MAE 302 Course Syllabus Fall 2009

1.1. Instructor's name, office address, telephone number, e-mail address, regularly scheduled class meeting times, and office hours for out-of-class consultation.

Sec: 001
Location: BR 3216
Days: MW
Time: 1:30-2:45 PM

Instructor: M. A. Boles
Office: BR 3184
E-Mail Address: boles@eos.ncsu.edu
Office Telephone: 919-515-5234
Office Hours: 12:00-1:20 PM MW

1.2. Course prerequisites or restrictive statements.

Prerequisites: CSC 112 and a grade of C or better in MAE 301

1.3. Designation of course as a General Education Requirement (GER). N/A

1.4. Student learning outcomes for the course.

Course Motivation: This course places emphasis on the analysis and design of power and refrigeration cycles and the application of the basic principles to engineering design problems with systems involving mixtures of ideal gases, psychrometrics, non-ideal gases, chemical reactions, combustion, chemical equilibrium, and one-dimensional compressible flow.

Course Objectives: The students will be asked to demonstrate their knowledge of the material covered in MAE 302 through their mastery of the following course objectives. Through the study of MAE 302 the student will be able to:

- Sketch figures of systems and control volumes;
- Sketch process diagrams for the processes occurring within systems and control volumes;
- Develop the governing equations for conservation of mass, conservation of energy, and process relations for processes occurring in systems and control volumes;
- Determine the required thermodynamic properties from tables for real substances (water and refrigerant 134a), tables for ideal gases, and equations of state for ideal gases. substitute these property values with units into the governing equations and simplify;
- Analyze ideal gas power cycles to perform energy balances, determine heat and work transfers, and calculate the cycle efficiency;
- Analyze steam power cycles to perform energy balances, determine heat and work transfers, and calculate the cycle efficiency;
- Analyze vapor compression refrigeration cycles to perform energy balances, determine heat and work transfers, and calculate the cycle coefficient of performance;
- Calculate properties of ideal gas mixtures;
- Determine the properties of dry air-water vapor mixtures, plot processes on a psychrometric chart, and analyze process involving dry air-water vapor mixtures to perform energy and mass balances for the processes;

- Determine balanced chemical reaction equations and analyze typical combustion processes to perform energy balances to determine the heat transfer released or estimate the maximum possible product gas temperature during combustion;
- Calculate stagnation properties of high-speed flows and apply these properties to isentropic flow though nozzles and to the process occurring across a normal shock wave.

1.5. All required Textbook(s), title(s), date(s), price(s), Calculators, price(s)

Y. A. Çengel and M. A. Boles, Thermodynamics: an Engineering Approach (Packet including Property Table Booklet), 6th Ed, The McGraw Hill Companies, New York, 2008. $143.75 (new), $107.85 (used) (This course uses the same text as MAE 301 and no new text is required.)

Only models of calculators approved by the instructor are permitted to be used in the classroom during tests and the final exam. *No other models of calculators or variations of the models listed below are permitted during tests and the final exam.* The following are the only calculators that will be permitted in the classroom during tests and the final exam and are the only ones allowed on the Fundamentals of Engineering Exam. Prices for these calculators range from $9.95 to $20.00.

Hewlett Packard – HP 33S
Casio – FX 115MS or FX 115MSPlus
Texas Instruments – TI 30X IIS
Texas Instruments – TI 36X SOLAR

1.6. Course organization and scope. List of topics and approximate time allocated to each major topic.

Topics covered: (number of classes): Based on 3 classes per week for 14 week semesters, classes meet 3 days per week for 50 minute lectures (or 2 days per week for 75 minute lectures):

1. Gas power cycles (6)
2. Steam power cycles (8)
3. Refrigeration cycles (3)
4. Ideal gas mixtures and psychrometrics (6)
5. Combustion processes (6)
6. Chemical equilibrium (3)
7. Ideal compressible flow (6)
8. Review and tests (4)

1.7. Projected schedule of reading assignments.

	Day	Topic	Sections
Aug.	19	Basic Considerations, Carnot cycle,	9.1-9.4
		Air standard cycle Otto Cycle	9.5
	24	Diesel Cycle	9.6
		Stirling, Ericsson, Brayton Cycles	9.7
	26	Brayton Cycles	9.8
	31	Brayton Cycle with Regeneration, Intercooling, Reheating	9.9-9.10
		Ideal Jet-Propulsion Cycles Second-Law Analysis	9.11-9.12
	2	Carnot and Rankine Vapor Cycles	10.1-10.3
		Parameters Affecting Efficiency, Reheat Cycle	10.4-10.5
Sep.	7	***Holiday***	
	9	Regenerative Rankine Cycle	10.6
	14	**Test 1**	
	16	Second-Law Analysis of Vapor Power Cycles	10.7
		Cogeneration	10.8
	21	Combined Gas-Vapor Power Cycles	10.9
		Refrigerators & Heat Pumps, Reversed Carnot Cycle	11.1-11.2
	23	Ideal Refrigeration cycle	11.3
	28	Actual Vapor-Compression Refrigeration Cycle	11.4
		Advanced Refrigeration Topics	11.5-11.9
	30	Composition of Gas Mixtures	13.1
Oct.	5	P-v-T Behavior of Gas Mixtures	13.2
		Properties of Gas Mixtures	13.3
	7	No Class	
	12	**Test 2**	
	14	Properties of Gas-Vapor Mixtures	14.1-14.3
	19	Adiabatic Saturation and Wet-Bulb Temperatures	14.4
	21	Psychrometric Chart	14.5-14.6
	26	Air Cond. Processes	14.7
		Fuels and Combustion	15.1
	28	Theoretical and Actual Combustion Processes	15.2

