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ABSTRACT

This task analysis report for the Robotics/Automated Systems Technician (RAST) curriculum project first provides a RAST job description. It then discusses the task analysis, including the identification of tasks, the grouping of tasks according to major areas of specialty, and the comparison of the competencies to existing or new courses to determine the suitability of the course to a new curriculum for robotics/automated systems. Division of courses into modules is also discussed. A sample seven-quarter RAST program course sequencing chart is provided. Following the five-page narrative are extensive appendixes. Appendix A lists the competencies--both terminal and enabling--required of a RAST. Appendix B, Section 1, contains course descriptions for the core of courses common to several areas of specialty. A description of each specialty course is included in Appendix B, Section 2. Each course is described by a brief narrative stating purpose and goals for student learning. Course outlines, a listing of student competencies, and a list of recommended texts follow. Sample modules are provided for specialty courses. Appendix C contains brief descriptions of physics modules changes to include principles required for RAST training. (YLB)

ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS AND DESCRIPTION OF REQUIRED JOB COMPETENCIES REPORT

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TASK ANALYSIS AND DESCRIPTION OF
REQUIRED JOB COMPETENCIES OF ROBOTICS/AUTOMATED SYSTEMS TECHNICIANS

The research reported herein was performed pursuant to a contract with the Office of Vocational and Adult Education, U.S. Department of Education. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Department of Education position or policy.

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS AND DESCRIPTION OF REQUIRED JOB COMPETENCIES REPORT

BACKGROUND

In August 1983 the United States Department of Education Office of Vocational and Adult Education awarded the Center for Occupational Research and Development (CORD) a contract to design a model curriculum for training Robotics/Automated Systems Technicians. A need for this model had been established by the rapid development of new, often seemingly unrelated, curricula at several community and junior colleges and technician schools in response to demands from local industry. These local industries normally install a limited number of one or two types of robots; therefore, they request local institutions to train technicians to work on only these types. Persons trained in these limited programs will be able to work on only a very limited variety of robots.

The project being funded by the United States Department of Education is to develop a broad-based, interdisciplinary Robotics/Automated Systems Technician curriculum. Such a curriculum will train persons in the basic fundamentals that apply to the operation of all types of robots--hydraulic, electric, and pneumatic. The first courses of the curriculum include mathematics and physics--courses that establish the footings upon which the rest of the training is based. This type of training will create technicians who have broad understandings of several disciplines, and are able to work on a wide variety of robotic systems. These persons will also--in view of the interrelated method of teaching physics--be able to understand the interworkings of the various systems in robots; they will better understand the cause and effect of faults and their symptoms, thereby facilitating quicker and more accurate diagnoses of problems. They will be able to find the cause of a failure scientifically--logically and systematically--not haphazardly.

JOB DESCRIPTION AND TITLES

One of the first tasks in developing a curriculum for a Robotics/Automated Systems Technician is to define the jobs and tasks a person will be expected to perform. The initial portion of this effort is to prepare a job description for the technician. The Robotics/Automated Systems Technician job description agreed to by the Panel of Experts (POE) for CORD's Robotics/Automated Systems Technician training project is:

> Robotics/Automated Systems Technicians are technical specialists with broad-based electromechanical skills who are familiar with electronic, mechanical, hydraulic and pneumatic devices. They are usually specialists in robotics or processing equipment and can set up automatic machines that work together as part of a total automated system. In their area of specialization, they can install, set up, troubleshoot, integrate, program, modify, test, operate and repair systems and components. They are field-service, installation or service technicians. They will work either under the supervision of an engineer, as a member of a team or as a supervisor of other technicians.

In their respective jobs, the technicians may have several job titles including Robotics Technician, Automated Systems Technician, Maintenance/Robots, Electromechanical Technician or Robotics/Automated Systems Technician. Due to the diversity of job titles, and descriptions that go with the titles, it is impossible to make a correlation between title and specific duties of a technician.

TASK ANALYSIS

The development of a task or competency list for a specific job is usually accomplished by watching a worker perform normal job functions for several days and making notes of each task performed. To save both time and money on this project, and in concurrence with the POE, the task listing for this project was accomplished without an on-site task analysis. Rather, several task analyses, provided by outside sources, were combined to create a very comprehensive list.

This list has had duplicate or similar tasks or competencies deleted, and has been presented to, discussed and approved by the POE. Competencies are separated into ten disciplines according to their major emphasis. These disciplines are: Electrical/Electronics; Pneumatics; Hydraulics; Mechanics; Computers; Factory Processes; Design; Automated Systems; Electromechanical; and General.

Competencies--skills that technicians are required to perform-- within each division are identified as to whether they are enabling or terminal.

A terminal competency is a specific, definable task a technician must be able to perform as a part of normal work routine. An enabling competency is one that is all or part of the basis for a technician being able to perform a terminal competency. The enabling competency may be either 1) having the ability to perform a simple task or 2) knowing facts that allow interpretation of specific data related to a terminal competency. Appendix A lists the competencies required of a Robotics/Automated Systems Technician.

When competencies have been identified, agreed to, and separated into specific disciplines, they can be compared to existing or new courses. This comparison determines the suitability of a course to a new curriculum, in this case robotics/automated systems. Appendix A lists both core courses and specialty courses (for robotics/automated systems). The data shown on the matrix indicates which competencies are satisfied by each of the courses--both existing and proposed.

Each course will eventually be divided into four to seven modules. In most cases a student can work through a module with minimal help from instructors. However, there are courses such as physics for which an instructor is required--at least to lecture on the principles being studied and to maintain safety in the laboratory. When course work is divided into modules, a student is better able to visualize progress through a course.

Table I is an example seven-quarter program for completing all training required to become a Robotics/Automated Systems Technician. As can be recognized by studying this program, students will be required to spend a great deal of time in the class/lab each quarter. Most terms have a higher requirement for time to be spent in laboratories--thus providing students with ample "hands-on" experience. Students will be working with and on the type of equipment they will find in industry--not the typical university lab equipment.

According to the requirements shown in Table I, students will average 26 1/2 hours each week in contact with their instructors. With the majority of this time being spent in "hands-on" experiments, students will learn the operating principles of individual devices and how systems interact with each other. They will learn to use logical, systematic procedures when troubleshooting and repairing a failed machine.

Table 1
COURSE SEQUENCING CHART
Robotics/Automated Systems
Suggested Program (Quarter System)

	Lecture	Lab	Weekly Contact Hours
<u>First Quarter</u>			
Algebra	3	2	5
UTC Physics I	3	6	9
Technical Communications	3	2	5
Computer Basics	2	4	6
Fundamentals of Robotics & Automated Systems	2	3	5
	13	17	30
<u>Second Quarter</u>			
Trigonometry	3	2	5
UTC Physics II	3	6	9
Fundamentals of Electricity & Electronics	3	4	7
Graphics	1	6	7
	10	18	28
<u>Third Quarter</u>			
Analytic Geometry & Calculus	3	2	5
UTC Physics III	3	6	9
Controllers for Robots & Automated Systems	2	6	8
Mechanical Devices and Systems	2	4	6
	10	18	28
<u>Fourth Quarter</u>			
Analog Circuits & Active Devices	3	4	7
Digital Electronics	2	4	6
Electromechanical Devices	3	4	7
Automated Systems & Support Components	2	6	8
	10	18	28
<u>Fifth Quarter</u>			
Industrial Electrical Power & Equipment	3	4	7
Computer Applications	3	4	7
Fluid Power	3	4	7
Robotics & Automated Systems Interfaces	2	6	8
	11	18	29
<u>Sixth Quarter</u>			
Instrumentation & Controls	2	4	6
Economics in Technology	4	0	4
Manufacturing Processes	4	3	7
Robotics/Automated Systems at Work	2	6	8
	12	13	25
<u>Seventh Quarter</u>			
Properties of Materials	2	4	6
Industrial Relations	5	0	5
Automated Work Cell Integration	2	6	8
	9	10	19

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Appendix B, Section 1, contains course descriptions for the core of courses that are common to several areas of specialty. A description of each specialty course is included in Appendix B, Section 2. Each course is described first by a brief narrative that states the purpose and goals for student learning. The last, and largest, portion of each description is a list of competencies taken from the matrix in Appendix A, and listed under the course(s) that will satisfy that competency. The POE has reviewed the course descriptions and offered suggestions that have been incorporated into the documents contained in Appendix B. Appendix B contains course descriptions for the core of courses that are common to several areas of specialty. Appendix C contains brief descriptions of the UTC Physics Applications that need to be either changed or written; they will then include the principles required for Robotics/Automated Systems Technician training.

APPENDIX A

COURSE/COMPETENCY MATRIX

ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING

BASIC — TECHNICAL CORE — SPECIALTY

A - Electrical/Electronic

Terminal Competencies

	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOTICS/AUTOMATED SYSTEMS INTERFACES	ROBOTICS/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
1. Use manufacturers' parts list and drawings concerning replacement parts for Robots/Automated Systems to																												
a. Identify part numbers							●						●															
b. Order replacement parts							●						●															
c. Install replacement parts							●						●															
2. Adjust, troubleshoot, repair, and/or replace:																												
a. Power supplies											●							●		●								
b. Servo amplifiers											●							●						●				
c. Motor control circuits											●							●		●				●	●			
d. Electronic sensors												●						●		●				●				
e. Transducers												●						●		●				●				
3. Attach and replace connectors to wire and fiber optic cables.											●							●		●								
4. Install low & high voltage and interconnecting signal (wire and fiber optic) cables.											●							●										
5. Troubleshoot and repair wire and fiber optic system cable faults.											●							●										
6. Conduct routine preventive maintenance on electrical and electronic equipment in accordance with manufacturer's recommendations.											●									●								
7. Troubleshoot electronic failures to the circuit board level; replace defective circuit board.											●							●			●							

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

Task	BASIC										TECHNICAL CORE												SPECIALTY					
	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS	AND SUPPORT COMPONENTS ROBOT/AUTOMATED SYSTEMS	INTERFACE ROBOT/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
8. Conduct routine preventive maintenance on ac and dc motors in accordance with manufacturer's recommendations.																				●		●						
9. Install, adjust, troubleshoot and repair or replace to manufacturer's specifications:																												
a. Control devices																		●						●				
b. Relays (electromechanical and solid state)											●							●		●		●						
c. Sensors																		●						●				
d. Limit switches																		●				●		●	●			
e. Transducers																		●						●	●			
f. 1 Φ and 3 Φ electrical equipment											●									●		●			●			
10. Connect fiber-optic cables to electronic equipment.											●							●										
11. Troubleshoot, repair or replace fiber optic components/systems.																		●						●	●	●		
12. Program stepper motors.																				●		●		●	●			
13. Apply bridge circuits to measuring voltages and currents.											●							●										
14. Replace components on circuit boards.												●							●									
15. Solder and desolder electrical connections.											●	●						●	●	●								
16. Install and remove circular (multipin), coaxial, and in-line plugs and receptacles.											●								●									
17. Measure and set voltages and currents.																												
a. Facility power																				●								
b. Equipment power supply												●													●			

