOLUTION METHOD TO DEMONSTRATE YOUR KNOWLEDGE OF THE SOLUTION METHOD. A SUBSTANTIAL PORTION OF THE GRADE WILL BE BASED ON YOUR METHODS.

Problem 1 [200]

1500
900
1000

2.00 cfs of water at 100 °F is entering the piping network at A and exiting at B. The pipes are: #1 - 3.0 in, 1000 ft, $C = 120$; #2 - 4.0 in, 200 ft, $C = 140$; #3 - 8.0 in, 1200 ft, $C = 110$. Using the Hazen-Williams approach presented in class, determine the following:

- [50] Velocities, V_1 , V_2 and V_3 [ft/s]
- [40] Corresponding flowrates, Q_1 , Q_2 and Q_3 [ft³/s]
- [50] Headloss [ft] in pipes #1, #2 and #3.
- [60] The pressure, P_B [psf] at B if the pressure at A = 20 psi (gage).

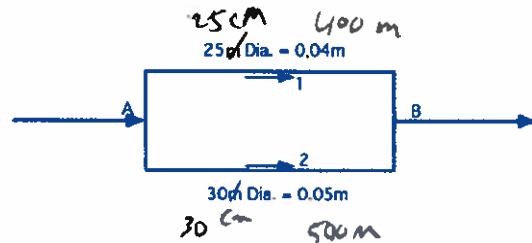
Show your work fully.



Problem 2 [150] (Show your work fully)

The total discharge (flowrate) of water from into A and out of B (from left to right) in the figure below is 15 liters/s. The diameter and lengths of the pipe segments are given as shown in the diagram. Use the Darcy equation in your calculations. The flow in the pipes is fully turbulent (Hint: use this information to determine the friction factor, f in the pipes).

- [100] Determine the headloss [m] across A-B in pipes #1 and #2 if the pipes are new cast iron pipes (use data in Table 15.1) and the temperature of the water is 10° C.
- [50] Determine the flowrate in pipes #1 and #2 in liters/s.



Problem 3 [550] (Show your work fully)

Water is flowing in the water distribution network shown. Pipe data are provided in the table. All pipes are ductile iron pipes ($\epsilon = 0.26$ mm). Assume that flow in the system is fully turbulent. As such, you can determine the friction factor of each pipe in the system. Use the Darcy equation to calculate headloss for the Hardy Cross method. Provide a spreadsheet solution similar to the example presented in class.

Note: $0.500 \text{ m}^3/\text{s} = 30,000 \text{ l/min}$.

On your solution:

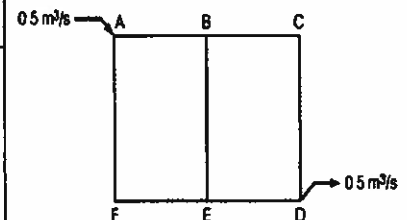
- [100] Determine the friction factor, f , for each pipe.
- [50] Provide the assumed flowrates [liter/minute] for each pipe in iteration #1.
- [400] Determine the flow in each pipe in liters/min using the Hardy Cross method. CLOCKWISE FLOWS ARE POSITIVE. Summarize your calculations in a table. Please use a spreadsheet to solve the problem AND provide elaborate sample calculations for each cell as appropriate. You are to perform ONLY 2 iterations. Use the data at the END of iteration #2 to answer the rest of the questions.

Print and submit a hardcopy with your Hardy Cross work - but you must also submit the Spreadsheet.

Hardy Cross Requirements [Start with assumed flowrates in the table below]

Pipe Segment	AB	CD	BC
Assumed Flow [liter/min]	+18,000	+6,000	+6,000

Pipe	L (m)	D (mm)
AB	1000	300
BC	750	325
CD	800	200
DE	700	250
EF	900	300
FA	900	250
BE	950	350



- [100] If the pressure at point F is 500 kPa, and the elevation of points A, B and C is 200 m, while the elevation of points F, E and D is 170 m, determine the water pressures [kPa] at each of the intersections or nodes.

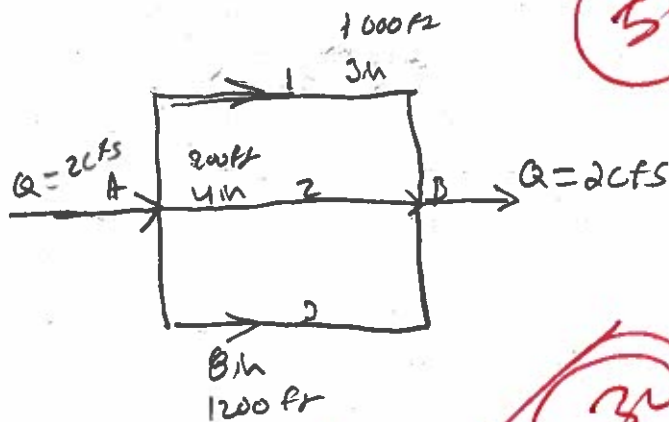
Submit your spreadsheet in CANVAS.

Given:

$$Q = 2 \text{ cfs}$$

$$T = 100^\circ \text{F}$$

$$C = 110 \text{ pipe factor}$$



Find

a) V_1, V_2, V_3

b) Q_1, Q_2, Q_3

c) h_L for pipe 1, 2, 3

d) P_B at B if the pressure at A is 20 psi

Solution:

a) $h_{L1} = h_{L2} = h_{L3}$

$$h_L = \frac{3.022 V^{1.85}}{C^{1.85} D^{4.85}} \Rightarrow \frac{3.022 V_1^{1.85} (1000)}{110^{1.85} \left(\frac{3}{12}\right)^{4.85}} = \frac{3.022 V_2^{1.85} (200)}{110^{1.85} \left(\frac{2}{12}\right)^{4.85}} = \frac{3.022 V_3^{1.85} (1200)}{110^{1.85} \left(\frac{8}{12}\right)^{4.85}}$$

$$.714 V_1^{1.85} = .770 V_2^{1.85} = .322 V_3^{1.85} \Rightarrow V_1 = \sqrt[1.85]{1.075 V_2^{1.85}}$$

$$A_1 = \frac{\pi}{4} \left(\frac{3}{12}\right)^2 = .049 \text{ ft}^2, A_2 = \frac{\pi}{4} \left(\frac{2}{12}\right)^2 = .007 \text{ ft}^2$$

$$A_3 = \frac{\pi}{4} \left(\frac{8}{12}\right)^2 = .349 \text{ ft}^2$$

$$Q = Q_1 + Q_2 + Q_3$$

$$2 = V_1 (.049) + \sqrt[1.85]{.970 V_1^{1.85} (.007)} + \sqrt[1.85]{.722 V_1^{1.85} (.349)}$$

$$V_1 = 2.98 \text{ ft/s}$$

$$V_2 = 2.02 \text{ ft/s}$$

$$V_3 = 4.59 \text{ ft/s}$$

b)

$$Q_1 = (2.98)(.049) = 0.146 \text{ ft}^3/\text{s}$$

$$Q_2 = (2.02)(.007) = 0.25 \text{ ft}^3/\text{s}$$

$$Q_3 = (4.59)(.349) = 1.602 \text{ ft}^3/\text{s}$$

$$c) \quad h_{L1} = \frac{3.022 (2.98)^{1.85} (1000)}{(110)^{1.85} \left(\frac{3}{12}\right)^{1.165}} = 16.3 \text{ ft}$$

$$h_{L2} = \frac{3.022 (2.82)^{1.85} (700)}{(110)^{1.85} \left(\frac{4}{12}\right)^{1.165}} = 16.3 \text{ ft}$$

$$h_{L3} = \frac{3.022 (4.54)^{1.85} (1200)}{110^{1.85} \left(\frac{8}{12}\right)^{1.165}} = 16.3 \text{ ft}$$

d)

$$z_A = z_B$$

$$\frac{P_A}{\gamma} + \frac{V_A^2}{2g} = \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + h_L$$

$$P_B = 20 \text{ psi} \left(\frac{12 \text{ in}}{1 \text{ ft}}\right) \left(\frac{12 \text{ in}}{1 \text{ ft}}\right) - 16.3 (62.4 \text{ lb/ft}^3)$$

$$P_B = 1862.88 \text{ psf}$$

② Given:

$$Q = 1015 \frac{L}{s} = 1015 \frac{m^3}{s}$$

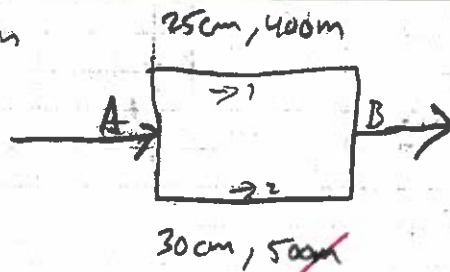
During summer
Turbulent

$f =$

Cast Iron Pipe

$$T = 10^\circ C$$

$$e = 0.26$$



Find:

a) determine head loss across A+B pipe

b) Q at 1+2 pipe

Solution

$$a) \frac{f_1 L_1 V_1^2}{2 D_1} = \frac{f_2 L_2 V_2^2}{2 D_2}$$

Moody chart

$$\frac{e}{d} = \frac{0.26}{250} = 0.00104$$

$$\frac{e}{d} = \frac{0.26}{300} = 0.00087$$

$$f_2 = 0.018$$

$$f_1 = 0.02$$

$$A_1 = \frac{\pi}{4} (1.25)^2 = 0.049 m^2$$

$$A_2 = \frac{\pi}{4} (1.3)^2 = 0.071 m^2$$

$$Q = Q_1 + Q_2 \Rightarrow Q = V_1 A_1 + V_2 A_2 \Rightarrow V_1 = \frac{Q - V_2 A_2}{A_1}$$

$$V_1 = \frac{1015 - V_2 (0.071)}{(0.049)} \Rightarrow V_1 = 206 - (1.449) V_2$$

$$\frac{f_1 L_1 V_1^2}{2 D_1} = \frac{f_2 L_2 V_2^2}{2 D_2} \Rightarrow \sqrt{\frac{V_1^2}{V_2^2}} = \sqrt{\frac{f_2 L_2 2 D_1}{f_1 L_1 2 D_2}} \Rightarrow \frac{V_1}{V_2} = \sqrt{\frac{(0.018)(500)(2)(1.25)}{(0.02)(400)(2)(1.3)}}$$

$$V_1 = 0.9682 V_2 \quad \text{so } \Rightarrow 0.9682 V_2 + 1.449 V_2 = 206$$

$$(0.9682 + 1.449) V_2 = 206$$

$$V_2 = \frac{206}{0.9682 + 1.449} \Rightarrow V_2 = 0.1266 m/s$$

$$V_1 = 0.9682 (0.1266) = 0.1226 m/s = V_1$$

$$h_L = h_{L1} = h_{L2}$$

$$b) h_{L1} = \frac{(0.02)(400)(0.1226)^2}{2 (1.25)} = 0.24 m$$

$$h_{L2} = \frac{(0.018)(500)(0.1266)^2}{2 (1.3)} = 0.24 m$$

$$Q = V_1 A_1 + V_2 A_2 \Rightarrow (0.1226)(0.049) + (0.1266)(0.071)$$

② b) $Q = 0.006 + .009 = .015 \frac{m^3}{s}$ okay

$$.015 \frac{m^3}{s} = 1015 \frac{m^3}{s}$$

$$Q_1 = (.006 \frac{m^3}{s}) \left(\frac{1000 L}{1 m^3} \right) \left(\frac{60 s}{1 min} \right) = 360 \frac{L}{min}$$

$$Q_2 = (.009 \frac{m^3}{s}) \left(\frac{1000 L}{1 m^3} \right) \left(\frac{60 s}{1 min} \right) = 540 \frac{L}{min}$$

