SAULT COLLEGE OF APPLIED ARTS AND TECHNOLOGY

SAULT STE. MARIE, ONTARIO

COURSE OUTLINE

COURSE TITLE:	MECHANICS OF MACHINES II		
CODE NO. :	MCH205	**SEMESTER:**	SIX
PROGRAM:	MECHANICAL ENGINEERING TECHNOLOGY		
AUTHOR:	KEVIN SLOSS		
DATE:	January 2014	**PREVIOUS OUTLINE DATED:**	November 2012
APPROVED:	*"Corey Meunier"* **CHAIR**		_____ **DATE**
TOTAL CREDITS:	FOUR		
PREREQUISITE(S):	MCH110 – APPLIED MECHANICS MTH551 – CALCULUS I FOR TECHNOLOGY		
HOURS/WEEK:	FOUR		

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I. COURSE DESCRIPTION:

This subject includes the study of the following: Static forces in machines, review of dynamics, inertia force and analysis of translation, rotation, and plane motion, balancing rotating and reciprocating masses, whirling of shafts.

II. LEARNING OUTCOMES AND ELEMENTS OF THE PERFORMANCE:

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

1. Static Forces in Machines

Potential Elements of the Performance:

- Identify and explain the transmission of forces in a machine
- Compare and explain static force analysis and dynamic force analysis
- Effectively draw free body diagrams of each link of a machine to arrive at the force analysis
- Utilizing the equations of equilibrium to calculate the forces in a machine
- Define a two force member
- Demonstrate the ability to isolate each link of a free body diagram in order to solve systems that have more than 3 unknowns
- Interpret and calculate the force analysis on a slider crank mechanism
- Interpret and calculate the force analysis on a four bar linkage
- Interpret and calculate the force analysis on a shaper mechanism

2. Inertia Forces in Machines

Potential Elements of the Performance:

- Define inertia forces
- Explain why it is important to consider inertia forces in a machine and site examples of when inertia force are required for design and when they can be neglected
- Define complete force analysis
- Identify and utilize the equations of motion
- Define the inertia force and the inertia torque
- Explain D'Alembert's principle and why it is important in solving dynamic systems
- Interpret and solve for inertia forces on a four bar linkage

- Define shaking force and explain why it is important
- Interpret and solve for both the static forces and inertia forces for a slider crank mechanism
- Interpret and solve for both the static forces and inertia forces for a shaper mechanism
- Interpret and solve for both the static forces and inertia forces for a cam mechanism
- Interpret and solve for both the static forces and inertia forces for a planetary gear train
- Determine the center of mass and moments of inertia of a system
- Identify what the acceleration of a body under the influence of a system of external forces in dependent on
- Define a dynamically equivalent system and utilize this concept to solve for a dynamic system
- Explain and utilize the concept of the center of percussion

3. Flywheels

Potential Elements of the Performance:

- Explain what a flywheel is and what it is used for
- Explain the two types of machines for which a flywheel is beneficial
- Define the coefficient of fluctuation
- Determine the mass of a flywheel for a given system
- Interpret the effects of a flywheel for an internal combustion engine through the use of a plot of output torque versus crank position

4. Balancing Rotating Masses

Potential Elements of the Performance:

- Explain why balancing of rotating masses is required
- Identify equations for single rotating masses
- Define dynamic balance and static balance
- Explain dynamic balancing and appropriate equations for several rotating masses in the same transverse plane
- Explain dynamic balancing and appropriate equations for several rotating masses lying in several transverse planes
- Explain how unbalanced machines at high speed are at greater risk than low speed machines
- Understand how to balance various machines utilizing methods different types of balancing methods
- Explain what a “balancing head” is and how it is used

5. Balancing Reciprocating Masses

Potential Elements of the Performance:

- Demonstrate the ability to reduce or eliminate shaking forces and shaking couple present for a four bar linkage
- Utilize the concept of dynamically equivalent systems when reducing or eliminating shaking forces and shaking couple
- Explain additional methods of reducing shaking couple in mechanisms
- Demonstrate the ability to reduce or eliminate shaking forces and shaking couple present for a slider crank mechanism
- Explain primary inertia force and secondary inertia force
- Define counterbalance and counterbalance force
- Demonstrate the ability to reduce or eliminate shaking forces and shaking couple present for multi-cylinder in-line engines
- Define and explain firing order
- Interpret diagrams related to 2 and 4 stroke engines
- Determine the angle that the crankshaft rotates from the beginning of one power impulse to the next
- Apply equations for balancing of an in-line engine and construct appropriate tables to explain
- Explain what a Lanchester balancer is
- Demonstrate how the vector method is utilized to analyzing balance of multi-cylinder engines
- Understand and explain balancing of V-type and opposed engines

