The worth of souls is great in the sight of God. (D&C 18:10)

Thought: Substitute your first name for "souls"

The worth of <u>Spencer</u> is great in the sight of God.

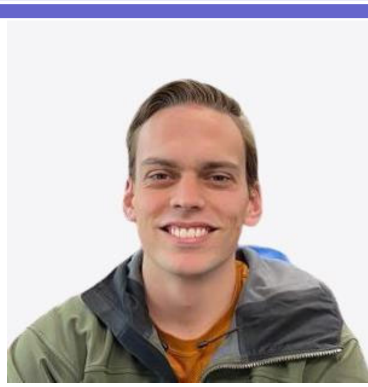
1

Case Study

- Printed copy of Excel sheet and accompanying explanation of equations
- Upload spreadsheet and other materials to Learning Suite (one per group)
- Make sure your team number and names of team members are on the cover sheet
- Email me your leadership self-evaluation
- Everything due by 5 pm today!

2

Thank you TAs!!!



Dawson McCrea

Parker LaTour

3

ABET Survey

Please do the student ratings for this class

- Tomorrow is the last day (not available during finals)
- 44% of class has already completed this evaluation
- Student rating will be counted as a HW assignment

4

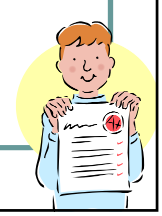
Dean’s Lectures

- 2 required
- Indicate this on the front page of the final exam
- Online videos available (see previous emails)
  - On YouTube, search “BYU College of Engineering”

5

Final Exam

- Room Chane: 245 CB (near women’s restroom)
- Tuesday, Dec. 13, 7 am
  - **Closed Book, Closed Notes/Homework**
  - Three 8.5×11 pages with notes on both sides
    - I am not supplying equations
    - I am supplying data (C_p’s, ΔH_f°, etc.)
  - Calculator needed
  - Straight edge needed
- Time limit is 3 hours
- Aligned with competencies!!
- Somewhat aligned with what was missed on previous exams



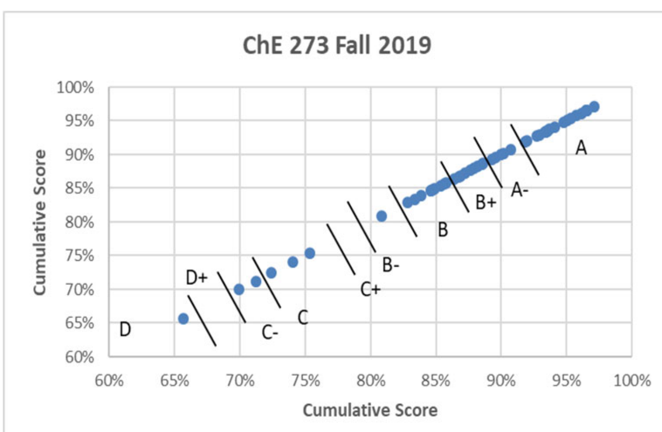
6

Grades

- High score on final exam gets an A in the class
  - May not be the highest cumulative score in the class!
- Must get 60% on the final exam to avoid penalty on grades (i.e., passing grade on final)!
  - Better to find out now rather than next year if you need to seek a different major

7

Grades from F 2019



8

Competencies

Students will be able 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.
Students will be able to calculate the work of pumps, turbines, and/or compressors.
Students will be able to design multiple-unit processes.
Students will understand process variables (e.g., P, T, flow rate, conc.) including procedures and equipment for their measurement.
Students will be able to set up and solve steady-state material balances.
Students will be able to set up and solve steady-state energy balances (1st law of thermodynamics) for closed and open systems.
Students will be able to set up and solve transient material balances.
Students will be able to solve simple fluid statics problems.
Students will be able to apply solution thermodynamics fundamentals to solve phase equilibrium problems including bubble point, dew point and flash calculations.
Students will understand and be able to use the extent of reaction in material balances for systems involving chemical reactions.
Students will understand and be able to apply the concepts of heat capacity, latent heat, heat of reaction, heat of combustion, and heat of formation.
Students will be able to read and understand phase diagrams and use these to determine physical phenomena.
Students will understand pure-component, PVT phase behavior including vapor pressure, critical point, freezing line, triple point, etc.
Students will be able to calculate internal energy, enthalpy, and entropy at system conditions assuming ideal behavior.