-10 for not
converting @ to L/s

50

300

③ Given:

$$E = 0.26 \text{ mm}$$

$$Q = 0.500 \text{ m}^3/\text{s} = 30,000 \text{ l/min}$$

$$C = 130$$

Pipe	L (m)	D (mm)	f
AB	1000	300	.019
BC	750	325	.018
CD	800	300	.021
DE	700	250	.02
EF	900	300	.019
FA	900	250	.02
BE	950	350	.0185

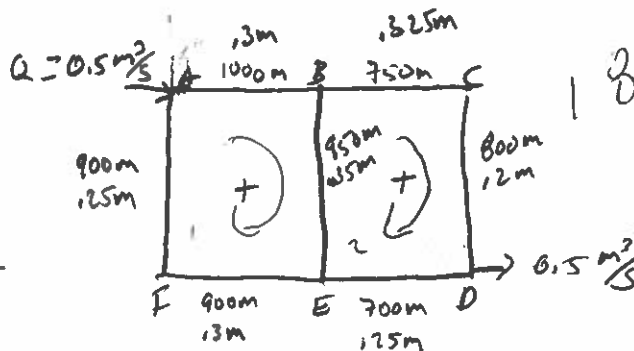
Find:

a) f for each pipe

b) Flow rate at each pipe in direction #1

c) Q using Hardy Cross

d) Determine the water pressure P_A at each of the intersection of pipes



Solution:

a) Moody Diagram

$$AB: \frac{E}{d} \Rightarrow \frac{.26}{300} = .00086, f = .019$$

$$BC = \frac{.26}{325} = .0008, f = .018$$

$$CD = \frac{.26}{200} = .0013, f = .021$$

$$DE = \frac{.26}{250} = .00104, f = .02$$

$$EF = \frac{.26}{300} = .00086, f = .019$$

$$FA = \frac{.26}{250} = .00104, f = .02$$

$$BE = \frac{.26}{350} = .00074, f = .0185$$

④ Flow Rate:

$$Q = 30,000 \text{ l/min}$$

$$Q_{AB} = 18,000 \text{ l/min}$$

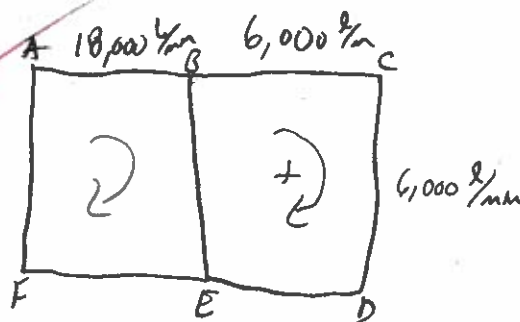
$$Q_{BC} = 6,000 \text{ l/min}$$

$$Q_{CD} = 6,000 \text{ l/min}$$

$$Q_{DE} = 6,000 \text{ l/min}$$

$$Q_{EF} = 6,000 \text{ l/min}$$

$$Q_{FA} = 6,000 \text{ l/min}$$



Iteration	Loop	Pipeline	Length (m)	diam (m)	K	Qa (m ³ /s)	hf = KQa ²	h _f /Q _I	Correction, d	New Q = Qa+d
1	1	AB	1000	0.30		646.08	0.3	58.15	193.82	0.259
		BE	950	0.35		283.97	-0.1	-2.84	28.40	-0.100
		EF	900	0.30		581.47	-0.1	-5.81	58.15	-0.100
		FA	900	0.25		1446.88	-0.1	-14.47	144.69	-0.100
						35.02		425.06		
	2	Pipeline	Length (m)	diam (m)	K	Qa (m ³ /s)	hf = KQa ²	h _f /Q _I	Correction, d	New Q = Qa+d
		BC	750	0.325		324.74	0.1	3.25	32.47	0.075
		CD	800	0.200		3924.93	0.1	39.25	392.49	
		DE	700	0.250		1125.35	-0.1	-11.25	112.54	
		EB	950	0.350		283.97	-0.1	-2.84	28.40	
							28.40	565.90		

Iteration	Loop	Pipeline	Length (m)	diam (m)	K	Qa (m ³ /s)	hf = KQa ²	h _f /Q _I	Correction, d	New Q = Qa+d
2	1	AB	1000	0.30		646.08	0.3	58.15	193.82	
		BE	950	0.35		283.97	-0.1	-2.84	28.40	
		EF	900	0.30		581.47	-0.1	-5.81	58.15	
		FA	900	0.25		1446.88	-0.1	-14.47	144.69	
						35.02		425.06		
	2	Pipeline	Length (m)	diam (m)	K	Qa (m ³ /s)	hf = KQa ²	h _f /Q _I	Correction, d	New Q = Qa+d
		BC	750	0.325		324.74	0.1	3.25	32.47	
		CD	800	0.200		3924.93	0.1	39.25	392.49	
		DE	700	0.250		1125.35	-0.1	-11.25	112.54	
		EB	950	0.350		283.97	-0.1	-2.84	28.40	
							28.40	565.90		

15.0

Calculated
values
Missing

$$c) \quad h + KQ_n = \frac{0.08263 FL}{D^5} Q$$

See Ex 10

$$\delta = \frac{-\epsilon h_f}{n \epsilon \left| \frac{h_f'}{a} \right|}$$

$$d) \quad F = 500 \text{ kPa}$$

A, B and C 200m

F, E and D 170m

X

BELOW
AVERAGE

SUBMIT THIS as cover sheet with your work Name [PRINT] MOUNI YAMBA

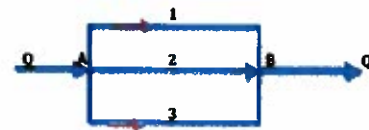
Instructions: IN ALL THE PROBLEMS YOU MUST PROVIDE ENOUGH DETAILS AND DESCRIPTION OF THE SOLUTION METHOD TO DEMONSTRATE YOUR KNOWLEDGE OF THE SOLUTION METHOD. A SUBSTANTIAL PORTION OF THE GRADE WILL BE BASED ON YOUR METHODS.

Problem 1[200]

2.00 cfs of water at 100 °F is entering the piping network at A and exiting at B. The pipes are: #1 - 3.0 in, 1000 ft, $C = 120$; #2 - 4.0 in, 200 ft, $C = 140$; #3 - 8.0 in, 1200 ft, $C = 110$. Using the Hazen-Williams approach presented in class, determine the following:

- [50] Velocities, V_1 , V_2 and V_3 [ft/s]
- [40] Corresponding flowrates, Q_1 , Q_2 and Q_3 [ft³/s]
- [50] Headloss [ft] in pipes #1, #2 and #3.
- [60] The pressure, P_B [psf] at B if the pressure at A = 20 psi (gage).

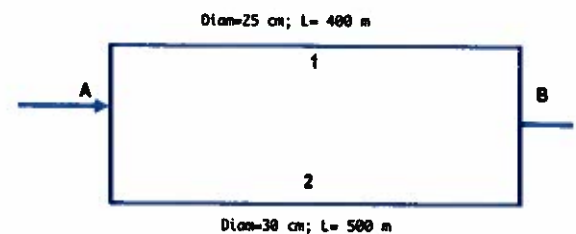
Show your work fully.



Problem 2[150] (Show your work fully)

The total discharge (flowrate) of water from into A and out of B (from left to right) in the figure below is 15 liters/s. The diameter and lengths of the pipe segments are given as shown in the diagram. Use the Darcy equation in your calculations. The flow in the pipes is fully turbulent (Hint: use this information to determine the friction factor, f in the pipes).

- [100] Determine the headloss [m] across A-B in pipes #1 and #2 if the pipes are new cast iron pipes (use data in Table 15.1) and the temperature of the water is 10° C.
- [50] Determine the flowrate in pipes #1 and #2 in liters/s.



Problem 3[550] (Show your work fully)

Water is flowing in the water distribution network shown. Pipe data are provided in the table. All pipes are ductile iron pipes ($\epsilon = 0.26$ mm). Assume that flow in the system is fully turbulent. As such, you can determine the friction factor of each pipe in the system. Use the Darcy equation to calculate headloss for the Hardy Cross method. Provide a spreadsheet solution similar to the example presented in class.

Note: $0.500 \text{ m}^3/\text{s} = 30,000 \text{ l/min}$.

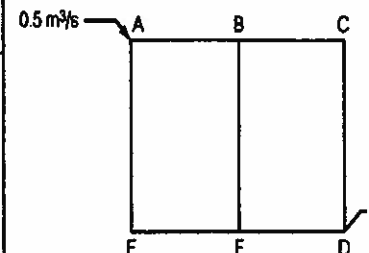
On your solution:

- [100] Determine the friction factor, f , for each pipe.
- [50] Provide the assumed flowrates [liter/minute] for each pipe in iteration #1.
- [400] Determine the flow in each pipe in liters/min using the Hardy Cross method. **CLOCKWISE FLOWS ARE POSITIVE.** Summarize your calculations in a table. Please use a spreadsheet to solve the problem AND provide elaborate sample calculations for each cell as appropriate. You are to perform **ONLY 2** iterations. Use the data at the **END** of iteration #2 to answer the rest of the questions.

Print and submit a hardcopy with your Hardy Cross work – but you must also submit the Spreadsheet.

Hardy Cross Requirements [Start with assumed flowrates in the table below]

Pipe	L (m)	D (mm)
AB	1000	300
BC	750	325
CD	800	200
DE	700	250
EF	900	300
FA	900	250
BE	950	350



- [100] If the pressure at point F is 500 kPa the elevation of points A, B and C is 200 m, the elevation of points F, E and D is 170 m, determine the water pressures [kPa] at the intersections or nodes.

