A Single Computer Based Data Acquisition and Control System
For a 4 Year MET Program

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Abstract

Under support from an Instrumentation and Laboratory Improvement grant from the National Science Foundation (DUE # 9851104), the laboratory portion of the Mechanical Engineering Technology (MET) program at Ward College is being revised. Analog signal conditioning, measurement and data storage is now being accomplished using the data acquisition and control package LabView, by National Instruments. This powerful tool has been implemented throughout the curriculum, ranging from introduction as freshmen with simple mechanical measurements and data storage, to culmination with a senior design project that typically involves control and automation, achieved using the LabView system. A primary focus of the paper will be the philosophy of the introduction of computer software packages in a four year engineering technology curriculum, and how they can be used to reinforce key concepts found in MET. The paper will also detail some of the introductory and advanced laboratories that have been developed, the specific hardware that was purchased, the results of student lab reports and assessment of student outcomes.

I.   Description of the Mechanical Engineering Technology Program

The four year program attempts to orient graduates towards problem solving ability using classical theoretical methods coupled with computer analysis packages aimed at practical application. These traits have been shown to be in high demand by industry.[1] The first year emphasizes basic mathematical, communication and experimental skills. A strong foundation of strength of materials is then established, leading to advance capabilities in the machine design sequence. Also, in the upper division the various specialties of mechanical engineering are investigated, leading up to the senior design project. A listing of the curriculum is shown in Appendix A. A major advantage of the program is the additional three hours of laboratory time assigned to most MET courses. This extra contact time allows for numerous experiments that reinforce the theory presented in class, which fits in well with reported successes of experimental learning[2] and permit the integration of numerous software packages which are a necessary part of any program in technology or engineering.[3] Graduates have typically found jobs as mechanical engineers in all varieties of industries, due to their integrated background in fundamental design skills coupled with the latest computer analysis and control methods. As can be seen from Appendix A, there is a thorough coverage of mathematics, physics, and technical communication as well as mechanical engineering theory and application. The program was initiated in 1995 and has grown from 8 to 46 majors as of Fall 2000.

II.   Description of the Software Package Integration

With today's rapidly changing computing environments, it made sense to select the windows based operating system. Most students enter the college with some familiarity of windows, and industry has generally adopted this graphical user interface (GUI). The chronological integration of software into each semester is now presented.

In the first semester the Microsoft Office Software Suite is introduced. WORD, PowerPOINT and EXCEL are all required in the freshmen course MET 116 - Manufacturing Processes. First, statistical analysis of data measurements is conducted using EXCEL and then a presentation and report on an emerging development in manufacturing is required.

In the second semester, the data acquisition capabilities of the computer are introduced. In the course MET 123 - Applied Materials Technology, students get their first exposure to LabView. Several weeks are spent covering the basics of LabView and then several laboratories using strain gauges and displacement measuring devices are conducted. The use of virtual instruments has been shown be an effective method of both teaching the theory of the device and accomplishing actual measurements[4] and this class has been no exception. Students leave with an understanding of data acquisition and, most importantly, they begin to develop an understanding of the link between equations and the physical processes which they can describe. One of these laboratories is explained in greater detail later in this paper.

In the fourth semester, students take the traditional Strength of Materials (MET 243) course in which various types of material behavioral tests are conducted. We are presently integrating LabView into this laboratory. However, students are again required to use the curve-fitting capabilities of EXCEL to find material constants in all laboratory exercises. Formal lab reports are then required which integrate the Microsoft Office software package.

In the fifth and sixth semesters, the students take Machine Design I and II – MET 363 and MET 483. These courses attempt to unify many of the diverse subjects that they have had in the lower division and are the subject of a previous paper.[5] In order to aid in the computation of the many equations that are encountered, students are introduced to the mathematics package MathCAD. They also gain experience using the finite element package ANSYS to analyze basic structural problems. These software packages are used to study the relationships between various parameters in a variety of mechanical applications such as shaft, gear train and bearing design and selection.

Also in the sixth semester, students take Industrial Instrumentation – EL 353, which covers all types of transducers including thermocouples, load cells, pressure gauges,etc. LabView is currently being integrated into this course as well.

In the seventh semester, students take MET 484 - Automation Systems, which utilizes LabView for both data acquisition and control. Several virtual instruments are created and used to control various experimental processes. They also take Fundamentals of Heat Transfer in which thermocouples are used for both steady-state and transient heat transfer measurements. Here

again, some laboratories have already been developed which utilize the LabView system and more are under development.

