SAULT COLLEGE OF APPLIED ARTS AND TECHNOLOGY

SAULT STE. MARIE, ONTARIO

COURSE OUTLINE

COURSE TITLE:	APPLIED THERMODYNAMICS		
CODE NO. :	MCH304	**SEMESTER:**	SIX
PROGRAM:	MECHANICAL TECHNOLOGY		
AUTHOR:	Frank Musso/Bob Allen		
DATE:	JAN 2012	**PREVIOUS OUTLINE DATED:**	JAN 2011
APPROVED:	"Corey Meunier"		
	CHAIR		**DATE**
TOTAL CREDITS:	FIVE		
PREREQUISITE(S):	MCH256 - THERMODYNAMICS		
HOURS/WEEK:	FOUR		

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I. COURSE DESCRIPTION:

It is the goal of this course to succeed in providing the student of thermodynamics with the tools to be able to apply the principles and techniques to address practical problems such as mixtures of vapours and gases, combustion, and steam plants.

II. LEARNING OUTCOMES AND ELEMENTS OF THE PERFORMANCE:

Upon successful completion of this course, the student will demonstrate the ability to:

1. Steam Plant

Potential Elements of the Performance:

- Understanding that the Carnot Cycle is the most efficient for the conversion of heat to work
- Understanding why the Carnot Cycle is not a practical cycle especially when using steam vapour as its working fluid
- Draw the Rankine cycle on a T-s diagram and a schematic of the equipment required in this cycle
- Explain each process of the Rankine cycle and list the equipment related to the process
- Identify the equation for the steady flow energy noting which terms can be considered zero
- Identify the steady flow energy equations that apply to turbines, condensers, pumps and coilers
- Interpret the formula for Rankine efficiencies in terms of enthalpies at various points in the cycle
- Explain and apply the equations for “isentropic efficiency” of expansion processes and compression processes in terms of enthalpies
- Undrstand the equation for work ratio
- Define “specific steam consumption” and write its formula and prove the units kg and kwh
- Calculate the cycle efficiency the work ratio and specific steam consumption for a steam plant at various operating parametes for 1) The carnot cycle 2) The Rankine Cycle and daw the process on T-s diagrams as appropriate
- Define the meaning of superheat
- Explain the effect of superheating upon specific steam consumption and efficiency
- Identify the equipment required to provide the Rankine cycle with superheat and what the T-s diagram would look like
- Explain and Sketch of the Rankine cycle with superheat showing the isentropic expansion terminating very near the dome. Also the advantage of such expansion

Dryness reaction

- Interpret the formulae and procedure for determining the dryness fraction of steam on a main by use of a throttling calorimeter

Steam Condenser

- Explain the function of a steam condenser
- Identify 2 Major types of steam condensers
- Describe and sketch the shell and pulse type surface condenser
- Describe and sketch the evaporative condenser
- Describe the operating principles of an air ejecter
- Describe the operating principles of an “injector” used to feed water into a boiler

Reheat Cycle

- Explain why reheating of the steam is done
- Apply the equation of the Rankine Cycle with reheat on a T-s diagram
- Apply the equation of the Rankine Cycle with reheat in terms of enthalpies
- Calculate the new efficiencies and specific steam consumption for cycles if reheat is added and describe the effect of reheat

Regenerative Cycles

- Draw the schematic of the equipment needed to run a regenerative cycle and draw the T-s diagram for a Rankine cycle modified by regeneration
- Calculate the efficiency and specific steam consumption for a cycle modified to include a feed heater
- Sketch the schematic and the T-s diagram of a Rankine cycle with two “closed heaters”
- How economizers and preheater coils increase plant efficiency
- Explain the meaning of Higher Calorific Value, Lower Calorific Value, Boiler Capacity, Equivalent Evaporation and Boiler Efficiency
- Explain the nature and application of the boilers such as radiant type, Super Contical type, Steam generators, Electrode type
- Explain Why “heating and process” boilers have higher efficiency than “power” boilers
- Define and sketch back pressure turbines, pass-out back pressure turbines, back pressure and exhaust turbines, and mixed pressure turbines

2. *Mixtures*

Potential Elements of the Performance:

Gibbs-Dalton Law

- Define Dalton's law relating partial pressure of gas constituents to pressure of a mixture
- Identify the formulae relating to Total mass to constituent masses and Total pressure to constituent pressures
- Define "gravimetric" and "volumetric" analysis
- State the analysis of "atmospheric air" by a) volume and b)air
- Determine the partial pressure of constituents in mixtures
- Explain and apply Gibbs-Dalton law which relates to internal energy, enthalpy, and entropy of gas mixture
- Apply the formulae arising out of Gibbs-Dalton Law

Volumetric Analysis of gas mixtures

- Explain and apply the formula and the precise meaning of the equation which relates the volumes of individual constituents to the volume of a mixture of gases
- Understand and apply the formula which relates moles of constituent gases in a mixture to the moles of mixture
- Identify the equations relating moles to kilograms, the apparent molecular weight to specific weight and the apparent gas constant to the specific gas constant
- Calculate the gas constant for mixtures
- Apply equations of ratios relating pressures, moles and volumes of mixtures and constituents
- Calculate partial pressures, volumetric analysis'
- Calculate total mass and mass of constituents, percentage of mass of constituents, apparent molecular weight of mixtures

Specific Heats of a gas mixture

- From the Gibbs-Dalton law relating internal energies of constituents and mixtures, the relationship for the specific heat of constituents and mixtures will be developed
- Explain similar Equations relating Cp and R
- Calculate work and heat flow during expansion/compression of a mixtures
- Calculate the change in entropy of a mixture and draw the T-s diagram

Molar Heats of constituents and mixtures

- Identify and apply the equations for molar heats of constituents and mixtures
- Identify and apply the equations relating molar heats to specific heats
- Calculate the molar heats and specific heats

Adiabatic mixing of perfect gases

- Understand and apply the formulae relating the temperature of a mixture to the temperatures of the constituents for non flow processes and steady flow processes
- Calculate the temperature and pressure for adiabatic mixing

Gas and Vapour mixtures

- Understand that the Gibbs-Dalton Law states that each constituent behaves as it alone occupied the whole vessel at the temperature of the vessel
- Explain what happens to liquid if various quantities of it are introduced into an evacuated vessel, until the vapour so formed finally assumes the pressure corresponding to its saturation pressure
- Complete various problems surrounding gas and vapour

3. Psychometry

Potential Elements of the Performance:

Psychometry

- Define psychometry
- Understand that at low vapour pressures (below 1 atmosphere), the vapour can be considered to act as a perfect gas, and the properties of the mixture obey the Gibbs-Dalton law
- Apply the formulae for the a) the relationship between total pressure, partial pressure of dry air and partial pressure of superheated vapour b) the relationship defining specific humidity c) the relationship defining relative humidity d) the relationship defining perant saturations
- Define “dew point” of a psychometric mixture and specific humidity
- Solve problems surrounding dew point, relative humidity, saturation

Measurement of relative humidity

- Sketch of a psychometric chart labelling every family of lines
- Demonstrate the use of the sling psychometer. Demonstrate the psychometric chart; how the relative humidity, percent saturation, dew point, temperature and specific humidity are determined
- Define “air conditioning”
- Demonstrate the process for air conditioning “summer” air on a T-s diagram and on a psychometric chart
- Interpret Drawing of a line diagram of a typical air conditioning plant showing circulating fan, eliminator,

heater, washer, refrigerator, pilers and preliminary heaters
- Identify and apply the fan work equation in terms of mass flow of air and vapour and temperature
- Solve problems surrounding fan work addition, heat input, coolers, condition of air and use the psychometric chart

4. Heat Transfer

Potential Elements of the Performance:

Heat Transfer
- Apply methods by which heat transfer occurs

Fourier's Law of conductiom
- Apply Fourier's law and the corresponding formula
- Complete problems using Fourier's law to determine heat transfer and other variables

Newton's Law of Cooling
- Apply Newton's law of cooling and the corresponding formula
- The equation for 1/V where V is the overall heat transfer for co-efficient, using the heat transfer coefficient, as it arises out of Newton's law and K the thermal conductivity as it arises out of Fourier's law
- The equation relating the per-unit heat transfer to the overall heat transfer co-efficient and T
- Complete problems using Newton's law to determine heat transfer and other variables