9

Course Expectations

Students will be able to perform unit conversions.
Students will be able to ensure dimensional consistency when evaluating equations.
Students will exhibit critical and creative thinking skills for analysis and evaluation of problems and cause-effect relationships.
Students will be able to make order of magnitude estimates, assess reasonableness of solutions, and select appropriate levels of solution sophistication.
Students will be able 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.
Students will be able to calculate the work of pumps, turbines, and/or compressors.
Students will be able to design multiple-unit processes.
Students will understand and commit to practice the AIChE code of ethics.
Students will function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
Students will understand process variables (e.g., P, T, flow rate, conc.) including procedures and equipment for their measurement.
Students will be able to set up and solve steady-state material balances.
Students will be able to set up and solve steady-state energy balances (1st law of thermodynamics) for closed and open systems.
Students will be able to set up and solve transient mass balances.
Students will be able to solve simple fluid statics problems.
Students will be able to apply solution thermodynamics fundamentals to solve phase equilibrium problems including bubble point, dew point and flash calculations.
Students will understand and be able to use the extent of reaction in material balances for systems involving chemical reactions.
Students will understand and be able to apply the concepts of heat capacity, latent heat, heat of reaction, heat of combustion, and heat of formation.
Students will be able to read and understand phase diagrams and use these to determine physical phenomena.
Students will understand pure-component, PVT phase behavior including vapor pressure, critical point, freezing line, triple point, etc.
Students will understand how molecular interactions to the behavior of material gives rise to macroscopic properties.
Students will be able to calculate internal energy, enthalpy, and entropy at system conditions assuming ideal behavior.

10

Ways to Prepare for Final Exam

- Get some SLEEP!
- Have a snack handy
- Rework previous exams
  - What did you miss?
- COMPETENCIES!
  - Do you really know this stuff?
  - If not, talk to me or the TAs!!!

11

Terms

- Extent of reaction (ξ)
- Element balances
- Adiabatic, isothermal, isentropic, etc.
- SCFM, SLPM, etc.
- Energy Balances (Path method vs. ΔH_f^0 method)
- ΔH_f^0 vs ΔH_r
- Q, W_s, ΔE_p, ΔE_k
- Mechanical Energy Balance (Bernoulli)
- Transient balances
- Manometers, pressure head
- Gauge vs. absolute pressure
- Vapor-liquid equilibrium
- Degrees of freedom
- Ideal vs. Non-ideal gas
- Kay's rule
- Gauge vs. atmospheric Pressure
- Combustion reactions
- Phase behavior
- Vapor pressures
- Relative humidity (Psychrometric)
- Raoult's Law: Dew pt, Bubble pt, and Flash
- Phase charts (vapor-liquid, liquid-liquid, solid-liquid, eutectic)
- Steam tables
- P-H diagram (refrigeration, etc.)

12

What was missed on the F'21 Final

Element balance	80%
Flash Calculation	97%
Rankine Cycle on P-H diagram	77%
Low heating value, find ΔH_f^0	80%
Steam Tables to find phase	58%
Adiabatic flame temperature	78%
Vapor pressure problem	72%
Multi-unit material balance with DOF	62%