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

A - Electrical/Electronic

Enabling Competencies	BASIC: ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	TECHNICAL CORE: FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	SPECIALTY: FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOT/AUTOMATED SYSTEMS INTERFACES	ROBOT/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION	
1. Read schematic diagrams.							●				●									●										
2. Read wiring diagrams.							●				●									●										
3. Interpret industrial electrical symbols and line diagrams from printed material and/or graphic display systems.											●									●										
4. Describe in writing how switches and solenoids work.							●				●									●		●								
5. Describe in writing SCR controls.							●					●						●												●
6. Analyze series and parallel circuits.											●																			
7. Use operational amplifiers as followers, inverters, summers, integrators, and differentiators.												●						●												
8. Use an oscilloscope to determine wave forms.					●			●			●																			
9. Determine signal frequency.											●							●												
10. Describe ac and dc current flow.				●							●																			
11. Describe lead acid battery construction.											●																			
12. Describe ac and dc electric motor operation.				●							●									●		●								

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

BASIC — TECHNICAL CORE — SPECIALTY

	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUNDAMENTALS OF ROBOTICS	[illegible]	AUTOMATED SYSTEMS	AUTOMATED SYSTEMS	[illegible]	[illegible]	ROBOTS/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
B - Pneumatic																														
Terminal Competencies																														
1. Maintain pressure regulators.																	●													
2. Install, adjust troubleshoot and repair or replace pneumatic:																														
a. Airlines																	●													
b. Pumps																	●													
c. Gages																	●													
d. Filters																	●													
e. Control valves																	●													
f. Actuators																	●													
g. Cylinders																	●													
h. Pressure switches																	●													
i. Positioner relays																	●													
3. Adjust a pneumatic-sensor temperature controller to a specified mixed air temperature.																	●													
4. Properly use dampers, thermostats, switches, pneumatic positioners, linkage assemblies and accessories in pneumatic systems.																	●													
5. Conduct routine preventive maintenance on pneumatic equipment in accordance with manufacturer's instructions.																	●													
Enabling Competencies																														
1. Sketch flow path symbols and air logic drawings.																	●													
2. Interpret flow path symbols and air logic drawings.																	●													
3. Identify and use proper size of pneumatic piping.																	●													

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

BASIC — TECHNICAL CORE — SPECIALTY

	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOTIC/AUTOMATED SYSTEMS INTERFACES	ROBOTIC/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
C - Hydraulic																												
Terminal Competencies																												
1. Install, adjust, troubleshoot, and repair or replace hydraulic:																												
a. Lines																	●											
b. Pumps																	●											
c. Gayes																	●											
d. Filters																	●											
e. Accumulators																	●											
f. Volume controls																	●											
g. Servo valves																	●	●		●				●		●	●	●
h. Directional control valves																	●									●	●	●
i. Pressure control valves																	●									●	●	●
2. Test for hydraulic oil quality and use external filter system to purify.																	●											
3. Control oil pressure and temperatures.																	●											
4. Null hydraulic servo systems.																	●											
5. Calculate hydraulic system pressure losses.																	●											
6. Conduct routine preventive maintenance on hydraulic equipment in accordance with manufacturer's specifications.																	●											
Enabling Competencies																												
1. Identify and use proper-size lines.																	●									●		
2. Describe the relationship between hydraulic pressure and flow.																	●											

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

BASIC — TECHNICAL CORE — SPECIALTY

	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	I/TC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOTICS/AUTOMATED SYSTEMS INTERFACES	ROBOTICS/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
D - Mechanical																												
Terminal Competencies																												
1. Set and adjust mechanical stops.																●												
2. Set actuators to proper end positions.																●												
3. Install and maintain linkage.																●												
4. Install and maintain gear trains.																●												
5. Conduct routine preventive maintenance on mechanical equipment in accordance with manufacturer's specifications.																●												
Enabling Competencies																												
1. Identify elements used in selection and design of processes that can be automated.																												
a. Welding															●													
b. Painting															●													
c. Material handling															●													
2. Determine speed and torque ratios.																●												

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

E - Computer

Terminal Competencies

Task	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOT/AUTOMATED SYSTEMS INTERFACES	ROBOT/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
	BASIC										TECHNICAL CORE												SPECIALTY					
1. Troubleshoot malfunctions in computer system to circuit board level.																			●					●	●			
2. Install, troubleshoot, remove and replace:																												
a. Memory devices																			●									
b. Displays																			●									
c. Control circuits																			●									
d. Keyboards and printers																			●									
e. Central processing unit (CPU)																			●									
f. Interface modules																			●									
3. Install input/output (I/O) devices in accordance with manufacturer's specifications:																												
a. Cathode-ray tubes (CRTs)								●											●									
b. Printers								●											●									
c. Tape drives																			●									
d. Disk drives								●											●									
e. Plotters																			●									
f. Flat screen displays (including gas plasma displays)																			●									
4. Install module or board-mounted RAM and ROM memory devices in accordance with manufacturer's specifications.																			●									
5. Load and run diagnostic routines.								●											●									
6. Interpret diagnostic printouts.								●											●									
7. Install programmable controllers.																								●	●	●		
8. Use diagnostic routine program language written in machine language(s).								●											●					●				

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

	BASIC										TECHNICAL CORE											SPECIALTY						
Task	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUNDAMENTALS OF ROBOTICS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	INTERFACING ROBOTIC/AUTOMATED SYSTEMS	ROBOTICS/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
9. Program and/or reprogram PCs (drum, relay, and microprocessor types) for specific sequence of events in performing an application.																								●				
a. Prepare a flow chart for a specific sequence of events in performing given application.																								●				
b. Enter instructions into control unit.																								●				
c. Run program to see if control unit executes properly.																								●				
d. Edit or debug program as necessary.																								●				
e. Download and upload system.																								●				
f. Recognize and resolve hardware/software impedance matching problems.																								●				
10. Write, enter, and debug programs in one structured language.								●											●									
11. Install, set up, calibrate, troubleshoot and repair or replace data transmissions systems.																			●									
Enabling competencies																												
1. Characterize digital circuits.								●													●							
2. Describe microprocessor input/output characteristics.								●											●									

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL DC, AC AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOT/AUTOMATED SYSTEMS INTERFACE	ROBOT/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
	BASIC										TECHNICAL CORE												SPECIALTY					
F - Electromechanical																												
Terminal Competencies																												
1. Install, adjust, troubleshoot and repair or replace:																												
a. Servo motors																		●				●						
b. AC pump motors (vacuum and pressure)																				●		●						
c. Speed-reduction units																●						●						
d. Clutches																●												
e. Stepping motors																				●		●		●				
f. Mechanical drives for feedback system																●				●								
2. Install, adjust, troubleshoot and repair or replace sensors for:																												
a. Flow control																●		●		●		●						
b. Liquid-level control																●		●		●		●		●				
c. Ultrasonic control																		●		●				●	●			
d. Optoelectric															●			●						●	●	●	●	
e. Tactile															●	●		●				●		●	●			
f. Video															●	●		●						●	●			
Enabling Competency																												
1. Describe the applications of the following systems to a robotic work cell:																												
a. Hydraulic/electrical/pneumatic positioners and sensors																	●	●						●	●			
b. Motor drives and servos											●							●				●		●	●			
c. Control systems including feedback																●		●				●		●				
d. Mechanical linkages/gears																●				●								
e. Electrical power system											●									●		●						

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

G. General

Terminal Competencies

Terminal Competencies	BASIC: ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	TECHNICAL CORE: FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	SPECIALTY: FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROL LOGIC FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOTIC/AUTOMATED SYSTEMS INTERFACES	ROBOTIC/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION	
1. Effectively select and utilize such test equipment as time-domain reflectometers, oscilloscopes, spectrum analyzers, function generators, chart recorders, and multimeters for troubleshooting and repair of electronic circuits.											●	●								●	●			●					
2. Identify and demonstrate proper operation, care and maintenance of hand power tools.														●		●											●	●	
3. Select and install the proper fastener for a given job.																●													
4. Identify and use appropriate lubricant.																●	●												
5. Use manual's troubleshooting charts to aid fault isolation/repair.																								●	●	●	●	●	●
6. Maintain work log sheets.							●			●																			
7. Draw logic diagrams.																			●		●			●					
8. Read, understand and comply with requirements of service bulletins.							●						●																
9. Convert measurements between English and SI systems.													●																
10. Use both inside and outside micrometers.														●		●													
11. Use manufacturer's manuals as a guide to troubleshoot, repair, test and operate a failed machine.							●				●					●										●	●	●	
12. Use manufacturer's manuals to determi.. a machine's normal operating characteristics.							●				●					●										●	●	●	
13. Using a manual, identify operational/functional systems.							●				●					●										●	●	●	

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

G. General

Enabling Competencies

Enabling Competencies	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOT/AUTOMATED SYSTEMS INTERFACE	ROBOT/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
	BASIC										TECHNICAL CORE												SPECIALTY					
1. Recognize a mechanical problem which may, at first examination, appear to be an electrical one and vice versa.																				●						●	●	●
2. Exhibit proper working habits (attitude and safety).										●																●	●	●
3. Interpret drawings of parts.							●						●															
4. Interpret graphs and charts.							●						●															
5. Read and use acceptable twelfth-grade English.							●																					
6. Perform trigonometric calculations.		●																										
7. Explain the difference between accuracy, precision, and repeatability.							●						●															
8. Explain the difference between direct and indirect measurements.													●	●														
9. Communicate																												
a. Orally							●																					
b. Listening							●																					
c. Reading							●																					
d. Write technical reports							●																					
e. Graphically							●						●															

