MIND OVER MATTER C 2027

DESCRIPTION: Participants must demonstrate an understanding of the conservation of mass and energy and basic fluid mechanics.

A TEAM OF UP TO: 2 **IMPOUND**: NO **EYE PROTECTION**: N/A **EVENT TIME**: 50 Minutes

EVENT PARAMETERS

A. Each team may bring **two (2)** 8.5" x 11" sheets of paper that may contain information on both sides in any form and from any source. The sheets of paper may be laminated or placed in a sheet protector to increase durability.
B. Each team may also bring writing utensils**, two rulers,** and two Class III calculators for use at any time during the event.

THE COMPETITION

A. The test will assess the team's understanding of mass and energy balances and basic fluid mechanics.
B. Units will be given in SI, English engineering, or other common engineering units. Unless otherwise requested, answers must be in metric units with appropriate significant figures.
C. The test will consist of questions in the following areas:
    a. **Mass Balances**
        i. Convert material flows between different bases
            1. *Mass, molar, and volumetric bases for all phases of matter*
            2. *Standard and true volumetric bases for ideal gases*
            3. *Dry and wet basis for humid flows*
        ii. Balances on a system of units
            1. *Combinations of splitters, mixers, recycles, and bypasses*
        iii. Balances on a system of units with reactor(s):
            1. *Irreversible reactions for liquids and gases*
            2. *Liquid-phase reversible reaction with an equilibrium constant Kc*
            3. *Complete and incomplete combustions (e.g., theoretical air, etc.)*
        iv. Balances on a system of units with flash(es)
            1. Perform vapor-liquid equilibrium (VLE) calculations for ideal binary mixtures given Antoine coefficients
                a. *e.g., dew point, bubble point, solution and partial pressure, etc.*
            2. Identify features on Pxy, Txy, and XY data or diagrams for ideal and non-ideal binary solutions to perform a mass (and energy) balance.
                a. *e.g., azeotropes, molar fractions, phase fractions, etc.*
        v. Balances on a system of units with HVAC unit(s)
            1. Identify features on a psychrometric chart to perform a mass (and energy) balance on psychrometric processes
                a. *Features: dry- and wet-bulb temperatures, humidity, etc.*
                b. *Processes: humidification and dehumidification, cooling, etc.*
            2. Identify features on a Pressure-Enthalpy (PH) diagram of R-134a to perform a mass (and energy) balance
                a. *Features: Saturated liquid and vapor line, enthalpy, etc.*
                b. *Processes: isothermal expansions, heating, cooling, etc.*
    b. **Energy Balance**
        i. Calculate the enthalpies of material streams given constant heat capacity or enthalpy tables listed below

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1. *Saturated and superheated steam tables, enthalpy-of-formation tables, psychrometric chart, and PH Diagram for R-134a*

ii. Balances on a system of units
   1. *e.g., reactors, flashes, HVAC, heat exchangers, turbines, etc.*

iii. Calculate the coefficient of performance and efficiency for power cycles.
   1. *Carnot and other systems of units in a closed loop*

c. Fluid Mechanics

i. Apply Pascal's principle and Archimedes' principle

ii. Calculate gauge pressure, absolute pressure, and head for static and dynamic systems

iii. Apply the continuity and Bernoulli's equation for inviscid-incompressible flow
   1. *Calculate total, static, and dynamic pressures/heads*

iv. Calculate the Reynolds number for fluids through various pipe geometries
   1. *Identify flow types as turbulent, transitional, or laminar*

D. The questions above will require knowledge of the following subjects:

a. Linear interpolation and lever rule
b. Solving non-linear equations and systems of linear equations.
c. Calculating area or volumes of basic shapes and trigonometry
d. Forces and work

E. Teams are recommended to include a unit conversion table in their notes page. A quadratic root solver and a linear interpolating program are recommended as well.

SCORING

1. The highest score wins.
2. Preselected questions/sections may be used as tiebreakers.

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EVENT SUPERVISOR INFORMATION

1. **Teams are not expected to bring their own data**
    a. The event supervisor will provide enthalpy data, Antoine coefficients, and other necessary data inside the exam document or as a separate document that is passed out and collected after the exam. Conversion factors between SI and English engineering units are encouraged, but not necessary.
2. **Balance on a Single Reactor and System of Units with Reactor(s)**
    a. Liquid phase reversible reactions must be able to be solved by a quadratic equation (See CSTR example).
3. **Enthalpy Balance on a Power Cycle**
    a. These problems should be solved only in terms of mass and energy balances, not in terms of gas expansion and compression enthalpy changes
4. **Avoid Mixing SI and English Engineering Units:**
    a. Make sure problems, figures, or diagrams are entirely based on SI or English engineering exclusively. (e.g., don't mix feet and meters, joules and BTUs, Rankine and Celsius, etc.)
5. **The question above must follow these caveats**:
    a. Calculus and transient balances will not be covered on the exam.