13

Psychrometric Chart

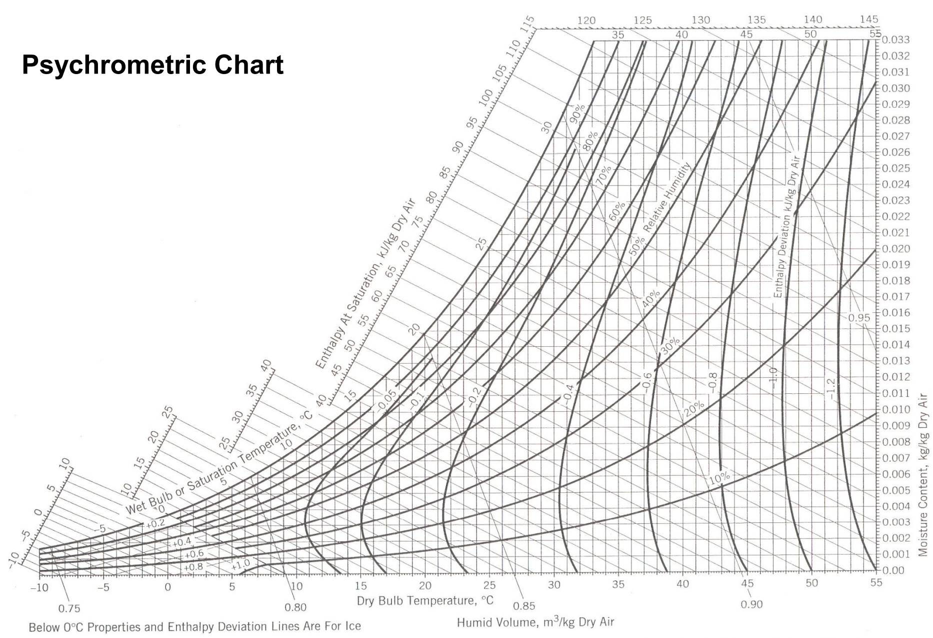


Figure 8.4-1 Psychrometric chart—SI units. Reference states: H_2O (L, 0°C, 1 atm), dry air (0°C, 1 atm). (Reprinted with permission of Carrier Corporation.)

14

Refrigerant 22 P-H diagram

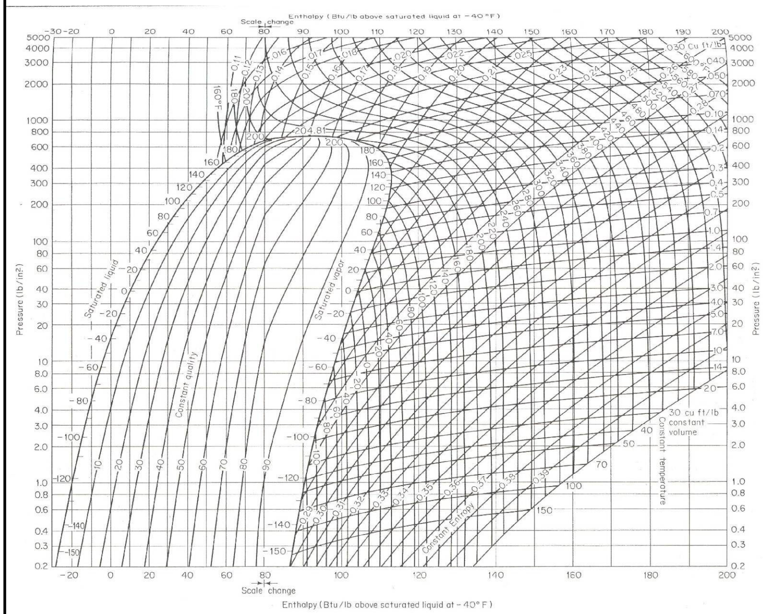
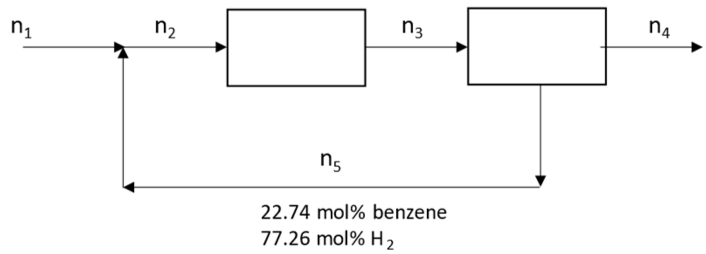