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

BASIC **TECHNICAL CORE** **SPECIALTY**

H - Factory Processes

Enabling Competencies

Competency	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS	ROBOT/AUTOMATED SUPPORT COMPONENTS	INTERFACING ROBOTS/AUTOMATED SYSTEMS	ROBOTS/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
1. Describe the following operations performed on a lathe:																													
a. Plane or straight turning														●															
b. Facing														●															
c. Parting														●															
d. Chamfering														●															
2. List common lathe accessories and attachments.														●															
3. Identify important features of a horizontal turret lathe.														●															
4. Describe a screw machine and the types of jobs accomplished on it.														●															
5. Define an electron beam and how it is used as a special cutting tool.														●															
6. Identify the machines and tools used for:																													
a. Stamping														●															
b. Piercing														●															
c. Bending														●															
d. Drawing														●															
e. Rolling														●															
7. Describe/list the cutting tools normally used on:																													
a. Mills														●															
b. Lathes														●															
c. Drill presses														●															
8. Describe painting processes.														●															

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

Task	BASIC										TECHNICAL CORE											SPECIALTY						
	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOT/AUTOMATED SYSTEMS INTERFACE	ROBOT/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
9. Define and give an example of the following measurement terms:																												
a. Tolerance													●	●														
b. Allowance													●	●														
c. Clearance													●	●														
d. Basic size													●	●														
e. Standard size													●	●														
f. Nominal size													●	●														
10. Describe the differences between MIG, TIG and stick arc welders.														●														
11. Describe gas welding equipment.														●														
12. Explain flow and dip coating.														●														
13. Describe anodizing.														●														
14. Describe electroplating equipment and explain the process.														●														
15. Describe aerobic and anaerobic adhesives.														●														
16. Explain the difference between thermoset and thermoplastic plastics.														●														
17. Describe injection molding.														●														
18. Describe vacuum forming.														●														
19. Compare similarities and differences of ECM and EDM.														●														
20. List important factors that control the quality of surface finish obtained by ultrasonic machining.														●														

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

I - Automated Systems

Terminal Competencies

1. Measure robot performance (distance, positioning, accuracy, and repeatability).
2. Use teaching pendant for testing, editing, and setup.
3. Disassemble, repair, test and return to service robots which have failed.
4. Install, adjust, troubleshoot, repair or replace:
   a. Industrial robots.
   b. End effectors
   c. Smart actuators
5. Coordinate the operation of several pieces of automatic equipment.
6. Adjust feedback loops that include:
   a. Encuders/decoders
   b. Optical sensors
   c. Electronic sensors
   d. Microprocessor
   e. Count stepper-motor pulses
   f. Optoelectronics
   g. Hall-effect devices
   h. Velocity sensors
   i. Position detectors
7. Interconnect robots and other equipment.
8. Adjust machines for accuracy and repeatability.
9. Set up machine vision systems.
10. Match off-the-shelf end effectors to the requirements of various manufacturing operations.
11. Analyze robot task requirements of a manufacturing operation.

	BASIC										TECHNICAL CORE												SPECIALTY					
	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELEC. [illegible]	[illegible] FUND. OF ROBOTICS	AND AUTOMATED SYSTEMS CONTROL LOGIC FOR ROBOTS AND [illegible]	AUTOMATED SYSTEMS [illegible]	[illegible]	[illegible] ROBOTS/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
1																							●					
2																							●	●				
3																										●	●	●
4																												
4a																										●	●	●
4b																										●	●	●
4c																										●	●	●
5																											●	●
6																												
6a																		●				●		●				
6b																		●						●				
6c																		●				●		●				
6d																		●	●					●				
6e																		●						●				
6f																		●						●				
6g																		●						●				
6h																		●						●				
6i																		●				●		●				
7																										●	●	●
8																										●	●	●
9																									●	●	●	●
10																							●			●	●	●
11														●												●	●	●

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

Task	BASIC										TECHNICAL CORE												SPECIALTY					
	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOTIC/AUTOMATED SYSTEMS INTERFACE	ROBOTIC/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
12. Analyze and select appropriate robot sensing requirements for certain manufacturing operations.														●										●		●	●	●
13. Start-up and debug a robot system.																										●	●	●
14. Start-up and shut down an automated production systems.																									●			●
15. Specify safety considerations for personnel, work area, operations, and maintenance.							●			●																●	●	●
16. Test wiring of each subassembly of a robot; test the overall, connected wiring of the total robot.																										●	●	●
17. Install a programmable controller and its input/output devices.																		●		●				●		●	●	●
18. Follow troubleshooting procedures recommended by the manufacturer to diagnose, isolate, and repair a robot/automated system.																										●	●	●
19. Analyze operating difficulties of installed robots; perform necessary corrective adjustments to return system to normal operation.																										●	●	●
20. Perform field testing of a robot and check to assure that its performance is in accordance with specifications.																										●	●	●
21. Perform electrical adjustments on servo power amplifiers.																		●		●				●	●			
22. Perform zeroing of encoders.																		●						●		●	●	●
23. Specify the robot coordinate system.																										●	●	●
24. Develop material handling specificatinns for a work cell.																												●
25. Specify the robot-to-material interfaces.																										●	●	●
26. Define the human interface with a robot.																										●		
27. Define axis control and feedback specifications.																										●	●	●
28. Set up, program, troubleshoot a system comprised of a minimum of two transfer lines, one robot, and at least one machining center.																											●	●

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

BASIC — TECHNICAL CORE — SPECIALTY

Task	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROL LOGIC FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	[illegible] ROBOTS/AUTOMATED SYSTEMS	[illegible] AT WORK	AUTOMATED WORK CELL INTEGRATION
29. Set up, etc., robot to either remove parts from transfer line and palletize them or to depalletize parts and place them on a transfer line.																										●	●	●
30. Given the above setups, the instructor will install a programming error. The student (team) will diagnose and correct the problem and test the solution.																												
a. Programming																								●	●	●	●	●
b. Mechanical stops																								●	●	●	●	●
c. Electrical																								●	●	●	●	●
d. Hydraulic power supply																										●	●	●
31. Set up a robot to either paint parts on a moving line or weld parts on a moving line (line will stop for welding cycle).																											●	●
32. Set up, etc., a robot to assemble two parts--use at least three fasteners:																												
a. Index																									●		●	●
b. RCC																									●		●	●
c. Pick up																									●		●	●
d. Fasteners																									●			
e. Install parts																									●			
33. Configure a system for counting regular/irregular shaped objects moving on an overhead track.																											●	●
34. Define signal-sensing-control and power interfaces involved in the first two problems.																										●	●	●
35. Operate the following equipment																												
a. End effectors																							●		●	●	●	●
b. Grippers																							●		●	●	●	●
c. Magnetic pickups																							●		●	●	●	●
d. Vacuum pickups																							●		●	●	●	●
e. Compliance devices																							●		●	●	●	●

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

	BASIC										TECHNICAL CORE												SPECIALTY					
	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUNDAMENTALS OF ROBOTICS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS	[illegible] AND SUPPORT COMPONENTS	INTERFACES ROBOTS/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
36. Adapt the following to robotic application:																												
a. Welder																										●	●	●
b. Adhesive applicators																										●	●	●
c. Paint sprayers																										●	●	●
d. Grinders																										●	●	●
37. Adapt the following to work with automated systems:																												
a. Conveyors																									●	●	●	●
b. Bulk feeders																									●	●	●	●
38. Set up, operate, troubleshoot, and repair automated:																												
a. Warehousing systems																											●	●
b. Machinery operations																											●	●
c. Coating/application systems																											●	●
d. Assembling stations																											●	●
e. Material handling systems																											●	●
39. Program a host computer to control several "lower-level" computers that in turn control portions of an automated system.																									●		●	●
Enabling Competencies																												
1. Identify major systems of a robot.																							●					
2. Describe robot drive system operation.																							●					
3. Describe operation of various types of industrial robots.																							●					
4. Describe mobility of an industrial robot.																							●					
5. Describe transmission operation.																												
a. Gears																●							●					
b. Pulleys, belts																●							●					
c. Bearings																●							●					

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

	BASIC										TECHNICAL CORE												SPECIALTY					
	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	BASICS OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROL SYSTEMS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	MAINTENANCE/TROUBLESHOOTING ROBOTS/AUTOMATED SYSTEMS	ROBOTS AT WORK	AUTOMATED WORK CELL INTEGRATION
6. Identify a robot's work envelope.																							●					
7. Be conversant in robot terminology.							●																●					
8. Demonstrate knowledge of safety requirements for working around robots.																							●			●	●	●

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

BASIC — TECHNICAL CORE — SPECIALTY

J - Design

	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOTIC/AUTOMATED SYSTEMS INTERFACES	MAINTAINING AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
Terminal Competencies																												
1. Create two-dimensional drawings using the graphics terminal, digitizer, and plotter as design and drafting tool.													●															
2. Sketch views not shown on a drawing.													●															
Enabling Competencies																												
1. Explain the hazard of accumulated tolerances (on a drawing).							●						●	●														
2. Determine critical dimensions.													●	●														
3. Describe the meaning of dimensions/tolerances shown on drawings.													●	●														
4. Identify the components of a computer-aided drafting system.													●	●						●								
5. Determine interrelationships of working dimensions.													●	●														
6. Determine critical dimensions.													●	●														

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APPENDIX B

SECTION 1: COURSE DESCRIPTION AND COMPETENCIES FOR CORE COURSES

Algebra
Trigonometry
Analytic Geometry and Calculus
UTC Physics I, II, and III
Technical Communications
Computer Basics
Economics in Technology
Industrial Relations
Fundamentals of Electricity and Electronics
Digital Electronics
Analog Circuits and Active Devices
Graphics
Properties of Materials
Mechanical Devices and Systems
Fluid Power
Instrumentation and Controls
Computer Applications
Electromechanical Devices
Industrial Electrical Power and Equipment
Manufacturing Processes

ALGEBRA

This course is designed to develop and update algebraic skills required for engineering technicians as applied to the solution of practical problems encountered in electrical, mechanical, thermal, hydraulic, pneumatic and optical technologies. Topics to be covered include functions and graphs, exponents, radicals, linear equations, determinants, factoring, quadratics, and various techniques for solutions of equations and systems of equations.