The Composite Wall
- Define the term "Thermal Resistance" in terms of the heat transfer co-efficient
- Complete problems surrounding the composite wall

Heat flow through a cylinder and a sphere
- Apply the formula and explanation of all the terms in the formula relating heat loss to the change in temperature
- Apply the formula for heat transfer through a spherical tank and an explanation for each term
- Solve appropriate problems

Heat Exchange
- Define the terms "recuperator" and "regenerator"
- Make sketches of parallel flow and counter flow recuperators and draw temperature length diagrams
- Apply the equations for counter flow heat transfer and for parallel flow, and the meanings of the variables in the equation. Also the effects of these equations when one of the fluids is a wet vapour or a boiled liquid
- Complete problems surrounding parallel and counter flow

III. TOPICS:

1. STEAM PLANT
2. MIXTURES
3. PSYCHOMETRY
4. HEAT TRANSFER

IV. REQUIRED RESOURCES/TEXTS/MATERIALS:

Eastop, T. D., Thermodynamics for Engineering Technologists, 4th Edition, Harlow, Eng. : Longman Scientific & Technical*, ISBN* 9780582305359 0582305357

V. EVALUATION PROCESS/GRADING SYSTEM:

Type of Grading	Duration	Mark Breakdown	Topics
Term Test 1	**2.0 hours**	**20%**	**Steam Plant**
Term Test 2	**2.0 hours**	**20%**	**Mixtures**
Term Test 3	**2.0 hours**	**20%**	**Psychometry**
Final Exam	**2.0 hours**	**20%**	**Heat Transfer**
Quizzes	**0.5 hours**	**5% x 4 = 20%**	**All material**

The following semester grades will be assigned to students:

Grade	**Definition**	*Grade Point Equivalent*
A+	90 – 100%	4.00
A	80 – 89%	
B	70 - 79%	3.00
C	60 - 69%	2.00
D	50 – 59%	1.00
F (Fail)	49% and below	0.00

CR (Credit)	Credit for diploma requirements has been awarded.
S	Satisfactory achievement in field /clinical placement or non-graded subject area.
U	Unsatisfactory achievement in field/clinical placement or non-graded subject area.
X	A temporary grade limited to situations with extenuating circumstances giving a student additional time to complete the requirements for a course.

NR	Grade not reported to Registrar's office.
W	Student has withdrawn from the course without academic penalty.

VI. SPECIAL NOTES:

Attendance:
Sault College is committed to student success. There is a direct correlation between academic performance and class attendance; therefore, for the benefit of all its constituents, all students are encouraged to attend all of their scheduled learning and evaluation sessions. This implies arriving on time and remaining for the duration of the scheduled session.

It is the departmental policy that once the classroom door has been closed, the learning process has begun. Late arrivers will not be granted admission to the room.

VII. COURSE OUTLINE ADDENDUM:

The provisions contained in the addendum located on the portal form part of this course outline.

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SAULT COLLEGE

MECHANICAL ENGINEERING TECHNOLOGY - 4043

Applied Thermodynamics – MCH304

DISTRIBUTION OF HOURS

Sequence/Type	Topics	# of Hours
Lecture	**Steam Plant**	14
Term Test	Term Test 1 – **Steam Plant**	2
Lecture	**Mixtures**	14
Term Test	Term Test 2 – **Mixtures**	2
Lecture	**Psychometry**	14
Term Test	Term Test 3 – **Psychometry**	2
Lecture	**Heat Exchange**	14
Final Exam	**Final Exam** – includes all course material	2
	Sub-Totals	
	Lectures	56
	Testing	8
	TOTAL HOURS	**64**

SAULT COLLEGE

MECHANICAL ENGINEERING TECHNOLOGY - 4043

Applied Thermodynamics – MCH304

COURSE PLAN – Based on the text Applied Thermodynamics for Engineering Technologists, 4th Edition, Eastop/McConkey)