Table 1: Units on the table below and their derived units are allowed to be on the exam. Units not on the table require a conversion factor to SI or English engineering units

Physical Quantity	SI Unit	English Engineering Unit	Misc.
Length	meter (m)	foot (ft), inch (in)	
Mass	kilogram (kg)	pound-mass (lbm)	
Volume	meter-cubed (m^3)	foot-cubed (ft^3)	liters (L), US gallons (gals)
Force	newton (N)	pound-force (lbf)	
Time	second (s)	second (s)	
Pressure	pascal (Pa) Bar (bar)	pounds per square inch (psi) pounds per square foot (psf)	atmosphere (atm) torr (tor)
Energy/Work	joule (J)	foot-pound (ft·lbf), British Thermal Unit (BTU)	calorie (cal)
Power	watt (W)	horsepower (hp), (BTU/s),	(cal/s)
Absolute Temperature	kelvin (K)	rankine (°R)	
Temperature	degree Celsius (°C)	degree Fahrenheit (°F)	
Amount	moles (mol)	pound-mol (lbm-mol)	Standard volumetric flows (STP, SCF, etc.)

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HELPFUL RESOURCES

The resources below cover more than what is expected from the event. Be sure to follow the rules stated above.

1. https://learncheme.com/quiz-yourself/interactive-self-study-modules/ (Self Study Modules)
    a. Problem Analysis, Material Balances, Energy Balances
2. https://learncheme.com/screencasts/mass-energy-balances/ (Screencasts)
    a. Material Balances, Energy Balances, Units and Conversions
3. https://learncheme.com/simulations/mass-energy-balances/ (Demos)
4. https://en.wikipedia.org/wiki/Chemical_engineering (Wiki page for Chemical Engineering)

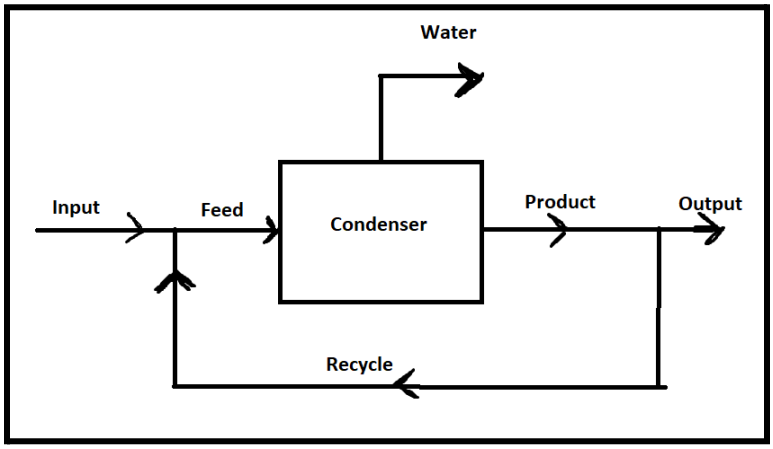
EXAMPLE QUESTION

A. Conversions

1. Convert 200 psi into atm
2. Convert 1000 kg/m^3 to lbm/ft^3
3. How many pounds of methane (CH4) are in 2.5 lb-mols?

B. Mass Balance

4. 100 kg/h of saltwater enters a single-effect evaporator at 3.5% w/w salt. If the first effect recovers 68% of the water from the saltwater, what is the salt concentration in the concentrate?



5. 100 mol/h of humid air enters the input stream with 20% mol/mol water, with the balance being air. The condenser removes 20% of the water molecules from the feed steam to the top as liquid water, ejecting the air into the product stream. The output air must contain 5% mol/mol water. What is the molar flow rate in the recycle stream? (mol/h)

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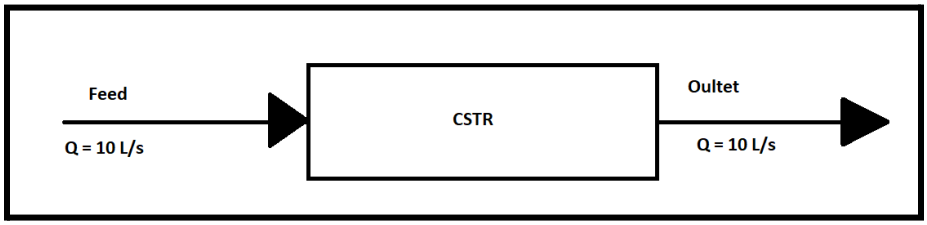
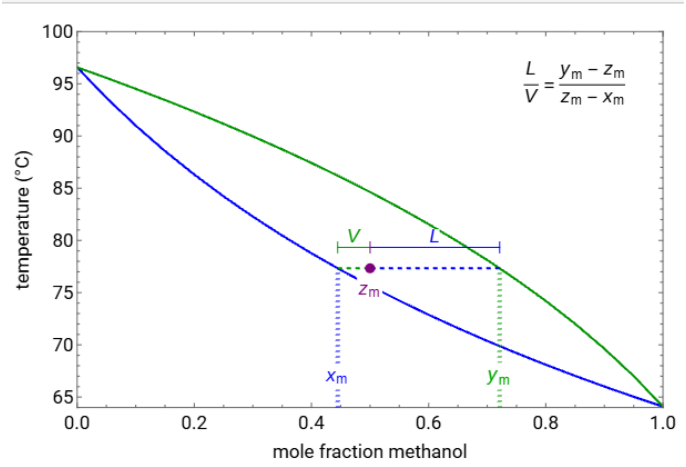
C. Reactor Balance