COURSE OUTLINE

	Student Contact Hours Class	Laboratory
I. Fundamental Concepts and Operations	10	
A. Numbers and Literal Symbols		
B. Fundamental Laws of Algebra		
C. The Laws of Exponents		
D. Scientific Notation		
E. Exponents and Radicals		
F. Addition and Subtraction of Algebraic Expressions		
G. Multiplication and Division of Algebraic Expressions		
H. Equations and Formulas		
II. Functions and Graphs	5	
A. Functions		
B. Cartesian Coordinates		
C. Graphing Functions		
D. Solving Equations Graphically		
III. Linear Equations and Determinants	10	
A. Linear Equations		
B. Graphical Solution of Systems of Two Linear Equations in Two Unknowns		
C. Algebraic Solution of Systems of Two Linear Equations in Two Unknowns		
D. Solution by Determinants of Systems of Two Linear Equations in Two Unknowns		
E. Algebraic Solutions of Three Linear Equations in Three Unknowns		
F. Solution by Determinants of Systems of Three Linear Equations in Three Unknowns		
IV. Factoring and Fractions	10	
A. Special Products		
B. Factoring		
C. Simplifying Fractions		

	Student Contact Hours Class	Laboratory
V. Quadratic Equations	5	
A. Quadratic Equations. Solution by Factoring		
B. Completing the Square		
C. The Quadratic Formula		
VI. Exponents and Radicals	6	
A. Positive Integers as Exponents		
B. Zero and Negative Integers as Exponents		
C. Fractional Exponents		
D. Simplest Radical Form		
E. Addition and Subtraction of Radicals		
F. Multiplication and Division of Radicals		
VII. Additional Solutions to Equations and Systems of Equations	6	
A. Graphical Solution of Systems of Equations		
B. Algebraic Solution of Systems of Equations		
C. Equations in Quadratic Form		
D. Equations with Radicals		

STUDENT COMPETENCIES

At the conclusion of this course, in the appropriate course areas indicated, the student will be able to:

I. Fundamental Concepts and Operations
- Write concepts mathematically using numbers and symbols.
- Perform mathematical operations using the fundamental laws of algebra and the laws of exponents.
- Make mathematical computations using scientific notation.
- Perform algebraic operations of addition, subtraction, multiplication, and division on algebraic terms.
- Perform basic mathematical operations on equations and formulas to solve for any given variable.

II. Functions and Graphs
- Graph equations and functions with two variables.
- Solve system of equations graphically.

III. Linear Equations and Determinants
- Graphically solve two linear equations with two unknowns.
- Algebraically solve two linear equations with two unknowns.
- Use determinants to solve two linear equations with two unknowns.
- Algebraically solve three linear equations with three unknowns.
- Use determinants to solve three linear equations with three unknowns.

IV. Factoring and Fractions
- Identify the general form of first-, second-, and third-degree equation products of two variables.
- Factor algebraic expressions containing common monomial factors into prime factors.

- Factor the difference of two squares.
- Factor trinomial expressions.
- Change a given algebraic fraction into a specified equivalent fraction.
- Perform operations of addition, subtraction, multiplication and division on algebraic fractions.
- Solve equations containing algebraic fractions.

V. Solution of Quadratic Equations
- Solve quadratic equations by factoring.
- Solve quadratic equations by completing the square.
- Solve quadratic equations by use of the quadratic formula.

VI. Exponents and Radicals
- Perform operations involving algebraic expressions with integral exponents.
- Perform operations involving algebraic expressions containing fractional exponents.
- Reduce radicals to simplest form.
- Perform operations with algebraic expressions containing radicals.

VII. Additional Types of Equations and Systems of Equations
- Graphically solve systems of first- and second-degree equations with two variables.
- Algebraically solve systems of first- and second-degree equations with two variables.
- Solve equations that are in quadratic form.
- Solve equations containing radicals.

RECOMMENDED TEXTS

Clar and Hart. Mathematics for the Technologies. Englewood Cliffs, NJ: Prentice-Hall.

Paul and Shaevel. Essentials of Technical Mathematics with Calculus. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Washington, Allyn J. Basic Technical Mathematics with Calculus. 3rd ed. Benjamin Cummings.

TRIGONOMETRY

This course is designed to develop trigonometric skills required for engineering technicians as applied to the solution of practical problems encountered in electrical, mechanical, thermal, hydraulic, pneumatic and optical technologies. Topics to be covered include trigonometric functions of angles, vectors, solutions to oblique triangles, graphs of trigonometric functions, j-operators, inverse functions and logarithms.

COURSE OUTLINE

	Student Contact Hours Class	Laboratory
I. Trigonometric Functions of Any Angle	3	
A. Signs of the Trigonometric Function		
B. Radian Measure		
C. Applications of the Use of Radian Measure		
II. Trigonometric Functions	5	
A. Angles		
B. The Right Triangle		
C. The Trigonometric Functions		
D. Values of the Trigonometric Functions		
III. Vectors and Triangles	10	
A. Vectors		
B. Application of Vectors		
C. Oblique Triangles		
D. The Law of Sines		
E. The Law of Cosines		
IV. Graphs of the Trigonometric Functions	7	
A. Graphs of Y = A sin x and Y = A cos x		
B. Graphs of Y = A sin bx and Y = A cos bx		
C. Graphs of Y = A sin (bx + c) and Y = A cos (bx + c)		
D. Graphs of Y = tan x, Y = cot x, Y = sec x Y = csc x		
E. Application of the Trigonometric Graphs		
F. Composite Trigonometric Curves		
V. The j-Operator	10	
A. Imaginary and Complex Numbers		
B. Operations with Complex Numbers		
C. Graphical Representation of Complex Numbers		
D. Polar Form of a Complex Number		
E. Exponential Form of a Complex Number		
F. Products, Quotients, Powers, and Roots of Complex Numbers		

	Student Contact Hours Class	Laboratory
VI. Properties of the Trigonometric Functions	5	
A. Fundamental Trigonometric Identities		
B. Sine and Cosine of the Sum and Difference of Two Angles		
C. Double-Angle Formulas		
D. Half-Angle Formulas		
VII. The Inverse Trigonometric Functions	5	
A. Inverse Trigonometric Functions		
B. Principal Values		
VIII. Logarithms	7	
A. Exponential and Logarithmic Functions		
B. Graphs of $Y = b^x$ and $Y = \log_b x$		
C. Properties of Logarithms		
D. Logarithms to the Base 10		
E. Logarithms to the Base e		

STUDENT COMPETENCIES

At the conclusion of this course, in the appropriate course areas indicated, the student will be able to:

I. Trigonometric Functions of Any Angle
- Define the six trigonometric functions.
- Determine the sign of the function of an angle.
- Find the value of a given function of an angle.
- Find the value of the angle of the inverse trigonometric function.
- Convert between systems of angular measurement.
- Make trigonometric computations with angles measured in radians.

II. Trigonometric Functions
- Define trigonometric functions using the standard right triangle.
- Solve right triangles.

III. Vectors and Triangles
- Define vector quantities and give examples.
- Graphically represent a vector.
- Graphically add and subtract vectors.
- Use vectors to solve problems by resolving vectors into rectangular components.
- Solve oblique triangles using the law of sines.
- Solve oblique triangles using the law of cosines.

IV. Graphs of the Trigonometric Functions
- Graph the trigonometric functions $Y = A \sin x$ and $Y = A \cos x$.
- Graph the trigonometric functions $Y = A \sin bx$ and $Y = A \cos bx$.
- Graph the trigonometric functions $Y = A \sin (bx + c)$ and $Y = A \cos (bx + c)$.
- Determine amplitude, period, and phase of periodic (sinusoidal) motion.

- Graph the trigonometric functions Y = tan x, Y = cot x, Y = sec x, Y = csc x.
- Describe various types of motion in terms of the sine curve.
- Graphically combine two or more trigonometric curves.

V. The j-Operator
- Define and describe the complex number system.
- Perform basic algebraic operations with complex numbers.
- Represent complex numbers graphically.
- Write complex numbers in polar form.
- Write complex numbers in exponential form.
- Calculate the product, quotient, powers, and roots of complex numbers.

VI. Properties of the Trigonometric Functions
- Recognize and verify the basic trigonometric identities.
- Compute the sine and cosine of the sum and differences of two angles.
- Compute the value of the sine and cosine of the double angle.
- Compute the value of the sine and cosine of the half angle.

VII. The Inverse Trigonometric Functions
- Recognize and define inverse trigonometric functions.
- Compute the principal value of a given trigonometric function.

VIII. Logarithms
- Recognize and define an equation in exponential form.
- Recognize and define an equation in logarithmic form.
- Graph exponential and logarithmic functions.
- Perform algebraic operations with logarithmic expressions using the properties of logarithms.
- Write a number as a logarithm to the Base 10.
- Write a number as a logarithm to the Base e.
- Solve exponential and logarithmic equations.

RECOMMENDED TEXTS

Clar and Hart. Mathematics for the Technologies. Englewood Cliffs, NJ: Prentice-Hall.

Paul and Shaevel. Essentials of Technical Mathematics with Calculus. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Washington, Allyn J. Basic Technical Mathematics with Calculus. 3rd ed. Benjamin Cummings.

ANALYTIC GEOMETRY AND CALCULUS

This course is designed to develop analytic geometry and calculus skills required for engineering technicians as applied to the solution of practical problems encountered in electrical, mechanical, thermal, hydraulic, pneumatic, and optical technologies.

COURSE OUTLINE

	Student Contact Hours Class	Laboratory
I. Elements of Analytic Geometry	12	
A. The Straight Line		
B. The Circle		
C. The Parabola		
D. The Ellipse		
E. The Hyperbola		
F. Polar Coordinates		
II. Derivatives and Applications	10	
A. Limits		
B. The Slope of a Tangent to a Circle		
C. The Derivative		
D. Derivatives of Polynomials		
E. Derivatives of Products and Quotients of Functions		
F. The Derivative of a Power of a Function		
G. The Derivative as a Rate of Change		
H. Maximum and Minimum Problems		
III. Integration and Applications	10	
A. Differentials and Inverse Differentiation		
B. The Indefinite Integral		
C. The Area Under a Circle		
D. The Definite Integral		
E. Finding Areas by Integration		
F. Trapezoidal Rule for Approximating Areas		
G. Volumes by Integration		
H. Applications of the Integral		
IV. Differentiation of Transcendental Functions	10	
A. Derivatives of the Sine and Cosine Functions		
B. Derivatives of the Other Trigonometric Functions		
C. Derivatives of the Inverse Trigonometric Functions		
D. Derivatives of the Logarithmic Function		

	Student Contact Hours	
	Class	Laboratory
V. Integration Techniques	10	
A. The General Power Formula		
B. The Logarithmic and Exponential Form		
C. Basic Trigonometric Forms		
D. Integration by Parts		
E. Integration by Substitution		
F. Use of the Tables		

STUDENT COMPETENCIES

At the conclusion of this course, in the appropriate course areas indicated, the student will be able to:

I. Elements of Analytic Geometry
- Find the straight-line distance between two points on a graph.
- Define and find the slope of a line.
- Write the equation of a straight line given various properties of the line such as points on the line, slope, and/or intercepts.
- Define a circle and write the equation of a circle with the center at (0,0) and with the center at any coordinate (x,y).
- Define and derive the equation of a parabola given appropriate data.
- Define and derive the equation of an ellipse given appropriate data.
- Define and derive the equation of a hyperbola given appropriate data.
- Convert from rectangular to polar coordinates.

