Name: _____.

MET 350 Thermal Applications
Dr. Orlando Ayala
Spring 2025
Test 3

Take home – Due Sunday May 4th, 2025, before midnight.

READ FIRST

1. RELAX!!!! DO NOT OVERTHINK THE PROBLEMS!!!! There is nothing hidden. The test was designed for you to pass and get the maximum number of points, while learning at the same time. HINT: THINK BEFORE TRYING TO USE/FIND EQUATIONS (OR EVEN FIND SIMILAR PROBLEMS)

2. The total points on this test are one hundred (100). Ten (10) points are from your HW assignments, and ten (10) other points are based on the basis of technical writing. The other eighty (80) points will come from the problem solutions. For the technical writing I will follow the attached rubric.

3. There are 2 problems worth (80/2) points each. There is an additional problem worth 10 extra points towards this test. Because of these extra points, there will not be extra points for test reflections, and you are given extra days to turn in the test to account for the completion of the extra problem. Please note, that you will still have another opportunity for other points towards the final grade if you complete the ePortfolio website (read syllabus & ePortfolio assignment).

4. What you turn in should be only your own work. You cannot discuss the exam with anyone, except me and your partner. I will allow you to partner up with another student for this test. This test can be handled by one person, so if you do not want to partner with someone else, please do not do it. Anyway, call me, skype me, text me, email me, come to my office, if you have any question.

5. I do not read minds. You should be explicit and organized in your answers. Use drawings/figures. If you make a mistake, do not erase it. Rather use that opportunity to explain why you think it is a mistake and show the way to correct the problem.

6. You have to turn in your test ON TIME and ONLY through CANVAS. You must submit only one file and it has to be a pdf file. For the ePortfolio (which is optional) you are supposed to upload this artifact to your Google drive. I will provide more instructions later.

7. Do not start at the last minute so you can handle anything that could happen. Late tests will not be accepted. Test submitted through email will not be accepted either.

8. Cheating is completely wrong. The ODU Student Honor Pledge reads: "I pledge to support the honor system of Old Dominion University. I will refrain from any form of academic dishonesty or deception, such as cheating or plagiarism." By attending Old Dominion University, you have accepted the responsibility to abide by this code. This is an institutional policy approved by the Board of Visitors. It is important to remind you the following part of the Honor Code:

> IX. PROHIBITED CONDUCT
> A. Academic Integrity violations, including:
> 1. *Cheating*: Using unauthorized assistance, materials, study aids, or other information in any academic exercise (Examples of cheating include, but are not limited to, the following: using unapproved resources or assistance to complete an assignment, paper, project, quiz or exam; collaborating in violation of a faculty member's instructions; and submitting the same, or substantially the same, paper to more than one course for academic credit without first obtaining the approval of faculty).

With that said, you are NOT authorized to use any online source of any type, unless is ODU related.

1) A given space is to be maintained at 75 F and a relative humidity of 50%. The total heat gain to the space is 72,000 Btu/hr (this heat is physically passing through the walls, if you want to learn how to calculate this you should take MET440). There is no infiltration of outside air into the space neither there is any source of water inside the space, thus the humidity ratio of the air remains the same between states 2 and 3. Due to a process occurring inside the conditioned space, there is a need of fresh outdoor air in the amount of 500 cfm, which is provided as shown in the sketch. Assume that the air in the cooling and dehumidyfing unit is being constantly mixed so the cooling and dehumidyfing processes follow an ideal behaviour. Also assume that the fan is ideal and does not change the air state condition. The outdoor air has a temperature and relative humidity of 90 F and 60%, respectively. Determine:

    a. The quantity of the air supplied to the space.
    b. The state of the air at each of the points shown in the drawing (provide the dry bulb temperature and the humidity ratio of each state).
    c. Draw all the processes in the attached psychrometric chart.
    d. The required capacity of the cooling and dehumidyfing unit.
    e. The amount of liquid water drained in the cooling and dehumidyfing unit.