6. Gyroscopic Effects

Potential Elements of the Performance:

- Define the gyroscopic effect
- Identify important applications of the gyroscopic effect
- Understand and utilize the right hand rule
- Explain the axis of precession, the angle of precession and the angular velocity of precession
- Explain and calculate gyroscopic torque and gyroscopic couple

7. Critical Whirling Speeds and Torsional Vibrations of Shafts

Potential Elements of the Performance:

- Define and explain critical whirling speed
- Demonstrate the ability to determine the critical speed for a shaft with one disk
- Explain what is meant by fundamental critical speed

- Utilize the Rayleigh's method to determine the fundamental natural frequency of transverse vibration for a shaft with a number of disks
- Determine the critical speed for a shaft supporting a uniformly distributed mass or a shaft which supports no masses except its own
- Utilize Dunkerley's method to determine the critical speed of a shaft having any number of disks of masses and the mass of the shaft is to be included
- Determine critical speeds of shafts with variable diameters
- Explain other factors effecting critical speeds such as bearing deflection, gyroscopic effect, dampening, fits for the hub of an impellor
- Explain torsional vibrations
- Determine the torsional vibration for shaft with single disk and a shaft with two disks
- Demonstrate the ability to determine the torsional spring constant for a stepped shaft
- Determine the natural frequency of torsional vibration for a geared system

III. TOPICS:

1. Static Forces of Machines
2. Inertia Forces in Machines
3. Flywheels
4. Balancing Rotating Masses
5. Balancing Reciprocating Masses
6. Gyroscopic Effects
7. Critical Whirling Speeds and Torsional Vibration of Shafts

IV. REQUIRED RESOURCES/TEXTS/MATERIALS:

Martin, George H, Kinematics and Dynamics of Machines 2nd Edition, Waveland Press Inc., ISBN 1-57766-250-4

V. EVALUATION PROCESS/GRADING SYSTEM:

Type of Grading	Duration	Mark Breakdown	Topics
Mid Term	**2.0 hours**	**30%**	**Review of chapters 16, 17 & 18 (Static Forces in Machines, Inertia Forces in Machines, Flywheels)**
Final Exam	**2.0 hours**	**30%**	**Review of chapters 19, 20, 21 & 22 (Balancing Rotating & Reciprocating Machines, Gyroscopic Effects, Torsional Vibration of Shafts)**
Assignments (weekly)		**40%**	**All Course 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.

VII. COURSE OUTLINE ADDENDUM:

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

APPENDIX

SAULT COLLEGE

MECHANICAL ENGINEERING TECHNOLOGY - 4043

Mechanics of Machines II – MCH205

DISTRIBUTION OF HOURS

Sequence/Type	Topics	# of Hours
Lecture	Static Forces of Machines	10
Lecture	Inertia Forces in Machines	10
Lecture	Flywheels	4
Test	Review Class and Term 1 Test	4
Lecture	Balancing Rotating Masses	8
Lecture	Balancing Reciprocating Masses	8
Lecture	Gyroscopic Effects	4
Lecture	Critical Whirling Speeds and Torsional Vibration of Shafts	8
Test	Review and Final Exam	4
	Sub-Totals	
	Lectures	56
	Testing	4
	TOTAL HOURS	**60**

MECHANICAL ENGINEERING TECHNOLOGY - 4043
Mechanics of Machines II – MCH205

COURSE PLAN – Based on the text Kinematics and Dynamics of Machines, 2nd Edition, by Martin, George H.)

Week/Hours	Topic/Chapter	Concepts Covered
Week 1/2/3 (10 Hour s of Lecture)	**Chapter 16 "Static Forces in Machines" in Kinematics and Dynamics of Machines**	1. Compare and explain static force analysis and dynamic force analysis 2. Identify and explain the transmission of forces in a machine 3. Effectively draw free body diagrams of each link of a machine to arrive at the force analysis 4. Utilizing the equations of equilibrium to calculate the forces in a machine 5. Define a two force member 6. Demonstrate the ability to isolate each link of a free body diagram in order to solve systems that have more than 3 unknowns 7. Interpret and calculate the force analysis on a slider crank mechanism 8. Interpret and calculate the force analysis on a four bar linkage 9. Interpret and calculate the force analysis on a shaper mechanism
Week 3/4/5 (10 Hours Lecture)	**Chapter 17 "Inertia Forces in Machines" in Kinematics and Dynamics of Machines**	1. Define inertia forces 2. Explain why it is important to consider inertia forces in a machine and site examples of when inertia force are required for design and when they can be neglected 3. Define complete force analysis 4. Identify and utilize the equations of motion 5. Define the inertia force and the inertia torque 6. Explain D'Alembert's principle and why it is important in solving dynamic systems 7. Interpret and solve for inertia forces on a four bar linkage 8. Define shaking force and explain why it is important 9. Interpret and solve for both the static forces and inertia forces for a slider crank mechanism 10. Interpret and solve for both the static forces and