	Day	Topic	Sections
Nov.	2	Balanced reaction equations	15.2
		Enthalpy of Formation and Enthalpy of Combustion	15.3
	4	Enthalpy of Formation and Enthalpy of Combustion	15.3
	9	First-Law Analysis of Reacting Systems	15.4
		Adiabatic Flame Temperature	15.5
	11	Entropy Change of Reacting Systems	15.6
	16	Second-Law Analysis of Reacting Systems	15.7
		Stagnation Properties	17.1
	18	Speed of sound and Mach number	17.2
	23	**Test 3**	
	25	***Holiday***	
	30	One Dimensional Isentropic Flow	17.3
		Isentropic Flow through Nozzles	17.4
Dec.	2	Review	
Dec.	16	**Final Exam 1:00 - 4:00 PM**	

1.8. Projected schedule of any homework due dates, quizzes and tests.

All homework will be assigned on Wednesday of the current week of class and will be due on Wednesday of the next week. All homework papers are to be stapled in the upper left-hand corner and placed on the instructor’s desk before the start of class. Tests and final exam are scheduled according to the projected schedule of reading assignments given above in Section 1.7. Unless given further notice, the exam time for this section is that listed in the Semester Examination Schedule published by the Department of Registration and Records.

1.9. Course grades are determined as follows:

The grading components are 10% homework, 20% Test 1, 20% Test 2, 20% Test 3, and 30% Final Exam. No incompletes are accepted for this course without verifiable, written doctor's note indicating more than one week's incapacitation. Grade percentages may be modified according to TA support.

The final grade will be based on the final average and determined as follows:
90 and above A
80 and < 90 B
70 and < 80 C
60 and < 70 D

Below 60 F
Plus/minus grades will be used for those border line cases where there is excellent attendance, excellent homework grades, and improvement in test and exam grades.

1.10. Instructor's policies on incomplete grades and late assignments.

Incompletes are accepted only for medical reasons. Makeup work, if any, must be arranged within two weeks of due date at the option of the instructor, prior to two weeks before the end of classes.

1.11. Instructor's policies on attendance:

Students are expected to attend all classes, and attendance may be recorded from time to time and may be used to determine grades for border line cases. **NCSU policy on attendance, including what constitutes an 'Excused Absence,' is at this link** (**www.ncsu.edu/policies/academic_affairs/courses_undergrad/REG02.20.3.php**)**.**

Work that is late due to an excused absence will either be 'excused' from your grade, or it may be turned in late. It is the students' responsibility to contact the instructor to discuss the most appropriate action.

In the event that a test is scheduled for a day in which the University is closed due to inclement weather, that test will be held at the next regularly scheduled class when the University is officially open.

1.12. Instructor's Academic Integrity statement, which consists of:

1.12.1. The faculty acknowledges the existence of the University policy on academic integrity found in the Code of Student Conduct Policy (POL11.35.1) and expects students to adhere to it.

1.12.2. the utilization implication of the Honor Pledge[1]; and,

An Honor Pledge is expected to be signed and dated on each test, final exam, and any additional special assignments. The Honor pledge will be as follows: "I have neither given nor received unauthorized aid on this test, exam or special assignment. I have not discussed the contents of this test or exam prior to taking it."

1.12.3. the expectations of faculty concerning honesty in the completion of test and assignments.

It is the expectation of faculty that students neither give nor receive unauthorized aid on any test, exam, or special assignment. The faculty recognizes the value of discussions by students regarding weekly homework assignments in student groups, with teaching assistants, and the faculty. However, homework assignments submitted for grading must be the product of the student submitting the work. Possession of copies of a solution manual by students is prohibited. In fact the solution manual for this course specifically states at the bottom of each original page that if you are a student using the solution manual, you are using it without permission.

1.13. Statement for students with disabilities:

Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with Disability Services for Students at 1900 Student Health Center, Campus Box 7509, 919-515-7653. For more information on NC State's policy on working with students with disabilities, please see the Academic Accommodations for Students with Disabilities at **http://www2.ncsu.edu/ncsu/provost/info/hat/current/appendix/appen_k.html**.

1.14. Statement on laboratory safety:

There are no laboratory assignments for this course; therefore, no special safety training or equipment is needed.

1.15. Statement on extra expenses:

There are no charges or fees beyond the purchase of your calculator and textbook packet which should include the textbook and property table booklet.