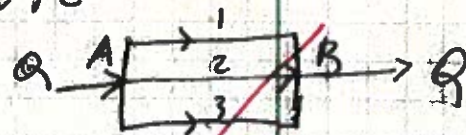
Problem 1

Given: $Q = 2.00 \text{ cfs}$ $D_1 = \frac{2}{12} \text{ ft} = 0.25 \text{ ft}$

$L_1 = 1000 \text{ ft}$, $C_1 = 120$

$D_2 = \frac{1}{3} \text{ ft}$, $L_2 = 200 \text{ ft}$, $C_2 = 140$

$D_3 = \frac{2}{3} \text{ ft}$, $L_3 = 1200 \text{ ft}$ $C_3 = 110$



Hazen-Williams equation:

$h_{f1} = h_{f2} = h_{f3}$

$$\frac{(3.022) V_1^{1.85} L_1}{C_1^{1.85} D_1^{1.165}} = \frac{(3.022) V_2^{1.85} L_2}{C_2^{1.85} D_2^{1.165}}$$

$$\frac{V_1^{1.85} \times 1000 \text{ ft}}{120^{1.85} \times (0.25)^{1.165}} = \frac{V_2^{1.85} \times 200 \text{ ft}}{140^{1.85} \times (\frac{1}{3})^{1.165}}$$

$$0.716 V_1^{1.85} = 0.077 V_2^{1.85}$$

$$\frac{V_1}{V_2} = \sqrt[1.85]{\frac{0.077}{0.716}} \Rightarrow \frac{V_1}{V_2} = 0.3$$

$$V_2 = \frac{V_1}{0.3} \quad (1)$$

$$0.716 V_1^{1.85} = \frac{V_3^{1.85} \times 1200}{110^{1.85} \times (\frac{2}{3})^{1.165}}$$

$$0.716 V_1^{1.85} = 0.322 V_3^{1.85}$$

$$\frac{V_1}{V_3} = \sqrt[1.85]{\frac{0.322}{0.716}} = 0.6492$$

$$\frac{V_1}{V_3} = 0.6492 \Rightarrow V_3 = \frac{V_1}{0.6492}$$

$$\frac{1}{4} \pi (D_1^2 V_1 + D_2^2 V_2 + D_3^2 V_3) = Q$$

$$0.049 V_1 + 0.087 \left(\frac{V_1}{0.3}\right) + 0.349 \left(\frac{V_1}{0.6492}\right) = 2$$

$$0.049 \times 0.3 \times 0.6492 V_1$$

$$+ 0.087 \times 0.6492 V_1 + 0.3 \times$$

$$0.349 V_1 = 2 \times 0.3 \times 0.6492$$

$$0.00954 V_1 + 0.0565 V_1$$

$$+ 0.1047 V_1 = 0.389484$$

$$0.17074 V_1 = 0.389484$$

$$V_1 = \frac{0.389484}{0.17074}$$

$$V_1 = 2.28 \text{ ft/s}$$

$$V_2 = \frac{2.28}{0.3}$$

$$V_2 = 7.61 \text{ ft/s}$$

$$V_3 = \frac{2.28}{0.6492}$$

$$V_3 = 3.51 \text{ ft/s}$$

$$b.) Q = AV = \frac{\pi D^2 V}{4} = \frac{\pi D^2 v}{4}$$

$$Q_1 = \frac{\pi D_1^2 V_1}{4} = \frac{\pi \left(\frac{3}{12}\right)^2 \times 2.28}{4}$$

$$Q_1 = 0.112 \text{ ft}^3/\text{s}$$

$$Q_2 = \frac{\pi D_2^2 V_2}{4} = \frac{\pi \left(\frac{1}{3}\right)^2 \times 7.61}{4}$$

$$Q_2 = 0.664 \text{ ft}^3/\text{s}$$

$$Q_3 = \frac{\pi D_3^2 V_3}{4} = \frac{\pi \left(\frac{2}{3}\right)^2 \times 3.51}{4}$$

$$Q_3 = 1.225 \text{ ft}^3/\text{s}$$

$$c.) h_{f1} = \frac{3.022 V_1^{1.85}}{C_1^{1.85} D_1^{1.65}}$$

$$h_{f1} = \frac{3.022 \times 2.28^{1.85} \times 1000 \text{ ft}}{120^{1.85} \times 0.25^{1.65}}$$

$$h_{f1} = 9.94 \text{ ft}$$

$$h_{f2} = \frac{3.022 \times 7.61^{1.85} \times 200}{140^{1.85} \times (1/3)^{1.65}}$$

$$h_{f2} = 9.94 \text{ ft}$$

$$h_{f3} = \frac{3.022 \times 3.51^{1.85} \times 1200}{110^{1.85} \times (2/3)^{1.65}}$$

$$h_{f3} = 9.93 \text{ ft}$$

$$d.) Z_A + \frac{P_A}{\gamma} + \frac{V_A^2}{2g}$$

$$= Z_B + \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + h_f$$

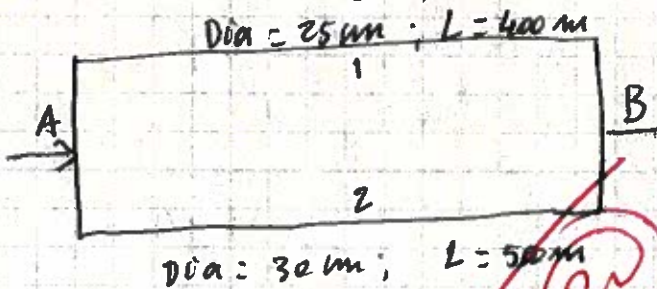
$$P_B = P_A - h_f \gamma$$

$$P_B = 20 \text{ Psi} \left(\frac{144 \text{ in}^2}{1 \text{ ft}^2} \right)$$

$$= 9.94 \text{ ft} \left(\frac{62.4 \text{ lb}}{\text{ft}^3} \right)$$

$$P_B = 2259.744 \text{ Psf}$$

Problem 2



given

$$\text{Total discharge} = 15 \text{ L/sec} \\ = 15 \times 10^{-3} \text{ m}^3/\text{sec}$$

Pipe 1

$$L_1 = 400 \text{ m}, d_1 = 25 \text{ cm} = 0.25 \text{ m}$$

$$\text{For cast iron } \epsilon = 0.26 \text{ mm}$$

$$\frac{\epsilon}{d} = \frac{0.26}{250} = 0.0010$$

$$\text{From Moody diagram, } f_1 = 0.02$$

Pipe 2

$$L_2 = 500 \text{ m}, d_2 = 30 \text{ cm} = 0.30 \text{ m}$$

$$\text{For cast iron } \epsilon = 0.26 \text{ mm}$$

$$\frac{\epsilon}{d} = \frac{0.26}{300} = 0.00086$$

$$\text{From Moody diagram,}$$

$$f_2 = 0.018$$

$$\text{Total discharge } Q = 15 \times 10^{-3} \text{ m}^3/\text{sec}$$

Pipes are in parallel

$$\text{connection} \Rightarrow H_1 = H_2$$

$$\Rightarrow \frac{16 f_1 L_1 Q_1^2}{\pi^2 D_1^5 \rho g} = \frac{16 f_2 L_2 Q_2^2}{\pi^2 D_2^5 \rho g}$$

$$\frac{0.02 \times 400 \times Q_1^2}{0.25^5} = \frac{0.018 \times 500 \times Q_2^2}{(0.30)^5}$$

$$128 Q_1^2 = 100 Q_2^2$$

$$\frac{Q_1^2}{Q_2^2} = \frac{100}{128}$$

$$\frac{Q_1}{Q_2} = 0.781$$

$$\frac{Q_1}{Q_2} = 0.884$$

$$Q_1 = 0.884 Q_2$$

$$Q = Q_1 + Q_2$$

$$15 \times 10^{-3} = 0.884 Q_2 + Q_2$$

$$Q_2 = 0.008 \text{ m}^3/\text{sec}$$

$$Q_1 = 0.884 \times 0.008$$

$$Q_1 = 0.007 \text{ m}^3/\text{sec}$$

— 20 mins
for not
converting
to HPS

50

Problem 3Given: $\epsilon = 0.26 \text{ mm}$

a) Completely Turbulent Flow:

$$f = \left[1.14 + 2 \log_{10} \left(\frac{D}{\epsilon} \right) \right]^{-2}$$

$$f_{AB} = \left[1.14 + 2 \log_{10} \left(\frac{300}{0.26} \right) \right]^{-2} = 0.0189$$

$$f_{BC} = \left[1.14 + 2 \log_{10} \left(\frac{325}{0.26} \right) \right]^{-2} = 0.0186$$

$$f_{CD} = \left[1.14 + 2 \log_{10} \left(\frac{200}{0.26} \right) \right]^{-2} = 0.0210$$

$$f_{DE} = \left[1.14 + 2 \log_{10} \left(\frac{250}{0.26} \right) \right]^{-2} = 0.0195$$

$$f_{EF} = \left[1.14 + 2 \log_{10} \left(\frac{300}{0.26} \right) \right]^{-2} = 0.0189$$

$$f_{FA} = \left[1.14 + 2 \log_{10} \left(\frac{300}{0.26} \right) \right]^{-2} = 0.0198$$

$$f_{BE} = \left[1.14 + 2 \log_{10} \left(\frac{300}{0.26} \right) \right]^{-2} = 0.0183$$

b) Assumed flows:

$$AB = +18,000 \text{ L/min}$$

$$BC = +6,000 \text{ L/min}$$

$$CD = +6,000 \text{ L/min}$$

$$DE = -24,000 \text{ L/min}$$

$$EF = -12,000 \text{ L/min}$$

$$FA = -12,000 \text{ L/min}$$

$$BE = 12,000 \text{ L/min}$$

c.) Sample Pipeline AB

50

$$L = 1000 \text{ m}$$

$$D = 300 \text{ mm} = 0.3 \text{ m}$$

$$f = 0.0189$$

$$Q_{AB} = 18,000 \text{ L/min} = 300 \text{ L/s}$$

$$K = \frac{8 \cdot 263 \times 10^{-8} f L}{D^5} = \frac{(8 \cdot 263 \times 10^{-8}) \times (0.0189) (1000)}{(0.3)^5}$$

$$K = 6.427 \times 10^{-4}$$

$$h_f = K Q^2 = 6.42 \times 10^{-4} (300 \text{ L/s})^2 = 57.84 \text{ m}$$

$$\frac{h_f}{Q_a} = \left| \frac{57.84}{300} \right| = \underline{0.1928}$$

$$\delta = - \frac{\epsilon h_f}{n \sum \left| \frac{h_f}{Q} \right|} = - \frac{152.28}{2(0.665)} = -114.5 \text{ L/s}$$

$$Q = Q_A + \delta = 300 \text{ L/s} - 114.5 \text{ L/s} = \underline{185.5 \text{ L/s}}$$

d.) Given: $P_F = 500 \text{ kPa}$

$$Z_A = Z_B = Z_C = 200 \text{ m}$$

$$Z_F = Z_E = Z_D = 170 \text{ m}$$

$$Z_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} = Z_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2} + h_f$$

For Pipe AB: $200 + \frac{P_A}{9.8} = 170 + \frac{500}{9.8} + 149.14$

$$\Rightarrow P_A = \frac{[(170 \times 9.8) + 500 + 149.14 \times 9.8] - 200 \times 9.8}{9.8}$$

$$P_A = 1667.57 \text{ KPa}$$

For Pipe AB:

$$200 + \frac{1667.57}{9.8} = 200 + \frac{P_B}{9.8} + 22.11$$

$$\Rightarrow P_B = 1450.56 \text{ KPa}$$

For Pipe BC:

$$200 + \frac{1450.56}{9.8} = 200 + \frac{P_C}{9.8} + 0.18 \text{ m}$$

$$\Rightarrow P_C = 1449.8 \text{ KPa}$$

For Pipe BE

$$200 + \frac{1449.8}{9.8} = 170 + \frac{P_E}{9.8} + 11.99$$

$$P_E = 1626.5 \text{ KPa}$$

For Pipe CD

$$200 + \frac{1450.56}{9.8} = 170 + \frac{P_D}{9.8} + 2.47$$

$$P_D = 1718.8 \text{ KPa}$$

Problem 3

Iteration	Loop	Pipeline	Length(m)	Dia(mm)	Dia(m)	factor,f	K	Qa(L/min)	Qa(L/s)	K*Qa^2	m/Q	6	Q=Qa+6
1	Sum	AB	1000	300	0.3	0.0189	0.00064267	18000	300	57.841	0.1928033	-114.502	185.498
		BE	950	350	0.35	0.0183	0.0002735	12000	200	10.94038	0.0547019	9.380925	209.3809
		EF	900	300	0.3	0.0189	0.0005784	-12000	-200	23.1364	0.115682	-114.502	-314.502
		FA	900	250	0.25	0.0196	0.0015078	-12000	-200	60.31223	0.3015612	-114.502	-314.502
		Sum								152.23	0.6647484		
2	Sum	BC	750	325	0.325	0.0186	0.0003179	6000	100	3.179034	0.03117903	-123.883	-23.8829
		CD	800	200	0.2	0.021	0.0043381	6000	100	43.38075	0.4338075	-123.883	-23.8829
		DE	700	250	0.25	0.0198	0.0011727	-24000	-400	187.6381	0.4690951	-123.883	-523.883
		2 BE	950	350	0.35	0.083	0.0002735	12000	-200	10.94038	0.0547019	-9.38093	-209.381
		Sum								152.23	0.6647484		
Iteration Loop 2	Pipeline	AB	1000	300	0.3	0.0189	0.00064267	18000	300	57.841	0.1928033	-114.502	185.498
		BE	950	350	0.35	0.0183	0.0002735	12000	200	10.94038	0.0547019	9.380925	209.3809
		EF	900	300	0.3	0.0189	0.0005784	-12000	-200	23.1364	0.115682	-114.502	-314.502
		1 FA	900	250	0.25	0.0198	0.0015078	-12000	-200	60.31223	0.3015612	-114.502	-314.502
		Sum								152.23	0.6647484		