Finally, the eighth semester senior design course typically involves a competition in which students competitively design some process. They utilize LabView for the control of the process. This year, an automated bottle filling operation was required in response to an industrial sponsorship.

The key to the success of the curriculum is the consistent presentation of problem solving techniques and the use of the same software packages. The students gain real experience on all of the software packages mentioned above due to the numerous laboratory exercises. The courses and the software used in each is summarized in Table 1.

Table I - Listing of Courses and Software in the MET Program

Semester 1: MET 116 - Manufacturing	Semester 2: MET 123 - App. Exp. Anal.
WORD - report EXCEL - statistic PowerPoint - presentation	LabVIEW - data acquisition EXCEL - plotting
Semester 3: MET 236 - Statics	Semester 4: MET 243 - Strength of Materials
	LabVIEW - data acquisition EXCEL - curve fitting of data WORD - report preparation
Semester 5: MET 363 - Machine Design I	Semester 6: MET 483 - Machine Design II
MathCAD - problem solution WORD - report preparation ANSYS FE - stress analysis	MathCAD - problem solution WORD - report preparation ANSYS FE- stress analysis
Semester 7: MET 484 - Automation Systems	Semester 8: MET 482 - Senior Design Project
LabVIEW - Control and automation	LabVIEW - control WORD - documentation/reports PowerPoint - presentation

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One of the common threads which runs through all of mechanical engineering is the need to measure various physical parameters such as temperature, pressure, etc. LabView has proved

to be a good choice for conditioning and acquiring data from a variety of devices, several of which are listed in Table 2.

Table 2 – Signal Conditioning Required for Various Transducers		
Parameter	Transducer	Signal Output/ Conditioning
Temperature	T.C, RTD, Thermistor	T.C. Reader, voltage output
Displacement/ Rotation	LVDT's, RVDT's DCDT's	AC or DC power supplies, voltage output
Pressure/Flow Rate	Strain Gauge Based	Wheatstone Bridge
Velocity	Velicometers, Laser	
Mechanical Strain	Strain gauges, Extensometers	Wheatstone Bridge amplifiers, voltage output
Vibration	Accelerometers, Vibrometers, Laser	High frequency power supplies, "peak picking", FFT's

At the heart of the MET program is the laboratory which has been outfitted thanks to the NSF-ILI grant. The laboratory can accommodate 16 students, with complete data acquisition systems including a Pentium based PC.   The full-development version of LabView 5.2.1 is loaded on all machines and the following hardware has been attached to each computer:

1.   Computer Board: PCI-6024, Low-Cost Multifinction I/O Board 200 K/s, 16 Single Ended Inputs, 2 analog outputs, 8 digital outputs

2.   External Chassis: SC-2345 Shielded Carrier with SCC-PWR01 power option, accepts 8 conditioning modules, and support 2 analog and 2 digital outputs

3.   Various Plug in Conditioning Modules, currently each station has been equipped with:

(2)   SCC-TC02 Thermocouple input modules with screw terminals
                - accepts all types of thermocouples with cold junction

(2)   SCC-FT01 Feed-through modules
               -accepts +/- 10 volts direct input

(2)   SCC-SG01 Two channel, quarter bridge strain gauge modules
               -provides Wheatstone Bridge completion for 120 gauges