1.16. Statement on transportation:

No transportation is required for this course.

1.17. Statement on personal communication devices:

All personal communication devices and computers must be turned off upon entering the classroom. Substantial penalties are applied to the final grade of those students who allow their device to be activated and, thus, disrupt the class. For the class as a whole, the first disruption is free. The second disruption results in a 5-point reduction in the final average of the person that possesses that device; the third results in a 10-point reduction in the final average of the person that possesses that device; etc.

Helpful Relations

General Relations: $h = u + pv, \quad g = h - Ts, \quad du = Tds - Pdv, \quad dh = Tds + vdP$

$$C_v = \left(\frac{\partial u}{\partial T}\right)_v = \left(\frac{du}{dT}\right)_{IG}, \quad C_P = \left(\frac{\partial h}{\partial T}\right)_P = \left(\frac{dh}{dT}\right)_{IG}, \quad \eta_c = \frac{w_{c,s}}{w_{c,a}}, \quad \eta_t = \frac{w_{t,a}}{w_{t,s}}, \quad \varepsilon_{regen} = \frac{\Delta h_{comp\,gas,act}}{\Delta h_{comp\,gas,\max}}$$

Closed System First Law: $Q_{net} - W_{net} = \Delta U$

Conservation of Mass for Steady-Flow: $\sum_{inlets} \dot{m}_i = \sum_{exits} \dot{m}_e \qquad \dot{m} = \rho A\vec{V} = \frac{A\vec{V}}{v}$

First Law for Steady-Flow: $\dot{Q}_{net} + \sum_{inlets} \dot{m}_i \left(h + \frac{\vec{V}^2}{2} + gz\right)_i = \dot{W}_{net} + \sum_{exits} \dot{m}_e \left(h + \frac{\vec{V}^2}{2} + gz\right)_e$

Boundary Work: $W_b = \int_1^2 PdV$ **Steady-flow Work:** $w_{sf} = \frac{\dot{W}_{rev,sf}}{\dot{m}} = -\int_1^2 vdP$

Ideal Gas Relations: $PV = mRT, \quad \frac{P_2V_2}{T_2} = \frac{P_1V_1}{T_1}, \quad C_P = \frac{k}{k-1}R, \quad C_v = \frac{R}{k-1}, \quad k = \frac{C_P}{C_v}$

$$\Delta S = m\left[\int_{T_1}^{T_2} \frac{C_P(T)dT}{T} - R\ln\left(\frac{P_2}{P_1}\right)\right] \qquad \Delta S = m\left[\int_{T_1}^{T_2} \frac{C_v(T)dT}{T} + R\ln\left(\frac{v_2}{v_1}\right)\right]$$

Polytropic Process Relations:

general: $P_2V_2^{\,n} = P_1V_1^{\,n}, \quad W_b = \frac{P_2V_2 - P_1V_1}{1-n}, \quad n \neq 1 \quad and \quad W_b = PV\ln\left(\frac{V_2}{V_1}\right), \quad n = 1$

ideal gas: $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = \left(\frac{V_1}{V_2}\right)^{n-1}, \quad W_b = \frac{mR(T_2 - T_1)}{1-n}, \quad n \neq 1 \quad and \quad W_b = mRT\ln\left(\frac{V_2}{V_1}\right), \quad n = 1$

For ideal gases undergoing an isentropic process with constant specific heats, n = k = C_P/C_v.

Ideal Gas Mixture Relations: $y_i = \frac{mf_i / M_i}{\sum(mf_i / M_i)} \qquad mf_i = \frac{y_i M_i}{\sum(y_i M_i)}$

Psychrometric Relations:

$$\phi = \frac{P_v}{P_g} \qquad \omega = \frac{m_v}{m_a} = 0.622\frac{P_v}{P - P_v} \qquad h_a = C_{p,a}T \qquad h_v = 2501.3 + 1.82T \quad (kJ/kg) \quad T\,in\,C^\circ$$

$$h = h_a + \omega h_v$$

Chemical Equilibrium Relations: $\Delta\nu = \nu_C + \nu_D - \nu_A - \nu_B$

$$\nu_A A + \nu_B B \rightleftarrows \nu_C C + \nu_D D, \qquad K_P = \frac{P_C^{\nu_C} P_D^{\nu_D}}{P_A^{\nu_A} P_B^{\nu_B}} = \frac{N_C^{\nu_C} N_D^{\nu_D}}{N_A^{\nu_A} N_B^{\nu_B}}\left(\frac{P}{N_{total}}\right)^{\Delta\nu}$$

Ideal Gas Isentropic Compressible Flow Relations:

$$C = \sqrt{kRT} \qquad T_o = T + \frac{\vec{V}^2}{2C_P} \qquad \frac{T}{T_o} = \left(1 + \frac{k-1}{2}M^2\right)^{-1} \qquad \frac{P}{P_o} = \left(1 + \frac{k-1}{2}M^2\right)^{\frac{-k}{k-1}}$$