FIG. 3-38. Enthalpy–log pressure diagram for Refrigerant 22. Temperature in °F., volume in cu. ft./lb., entropy in B.t.u./(lb.)(°R.), quality in weight per cent. Copyright E.I. du Pont de Nemours & Company. Reprinted by permission of the copyright owner. The 1967 Karlsruhe *H*–log *P* chart in the metric system covers a range of −90° to 250°C., 0.035 to 121 bars. The Landolt-Börnstein 1967 tables, vol. IVa, give saturation properties from −100° to 96°C., while D'Ans-Lax, "Taschenbuch," 1967, tables at somewhat coarser increments extend from −100° to 70°C. In Vargaftik, "Thermophysical Properties of Substances," Moscow, 1963, tables mostly cover the range −100° to 50°C. The 1967 A.S.H.R.A.E. "Fundamentals" volume contains the above diagram and also an enlarged section for pressures to 300 lb./sq. in. abs. Detailed saturation tables for −155(1)204 and 204.81°F. and superheat tables from −150° to 480°F., 0.2 to 540 lb./sq. in. abs. are contained in *du Pont Bulletin* T-22, 1964. The 1967 A.S.H.R.A.E. "Fundamentals" volume also contains saturation tables for −150(5)-100(2)204 and 204.81°F.

Table B.7 Properties of Superheated Steam[a]