A wide variety modules can be plugged into the SC2345 chassis and can also support in-line filtering modules. The SC 2345 also offers 2 digital and 2 analog outputs, so process control can also be achieved. The strain relief clamps also prevent damage when a wire is accidently pulled. The external hardware is shown in figure 1.
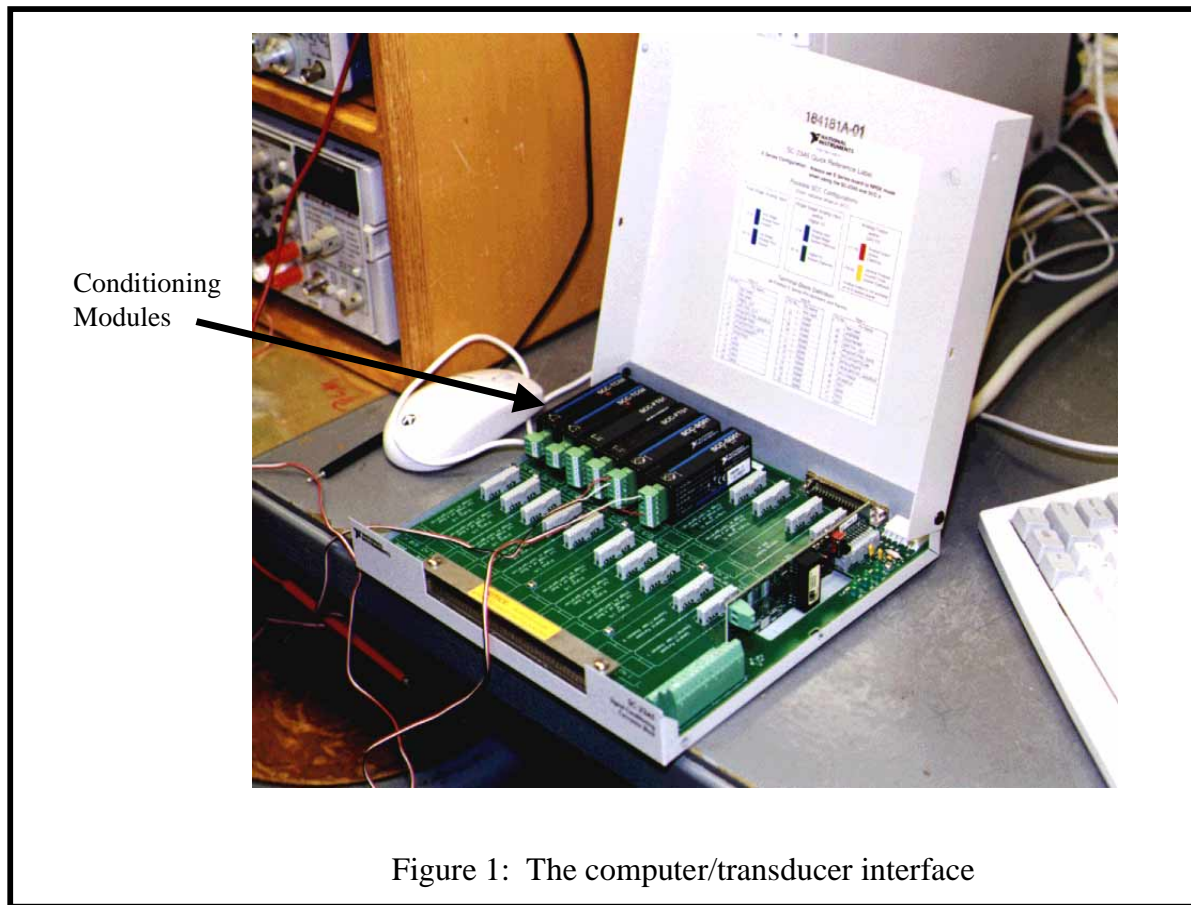