25

head loss should have same sign (after-) as the flows (Qa)

Correction (cd) for pipe BE in loop 1 should have same value and opposite sign (+/-)

round

reverse

CVEG 4303
WATER RESOURCES ENGINEERING
SPRING 2022

HOMework
05

ABOVE
AVERAGE



Department of Civil & Environmental Engineering



CVEG 4303 P01

Water Resources Engineering

Spring 2022

Dr. Nzewi

Homework 05

Assigned: 03/29/2022

Due: Monday, April 04, 2022 at 3:00 PM (SLIDE UNDER OFFICE DOOR) Canvas 04/03/2022 11:30 PM

SUBMIT THIS as cover sheet with your work

Name [PRINT]

NAALVIKA AGGARWAL

Instructions:

IN ALL THE PROBLEMS YOU MUST PROVIDE ENOUGH DETAILS AND DESCRIPTION OF THE SOLUTION METHOD TO DEMONSTRATE YOUR KNOWLEDGE OF THE SOLUTION METHOD. A SUBSTANTIAL PORTION OF THE GRADE WILL BE BASED ON YOUR METHODS.

Problem 1 [150]

Solve Problem 15.51 in the textbook.

Show your work fully.



Problem 2 [250]

Solve Problem 15.53 in the textbook. Provide your pump data in tabular format using the example presented in the textbook. Be sure to present all the necessary graphs.

Show your work fully.

Problem 3 [250]

Solve Problem 15.54 in the textbook. Provide your pump data in tabular format using the example presented in the textbook. Be sure to present all the necessary graphs.

Make the following changes to the problem data in the textbook (Be careful that you make all these changes)

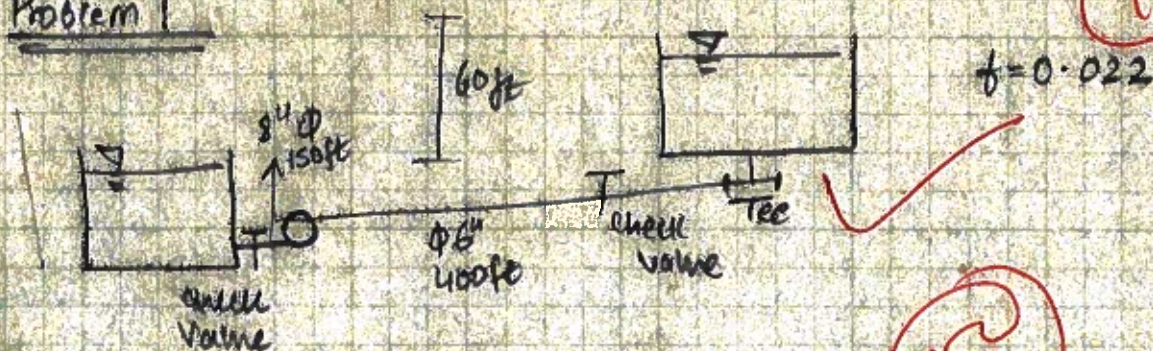
- a) The pipe is 1500 ft
- b) The DIAMETER of the pipe is 12 inches
- c) The total static head is NOW 50 ft
- d) Minor losses is now 15 times the velocity head.
- e) Friction factor, $f = 0.018$

Show your work fully.

Problem 4 [150]

Solve Problem 15.55 in the textbook.

Show your work fully

Problem 1

Pipe 1: $\phi = 8"$
 $L = 150$ ft

Pipe 2: $\phi = 6"$
 $L = 400$ ft

$$K \text{ for pipe 1} = K_1 = 1 + 2.5 \text{ (exit + check valve)} = 3.5$$

$$K \text{ for pipe 2} = K_2 = 0.5 + 2.5 + 1.5 \text{ (entrance + check valve + tee)} = 4.5$$

We know,

$$H_p = \frac{60}{8} + \frac{0.81}{8} \left(\frac{f L Q^2}{d^5} + \frac{K_m Q^2}{d^4} \right)$$

$$\text{So, } h_{f1} = \frac{f L Q^2}{d^5}$$

$$= \frac{(0.022)(150) Q^2}{(8/12)^5}$$

$$= 25.059 Q^2$$

$$h_{f2} = \frac{f L Q^2}{d^5}$$

$$= \frac{(0.022)(400) Q^2}{(6/12)^5}$$

$$= 281.6 Q^2$$

$$h_{m1} = \frac{K_m Q^2}{d^4} = \frac{3.5 Q^2}{(8/12)^4}$$

$$= 17.418 Q^2$$

$$h_{m2} = \frac{4.5 Q^2}{(6/12)^4}$$

$$= 72 Q^2$$

$$\text{So, } H_p = 60 + \left(\frac{0.81}{32.2} \right) (25.059 Q^2 + 281.6 Q^2 + 17.418 Q^2 + 72 Q^2)$$

$$H_p = 60 + 9.90 Q^2$$

So, ^{Given:} Q (gpm)	Q (cfs)	Given: H (ft)	H (ft)	Given: η (%)
0	0	230	0	0
1000	2.23	228.5	109.28	54
2000	4.46	221	257.11	78.4
3000	6.69	200	503.49	87
3500	7.80	183.5	662.87	87.6
4000	8.92	157	848.43	88.7

Sample calculation for $Q = 0$

$$H_p = 60 + 9.97Q^2 = 60 + 0 = 60 \text{ ft}$$

a) So, the intersection point on graph 1 is the pump operation point

$$\text{Point} = (1800, 220)$$

So, capacity = 1800 gpm

Operating head = 220 ft

b) At $Q = 1000$ gpm, $\eta = 54\%$

At $Q = 2000$ gpm, $\eta = 78.4\%$

$$\text{So, at } 1800 \text{ gpm, } \eta = 54 + (1800 - 1000) \left(\frac{78.4 - 54}{2000 - 1000} \right)$$

$$\text{operation efficiency} = 73.52\%$$

c) Not suitable as maximum efficiency is 88.7%, but operation efficiency is 73.52%, less than the latter.

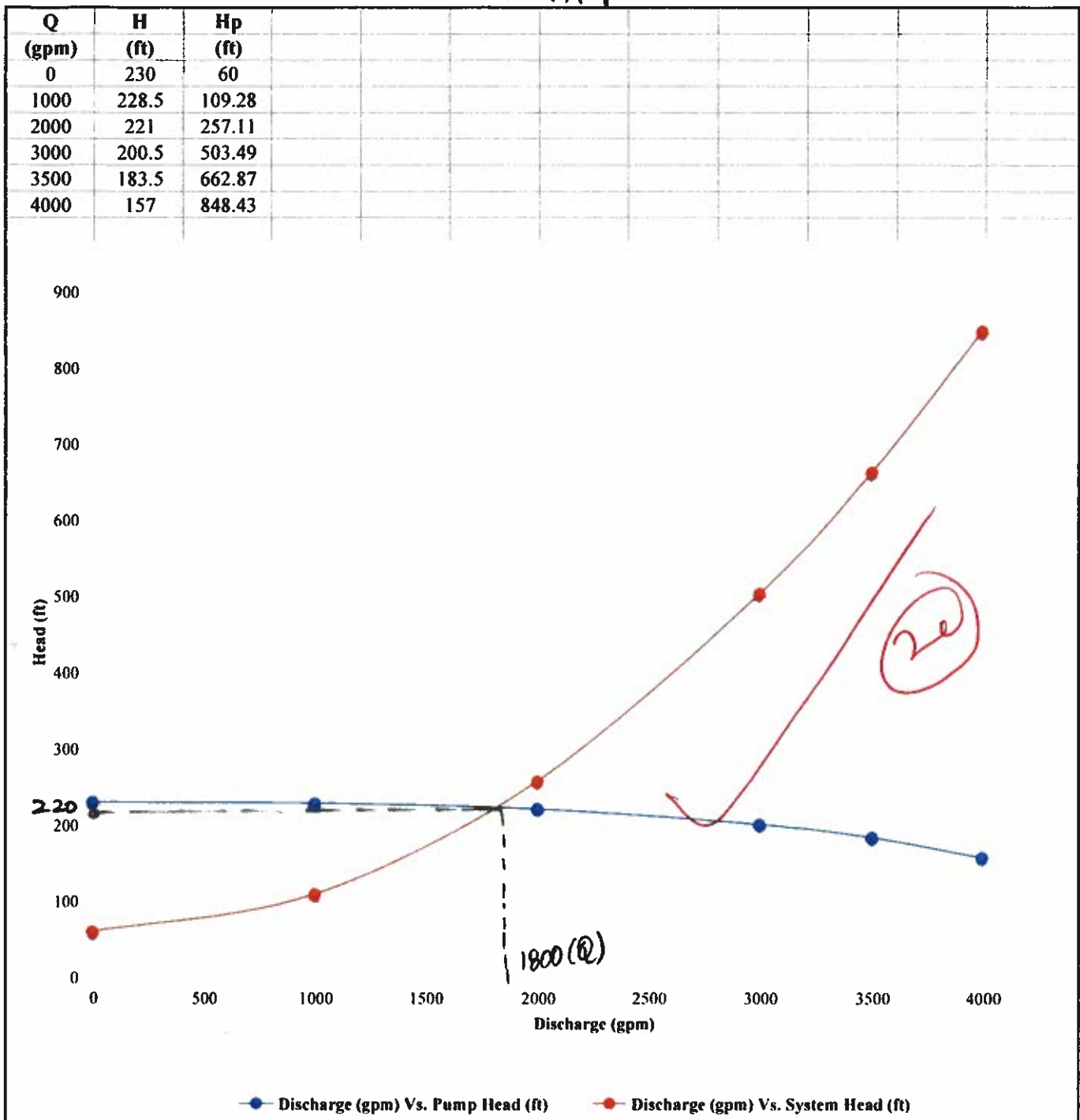
d) Input power, $P = \frac{\gamma Q H}{550 \eta}$