II. Derivatives and Applications
- Determine if a function is continuous.
- Determine the limits of a function if they exist.
- Find the slope of the tangent to a curve.
- Define and find the derivative of a function.
- Find the derivative of a polynomial by the Δ-process.
- Derive the derivatives of products and quotients of functions.
- Derive the derivative of a power of a function.
- Use differential calculus to solve problems involving rate of change.
- Use differential calculus to solve maximum and minimum problems.

III. Integration and Applications
- Find the differential of a function.
- Find the antiderivative of a function.
- Define and find the indefinite integral of a function.
- Find the area under a curve.
- Define the definite integral of f(n).
- Find the area under a curve by integration.
- Use the trapezoidal rule to approximate the area under a curve.
- Find volumes by integration.
- Apply integral calculus to solve problems involving moments of inertia, work, average values, etc.

IV. Differentiation of Transcendental Functions
- Compute derivatives of the sine and cosine functions.

- Compute derivatives of the other trigonometric functions.
- Compute derivatives of the inverse trigonometric functions.
- Compute derivatives of the logarithmic functions.

V. Integration Techniques
- Integrate functions by use of the general power formula.
- Integrate functions in logarithmic and exponential form.
- Integrate the trigonometric functions.
- Perform integration by parts.
- Perform integration by substitution.
- Perform integration by use of tables.

RECOMMENDED TEXTS

Clar and Hart. Mathematics for the Technologies. Englewood Cliffs, NJ: Prentice-Hall.

Paul and Shaevel. Essentials of Technical Mathematics with Calculus. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Washington, Allyn J. Basic Technical Mathematics with Calculus. 3rd ed. Benjamin Cummings.

UTC PHYSICS I

A practical approach to the teaching of basic physics of force, work, rate, momentum, and resistance is presented in UTC Physics I. Students are shown, by classroom demonstration, how these five concepts are applied to four energy systems--mechanical, fluid, electrical, and thermal. Students perform practical laboratory experiments that relate each concept to the four energy systems.

COURSE OUTLINE

	Student Contact Hours	
	Class	Laboratory
I. Force	9	18
A. Mechanical Systems		
1. Linear force		
2. Units of mass and force		
3. Forcelike quantities		
4. Torque		
B. Fluid Systems		
1. Pressure		
2. Density/pressure relationships		
C. Electrical Systems		
1. Electromotive force (emf)		
2. Methods of producing an emf		
D. Thermal Systems		
1. Temperature difference		
2. Temperature scales		
II. Work	7	14.5
A. Mechanical Systems		
1. Mechanical work, translational		
2. Mechanical work, rotational		
B. Fluid Systems		
1. Pressure/volume relationships		
2. Energy considerations		
C. Electrical Systems		
1. Charge movement and emf		
2. Conversion factors for electrical systems		
3. Current		
D. Thermal Systems		
1. Heat flow		
2. Heat measure		
3. Change of state		
III. Rate	6	12
A. Mechanical Systems		
1. Speed and velocity, linear motion		

	Student Contact Hours: Class	Student Contact Hours: Laboratory
2. Acceleration, linear		
3. Rotational motion, angular velocity		
4. Angular acceleration		
B. Fluid Systems		
1. Volume flow rate		
2. Mass flow rate		
C. Electrical Systems		
1. Current		
2. Ac/dc		
D. Thermal Systems		
1. Heat energy transfer		
2. Heat flow rate		
IV. Momentum	3	6
A. Linear Momentum		
B. Impulse and Momentum Change		
C. Conservation of Momentum		
D. Angular Momentum		
E. Momentum in Fluid Systems		
V. Resistance	6	12
A. Mechanical Systems		
1. Dry friction		
2. Static and kinetic friction		
B. Fluid Systems		
1. Fluid resistance in pipes		
2. Viscosity		
C. Electrical Systems		
1. Ohm's law		
2. Resistivity of conductors		
D. Thermal Systems		
1. Thermal resistance		
2. Insulation		

STUDENT LABORATORIES

I. Force

- Gravity - Scales and balances are used to determine the weight and mass of several objects.
- Addition of Mechanical Forces - Students solve a series of force problems with multiple forces acting on a single point through use of a force table and a scale.
- Addition of Torques - Students extend their experience with force problems to an investigation of torques.
- Stress and Strain - An introduction to strength of materials is accomplished by application of Hooke's law and measurement of the ultimate tensile strength of brass, copper, and aluminum wire.
- Density, Buoyancy, and Specific Gravity - The properties of density, buoyancy and specific gravity are defined and illustrated. A hydrometer is used to determine the amount of antifreeze in radiators and the amount of acid in batteries.

- Manometers - Use of a U-tube manometer for verification of proper calibration of a pressure gage introduces concepts of pressure measurement.
- Electric Forces and Fields - Students investigate geometry of electric field lines and their relationship to electrode shape with respect to static electric fields.
- Magnetic Forces and Fields - The relationship of electric and magnetic fields is investigated through construction and operation of an electromagnet.
- Thermometers - The four temperature scales, conversion equations, various types of thermometers, and calibration of a liquid-in-glass thermometer are investigated.
- Temperature Difference and Heat Flow - Heat transmission via conduction, convection, and radiation is investigated through experimental measurements and observations.

II. Work
- Work Done on an Elevator - Mechanical work required to lift objects vertically and via an inclined plane is determined by experimental means and compared.
- Work Done by a Winch - The concept of work in rotational systems is investigated via experimental measurements and observations with a simple winch.
- Work Done by a Water Pump - Efficiency and work accomplished by a water pump are calculated from experimental data obtained through measurement of fluid moved, time, current, and voltage.
- Heat Energy Required for a Temperature Increase - A calorimeter is employed in determination of some thermal properties of materials.
- Fundamentals of Air Conditioning - Students perform practical measurements in determining efficiency of actual air conditioning equipment found in their environments.

III. Rate
- Velocity at Constant Acceleration - Students apply equations of motion to pneumatic data obtained on an inclined track and a level track.
- Displacement at a Constant Acceleration - Using data extracted from experimentation with inclined and level track sections, students solve for any two motion parameters when given the three remaining motion parameters.
- Rotational Motion - Using equations and principles of rotational motion, students determine angular velocity and angular acceleration of a phonograph turntable.
- Electric Current - Ac and dc ammeters are used to make current measurements and acquaint students with their operation.
- Frequency - Students use pendulum, laser, and oscilloscope to study frequency in mechanical and electrical systems.
- Heating and Cooling Rate - Practical experience is provided in measurement, calculation, and graphical plotting of data extracted from experimental procedures dealing with heating and cooling.

IV. Momentum

- Angular Momentum of a Flywheel - Student is provided with a procedure for calculation of angular momentum of a flywheel device and gains exposure to the analogy between translational and rotational quantities.
- Impulse and Momentum - Impulse and change in momentum in mechanical systems of modern technology are investigated.
- Gyroscope - Investigations in angular momentum and effects of external forces on a spinning gyroscope are presented. Students construct a simple gyrocompass.

V. Resistance

- Effects of Lubricants - The coefficients of static and kinetic friction are calculated for various situations involving different materials sliding on an aluminum plate, both with and without lubrication.
- Rolling Friction - Effects of rolling friction are compared to sliding friction and the coefficient of rolling friction is determined in two cases.
- Viscosity - Methods for the measure of viscosity and the effect of temperature on viscosity of lubricants are investigated by use of a rolling sphere viscometer and several lubricating oils at varying temperatures.
- Fluid Resistance in Pipes - Effects of pipe length and diameter on friction losses are investigated with respect to fluid motion in pipes.
- Valves and Regulators - Student gains familiarity with use and care of gas regulators and valves and performs measurements with respect to resistance of these devices.
- Ohm's Law - A volt-ohm-milliammeter, dc power supply, and single resistor circuit are employed in examination of the interrelationship of voltage, current, and resistance.
- Series and Parallel Resistors - Series and parallel circuits of light bulbs are used to investigate effects of series/parallel circuit arrangements on electrical current.
- Conductors, Semiconductors, and Insulators - Electrical properties of conductors, semiconductors, and insulators are investigated.
- Resistance of Wires - Effects of length, cross-sectional area, and temperature on the resistance of electrical wires are investigated.
- Resistance of Semiconductor Junctions - Students measure resistances of several diodes and transistors through use of a milliammeter, microammeter, and voltmeter.
- Volt-Ohm-Milliammeter - Additional investigations into Ohm's law are pursued while the student is exposed to proper methods of operation of the the VOM.
- Thermal Conductivity - Effects o, thermal conductivity and thickness of material on heat flow are investigated through use of a hot plate, heat lamps, and oven thermometers.

STUDENT COMPETENCIES

At the conclusion of this course, in the appropriate course areas indicated, the student will be able to:

I. Force

- Define the following physical quantities and, where applicable, state their units in both SI (International System of Units) and English units:
  - Force
  - Torque
  - Pressure
  - Voltage
  - Temperature difference
- Given two or more mechanical forces acting along the same line, determine the resultant force.
- Given two of the following quantities in a mechanical rotational system, determine the third:
  - Force
  - Lever arm
  - Torque
- Given two of the following quantities in a fluid system, determine the third:
  - Force
  - Area
  - Pressure
- Given two of the following quantities in a fluid system, determine the third:
  - Pressure
  - Height of fluid
  - Weight density
- Given two or more voltage sources connected in series, determine the resultant voltage.
- Given a temperature in either degrees Celsius or degrees Fahrenheit, determine the equivalent temperature on the other scale.
- Describe how pressure in fluidal systems, voltage in electrical systems, and temperature difference in thermal systems are similar to force and torque in mechanical systems.
- Describe the conditions that must be met for equilibrium in each of the following energy systems:
  - Mechanical
  - Fluid
  - Electrical
  - Thermal
- Successfully complete the laboratory activities entitled:
  - Gravity
  - Addition of Mechanical Forces
  - Addition of Torques
  - Stress and Strain
  - Density, Buoyancy, and Specific Gravity
  - Manometers
  - Electric Forces and Fields
  - Magnetic Forces and Fields