Week/Hours	Topic/Chapter	Concepts Covered
Week 1/2/3/4 (14 hours Lecture and 2 hours Term Test)	**Topic 1: Steam Plant** Rankine Cycle, Dryness Reaction, Steam Condenser, Reheat Cycle, Regenerative Cycles (176 to 217)	**<u>Rankine Cycle</u>** 1. Understanding that the Carnot Cycle is the most efficient for the conversion of heat to work 2. Understanding why the Carnot Cycle is not a practical cycle especially when using steam vapour as its working fluid 3. Draw the Rankine cycle on a T-s diagram and a schematic of the equipment required in this cycle 4. Explain each process of the Rankine cycle and list the equipment related to the process 5. The equation for the steady flow energy noting which terms can be considered zero 6. The steady flow energy equations that apply to turbines, condensers, pumps and coilers 7. The formula for Rankine efficiencies in terms of enthalpies at various points in the cycle 8. The equations for “isentropic efficiency” of expansion processes and compression processes in terms of enthalpies 9. The equation for work ratio 10. Define “specific steam consumption” and write its formula and prove the units kg and kwh 11. Calculate the cycle efficiency the work ratio and specific steam consumption for a steam plant at various operating parametes for 1) The carnot cycle 2) The Rankine Cycle and daw the process on T-s diagrams as appropriate 12. The meaning of superheat 13. The effect of superheating upon specific steam consumption and efficiency 14. The equipment required to provide the Rankine cycle with superheat and what the T-s diagram would look like 15. A sketch of the Rankine cycle with superheat showing the isentropic expansion terminating very near the dome. Also the advantage of such expansion **<u>Dryness reaction</u>** 16. The formulae and procedure for determining the dryness fraction of steam on a main by use of a throttling calorimeter **<u>Steam Condenser</u>** 17. The function of a steam condenser 18. 2 Major types of steam condensers

		19. Describe and sketch the shell and pulse type surface condenser 20. Describe and sketch the evaporative condenser 21. Describe the operating principles of an air ejecter 22. Describe the operating principles of an "injector" used to feed water into a boiler **Reheat Cycle** 23. Why reheating of the steam is done 24. The equation of the Rankine Cycle with reheat on a T-s diagram 25. The equation of the Rankine Cycle with reheat in terms of enthalpies 26. Calculating the new efficiencies and specific steam consumption for cycles if reheat is added and describe the effect of reheat **Regenerative Cycles** 27. Draw the schematic of the equipment needed to run a regenerative cycle and draw the T-s diagram for a Rankine cycle modified by regeneration 28. Calculating the efficiency and specific steam consumption for a cycle modified to include a feed heater 29. Sketch the schematic and the T-s diagram of a Rankine cycle with two "closed heaters" 30. How economizers and preheater coils increase plant efficiency 31. The meaning of Higher Calorific Value, Lower Calorific Value, Boiler Capacity, Equivalent Evaporation and Boiler Efficiency 32. The nature and application of the boilers such as radiant type, Super Contical type, Steam generators, Electrode type 33. Why "heating and process" boilers have higher efficiency than "power" boilers 34. Define and sketch back pressure turbines, pass-out back pressure turbines, back pressure and exhaust turbines, and mixed pressure turbines
Week 5/6/7/8 (14 Hours Lecture and 2 hour Term Test)	**Topic 2: Mixtures** Gibbs-Dalton Law, Volumetric Analysis of gas mixtures, Specific heats of gas mixtures, Molar heats of Constituents and Mixtures, Adiabatic Mixtures of prefect gases, Gas and Vapour Mixtures (482 to 512)	**Gibbs-Dalton Law** 1. Dalton's law relating partial pressure of gas constituents to pressure of a mixture 2. The formulae relating to Total mass to constituent masses and Total pressure to constituent pressures 3. Define "gravimetric" and "volumetric" analysis 4. State the analysis of "atmospheric air" by a) volume and b)air 5. Determine the partial pressure of constituents in mixtures 6. Gibbs-Dalton law which relates to internal energy, enthalpy, and entropy of gas mixture 7. The formulae arising out of Gibbs-Dalton Law **Volumetric Analysis of gas mixtures** 8. The formula and the precise meaning of the equation which relates the volumes of individual constituents to the volume of a mixture of gases 9. The formula which relates moles of constituent gases in a