6. A CSTR is filled with a catalyst that turns A into B using the following reaction: 2A →B. The feed stream contains solvent entering at a flow rate of 10 L/s. The concentration of A in the feed stream is 10 mols/L. The equilibrium constant (Kc) of the reaction is 100. What is the outlet molar flow rate of B if the solution exits the reactor at equilibrium? (FB = 48.9 mols/s).

7. A batch reactor uses A in the following reaction to make products B and C: A →B and A→C. 100 mols of A is fed into the reactor. If the conversion factor of A is 70% and the yield of B is 80%, how many moles of A, B, and C are in the reactor?

D. Flash Balance



8. 100 mols/h of 50% mol/mol methanol with the balance water enters a flash unit. Using the TXY diagram above, answer the following question: What is the molar flow rate of the liquid and vapor stream?

E. Heat Balance

9. John needs a cup of coffee in the morning. 10 g/s of water enters the coffee maker at 20 degrees Celsius. The heating coils heat the water to 80 degrees Celsius. If the heat capacity of water is 4.184 J/gK, how much heat does the heating coil provide?
10. 10 kg/s of saturated steam at 70 psig is throttled to 20 psig by a valve. The superheated steam is passed to a heat exchanger, reboiling the product in a distillation column. The heat exchange, without pressure loss, causes the steam to condense into a saturated liquid. How much enthalpy did the steam lose in the heat exchanger? (This problem requires a steam table)

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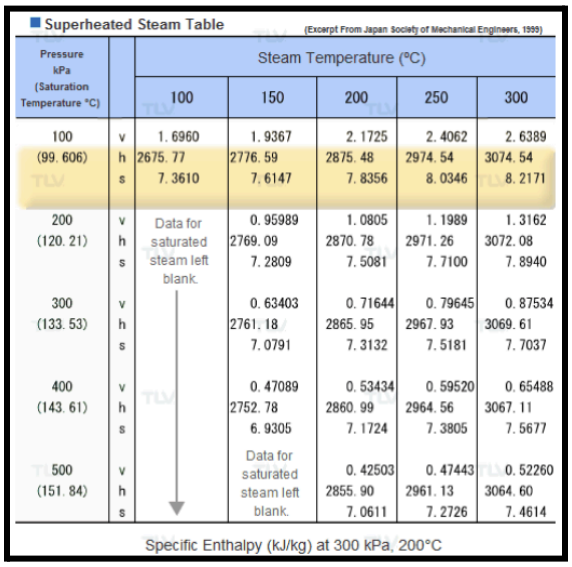

Superheated Steam Table

(Excerpt From Japan Society of Mechanical Engineers, 1999)

Pressure kPa (Saturation Temperature °C)		Steam Temperature (°C) 100	150	200	250	300
100	v	1.6960	1.9367	2.1725	2.4062	2.6389
(99.606)	h	2675.77	2776.59	2875.48	2974.54	3074.54
	s	7.3610	7.6147	7.8356	8.0346	8.2171
200	v	Data for saturated steam left blank.	0.95989	1.0805	1.1989	1.3162
(120.21)	h		2769.09	2870.78	2971.26	3072.08
	s		7.2809	7.5081	7.7100	7.8940
300	v		0.63403	0.71644	0.79645	0.87534
(133.53)	h		2761.18	2865.95	2967.93	3069.61
	s		7.0791	7.3132	7.5181	7.7037
400	v		0.47089	0.53434	0.59520	0.65488
(143.61)	h		2752.78	2860.99	2964.56	3067.11
	s		6.9305	7.1724	7.3805	7.5677
500	v		Data for saturated steam left blank.	0.42503	0.47443	0.52260
(151.84)	h			2855.90	2961.13	3064.60
	s			7.0611	7.2726	7.4614

Specific Enthalpy (kJ/kg) at 300 kPa, 200°C

11. Given the steam table above, estimate the enthalpy of steam at 350 kPa and 150C.

F. Fluid Statics

12. A Casio G-Shock is water-resistant up to 20 bar-gauge (bar-g). Estimate the depth in water the watch can handle.

G. Continuity and Bernoulli's Equation

13. 1ft^3/s of water flows into a four-inch ID pipe. A contraction further down the pipe has an ID of 3 inches. Calculate the velocity of the water at the three-inch and four-inch pipes
14. A tank of water was shot by a bullet, causing a circular leak to form. If the hole was punched 5 meters below the surface of the water, what is the exit velocity of the water?

H. Reynolds Number

15. Calculate the Reynolds number of water traveling at 1m/s in a 10 cm ID pipe. (Dencity = 1000 kg/m^3) (viscocity = 1 Pa*s)