Thermometers
Temperature Difference and Heat Flow

II. Work

- Define work and energy in general terms that apply to any energy system, and distinguish work from energy in the following systems:
  - Mechanical translational
  - Mechanical rotational
  - Fluid
  - Electrical
  - Thermal
- Define the following units of work and energy:
  - Foot-pound
  - Newton-meter
  - Joule
  - Calorie
  - British thermal unit
- Define the following terms and explain their usefulness in determining work done:
  - Radian (mechanical system)
  - Charge (electrical system)
  - Volume displaced (fluid system)
  - Heat capacity (thermal system)
- Given two of the following quantities in a mechanical translational system, determine the third:
  - Force
  - Displacement
  - Work
- Given two of the following quantities in a mechanical rotational system, determine the third:
  - Torque
  - Angular displacement
  - Work
- Given two of the following quantities in a fluid system, determine the third:
  - Pressure difference
  - Volume displaced
  - Work
- Given two of the following quantities in an electrical system, determine the third:
  - Voltage
  - Charge transferred
  - Work
- Given the temperature difference across a uniform thickness of a substance, the dimensions of the substance, and its thermal conductivity, calculate the heat flow rate through the substance.
- Given two of the following quantities in a thermal system, determine the third:
  - Temperature change of object
  - Heat capacity of object
  - Work (heat energy transferred)
- Define and give examples of:
  - Latent heat
  - Sensible heat

- State the general equation for work, and explain how it applies to each of the following energy systems:
  - Mechanical translational
  - Mechanical rotational
  - Fluid
  - Electrical
  - Thermal
- Successfully complete the laboratory activities entitled:
  - Work Done on an Elevator
  - Work Done by a Winch
  - Work Done by a Water Pump
  - Heat Energy Required for a Temperature Increase
  - Fundamentals of Air Conditioning

III. Rate

- Define the following rates and, where applicable, express their basic units both in SI and English systems of units:
  - Speed and velocity
  - Acceleration
  - Angular velocity
  - Angular acceleration
  - Volume flow rate
  - Mass flow rate
  - Electric current
  - Heat flow rate
- In a linear mechanical system, given all the quantities except one in each of the following groups, determine the unknown quantity:
  - Displacement, elapsed time, velocity
  - Initial velocity, final velocity, elapsed time, acceleration
  - Mass, force, acceleration
- In a rotational mechanical system, given all the quantities except one in each of the following groups, determine the unknown quantity:
  - Angular displacement, elapsed time, angular velocity
  - Initial angular velocity, final angular velocity, elapsed time, angular acceleration
- In a fluid system, given all the quantities except one in each of the following groups, determine the unknown quantity:
  - Volume of fluid moved, elapsed time, volume flow rate
  - Mass of fluid moved, elapsed time, mass flow rate
- Given two of the following quantities in an electrical system, determine the third:
  - Charge transferred
  - Elapsed time
  - Current
- Given two of the following quantities in a thermal system, determine the third:
  - Heat energy transferred
  - Elapsed time
  - Heat flow rate
- State the general equation for rate, and explain how it applies to each of the following energy systems:
  - Mechanical translational
  - Mechanical rotational

Fluid
Electrical
Thermal

- Successfully complete the laboratory activities entitled:
  Velocity at Constant Acceleration
  Displacement at a Constant Acceleration
  Rotational Motion
  Electric Current
  Frequency
  Heating and Cooling Rate

IV. Momentum

- Define the following terms; state the appropriate units in the mk/s system (SI) and the cgs system; and give the equation for each:
  Linear momentum
  Angular momentum
  Impulse
  Angular impulse
  Moment of inertia
- Given two of the following quantities, determine the third:
  Mass of an object
  Velocity of the object
  Momentum of the object
- Given two of the following quantities, determine the third:
  Moment of inertia of an object
  Angular velocity of the object
  Angular momentum of the object
- Given all the following quantities describing a linear collision except one, determine the unknown quantity:
  Mass of first object
  Initial velocity of first object
  Final velocity of first object
  Mass of second object
  Initial velocity of second object
  Final velocity of second object
- Explain the following concepts in a short paragraph each:
  Conservation of linear momentum
  Conservation of angular momentum
- Use a given equation to calculate the force produced on one blade of a reaction turbine, given the velocity of fluid and the mass of fluid per unit time striking the blade.
- Successfully complete the laboratory activities entitled:
  Angular Momentum of a Flywheel
  Impulse and Momentum
  Gyroscope

V. Resistance

- Define resistance in a general way, and state the final form of the energy expended when a forcelike quantity does work to overcome resistance in any energy system.
- Calculate the magnitudes of starting and sliding frictional forces, given the mass or weight of the object, the coefficients of friction, and the angle of incline.

- Given two of the following quantities in fluid, electrical, and thermal systems, determine the third:
  Forcelike quantity
  Rate
  Resistance
- Describe the difference between laminar and turbulent flow.
- State the factors contributing to fluid resistance in pipes.
- State the factors contributing to electrical resistance in wires.
- State the factors contributing to the thermal resistance of objects.
- Describe--with the use of graphs--the definition of resistance as the ratio of forcelike quantity to rate in fluid, electrical, and thermal systems. Include the units of forcelike quantity, rate, and resistance for each system.
- State the fundamental difference between sliding friction and resistance as it applies to fluid, electrical, and thermal systems.
- Successfully complete the laboratory activities entitled:
  Effects of Lubricants
  Rolling Friction
  Viscosity
  Fluid Resistance in Pipes
  Valves and Regulators
  Ohm's Law
  Series and Parallel Resistors
  Conductors, Semiconductors, and Insulators
  Resistance of Wires
  Resistance of Semiconductor Junctions
  Volt-Ohm-Milliammeter
  Thermal Conductivity

RECOMMENDED TEXT

Unified Technical Concepts--Physics for Technicians and UTC Application Modules, Volume I. Waco, TX: Center for Occupational Research and Development, 1983.

I. 1-0 Force
   1M1 Gravity
   1M2 Addition of Mechanical Forces
   1M3 Addition of Torques
   1M5 Stress and Strain
   1F2 Density, Buoyancy, and Specific Gravity
   1E3 Electric Forces and Fields
   1E4 Magnetic Forces and Fields
   1T1 Thermometers
   1T2 Temperature Difference and Heat Flow

II. 2-0 Work
   2M1 Work Done on an Elevator
   2M2 Work Done by a Winch
   2F1 Work Done by a Water Pump
   2T1 Heat Energy Required for a Temperature Increase
   2T4 Fundamentals of Air Conditioning

III. 3-0 Rate
- 3M2 Velocity at Constant Acceleration
- 3M3 Displacement at a Constant Acceleration
- 3M5 Rotational Motion
- 3E1 Electric Current
- 3E2 Frequency
- 3T1 Heating and Cooling Rate

IV. 4-0 Momentum
- 4M1 Angular Momentum of a Flywheel
- 4M2 Impulse and Momentum
- 4M4 Gyroscopes

V. 5-0 Resistance
- 5M2 Effects of Lubricants
- 5M3 Rolling Friction
- 5F2 Viscosity
- 5F3 Fluid Resistance in Pipes
- 5F4 Valves and Regulators
- 5E1 Ohm's Law
- 5E2 Series and Parallel Resistors
- 5E4 Conductors, Semiconductors, and Insulators
- 5E5 Resistance of Wires
- 5E6 Resistance of Semiconductor Junctions
- 5E8 Volt-Ohm-Milliammeter
- 5T1 Thermal Conductivity

REFERENCES

Dierauf, Edward J., Jr., and Court, James E. Unified Concepts in Applied Physics. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1979.

UTC PHYSICS II

The second quarter of Physics builds on the foundation developed in the first quarter by presenting concepts of power, energy, force transformers, and energy convertors. Appropriate laboratories provide practical hands-on experience working with associated devices in the four energy systems (mechanical, fluid, electrical, and thermal).

COURSE OUTLINE

	Student Contact Hours	
	Class	Laboratory
VI. Power	7.5	15
A. Power Equations		
1. Power defined		
2. Basic equation form		
B. Efficiency		
C. Mechanical Systems		
1. Translational		
2. Rotational		
D. Fluid Systems		
E. Electrical Systems		
F. Thermal Systems		
VII. Potential and Kinetic Energy	7.5	15
A. Mechanical Systems		
1. Translational		
2. Rotational		
B. Fluid Systems		
1. Volume/mass conversion		
2. Bernoulli's equation		
C. Electrical Systems		
1. Charge relationships		
2. Capacitors		
D. Thermal Systems		
VIII. Force Transformers	7.5	15
A. Principles of Force Transformers		
B. Mechanical Systems		
1. The pulley		
2. The lever		
3. The inclined plane		
4. The screw		
5. The wheel and the axle		
C. Fluid Systems		
1. The hydraulic lift		
2. Mechanical advantage of a hydraulic lift		
D. Electrical Systems--Electrical Transformers		

	Student Contact Hours Class	Laboratory
IX. Energy Convertors	8.5	17.5

IX. Energy Convertors
   A. General Considerations and Background
   B. Convertors of Mechanical Input Energy
      1. Fluid output energy
      2. Electrical output energy
   C. Convertors of Fluid Input Energy
      1. Mechanical output energy
      2. Electrical output energy
   D. Convertors of Electrical Input Energy
      1. Mechanical output energy
      2. Thermal output energy
      3. Optical output energy
   E. Convertors of Thermal Input Energy
      1. Mechanical output energy
      2. Fluid output energy
      3. Electrical output energy
   F. Convertors of Optical Input Energy
      1. Electrical output energy
      2. Thermal output energy

STUDENT LABORATORIES

VI. Power

- Hydraulic Power - Student determines experimentally the horsepower produced by a water pump sending fluid through a hydraulic system.
- Electrical Power Measurement - A kilowatt-hour meter is used to measure power consumed by various electrical devices. Student gains experience in power calculations.
- Efficiency of Electric Motors and Generators - A wattmeter and a prony brake are used to determine efficiency of an electric motor. Involves experimental measurements and calculations.
- Heat Exchangers - Pump, portable fan, wattmeter, and automobile radiator tor are employed in investigation of power exchange.

VII. Potential and Kinetic Energy

- Rotational Kinetic Energy of a Flywheel - Student constructs a simple flywheel from a wheel and axle and determines its energy-storage efficiency.
- Venturi Meters - A triple-arm manometer is used in conjunction with a venturi meter to determine velocity of flow for a fluid; discussion of potential and kinetic energy changes in the pipe is included.
- Pitot Tubes - A pitot tube is employed to investigate measurement of velocity of an automobile. Attention given to various features of construction of the pitot tube.
- Gas Laws - A manometer is employed in investigation of Gay-Lussac's law and Boyle's law. Involves measurements and calculations.
- Energy Stored in a Capacitor - Student obtains experimental data from capacitor discharge curves to calculate energy-storage capability of the capacitor.