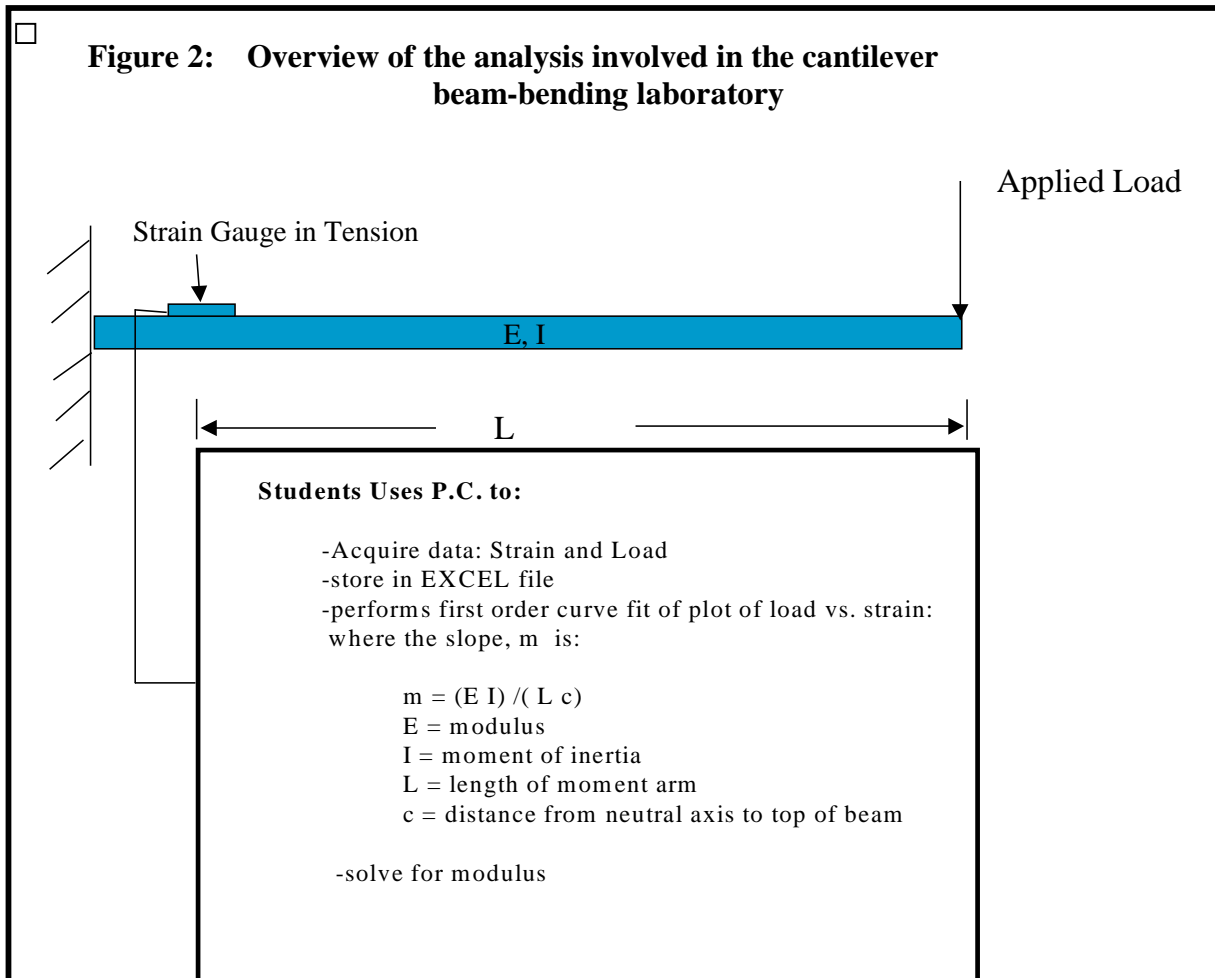Figure 1: The computer/transducer interface

III.   Representative Laboratory Exercises

Labview has been used in three courses to date. The second semester freshmen course Applied Materials Technology – MET 123, Fundamentals of Heat Transfer - MET 473 and Automation Systems – MET 484. Again, the students are initially exposed to LabView in the first year, in

which they learn rudimentary programming skills. Often times, the necessary "Virtual Instrument" (V.I.) can be found among the many samples found in the software. The students typically start with one of the data acquisition V.I.'s in then modify for a specific task detailed in a laboratory exercise.

The first V.I. they make is to measure the strain that is developed in a cantilever beam placed that is loaded in bending as shown in Figure 2.

Figure 2:   Overview of the analysis involved in the cantilever beam-bending laboratory

Applied Load

Strain Gauge in Tension

E, I

L

Students Uses P.C. to:

-Acquire data: Strain and Load
-store in EXCEL file
-performs first order curve fit of plot of load vs. strain:
 where the slope, m is:

m = (E I) /(L c)
E = modulus
I = moment of inertia
L = length of moment arm
c = distance from neutral axis to top of beam

-solve for modulus

The students first physically apply strain gauges to the beam and then prepare to load the beam. They then modify the basic LabView V.I. for strain gauge measurement allowing the program to store strain data when a particular virtual button is pushed. LabView creates graphical user interfaces that resemble a control panel complete with buttons, charts, and all forms of storage and analysis capabilities. To give the reader an idea of the nature of LabView, the V.I. that is used for the strain gauging lab is shown in figure 3. The student then must transfer the data to an EXCEL spreadsheet file and plot Load vs. Strain, a first order relationship, and perform a first order curve fit analysis using the linear regression method provided by EXCEL. Given the known relations of elastic beam theory, they then compute the modulus of the material that was loaded. The lab has proved to be an excellent "warm up" for both the Statics – MET 236 and the Strength of Materials – MET 243, courses.

Figure 3: Reproduction of the virtual instrument used for strain gauge measurement.