		mixture to the moles of mixture 10. The equations relating moles to kilograms, the apparent molecular weight to specific weight and the apparent gas constant to the specific gas constant 11. Calculating the gas constant for mixtures 12. Equations of ratios relating pressures, moles and volumes of mixtures and constituents 13. Calculating partial pressures, volumetric analysis' 14. Calculating total mass and mass of constituents, percentage of mass of constituents, apparent molecular weight of mixtures **Specific Heats of a gas mixture** 15. From the Gibbs-Dalton law relating internal energies of constituents and mixtures, the relationship for the specific heat of constituents and mixtures will be developed 16. Similar Equations relating Cp and R 17. Calculating work and heat flow during expansion/compression of a mixtures 18. Calculate the change in entropy of a mixture and draw the T-s diagram **Molar Heats of constituents and mixtures** 19. The equations for molar heats of constituents and mixtures 20. The equations relating molar heats to specific heats 21. Calculating the molar heats and specific heats **Adiabatic mixing of perfect gases** 22. The formulae relating the temperature of a mixture to the temperatures of the constituents for non flow processes and steady flow processes 23. Calculating the temperature and pressure for adiabatic mixing **Gas and Vapour mixtures** 24. Understanding that the Gibbs-Dalton Law states that each constituent behaves as it alone occupied the whole vessel at the temperature of the vessel 25. What happens to liquid if various quantities of it are introduced into an evacuated vessel, until the vapour so formed finally assumes the pressure corresponding to its saturation pressure 26. Complete various problems surrounding gas and vapour
Week 9/10/11/12 (14 Hours Lecture and 2 hour Term Test)	**Topic 3: Psychometry** Psychometry, relative humidity, (517 to 545)	**Psychometry** 1. Define psychometry 2. Understand that at low vapour pressures (below 1 atmosphere), the vapour can be considered to act as a perfect gas, and the properties of the mixture obey the Gibbs-Dalton law 3. The formulae for the a) the relationship between total pressure, partial pressure of dry air and partial pressure of superheated vapour b) the relationship defining specific humidity c) the relationship defining relative humidity d) the relationship

		defining perant saturations 4. Define "dew point" of a psychometric mixture and specific humidity 5. Problems surrounding dew point, relative humidity, saturation **Measurement of relative humidity** 6. Sketch of a psychometric chart labelling every family of lines 7. Demonstrate the use of the sling psychometer. Demonstrate the psychometric chart; how the relative humidity, percent saturation, dew point, temperature and specific humidity are determined 8. Define "air conditioning" 9. Demonstrate the process for air conditioning "summer" air on a T-s diagram and on a psychometric chart 10. Drawing of a line diagram of a typical air conditioning plant showing circulating fan, eliminator, heater, washer, refrigerator, pilers and preliminary heaters 11. The fan work equation in terms of mass flow of air and vapour and temperature 12. Solve problems surrounding fan work addition, heat input, coolers, condition of air and use the psychometric chart
Week 13/14/15/16 (14 Hour Lecture and 2 hour final exam)	**Topic 4: Heat Transfer** Fourier's law of conduction, Newton's law of cooling, The composite wall, heat flow through a cylinder and sphere, Heat exchange (671 to 794)	**Heat Transfer** 1. Methods by which heat transfer occurs **Fourier's Law of conduction** 2. Fourier's law and the corresponding formula 3. Complete problems using Fourier's law to determine heat transfer and other variables **Newton's Law of Cooling** 4. Newton's law of cooling and the corresponding formula 5. The equation for 1/V where V is the overall heat transfer for co-efficient, using the heat transfer coefficient, as it arises out of Newton's law and K the thermal conductivity as it arises out of Fourier's law 6. The equation relating the per-unit heat transfer to the overall heat transfer co-efficient and T 7. Complete problems using Newton's law to determine heat transfer and other variables **The Composite Wall** 8. Define the term "Thermal Resistance" in terms of the heat transfer co-efficient 9. Complete problems surrounding the composite wall Heat flow through a cylinder and a sphere 10. The formula and explanation of all the terms in the formula relating heat loss to the change in temperature 11. The formula for heat transfer through a spherical tank and an

		explanation for each term 12. Solve appropriate problems **Heat Exchange** 13. Define the terms "recuperator" and "regenerator" 14. Make sketches of parallel flow and counter flow recuperators and draw temperature length diagrams 15. The equations for counter flow heat transfer and for parallel flow, and the meanings of the variables in the equation. Also the effects of these equations when one of the fluids is a wet vapour or a boiled liquid 16. Complete problems surrounding parallel and counter flow