		inertia forces for a shaper mechanism 11. Interpret and solve for both the static forces and inertia forces for a cam mechanism 12. Interpret and solve for both the static forces and inertia forces for a planetary gear train 13. Determine the center of mass and moments of inertia of a system 14. Identify what the acceleration of a body under the influence of a system of external forces in dependent on 15. Define a dynamically equivalent system and utilize this concept to solve for a dynamic system 16. Explain and utilize the concept of the center of percussion
Week 6 (4 Hours of Lecture)	**Chapter 18 "Flywheels" in Kinematics and Dynamics of Machines**	1. Explain what a flywheel is and what it is used for 2. Explain the two types of machines for which a flywheel is beneficial 3. Define the coefficient of fluctuation 4. Determine the mass of a flywheel for a given system 5. Interpret the effects of a flywheel for an internal combustion engine through the use of a plot of output torque versus crank position
Week 7 (2 Hours of Review & 2 Hour Test)	**Review and Term Test 1**	
Week 8/9 (8 Hours of Lecture)	**Chapter 19 "Balancing Rotating Masses" in Kinematics and Dynamics of Machines**	1. Explain why balancing of rotating masses is required 2. Identify equations for single rotating masses 3. Define dynamic balance and static balance 4. Explain dynamic balancing and appropriate equations for several rotating masses in the same transverse plane 5. Explain dynamic balancing and appropriate equations for several rotating masses lying in several transverse planes 6. Explain how unbalanced machines at high speed are at greater risk than low speed machines 7. Understand how to balance various machines utilizing methods different types of balancing methods 8. Explain what a "balancing head" is and how it is used

Week 10/11 (8 Hours of Lecture)	**Chapter 10 "Balancing Reciprocating Masses" in Kinematics and Dynamics of Machines**	1. Demonstrate the ability to reduce or eliminate shaking forces and shaking couple present for a four bar linkage 2. Utilize the concept of dynamically equivalent systems when reducing or eliminating shaking forces and shaking couple 3. Explain additional methods of reducing shaking couple in mechanisms 4. Demonstrate the ability to reduce or eliminate shaking forces and shaking couple present for a slider crank mechanism 5. Explain primary inertia force and secondary inertia force 6. Define counterbalance and counterbalance force 7. Demonstrate the ability to reduce or eliminate shaking forces and shaking couple present for multi-cylinder in-line engines 8. Define and explain firing order 9. Interpret diagrams related to 2 and 4 stroke engines 10. Determine the angle that the crankshaft rotates from the beginning of one power impulse to the next 11. Apply equations for balancing of an in-line engine and construct appropriate tables to explain 12. Explain what a Lanchester balancer is 13. Demonstrate how the vector method is utilized to analyzing balance of multi-cylinder engines 14. Understand and explain balancing of V-type and opposed engines
Week 12 (4 Hours of Lecture)	**Chapter 21 "Gyroscopic Effects" in Kinematics and Dynamics of Machines "Gears"**	1. Define the gyroscopic effect 2. Identify important applications of the gyroscopic effect 3. Understand and utilize the right hand rule 4. Explain the axis of precession, the angle of precession and the angular velocity of precession 5. Explain and calculate gyroscopic torque and gyroscopic couple
Week 13 (8 Hours of Lecture)	**Chapter 22 "Critical Whirling Speeds and Torsional Vibrations of Shafts" in Kinematics and Dynamics of**	1. Define and explain critical whirling speed 2. Demonstrate the ability to determine the critical speed for a shaft with one disk 3. Explain what is meant by fundamental critical speed 4. Utilize the Rayleigh's method to determine the fundamental natural frequency of transverse

	Machines	vibration for a shaft with a number of disks 5. Determine the critical speed for a shaft supporting a uniformly distributed mass or a shaft which supports no masses except its own 6. Utilize Dunkerley's method to determine the critical speed of a shaft having any number of disks of masses and the mass of the shaft is to be included 7. Determine critical speeds of shafts with variable diameters 8. Explain other factors effecting critical speeds such as bearing deflection, gyroscopic effect, dampening, fits for the hub of an impellor 9. Explain torsional vibrations 10. Determine the torsional vibration for shaft with single disk and a shaft with two disks 11. Demonstrate the ability to determine the torsional spring constant for a stepped shaft 12. Determine the natural frequency of torsional vibration for a geared system
Week 14 (2 Hours of Review & 2 Hour Test)	**Review and Term Test 2**	