At $\eta = 73.52\%$, $Q = 1800$ gpm = 4.01 cfs

$$\text{So, } P = \frac{(62.4)(4.01)(220)}{550 \times 0.7352} = 186.2 \text{ hp}$$

Graph 1

GRAPH-1



Problem 2

Q (gpm)	Q (cfs)	H (ft)	HP (ft) [40+29.3Q ²]	Efficiency η (%)	Total H (ft) (TH)
0	0	124	40	0	248
500	1.12	119	76.75	54	238
800	1.78	112	132.83	64	224
1000	2.23	104	155.7	68	208
1300	2.89	90	289.72	70	180
1600	3.57	70	418.43	67	140

$$Z = 140 \text{ ft}$$

$$\text{Piped} = 6''$$

$$L = 1200 \text{ ft}$$

$$f = 0.022$$

Both pumps are identical, so $H_{P1} = H_{P2}$

$$\text{So, } h_{f1} = h_{f2}$$

$$\text{Therefore, } h_f = \frac{f L Q^2}{d^5} = \frac{(0.022)(1200)Q^2}{(6/12)^5} = 844.8 Q^2$$

$$h_m = 20 \left(\frac{Q^2}{(6/12)^4} \right) = 320 Q^2$$

$$\text{So, } H_p = \frac{2 + 0.81}{0} (h_f + h_m) = \frac{40 + 0.81}{22.2} (844.8 + 320)$$

$$= 40 + 29.30 Q^2$$

Sample calculation for $Q = 1.12 \text{ cfs}$

$$H_p = 40 + 29.3 (1.12)^2 = 76.75 \text{ ft}$$

a) Intersecting point of system and total head = (1030, 204)

$$\text{So, operation capacity} = \boxed{1030 \text{ gpm}} = \boxed{12.3 \text{ cfs}}$$

$$\text{operating condition of head} = \boxed{204 \text{ ft}}$$

b) Head developed by each pump = 102 ft or $\frac{204}{2} = \boxed{102 \text{ ft}}$

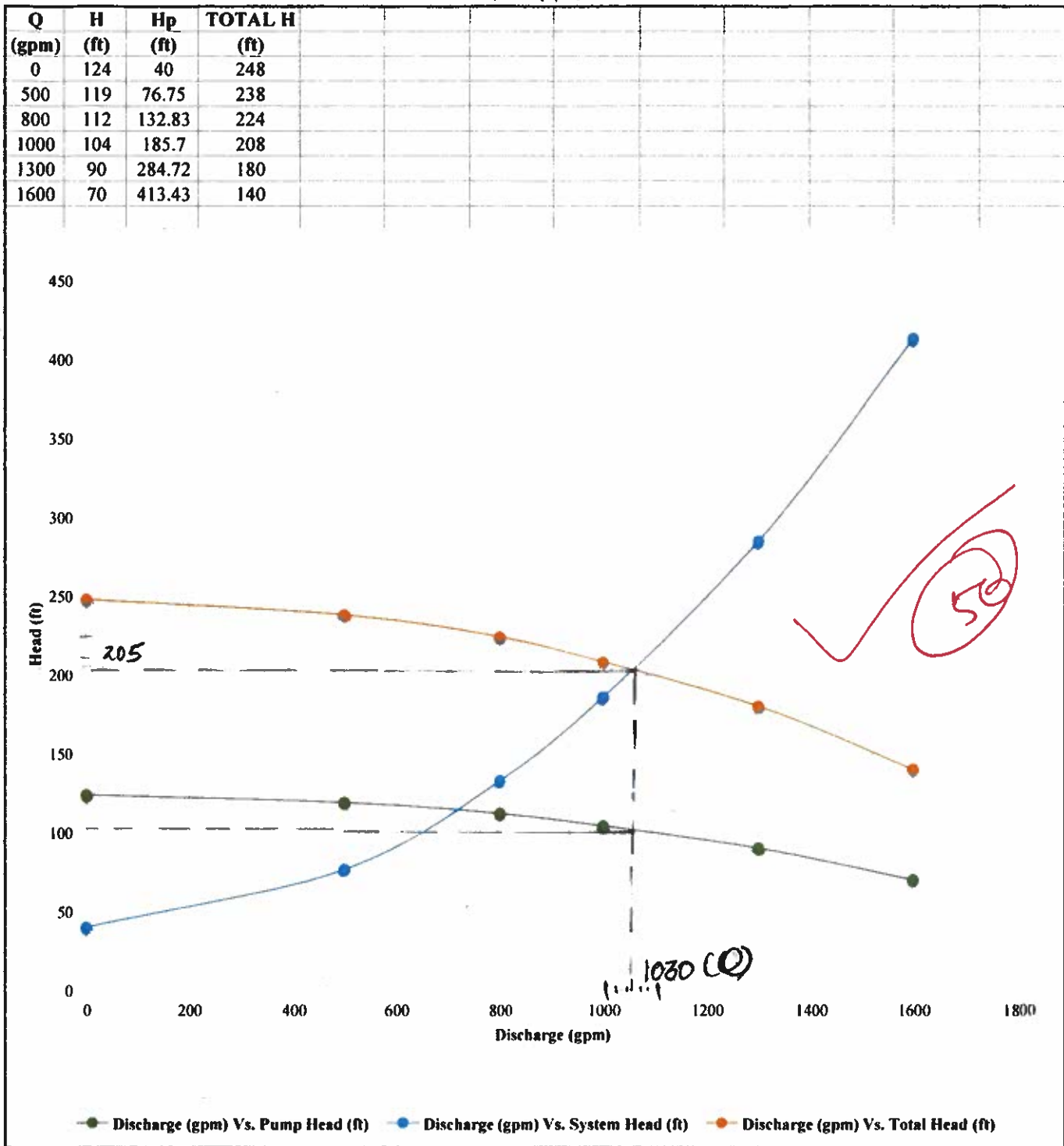
c) operation efficiency = efficiency at $Q = 1030 \text{ gpm}$

$$= 68 + \frac{(1030 - 1000)(70 - 68)}{(1300 - 1000)} = \boxed{68.2\%}$$

$$\text{So, input power} = \frac{\gamma Q (\text{Total H})}{550 \eta}$$

$$= \frac{(62.4)(12.3)(204)}{(550)(0.682)} = \boxed{78.05 \text{ hp}}$$

GRAPH 2



Problem 3

Pumps in parallel and identical, so $Q_1 = Q_2$

Q (gpm)	Q (cfs)	H (ft)	Total Q (2Q) (gpm)	Total Q (2Q) (cfs)	H _p (ft) [50 + 1.06Q ²]	η (%)
0	0	124	0	0	50	0
500	1.12	119	1000	2.228	51.19	54
800	1.78	112	1600	3.565	51.89	64
1000	2.28	104	2000	4.456	52.36	68
1300	2.89	90	2600	5.793	53.06	70
1600	3.57	70	3200	7.130	53.78	67

Pipe, $\alpha = 12"$
 $L = 1500$ ft

$\bar{x} = 50$ ft

$f = 0.018$

$$h_{f1} = h_{f2} = \frac{fLQ^2}{4.5} = \frac{(0.018)(1500)(Q^2)}{(12/12)^5} = 27Q^2$$

$$h_{m1} = h_{m2} = 15 \left(\frac{Q^2}{(12/12)^4} \right) = 15Q^2$$

$$60, H_p = \Delta \bar{x} + \frac{0.81}{3} (h_f + h_m) = 50 + \frac{0.81}{32.2} (27Q^2 + 15Q^2)$$

$$H_p = 50 + 1.06Q^2$$

Sample calculation for $Q = 1228$

$$H_p = 50 + 1.06(1228)^2 = 55.24 \text{ ft}$$

Intersection point of total capacity & system head = (2570, 86)

operation capacity = 2700 gpm Capacity of each pump = 1350 gpm

Operating head condition: 86 ft

operation efficiency = η at 2570 gpm

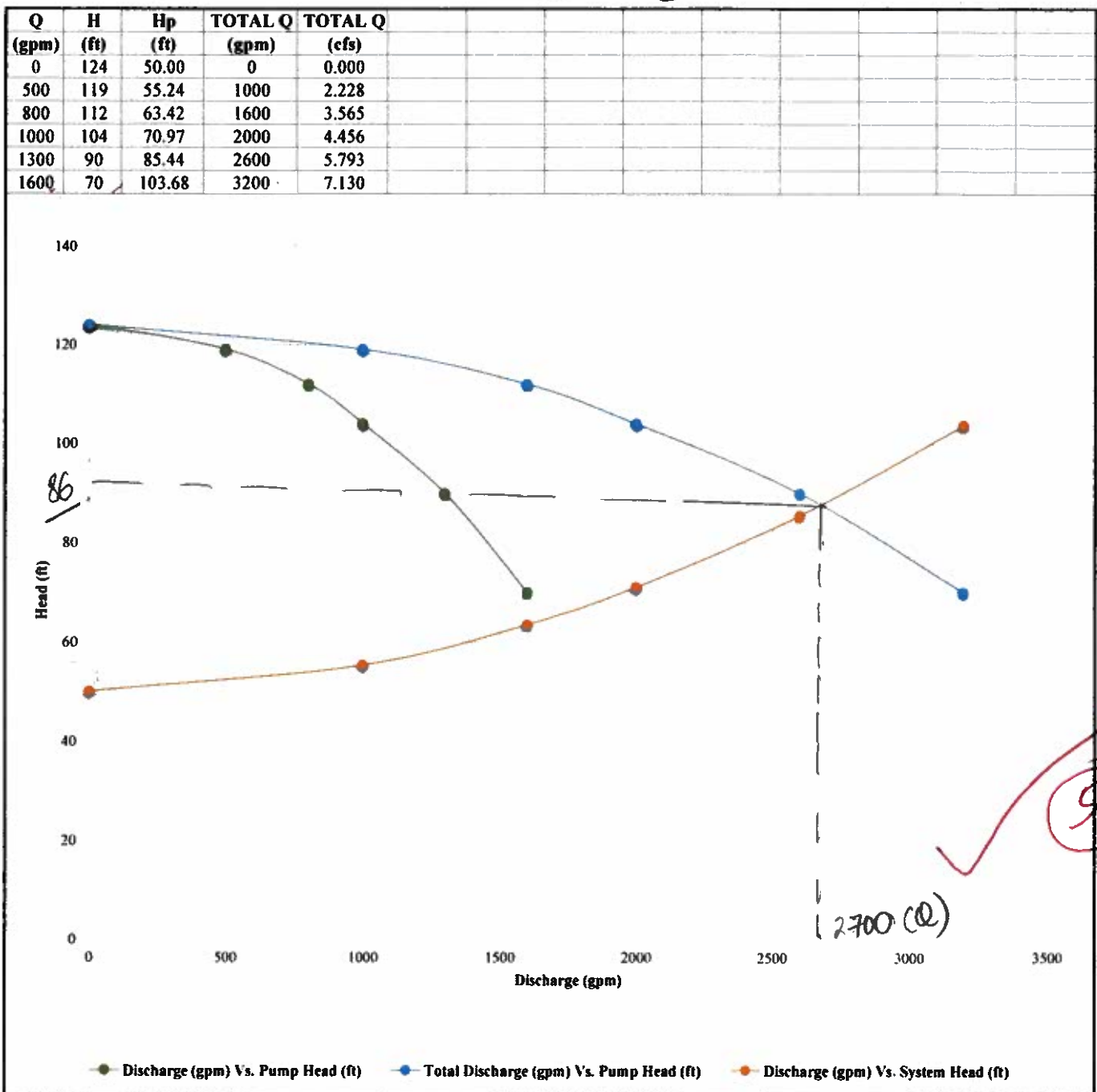
$$= 70 + (1350 - 1300) \left(\frac{67 - 70}{1600 - 1300} \right) = 69.5\%$$

$$\text{Input power} = \frac{Q H}{550 \eta} = \frac{(2700)(86)}{550(0.695)}$$

$$= 84.51 \text{ hp}$$

[2700 gpm]
 $L = 6.02$ cfs

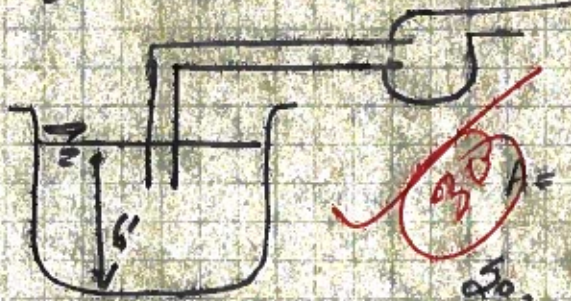
Graph 3



Intersecting point = (2700, 86)