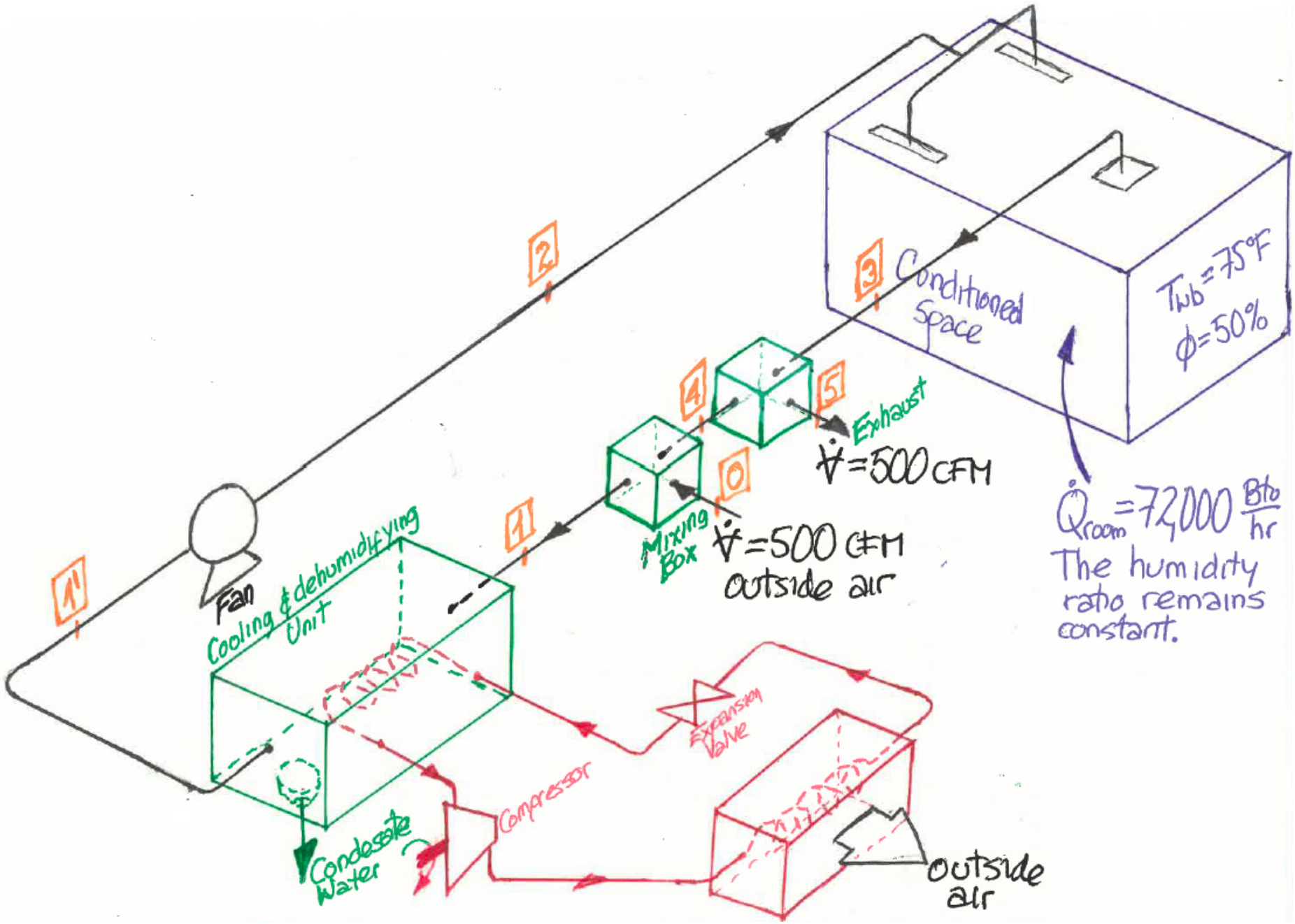
2) The cooling and dehumidyfing unit (also known as air handler unit) in the previous problem is part of a air-conditioner equipment that operates on a vapor-compression refrigeration cycle with refrigerant R-134a. You are required to design the equipment knowing that: the waste heat is rejected to the outside air, the refrigerant leaves the evaporator superheated by 2.7 ^{o}C and is subcooled by 6.3 ^{o}C at the exit of the condenser, and the isentropic efficiency of the compressor is 80%. For the design you must provide:

    a. The operating pressure of the evaporator and the condenser. Keep in mind that the temperatures of the refrigerant should be appropriate for the heat transfer to occur. Follow the rule of thumb provided in class.
    b. The state of the refrigerant after each of the elements of the vapor-compression refrigeration cycle (provide pressure, temperature, enthaply, and quality of each state).
    c. The P-v and T-s diagrams.
    d. The COP of your designed cycle.
    e. The required refrigerant mass flow rate.
    f. The power required by the compressor in HP.
    g. The waste heat rate.