- Energy Stored in an Inductor - An automobile ignition coil and an ammeter are employed in investigation of energy stored in a magnetic field.
- Series and Parallel Capacitors - Electrical consequences of placing capacitors in series or parallel circuit arrangements are investigated. Methods for determination of unknown capacitance are included.

VIII. Force Transformers

- Levers - Student constructs several levers and calculates the mechanical advantage of each from measurements taken.
- Drive Systems - A phonograph turntable is used in investigation of torque transformers, with examination of actions by gear systems, belt drives, and disk drives.
- Gear Trains - Student examines the gear drive of a metal-cutting lathe.
- Hydraulic Press - Students use disposable syringes, clear tubing,and slotted weights to construct and operate a simulated hydraulic press. Attention given to force transformation and mechanical advantage.
- Electrical Transformers - Student constructs an electrical transformer, performs measurements of voltage and current, and investigates relationships between measured and calculated values.

IX. Energy Convertors

- Turbines - Energy transformations are traced diagrammatically for gas, steam, wind, and water turbines. Student investigates these transformations in greater detail through experimentation with a water wheel and prony brake.
- Fluid Pumps - Principles, characteristics, and applications of the hydrodynamic pump and several types of positive-displacement pumps are discussed. Direct lab experience with a hydrodynamic pump is included.
- Fans and Blowers - Air horsepower and efficiency of a fan motor are experimentally determined.
- Vacuum Pumps - Student examines two types of pumps used to produce a vacuum in an enclosed chamber experimentally. Vacuum gages are used to obtain needed measurements.
- Electric Generators - Basic theory and design of dc generators are examined. Electronic measurement instruments are used to determine electrical power output from a generator.
- Alternators - Student uses an oscilloscope and a VOM to determine output power and efficiency of an alternator.
- Electric Motors - Student constructs a simple permanent-magnet motor and a series motor, operates, and evaluates motor performance.
- Solenoids and Relays - Student identifies relay terminals and operates starter and electric motor control circuits.
- Photovoltaic Materials - An optical power meter, milliammeter, and photovoltaic detector are used to measure efficiency of conversion of light energy to electrical energy from a HeNe laser.

STUDENT COMPETENCIES

At the conclusion of this course, in the appropriate course areas indicated, the student will be able to:

VI. Power

- Define "power" as it applies, in general, to all energy systems; write equations that relate work, elapsed time, force, and rate to power in these energy systems:
  - Mechanical
  - Fluid
  - Electrical
- List the SI and English units used to define power for each energy system.
- Given any two of the following quantities in any energy system, determine the third:
  - Work (or forcelike quantity x displacementlike quantity)
  - Elapsed time
  - Power
- Given any two of the following quantities in any energy system, determine the third:
  - Forcelike quantity
  - Rate
  - Power
- Define the following terms:
  - Input power
  - Output power
  - Efficiency
- Given any two of the following quantities in any energy system, determine the third:
  - Input power
  - Output power
  - Efficiency
- Convert values for power expressed in any energy unit to equivalent values expressed in any other unit.
- Successfully complete the laboratory activities entitled:
  - Hydraulic Power
  - Electrical Power Measurement
  - Efficiency of Electric Motors and Generators
  - Heat Exchangers

VII. Potential and Kinetic Energy

- Define potential energy, kinetic energy, and conservation of energy by using examples from mechanical systems.
- Given any two of the quantities in the following groups, determine the third:
  - Mass, velocity, kinetic energy
  - Mass, height, potential energy
  - Spring constant, spring displacement, potential energy
  - Moment of inertia, angular velocity, kinetic energy
  - Capacitance, voltage, potential energy

- Given Bernoulli's equation and the height of liquid in a tank, determine the exit velocity at the bottom of the tank if there is no fluid friction.
- List and describe three processes that transfer thermal energy.
- Discuss the conservation of energy as it applies to fluid, electrical, and thermal systems.
- Successfully complete the laboratory activities entitled:
  - Rotational Kinetic Energy of a Flywheel
  - Venturi Meters
  - Pitot Tubes
  - Gas Laws
  - Energy Stored in a Capacitor
  - Energy Stored in an Inductor
  - Series and Parallel Capacitors

VIII. Force Transformers

- Describe specific force transformers in the mechanical translational, mechanical rotational, fluidal, and electrical systems; discuss their fundamental similarity as transformers of forcelike quantities.
- Define the following terms:
  - Ideal mechanical advantage
  - Actual mechanical advantage
  - Efficiency
- Calculate the ideal mechanical advantage of a specific pulley, lever, screw, wheel and axle, hydraulic press or lift, and electrical transformer.
- Calculate the change in current in an ideal electrical transformer.
- Discuss how resistance in a transformer dissipates energy input and reduces efficiency.
- Describe the power input and power output characteristics of a transformer that operates continuously.
- Successfully complete the laboratory activities entitled:
  - Levers
  - Drive Systems
  - Gear Trains
  - Hydraulic Press
  - Electrical Transformers

IX. Energy Convertors

- Describe energy convertors in general terms that apply to all energy-conversion devices.
- Describe the operation of the following energy convertors:
  - Vane pump
  - Electric generator
  - Turbine
  - Electric motor
  - Electric heater
  - Internal combustion engine
  - Boiler
  - Solar collector

- Given two of the following quantities, determine the third:
  Input energy
  Output energy
  Efficiency
- Given the efficiency of all the energy convertors used in an energy conversion system, determine the overall system efficiency.
- Successfully complete the laboratory activities entitled:
  Turbines
  Fluid Pumps
  Fans and Blowers
  Vacuum Pumps
  Electric Generators
  Alternators
  Electric Motors
  Solenoids and Relays
  Photovoltaic Materials

RECOMMENDED TEXT

Unified Technical Concepts--Physics for Technicians and UTC Applications Modules, Volume I and II. Waco, TX: Center for Occupational Research and Development, 1983.

VI. 6-0 Power
6F1 Hydraulic Power
6E1 Electrical Power Measurement
6E3 Efficiency of Electric Motors and Generators
6T1 Heat Exchangers

VII. 7-0 Potential and Kinetic Energy
7M3 Rotational Kinetic Energy of a Flywheel
7F2 Venturi Meters
7F3 Pitot Tubes
7F5 Gas Laws
7E2 Energy Stored in a Capacitor
7E3 Energy Stored in an Inductor
7E4 Series and Parallel Capacitors

VIII. 8-0 Force Transformers
8M1 Levers
8M3 Drive Systems
8M4 Gear Trains
8F1 Hydraulic Press
8E1 Electrical Transformers

IX. 9-0 Energy Convertors
9F1 Turbines
9F2 Fluid Pumps
9F4 Fans and Blowers
9F5 Vacuum Pumps
9E1 Electric Generators
9E2 Alternators

9E3 Electric Motors
9E4 Solenoids and Relays
9E5 Photovoltaic Materials

REFERENCES

Dierauf, Edward J., Jr., and Court, James E. Unified Concepts in Applied Physics. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1979.

UTC PHYSICS III

The third quarter of Physics provides the student with practical knowledge of scientific principles involved in transducers, vibrations and waves, time constants, and radiation. Practical hands-on experience with devices common to many technologies is offered in the laboratory.

COURSE OUTLINE

	Student Contact Hours	
	Class	Laboratory
X. Transducers	8.5	17.5
A. Mechanical Transducers		
1. Microphone		
2. Piezoelectric pressure		
3. Strain gages		
4. Others		
B. Fluid Transducers		
1. Turbine flowmeter		
2. Pressure-sensing		
C. Electrical Transducers, Meter Movement		
D. Thermal Transducers		
1. Thermocouple		
2. Others		
E. Optical Transducers		
1. Photoconductive photocell		
2. Photovoltaic cell		
XI. Vibrations and Waves	7.5	15
A. Types of Waves		
1. Transverse		
2. Longitudinal		
B. Wave Characteristics		
1. Wave velocity		
2. The wave equation		
3. Superposition		
4. Standing waves		
5. Interference		
C. Wave Motion as a Unifying Concept		
1. Mechanical systems		
2. Fluid systems		
3. Electrical waves		
XII. Time Constants	7.5	15
A. Basic Considerations		
1. Thermal cooling		
2. Radioactive decay		
B. Mechanical Systems		
1. Translational		
2. Rotational		

	Student Contact Hours Class	Laboratory
C. Fluid Systems		
D. Electrical Systems		
E. Thermal Systems		
XIII. Radiation	7.5	15

XIII. Radiation
- A. Radiant Energy--Basics
- B. The Electromagnetic Spectrum
  1. Radio waves
  2. Television and radar
  3. Infrared
  4. Visible
  5. Ultraviolet
  6. X-rays
  7. Gamma
- C. The Nature of Electromagnetic Waves
- D. EM Radiation--Waves or Photons
- E. Characteristics of EM Radiation
  1. Reflection
  2. Refraction
  3. Polarization
  4. Propagation
- F. Particle Radiation
  1. Alpha rays
  2. Beta rays

STUDENT LABORATORIES

X. Transducers
- Strain Gages - Student measures strain with a strain gage, and measures resistance change in a conductor under stress.
- Accelerometers - Student uses an accelerometer and an oscilloscope to measure a variety of accelerations. Student is introduced to the use of piezoelectric crystals.
- Bourdon Tubes - Involves pressure measurements and calibration of a typical Bourdon tube.
- Fluid-Flow Measuring Devices - Various devices used in the measure of fluid flow are examined. These include an orifice plate and manometer system, turbine flowmeter, and magnetic flowmeter.
- Vacuum Gages - Units of measure for pressure are discussed. Practical experience in the use of a mechanical valve to investigate operation of various vacuum gages is obtained.
- Meter Movements - Student uses a meter movement to construct a voltmeter and an ammeter.
- Bimetallic Strips - Student constructs a bimetallic strip, measures its deflection with heat, and uses a bimetallic strip to construct a control circuit.

- Temperature Measuring Devices - Student measures temperatures using a mercury thermometer, a VOM in conjunction with a thermocouple and a thermistor, and examines other temperature measurement instruments.
- Thermocouples - Student investigates properties of a thermocouple and uses a thermometer and a voltmeter to determine thermoelectric voltage of different thermocouples.
- Thermistors - Resistance and temperature characteristics of a thermistor are investigated.