Problem 4

$$Q = 495 \text{ gpm} = 1.103 \text{ cfs}$$



$$d = 8 \text{ in}$$

$$L = 250 \text{ ft}$$

$$A = \frac{\pi d^2}{4} = 0.348 \text{ ft}^2$$

$$So, V = \frac{Q}{A} = \frac{1.103}{0.348}$$

$$= 3.169 \text{ ft/sec}$$

$$\epsilon \text{ for commercial steel pipe} = 1.5 \times 10^{-4} \text{ ft}$$

$$So, \frac{\epsilon}{d} = \frac{1.5 \times 10^{-4}}{8/12} = 2.25 \times 10^{-4} \quad (\text{Table 15.1})$$

$$Re = \frac{Vd}{\nu} = \frac{(3.169)(8/12)}{1.217 \times 10^{-5}} = 173596.27 \quad (\nu = 1.217 \times 10^{-5} \text{ at } 40^\circ\text{F})$$

$$= 1.735 \times 10^5$$

$$f = 0.017 \text{ (Moody diagram)}$$

$$h_f = \frac{fLV^2}{2g} = \frac{(0.017)(250)(3.169)^2}{(8/12)(2)(32.2)} = 0.994 \text{ ft}$$

$$K = 0.8 + 1.5 = 2.3 \text{ (entrance + bend)}$$

$$h_m = K \frac{V^2}{2g} = 2.3 \frac{(3.169)^2}{2 \times 32.2} = 0.359 \text{ ft}$$

$$h_L = h_f + h_m = 0.994 + 0.359 = 1.353 \text{ ft}$$

$$NPSH = \frac{P_0}{\gamma} - z - h_L - \frac{c_w}{\gamma}$$

$$c_w = 0.122 \text{ (@ } 40^\circ\text{F)}$$

$$P_0 = 14.6 \text{ psi (atmospheric)}$$

$$= \frac{14.6 \times 144}{62.4} - 10 - 1.353 - \frac{0.122 \times 144}{62.4}$$

$$= 22.058 \text{ ft Available NPSH}$$

Cavitation parameter, σ

$$\sigma = \frac{NPSH}{H} = \frac{22.058}{100} = \boxed{0.221}$$

No, there will be no cavitation problem

as available NPSH (22.058) is greater than required NPSH (9), and so we have plenty.

AVERAGE



Department of Civil & Environmental Engineering



CVEG 4303 P01

Water Resources Engineering

Spring 2022

Dr. Nzewi

Homework 05

Assigned: 03/29/2022

Due: Monday, April 04, 2022 at 3:00 PM (SLIDE UNDER OFFICE DOOR) Canvas 04/03/2022

SUBMIT THIS as cover sheet with your work

Name [PRINT] MOUNI YAMBA

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Problem 1 [150]

Solve Problem 15.51 in the textbook.

Show your work fully.

630
800

Problem 2 [250]

Solve Problem 15.53 in the textbook. Provide your pump data in tabular format using the example presented in the textbook. Be sure to present all the necessary graphs.

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Problem 3 [250]

Solve Problem 15.54 in the textbook. Provide your pump data in tabular format using the example presented in the textbook. Be sure to present all the necessary graphs.

Make the following changes to the problem data in the textbook (Be careful that you make all these changes)

- The pipe is 1500 ft
- The DIAMETER of the pipe is 12 inches
- The total static head is NOW 50 ft
- Minor losses is now 15 times the velocity head.
- Friction factor, $f = 0.018$

Show your work fully.

Problem 4 [150]

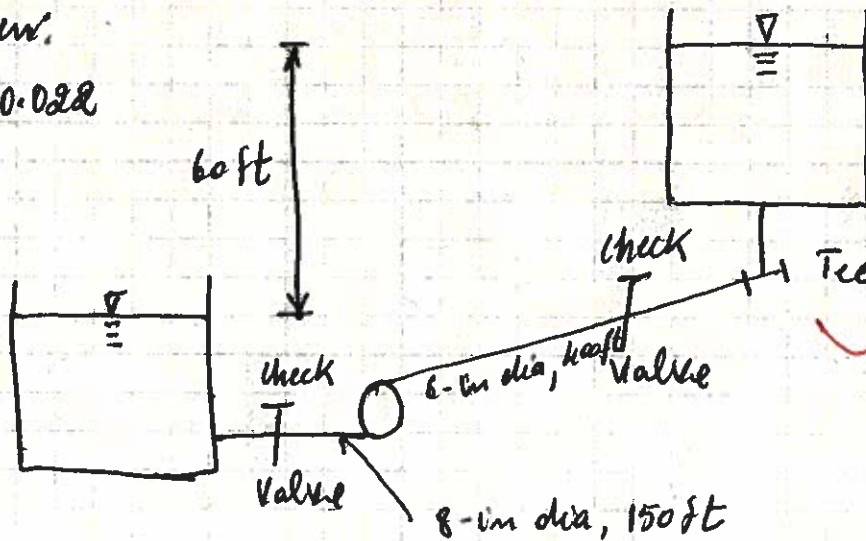
Solve Problem 15.55 in the textbook.

Show your work fully

Problem 1

Given:

$f = 0.022$



The coefficient of loss for Pipe 1 and Pipe 2 in table below.

loss	K_1 for Pipe 1	K_2 for Pipe 2
Entrance loss	0	0.5
Exit loss	1.0	0
check valve loss	2.5	2.5
Tee bend loss	0	1.5
Total loss	3.5	4.5

The energy relation for flow through the system

$$H_p = \Delta Z + \frac{0.81}{g} \left(\frac{f L_1 Q^2}{d_1^5} + \frac{f L_2 Q^2}{d_2^4} + \frac{\sum K_L Q^2}{d_2^4} \right)$$

$$H_p = 60 + \frac{0.81}{32.2} \left[\frac{0.022 \times 150 \times Q^2}{\left(\frac{8}{12}\right)^5} + \frac{0.022 \times 400 \times Q^2}{\left(\frac{6}{12}\right)^5} + \frac{3.5 Q^2}{\left(\frac{8}{12}\right)^4} + \frac{4.5 \times Q^2}{\left(\frac{6}{12}\right)^4} \right]$$

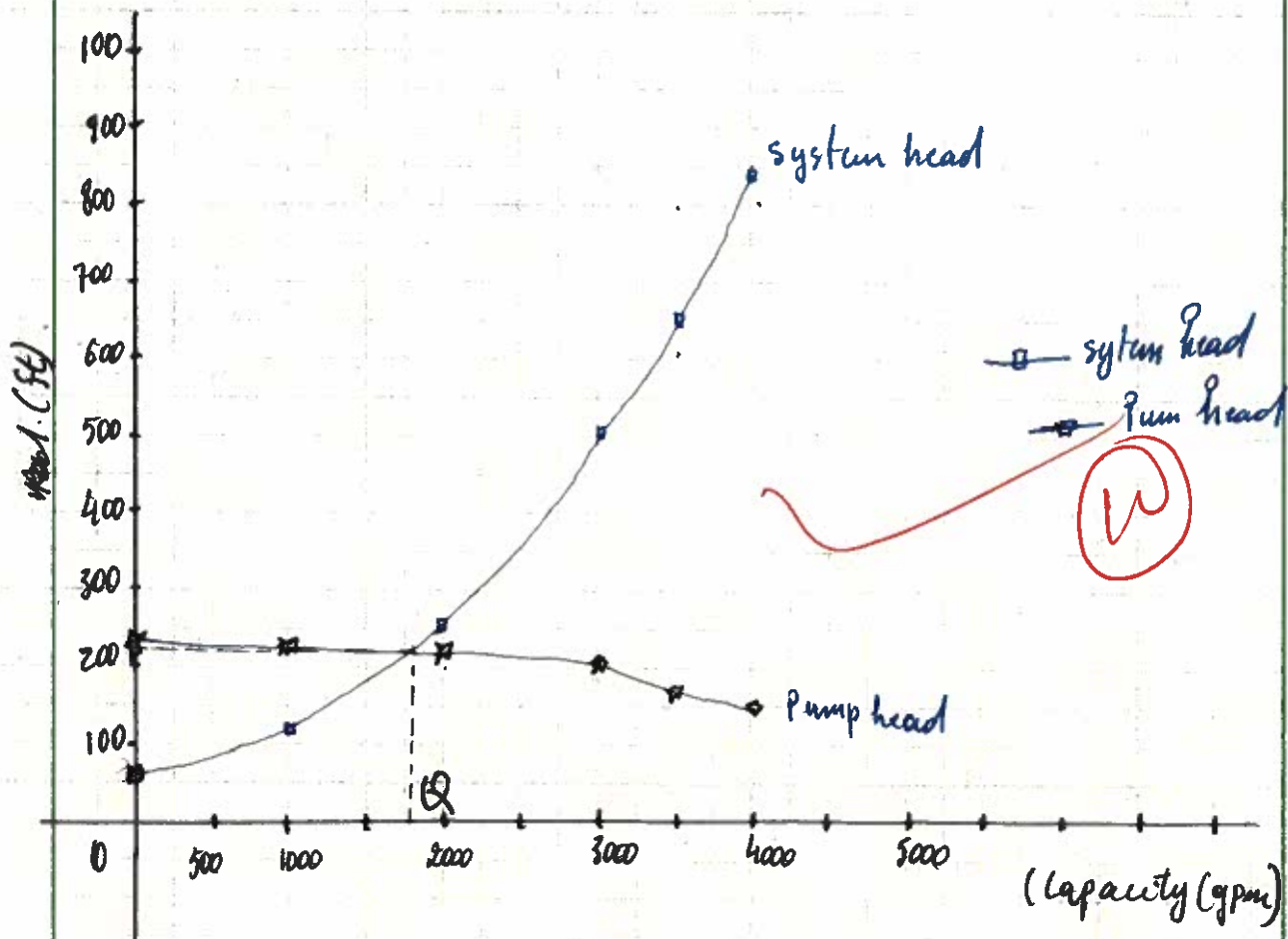
$$H_p = 60 + 0.025(25.059 Q^2 + 281.6 Q + 17.718 Q^2 + 72 Q^2)$$

$$H_p = 60 + 9.909 Q^2 \quad \textcircled{1}$$

We convert the capacity unit from gpm to cfs.
The table below show the discharge Q , H , H_p , η (%).