P(bar) ($T_{sat.}$°C)		Sat'd Water	Sat'd Steam	Temperature (°C) → 50	75	100	150	200	250	300	350
0.0	$\hat{H}$	—	—	2595	2642	2689	2784	2880	2978	3077	3177
(—)	$\hat{U}$	—	—	2446	2481	2517	2589	2662	2736	2812	2890
	$\hat{V}$	—	—	—	—	—	—	—	—	—	—
0.1	$\hat{H}$	191.8	2584.8	2593	2640	2688	2783	2880	2977	3077	3177
(45.8)	$\hat{U}$	191.8	2438.0	2444	2480	2516	2588	2661	2736	2812	2890
	$\hat{V}$	0.00101	14.7	14.8	16.0	17.2	19.5	21.8	24.2	26.5	28.7
0.5	$\hat{H}$	340.6	2646.0	209.3	313.9	2683	2780	2878	2979	3076	3177
(81.3)	$\hat{U}$	340.6	2484.0	209.2	313.9	2512	2586	2660	2735	2811	2889
	$\hat{V}$	0.00103	3.24	0.00101	0.00103	3.41	3.89	4.35	4.83	5.29	5.75
1.0	$\hat{H}$	417.5	2675.4	209.3	314.0	2676	2776	2875	2975	3074	3176
(99.6)	$\hat{U}$	417.5	2506.1	209.2	313.9	2507	2583	2658	2734	2811	2889
	$\hat{V}$	0.00104	1.69	0.00101	0.00103	1.69	1.94	2.17	2.40	2.64	2.87
5.0	$\hat{H}$	640.1	2747.5	209.7	314.3	419.4	632.2	2855	2961	3065	3168
(151.8)	$\hat{U}$	639.6	2560.2	209.2	313.8	418.8	631.6	2643	2724	2803	2883
	$\hat{V}$	0.00109	0.375	0.00101	0.00103	0.00104	0.00109	0.425	0.474	0.522	0.571
10	$\hat{H}$	762.6	2776.2	210.1	314.7	419.7	632.5	2827	2943	3052	3159
(179.9)	$\hat{U}$	761.5	2582	209.1	313.7	418.7	631.4	2621	2710	2794	2876
	$\hat{V}$	0.00113	0.194	0.00101	0.00103	0.00104	0.00109	0.206	0.233	0.258	0.282
20	$\hat{H}$	908.6	2797.2	211.0	315.5	420.5	633.1	852.6	2902	3025	3139
(212.4)	$\hat{U}$	906.2	2598.2	209.0	313.5	418.4	603.9	850.2	2679	2774	2862
	$\hat{V}$	0.00118	0.09950	0.00101	0.00102	0.00104	0.00109	0.00116	0.111	0.125	0.139
40	$\hat{H}$	1087.4	2800.3	212.7	317.1	422.0	634.3	853.4	1085.8	2962	3095
(250.3)	$\hat{U}$	1082.4	2601.3	208.6	313.0	417.8	630.0	848.8	1080.8	2727	2829
	$\hat{V}$	0.00125	0.04975	0.00101	0.00102	0.00104	0.00109	0.00115	0.00125	0.0588	0.0665
60	$\hat{H}$	1213.7	2785.0	214.4	318.7	423.5	635.6	854.2	1085.8	2885	3046
(275.6)	$\hat{U}$	1205.8	2590.4	208.3	312.6	417.3	629.1	847.3	1078.3	2668	2792
	$\hat{V}$	0.00132	0.0325	0.00101	0.00103	0.00104	0.00109	0.00115	0.00125	0.0361	0.0422
80	$\hat{H}$	1317.1	2759.9	216.1	320.3	425.0	636.8	855.1	1085.8	2787	2990
(295.0)	$\hat{U}$	1306.0	2571.7	208.1	312.3	416.7	628.2	845.9	1075.8	2593	2750
	$\hat{V}$	0.00139	0.0235	0.00101	0.00102	0.00104	0.00109	0.00115	0.00124	0.0243	0.0299
100	$\hat{H}$	1408.0	2727.7	217.8	322.9	426.5	638.1	855.9	1085.8	1343.4	2926
(311.0)	$\hat{U}$	1393.5	2547.3	207.8	311.7	416.1	627.3	844.4	1073.4	1329.4	2702
	$\hat{V}$	0.00145	0.0181	0.00101	0.00102	0.00104	0.00109	0.00115	0.00124	0.00140	0.0224
150	$\hat{H}$	1611.0	2615.0	222.1	326.0	430.3	641.3	858.1	1086.2	1338.2	2695
(342.1)	$\hat{U}$	1586.1	2459.9	207.0	310.7	414.7	625.0	841.0	1067.7	1317.6	2523
	$\hat{V}$	0.00166	0.0103	0.00101	0.00102	0.00104	0.00108	0.00114	0.00123	0.00138	0.0115
200	$\hat{H}$	1826.5	2418.4	226.4	330.0	434.0	644.5	860.4	1086.7	1334.3	1647.1
(365.7)	$\hat{U}$	1785.7	2300.8	206.3	309.7	413.2	622.9	837.7	1062.2	1307.1	1613.7
	$\hat{V}$	0.00204	0.005875	0.00100	0.00102	0.00103	0.00108	0.00114	0.00122	0.00136	0.00167
221.2(P_c)	$\hat{H}$	2108	2108	228.2	331.7	435.7	645.8	861.4	1087.0	1332.8	1635.5
(374.15)(T_c)	$\hat{U}$	2037.8	2037.8	206.0	309.2	412.8	622.0	836.3	1060.0	1302.9	1600.3
	$\hat{V}$	0.00317	0.00317	0.00100	0.00102	0.00103	0.00108	0.00114	0.00122	0.00135	0.00163
250	$\hat{H}$	—	—	230.7	334.0	437.8	647.7	862.8	1087.5	1331.1	1625.0
(—)	$\hat{U}$	—	—	205.7	308.7	412.1	620.8	834.4	1057.0	1297.5	1585.0
	$\hat{V}$	—	—	0.00100	0.00101	0.00103	0.00108	0.00113	0.00122	0.00135	0.00160
300	$\hat{H}$	—	—	235.0	338.1	441.6	650.9	865.2	1088.4	1328.7	1609.9
(—)	$\hat{U}$	—	—	205.0	307.7	410.8	618.7	831.3	1052.1	1288.7	1563.3
	$\hat{V}$	—	—	0.0009990	0.00101	0.00103	0.00107	0.00113	0.00121	0.00133	0.00155
500	$\hat{H}$	—	—	251.9	354.2	456.8	664.1	875.4	1093.6	1323.7	1576.3
(—)	$\hat{U}$	—	—	202.4	304.0	405.8	611.0	819.7	1034.3	1259.3	1504.1
	$\hat{V}$	—	—	0.0009911	0.00100	0.00102	0.00106	0.00111	0.00119	0.00129	0.00144
1000	$\hat{H}$	—	—	293.9	394.3	495.1	698.0	903.5	1113.0	1328.7	1550.5
(—)	$\hat{U}$	—	—	196.5	295.7	395.1	594.4	795.3	999.0	1207.1	1419.0
	$\hat{V}$	—	—	0.0009737	0.0009852	0.001000	0.00104	0.00108	0.00114	0.00122	0.00131

[a] Adapted from R. W. Haywood, *Thermodynamic Tables in SI (Metric) Units,* Cambridge University Press, London, 1968. Water is a liquid in the enclosed region between 50°C and 350°C. $\hat{H}$ = specific enthalpy (kJ/kg), $\hat{U}$ = specific internal energy



17