3) For the additional points, you are asked to revise part of your vapor-compression refrigeration cycle design. Your client wants to use water to absorb the waste heat of the cycle instead of rejecting it to the outside air. You must now provide a preliminary design of a cooling tower to cool the water in order to be reused back in the refrigeration cycle. To judge if the idea is feasible, you must provide:

    a. The volume flow rate of outside air into the cooling tower.
    b. The mass flow rate of the required makeup water.

    NOTE: assume the air leaves the cooling tower with a relative humidity of 90%. Also assume that the temperature changes of the water and the air are about 3 F.


1'
1
2
3
Conditioned Space
T_{wb} = 75°F
ϕ = 50%
4
5
Exhaust
$\dot{V}$ = 500 CFM
0
Mixing Box
$\dot{V}$ = 500 CFM outside air
$\dot{Q}_{room}$ = 72,000 Btu/hr
The humidity ratio remains constant.
Fan
Cooling & dehumidifying Unit
Expansion Valve
Compressor
Condensate Water
outside air

Problem solution rubric

	Exceeds Standard	Meets Standard	Approaches Standard	Needs Attention
	4	3	2	1
	10 points	7 points	4 points	0 points
1. Purpose 5%	The purpose of the section to be answered is clearly identified and stated.	The purpose of the section to be answered is identified, but is stated in a somewhat unclear manner.	The purpose of the section to be answered is partially identified, and is stated in a somewhat unclear manner.	The purpose of the section to be answered is erroneous or irrelevant.
2. Drawings & Diagrams 10%	Clear and accurate diagrams are included and make the section easier to understand. Diagrams are labeled neatly and accurately.	Diagrams are included and are labeled neatly and accurately.	Diagrams are included and are labeled.	Needed diagrams are missing OR are missing important labels.
3. Sources 5%	Several reputable background sources were used and cited correctly.	A few reputable background sources are used and cited correctly.	A few background sources are used and cited correctly, but some are not reputable sources.	Background sources are cited incorrectly.
4. Design considerations (assumptions, safety, cost, etc) 10%	Design is carried out with applicable assumptions and full attention to safety and cost, etc.	Design is generally carried out with assumptions and attention to safety, cost, etc.	Design is carried out with some assumptions and some attention to safety, cost, etc.	Assumptions, safety and cost were ignored in the design.
5. Data and variables 5%	All data and variables are clearly described with all relevant details.	All data and variables are clearly described with most relevant details.	Most data and variables are clearly described with most relevant details.	Data and variables are not described OR the majority lack sufficient detail.
6. Procedure 25%	Procedure is described in clear steps. The step description is in a complete and easy to understand short paragraph.	Procedure is described in clear steps but the step description is not in a complete short paragraph.	Procedure is described in clear steps. The step description is in a complete short paragraph but it is difficult to understand.	Procedure is not described in clear steps at all.
7. Calculations 20%	All calculations are shown and the results are correct and labeled appropriately. The units of all values are shown.	Some calculations are shown and the results are correct and labeled appropriately.	Some calculations are shown and the results labeled appropriately.	No calculations are shown OR results are inaccurate or mislabeled.
8. Summary 5%	Summary describes the design, the relevant information and some future implications.	Summary describes the design and some relevant information.	Summary describes the design.	No summary is written.
9. Materials 5%	All materials used in the design are clearly and accurately described.	Almost all materials used in the design are clearly and accurately described.	Most of the materials used in the design are clearly and accurately described.	Many materials are described inaccurately OR are not described at all.
10. Analysis 10%	The design is discussed and analyzed. Argumentative predictions are made about what might happen in case of change in the operation and how the design could be change.	The design is discussed and analyzed. Argumentative predictions are made about what might happen in case of change in the operation.	The design is discussed and analyzed. No argumentative predictions are made about what might happen in case of change in the operation and how the design could be change.	The design is not discussed and analyzed.