Q (gpm)	H (ft)	Q (cfs)	H (ft)	η (%)
0	230	0	60	0
1000	228.5	2.23	109.28	54
2000	221	4.46	257.11	78.4
3000	200.5	6.69	503.49	87
3500	183.5	7.8	662.87	87.6
4000	157	8.92	848.43	83.7

(table 2)



Refer Figure ①

The capacity is 1800 gpm

The operating head is 220 ft

b-) From table ②, the efficiency value is 73.52% for corresponding capacity value of 1800 gpm. Therefore, the operating efficiency is 73.52%.

c-)

From Table ②

The maximum efficiency of 87.6% occurred in 3500 gpm capacity. But the operating efficiency is low. Hence, the pump is not suitable.

d-)

The input Power (P)

$$P = \frac{\gamma Q H}{550 \eta}$$

$$1800 \text{ gpm} = 4.010 \text{ cfs}$$

$$P = \frac{62.4 \times 4.010 \times 220}{550 \times 0.735}$$

$$P = 136.17 \text{ hp}$$

Problem 2Given: $f = 0.022$

Let summarize the capacity, Pump head and Total Pump head values in tabular format

Q (gpm)	H_A (ft)	H_B (ft)	$H_A + H_B$ (ft)
0	124	124	248
500	119	119	238
800	112	112	224
1000	104	104	208
1300	90	90	180
1600	70	70	140

table ①

Using the relation for flow through the system:

$$H_p = \Delta Z + \frac{0.81}{g} \left(\frac{fLQ^2}{d^5} + \frac{\sum KQ^2}{d^4} \right)$$

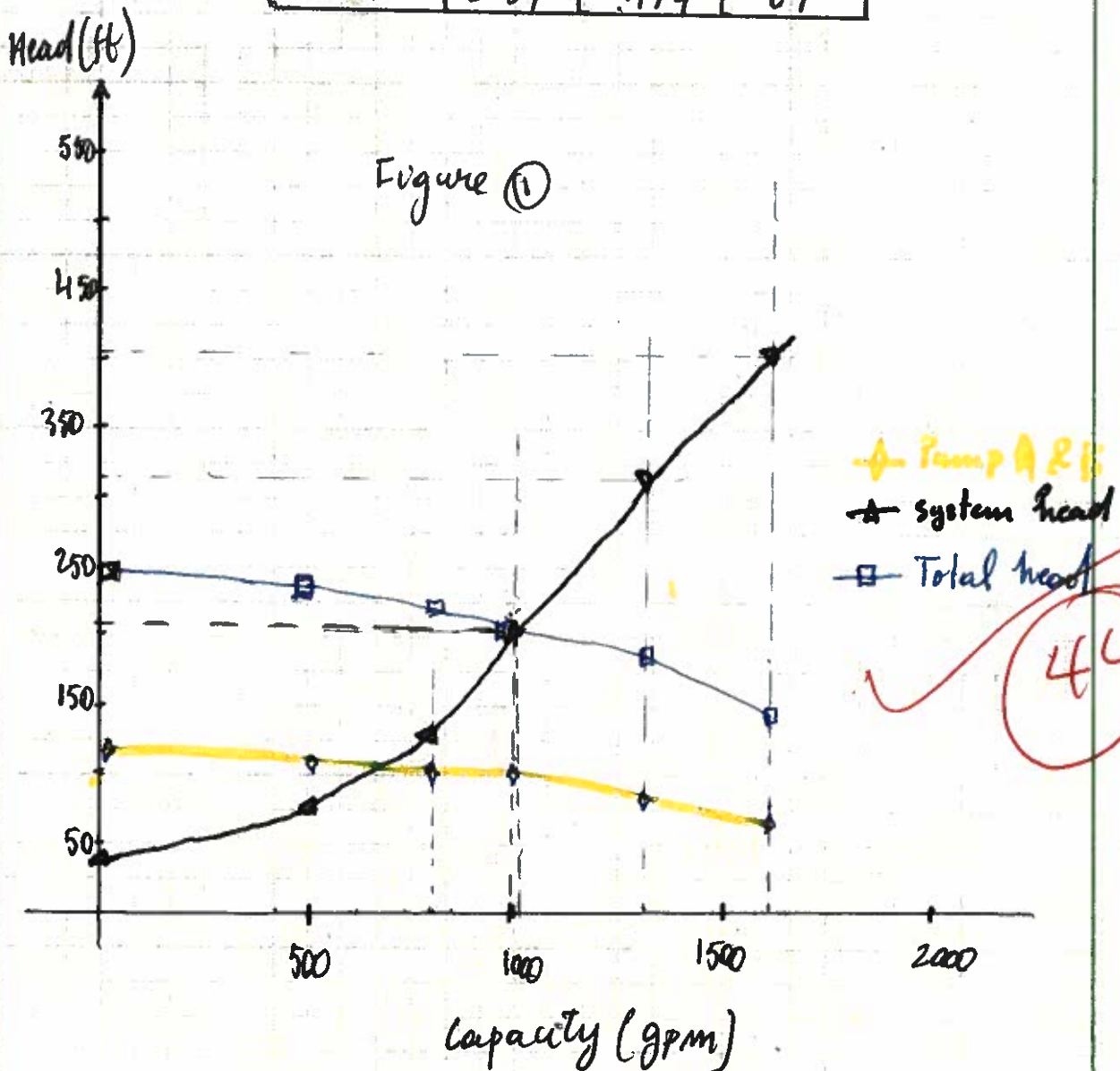
$$H_p = 40 + \frac{0.81}{32.2} \left[\frac{0.022 \times 1200 \times Q^2}{\left(\frac{6}{12}\right)^5} + \frac{20Q^2}{\left(\frac{6}{12}\right)^4} \right]$$

$$H_p = 40 + 29.30 Q^2 \quad \text{①}$$

The discharge and corresponding system head values as shown in table (a) below.

Q (gpm)	Q (cfs)	H_p (ft)	η (%)
0	0	40	0
500	1.12	77	54
800	1.79	134	64
1000	2.23	186	68
1300	2.9	287	70
1600	3.57	414	67

30



a)

From Figure 10

The capacity is 1,040 gpm.

The operating head is 204 ft.

b.)

From Figure 10, Head developed by each pump is 102 ft.

c.)

The operation efficiency (η) using the formula:

$$\eta = \frac{H_A + H_B}{\left(\frac{H_A}{\eta_1}\right) + \left(\frac{H_B}{\eta_2}\right)} = \frac{204}{\frac{102}{68.28} + \frac{102}{68.28}}$$

$$\eta = 68.28\%$$

The input power (P)

$$P = \frac{\gamma Q (H_A + H_B)}{550 \eta}$$

$$P = \frac{62.4 \times 2.3 \times 204}{550 \times 0.68}$$

$$P = 78.2 \text{ hp}$$

Problem 3

Given: data: $L = 1500 \text{ ft}$

$$d = 12 \text{ in} = \frac{12}{12} = 1 \text{ ft}$$

$$\Delta Z = 50 \text{ ft}$$

$$f = 0.018$$

Pump data in tabular format.

$H \text{ (ft)}$	$Q_A \text{ (gpm)}$	$Q_B \text{ (gpm)}$	$Q_A + Q_B$	$\eta \text{ (\%)}$
124	0	0	0	0
119	500	500	1000	54
112	800	800	1600	64
104	1000	1000	2000	68
90	1300	1300	2600	70
70	1600	1600	3200	67

Use the relation for flow through the system.

$$H_p = \Delta Z + \frac{0.81}{g} \left(\frac{f L Q^2}{d^5} + \frac{\sum K Q^2}{d^4} \right)$$

$$H_p = 50 + \frac{0.81}{32.2} \left(\frac{0.018 \times 1500 Q^2}{1^5} + \frac{15 Q^2}{1^4} \right)$$

$$H_p = 50 + 1.06 Q^2$$

0

20

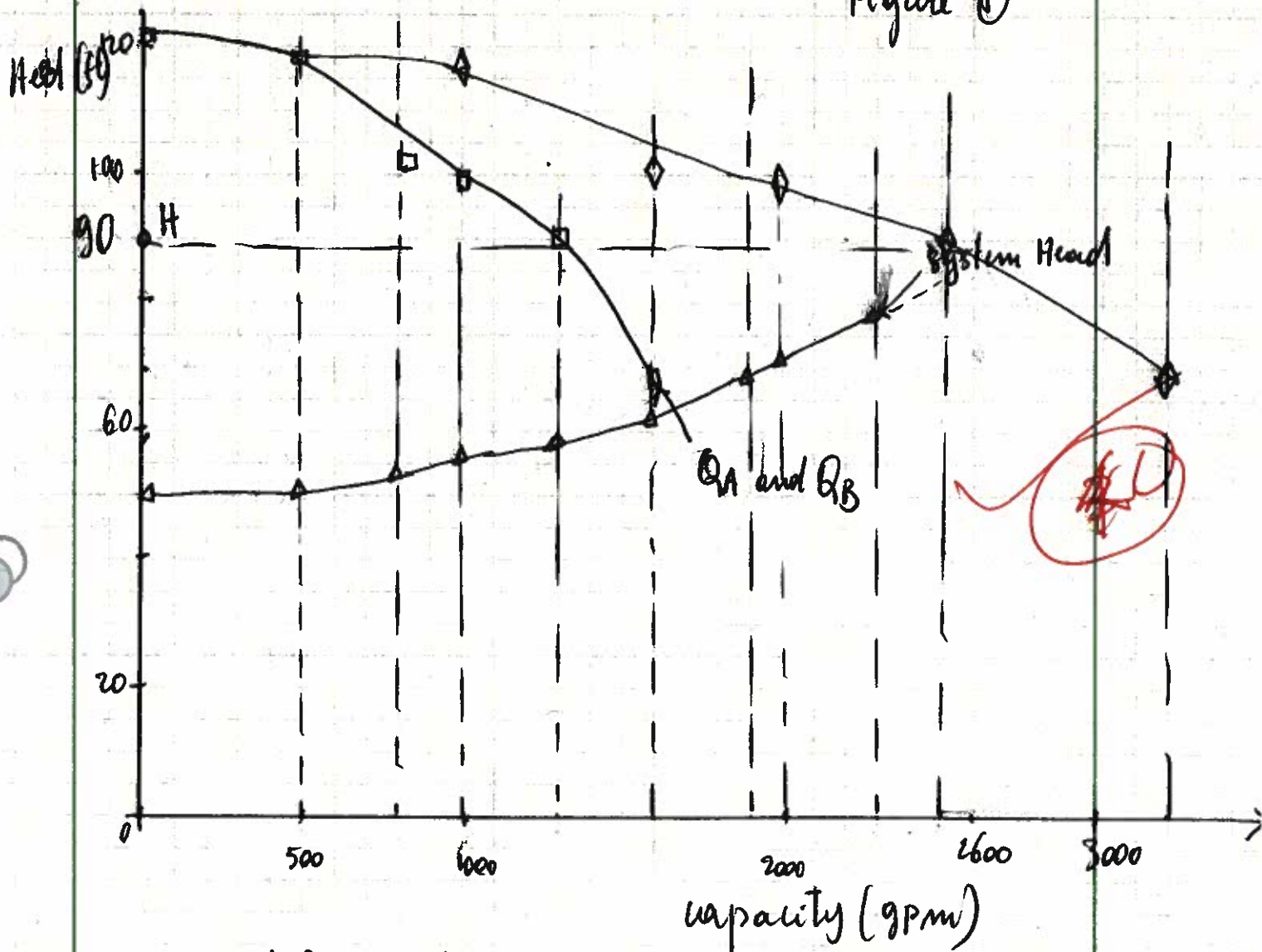
let summarize the discharge and
corresponding system head values