All measurement parameters can be adjusted from the control panel including:

-gauge factor
-excitation voltage
-channel number
-file to which data is stored
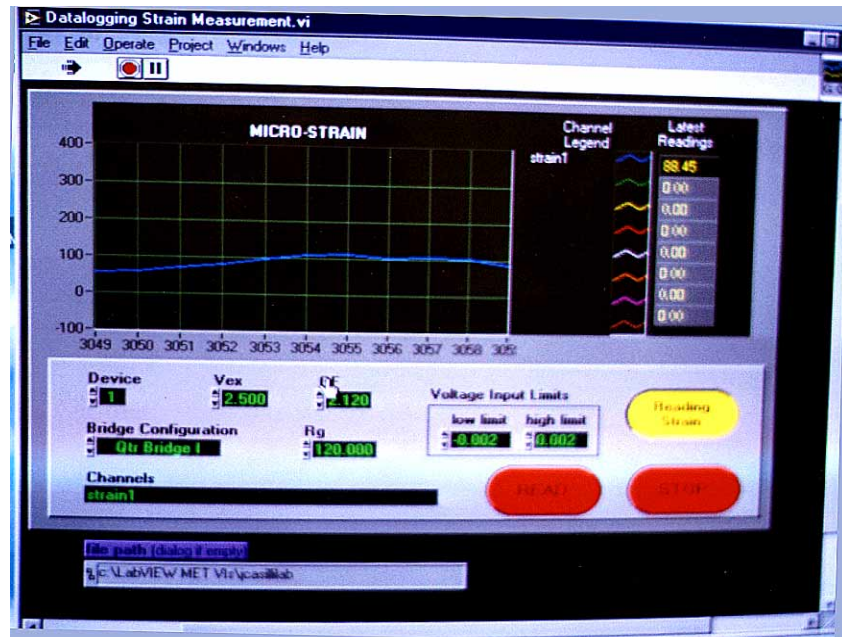
Another interesting laboratory is the transient heat transfer exercise in Fundamentals of Heat Transfer (a senior level course). Here, the students are given a block some engineering metal that has an array of thermocouples pre-positioned in the center as shown in figure 4.

Figure 4: Illustration of the apparatus used in the transient heat transfer lab.

-LabView records all T.C.'s simultaneously

-Data is exported to EXCEL and curve fitting techniques are used to solve for flux

Steel, Aluminum, etc.

Heat Flux

Imbedded Thermocouples at known positions
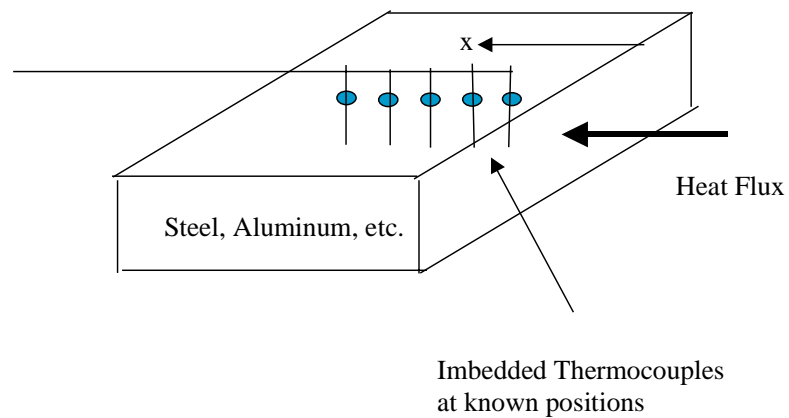
The students create a V.I. to measure and record 4 channels of temperature. A heater is then activated, and temperature vs. time at all locations is measured and recorded. These results are then combined with the basic theory of one-dimensional, transient heat transfer to find the heat transfer rate through the block. Typically, EXCEL will be used for curve fitting and MathCAD will be used to solve for the various parameters. WORD is then used for final report preparation.

IV.   Assessment Measures

Currently, assessment has consisted of student laboratories, examinations and projects. Student evaluations have also been conducted and success in follow-on courses has been tracked. In nearly all of these categories, a positive reaction to the use of the computer has been noted. When students enter classes in which computer applications that were previously covered, are again utilized, they feel much more confident about succeeding in the course. The integration of the many applications over the entire curriculum has led to a higher level of problem solving ability, which is evidenced by the complexity and sophistication of the laboratory reports. Student evaluations of courses in which LabView has been used have also been excellent.