$Q(\text{gpm})$	$Q(\text{cfs})$	$H_p(\text{ft})$
0	0	50
500	1.12	51.33
800	1.79	53.4
1000	2.23	55.3
1300	2.9	58.9
1600	3.57	63.5
1900	4.24	69.05
2100	4.46	71.08
2300	5.13	77.9

✓ 20

Let Plot the curve of capacity of Pump A and B versus pump head

Figure ①



- ◆— total capacity
- Pump A and B
- ▲— system head

Referring to Figure ①,

The operating capacity is 2600 gpm
The operating head is 90 ft

The capacity developed by each pump
is 1300 gpm

The operating efficiency (η)

$$\eta = \frac{Q_A + Q_B}{\left(\frac{Q_A}{\eta_1}\right) + \left(\frac{Q_B}{\eta_2}\right)}$$

$$\eta = \frac{2600}{\frac{1300}{70} + \frac{1300}{70}} = 70\%$$

30

The input Power (P)

$$P = \frac{\gamma (Q_A + Q_B) H}{550 \eta}$$

$$P = \frac{62.4 \times 4.73 \times 90}{550 \times 0.7}$$

$$P = 68.95 \text{ hp}$$

Problem 4Given data:

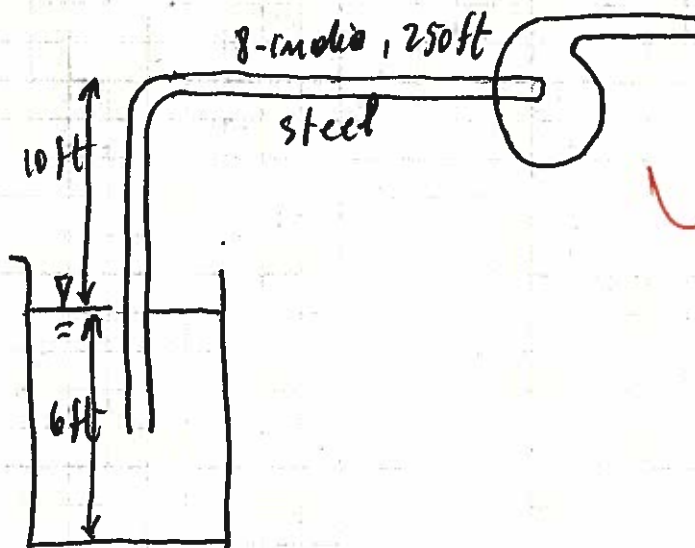
The Pump discharge = 495 gpm

Total head = 100 ft

Temperature = 40° F

Atmospheric pressure = 32.7 ft of water
 @ 40° F ; $\gamma = 62.4 \text{ lb/ft}^3$ $P_v = 0.12 \text{ Psi}$

$K_{bend} = 1.5$ and $K_{entrance} = 0.8$



a - Find the net positive suction head (NPSH)

$$NPSH = H_a + H_s - H_{vpa} - H_f$$

where, H_a = absolute pressure on fluids

H_s = static suction pressure

H_{vpa} = vapor pressure of fluid

H_f = friction losses in the suction pipe

$$H_s = 10 - \frac{4}{12} = -9.67 \text{ (negative because}$$

liquid level is below the centerline of pump level).

$$H_{vpa} = \text{Pressure} \times 2.31 / \text{sg}$$

$$= 0.12 \times 2.31$$

$$H_{vpa} = 0.28 \text{ ft}$$

friction loss: From friction chart, for 495 gpm and 8 in dia Pipe the friction loss per 100 ft = 0.1.

Therefore for 260 ft length of Pipe, Friction loss in Pipe = 0.26

$$\text{Bend loss} = \frac{Kv^2}{2g}$$

$$v = \frac{Q}{A}$$

$$Q = 495 \text{ gpm} = 1.103 \text{ ft}^3/\text{s}$$

$$A = \frac{\pi}{4} \left(\frac{8}{12} \right)^2 = 0.349 \text{ ft}^2$$

$$v = \frac{1.103 \text{ ft}^3/\text{s}}{0.349 \text{ ft}^2}$$

$$v = 3.16 \text{ ft/s}$$

$$\text{bend loss} = \frac{Kv^2}{2g} = \frac{1.5 \times 3.16^2}{2 \times 32.2}$$

$$\text{bend loss} = 0.23 \text{ ft}$$

$$\text{Entrance loss} = \frac{K V^2}{2g} = \frac{0.8 \times 3.16^2}{2 \times 32.2} = 0.12 \text{ ft}$$

$$\text{Total } H_f = 0.26 + 0.23 + 0.12 \\ = 0.61 \text{ ft}$$

$$\text{NPSH} = H_a + H_s - H_{vpa} - H_f \\ = 32.7 - 9.67 - 0.28 - 0.61$$

$$\boxed{\text{NPSH} = 22.14 \text{ ft}}$$

Given the required NPSH as 9, but we have 22.14, we have plenty. So there will be no cavitation problem.

b) The cavitation Parameter

$$C_a = \frac{\text{Local Pressure (P)} - \text{Vapor Pressure } P_v}{\frac{1}{2} \times \text{Density} \times \text{Velocity}^2}$$

$$C_a = \frac{P - P_v}{\frac{1}{2} \times \rho \times V^2} = \frac{32.7 - 0.12}{\frac{1}{2} \times 62.4 \times 3.16^2}$$

$$\boxed{C_a = 0.1045}$$

X

BELOW
AVERAGE



Department of Civil & Environmental Engineering

②

CVEG 4303 P01

Water Resources Engineering

Spring 2022

Dr. Nzewi

Homework 05

Assigned: 03/29/2022

Due: Monday, April 04, 2022 11:30 PM (SLIDE UNDER OFFICE DOOR) Canvas 04/03/2022 11:30 PM

SUBMIT THIS as cover sheet with your work

Name [PRINT]

Omar Hunter

Instructions:

IN ALL THE PROBLEMS YOU MUST PROVIDE ENOUGH DETAILS AND DESCRIPTION OF THE SOLUTION METHOD TO DEMONSTRATE YOUR KNOWLEDGE OF THE SOLUTION METHOD. A SUBSTANTIAL PORTION OF THE GRADE WILL BE BASED ON YOUR METHODS.

Problem 1 [150]

230
800

Solve Problem 15.51 in the textbook.

Show your work fully.

Problem 2 [250]

Solve Problem 15.53 in the textbook. Provide your pump data in tabular format using the example presented in the textbook. Be sure to present all the necessary graphs.

Show your work fully.

Problem 3 [250]

Solve Problem 15.54 in the textbook. Provide your pump data in tabular format using the example presented in the textbook. Be sure to present all the necessary graphs.

Make the following changes to the problem data in the textbook (Be careful that you make all these changes)

- a) The pipe is 1500 ft
- b) The DIAMETER of the pipe is 12 inches
- c) The total static head is NOW 50 ft
- d) Minor losses is now 15 times the velocity head.
- e) Friction factor, $f = 0.018$

Show your work fully.

Problem 4 [150]

Solve Problem 15.55 in the textbook.

Show your work fully

Problem 115.51

$$D = 14.75 \text{ in}$$

$$1800 \text{ rpm}$$

$$f = 0.022$$

20

Capacity (gpm)	Head (ft)	Power (hp)	Efficiency (%)
0	230	76.5	0
1000	228.5	107	54
2000	221	142.3	78.4
3000	200.5	174.5	87
3500	183.5	185	87.6
4000	157	189.5	83.7

Problem 2

20

15.53

Q (gpm)	H (ft)	Efficiency (%)
0	124	0
500	119	54
800	112	64
1000	104	68
1300	90	70
1600	70	67

$$H_s = 40 \text{ ft}$$

$$D = 6 \text{ in} \approx 0.5 \text{ ft}$$

$$L = 1200 \text{ ft}$$

$$H_m = V \times 20$$

$$f = 0.022$$

a.)

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 - h_m \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_f$$

$$P_1 = P_2$$

$$V_1 = 0$$

$$h_f = \frac{f L V_2^2}{2g D} = \frac{0.022(1200) V_2^2}{2(32.2)}$$

$$h_f = 0.41 V_2^2$$

$$h_m = 20 \frac{V_2^2}{2g} = \frac{20 V_2^2}{2(32.2)} = 0.311 V_2^2$$

$$\frac{V_2^2}{2(32.2)} + 0.311 V_2^2 + 0.41 V_2^2 = 40$$

$$0.0155 V_2^2 + 0.311 V_2^2 + 0.41 V_2^2 = 40$$

$$V_2 = 7.37 \text{ ft/s}$$

$$H_d = H + H_f + H_m$$

$$= 40 + 0.41V_2^2 + 0.31V_2^2$$

$$H_d = 79.16 \text{ ft} \approx 80 \text{ ft}$$

$$\frac{1300 - Q}{Q - 1600} = \frac{90 - 80}{80 - 70}$$

$$Q = 1450 \text{ gpm} = 3.19 \text{ cfs}$$

$$b) \frac{H_d}{2} = \frac{80}{2} = 40 \text{ ft}$$

$$c) \eta = ?$$

$$\frac{90 - 80}{80 - 70} = \frac{70 - \eta}{\eta - 67}$$

$$\eta = 68.5\%$$

$$\text{Power}_o = \rho g H_d Q$$

$$= 62.4(32.2)(80)(3.19)$$

$$= 512768.256 \text{ lb f/s}$$

$$\eta = \frac{\text{Power}_o}{\text{Power}_i}$$

$$\text{Power}_i = \frac{\text{Power}_o}{\eta} = \frac{512768.26}{0.685}$$

$$\text{Power}_i = 748566.79 \text{ lb f/s}$$

Problem 3

15.54

$$L = 1500 \text{ ft}$$

$$D = 12 \text{ in} \approx 1 \text{ ft}$$

$$H = 50 \text{ ft}$$

$$H_m = 15 \text{ V}$$

$$f = 0.018$$

$$H_2 = H + H_f + H_m$$

$$H_f = \frac{f L V_2^2}{2gD} = \frac{0.018 (1500) V_2^2}{2(32.2)(1)} = 0.42 V_2^2$$

$$H_m = \frac{15 V_2^2}{2g} = \frac{15 V_2^2}{2(32.2)} = 0.23 V_2^2$$

$$0.0155 V_2^2 + 0.23 V_2^2 + 0.42 V_2^2 = 50$$

$$V_2 = 8.65 \text{ ft/s}$$

$$H_d = 50 + 0.42V_2^2 + 0.23V_2^2$$

$$H_d = 98.84 \text{ ft} \approx 100 \text{ ft}$$

$$\frac{1000 - Q}{Q - 1300} = \frac{104 - 100}{100 - 90}$$

$$Q = 1085.71 \text{ gpm} \approx 239 \text{ cfs}$$

$$\frac{104 - 100}{100 - 90} = \frac{68 - h}{h - 70}$$

$$h = 68.57\%$$