Another measure of the success of the integrated use of LabView will be in the senior design project that is being offered in the spring of 2001. Here, students will be required to use the software system to control an automated assembly process.

In terms of mathematical problem solving and trending studies, MathCAD has had the greatest effect. Students are able to set up large mathematical problems which become "living documents," that can be modified and used to test the effect of input parameters.

The final assessment of the software integration, and the program for that matter, will be the success of the graduates. The MET program has just revised its graduate/employer survey to include a section on software usage. We hope to have the first results during the summer of 2001.

It should be noted that the LabView software and laboratory have only been used since the spring of 1999. MS Office has been utilized since 1997 and MathCAD has been used since 1996. Continued monitoring of student outcomes is clearly needed.

VI.   Conclusion and Future Plans

The software applications will continue to be integrated into the classes and laboratories throughout the MET curriculum. As more and more laboratories are developed, more experiential learning can take place in a consistent manner. Early courses will lay the foundation for the software applications and continued usage will foster retention. The use of a dedicated freshmen level course in LabView is also being considered, which will be in addition to the Visual Basic programming course (PG 111 – Programming for Technology) that is currently being used.

Acknowledgement

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Appendix A
Mechanical Engineering Technology Curriculum

Course Name	Credit Hours	Class Hours	Lab Hours	Contact Hours	Course Name	Credit Hours	Class Hours	Lab Hours	Contact Hours
SEMESTER 1					**SEMESTER 2**				
EN 111 English I: Expository Comm	3	3	0	3	MET 123 Applied Materials Tech	2	2	1	3
ET 111 Intro to Eng Technology	1	1	0	1	MTH 122 Math for Technolog II	3	3	0	3
MET 116 Manufacturing Processes	4	3	3	6	PG 111 Programming for Tech	3	3	0	3
MTH 112 Math for Technolog I	3	3	0	3	PHY 120 Algebra-Based Physics I	4	3	3	6
All-University Curriculum	3	3	0	3	Human/Soc Science Elective	3	3	0	3
SEMESTER TOTALS	**14**	**13**	**3**	**16**	**SEMESTER TOTALS**	**15**	**14**	**4**	**18**
SEMESTER 3					**SEMESTER 4**				
CH 110 College Chemistry I	4	3	3	6	EN 241 English II: Tech Comm	3	3	0	3
ES 220 Graphic Communication	2	2	1	3	ES 221 Advanced Graphic Comm Us	3	3	0	3
MET 236 Statics	3	3	0	3	MTH 241 Math for Technolog IV	3	3	0	3
MTH 232 Math for Tech III	3	3	0	3	PHY 250 Materials Science	3	3	0	3
PHY 121 Algebra-Based Physics II	4	3	3	6	MET 243 Strength of Materials	4	3	3	6
SEMESTER TOTALS	**16**	**14**	**7**	**21**	**SEMESTER TOTALS**	**16**	**15**	**3**	**18**
SEMESTER 5					**SEMESTER 6**				
EL 245 Elec/Electron Fund	4	3	3	6	EL 353 Industrial Instrumentation	4	3	3	6
MET 363 Machine Design	4	3	3	6	MET 365 Fluid Mechanics I	4	3	3	6
MTH 352 Math for Technolog V	3	3	0	3	Technical Specialty	4	3	3	6
Professional Elective	3	3	0	3	All-University Curriculum	3	3	0	3
All-University Curriculum	3	3	0	3					
SEMESTER TOTALS	**17**	**15**	**6**	**21**	**SEMESTER TOTALS**	**15**	**12**	**9**	**21**
SEMESTER 7					**SEMESTER 8**				
EN 481 Eng III: Adv Tech Com	3	3	0	3	MET 482 Senior Design Project	3	3	1	4
MET 470 Thermo I for Eng Tech	4	3	3	6	MET 484 Automation Systems	4	3	3	6
MET 475 Kinematics and Dynam	4	3	3	6	Professional Elective	3	3	0	3
Professional Elective	3	3	0	3	Technical Specialty	4	3	3	6
Technical Specialty	4	3	3	6	All-University Curriculum	3	3	0	3
SEMESTER TOTALS	**18**	**15**	**9**	**24**	**SEMESTER TOTALS**	**17**	**15**	**7**	**22**
PROGRAM TOTALS	**128**	**113**	**48**	**161**					

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