XI. Vibrations and Waves

- Vibration Isolation - An accelerometer and an oscilloscope are used to determine vibration transmission between an electric motor and its support.
- Resonance - Tuning forks, pendulums, and a resonance tube are used to experimentally investigate the phenomenon called resonance.
- Alternating Voltage and Current - Student uses an oscilloscope, a signal generator, and a VOM to investigate resistance and reactance, and to compare and contrast ac and dc characteristics.
- Phase Relationships in AC Circuits - Impedance, phase angle, and power factor in RC, RL, and RLC circuits are investigated with an ammeter and a voltmeter.
- Oscilloscope - Provides hands-on experience in the operation of an oscilloscope.
- Rectifiers - Examines rectification of signals in fluid, mechanical and electrical systems. Assembles circuits containing rectifiers and evaluates performance with an oscilloscope.

XII. Time Constants

- Rate of Emptying Tanks - Fluid-system behavior investigated for emptying of a large fluid container. Time constants measured.
- RLC Circuits - Student uses an oscilloscope, a VOM, and several circuit components to observe pulse shapes of overdamped, underdamped, and critically damped RLC circuits.
- Response Time of Thermocouples - Student measures response times for a conventional thermocouple and a thin-film thermocouple, and uses a thermocouple to measure thermal diffusivity of a metal sample.
- Time Constants of Heating and Cooling - Thermometers and insulated containers are used to determine the effect of surface characteristics of a hot body upon rates of cooling.

XIII. Radiation

- Inverse Square Law - Spreading of Light - Irradiance as a function of distance from the source is investigated with an optical power meter.
- The Optical Spectrum - Energy and frequency of photons will be calculated from measurements of wavelength made with a grating spectroscope for various laboratory light sources.
- Light Sources - A grating spectroscope and an optical power meter are used to observe the irradiance pattern and output spectra of incandescent and fluorescent light sources.

- Lasers - Student operates and uses a low-power HeNe laser and observes the unique characteristics of coherent light.
- Stroboscopes - Light Pulses - Students use the stroboscope to accomplish measurement of rotational rate of a fan, observe water drop formation, and check the timing of an automobile engine.
- Optical Filters - Absorption of Light - Transmission curves versus filter thickness are plotted, and the absorption coefficient of optical filters is calculated with the help of a laser and a power meter.
- Specular and Diffuse Reflection of Light - Characteristics of diffuse and specular reflections of light are compared with the help of a laser and a power meter.
- Image Formation with Mirrors - Real and virtual images are investigated with concave and convex mirrors. A solar furnace is constructed.
- Prisms - Refraction and Dispersion of Light - Light velocity and the index of refraction of a prism at several wavelengths will be investigated with the help of a prism spectrometer.
- Lenses - Focusing and Spreading of Light - Student constructs a small refracting-type telescope and investigates the action of light passing through lenses.

STUDENT COMPETENCIES

At the conclusion of this course, in the appropriate course areas indicated, the student will be able to:

X. Transducers
- Define a transducer, drawing a distinction between those transducers that require external energy sources and those that do not.
- Describe the operation of the following transducers:
  Strain gage
  Accelerometer
  Microphone
  Turbine flowmeter
  Barometer
  Meter movement
  Thermocouple
  Thermistor
  Bimetallic strip
  Photoconductive cell
  Photovoltaic cell
- Successfully complete the laboratory activities entitled:
  Strain Gages
  Accelerometers
  Bourdon Tubes
  Fluid-Flow Measuring Devices
  Vacuum Gages
  Meter Movements
  Bimetallic Strips
  Temperature Measuring Devices
  Thermocouples
  Thermistors

XI. Vibrations and Waves

- Distinguish between longitudinal and transverse waves by giving at least two examples of each type and by drawing and labeling a sketch of each.
- Define the following terms associated with waves and wave motion:
  - Propagating medium
  - Wavelength
  - Frequency
  - Period
  - Displacement
  - Amplitude
  - Phase
  - Standing wave
  - Constructive interference
  - Destructive interference
  - Beats
- Calculate the wavelength of a wave, given its velocity and frequency.
- Interpret the following equation, explaining the significance of each symbol:

$$y = A \sin 2\pi \left(\frac{x}{\lambda} - ft\right).$$

- Explain the meaning of the expression, "The current leads the voltage by a given phase angle." Use sine-wave sketches of both current and voltage.
- Describe the superposition principle.
- Describe wave phenomena in each of the following energy systems:
  - Mechanical
  - Fluid
  - Electrical
- Successfully complete the laboratory activities entitled:
  - Vibration Isolation
  - Resonance
  - Alternating Voltage and Current
  - Phase Relationships in AC Circuits
  - Oscilloscope
  - Rectifiers

XII. Time Constants

- Define the following terms:
  - Steady state
  - Transient
  - Damping
  - Time constant
  - Half-life
  - Decay constant
- Draw and label a graph showing an exponentially-decaying function. Include on the graph the time constants $T_{1/2}$ and $T_{1/e} \equiv \tau$. Also, write an equation for the function shown on the graph.

- Given the initial temperature of a hot body, the ambient temperature of its surroundings, and the thermal time constant of the system, determine the temperature of the body after a specified time interval.
- Given the number of radioactive atoms in a sample and the decay constant, determine the number of atoms remaining after a specified time interval.
- Given the values of resistance, capacitance, and applied voltage in an RC electrical circuit, determine the time constant for the circuit, the time required for the capacitor voltage to reach 99% of the applied voltage, and the circuit current and capacitor voltage after a specified time interval.
- Explain how the concept of time constants can be applied to the following energy systems; give a specific example in each case:
  - Mechanical translational
  - Mechanical rotational
  - Fluid
  - Electrical
  - Thermal
  - Optical
  - Nuclear
- Successfully complete the laboratory activities entitled:
  - Rate of Emptying Tanks
  - RLC Circuits
  - Response Time of Thermocouples
  - Time Constants of Heating and Cooling

XIII. Radiation

- Describe in one or two sentences the basic properties of each of the following types of radiation:
  - Sound
  - Light
  - Alpha and beta particles
- Define electromagnetic radiation (radiant energy), and describe a simple experiment that illustrates how electromagnetic radiation can be created.
- List the frequencies in the electromagnetic spectrum from long-wavelength EM waves of ac power (60 hertz) to gamma rays (10^{22} hertz), including each major part--radio, FM, television, radar, microwave, infrared, visible, ultraviolet, X-ray, and gamma ray.
- Given the equation $v = \lambda f$--relating wave speed, wavelength, and frequency--determine the radiation frequency for any part of the electromagnetic spectrum.
- Given the equation $E = hf$ or $E = h\,c/\lambda$, determine the energy of different waves in the EM spectrum.
- Describe qualitatively the nature of an electromagnetic wave in terms of electric and magnetic fields; state what is always required to generate an EM wave; and explain how EM waves are propagated through empty space without benefit of an elastic medium.

- Describe a photon, and explain why both wave- and particle-like (photon) phenomena are required to describe interaction of EM radiation with matter. Give examples in which the wave character is most useful in describing EM radiation and examples in which the photon character is most useful.
- Explain what is meant by the inverse square law and how this law is used to describe the fall-off of EM radiation propagating from a small source.
- Define polarization, and explain what is meant by polarized EM radiation--in particular, polarized light.
- Define visible radiation, and determine its limits numerically in terms of wavelength, frequency, and energy.
- Describe the reflection and refraction of EM radiation--especially light--and set up an experiment to verify the two laws.
- Differentiate between alpha and beta radiation and gamma radiation.
- Briefly explain each of the three parts in the symbol $_{92}U^{238}$.
- Given the appropriate equipment, illustrate and verify the inverse square law of EM radiation in the visible region.
- Given the appropriate equipment, produce and detect polarized light in the microwave region.
- Successfully complete the laboratory activities entitled:
  - Inverse Square Law - Spreading of Light
  - The Optical Spectrum
  - Light Sources
  - Lasers
  - Stroboscopes - Light Pulses
  - Optical Filters - Absorption of Light
  - Specular and Diffuse Reflection of Light
  - Image Formation with Mirrors
  - Prisms - Refraction and Dispersion of Light
  - Lenses - Focusing and Spreading of Light

RECOMMENDED TEXT

<u>Unified Technical Concepts--Physics for Technicians</u> and <u>UTC Application Modules, Volumes I and II</u>. Waco, TX: Center for Occupational Research and Development, 1983.

X. 10-0 Transducers
   10M1 Strain Gages
   10M2 Accelerometers
   10F1 Bourdon Tubes
   10F4 Fluid-Flow Measuring Devices
   10F5 Vacuum Gages
   10E1 Meter Movements
   10T2 Bimetallic Strips
   10T3 Temperature Measuring Devices
   10T4 Thermocouples
   10T5 Thermistors

XI. 11-0 Vibrations and Waves
   11M3 Vibration Isolation

11M4 Resonance
11E1 Alternating Voltage and Current
11E2 Phase Relationships in AC Circuits
11E3 Oscilloscope
11E4 Rectifiers

XII. 12-0 Time Constants
12F1 Rate of Emptying Tanks
12E3 RLC Circuits
12T1 Response Time of Thermocouples
12T2 Time Constants of Heating and Cooling

XIII. 13-0 Radiation
13L1 Inverse Square Law - Spreading of Light
13L2 The Optical Spectrum
13L3 Light Sources
13L4 Lasers
13L5 Stroboscopes - Light Pulses
13L6 Optical Filters - Absorption of Light
13L7 Specular and Diffuse Reflection of Light
13L8 Image Formation with Mirrors
13L9 Prisms - Refraction and Dispersion of Light
13L10 Lenses - Focusing and Spreading of Light
13N3 Radioactivity

REFERENCES

Dierauf, Edward J., Jr., and Court, James E. Unified Concepts in Applied Physics. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1979.

TECHNICAL COMMUNICATIONS

Technical Communications provides the student with a working knowledge of communication techniques, procedures, and formats used in industry and business. The student learns accepted methods of describing devices and processes; of making oral and written technical presentations; and of using written manuals, guides, specifications, and vendor instructions. Most importantly, the student is involved extensively in writing various technical reports and in preparing/delivering appropriate technical presentations.

COURSE OUTLINE

	Student Contact Hours Class	Laboratory
I. Introducing Technical Communications	10	0
A. Purpose of Course		
B. Definition of Technical Writing		
C. Basic Principles of Technical Writing		
D. Style		
1. Audience		
2. Purpose		
3. Scientific style		
E. Introduction to Oral Communications		
II. Conducting Research	10	0
A. Completing Preliminary Steps		
B. Assembling Sources		
1. Searching subject heading indexes		
2. Using the card catalog		
3. Consulting specialized guides		
4. Locating bibliographies		
5. Using indexes and abstract services		
6. Using reference materials		
C. Using Research Results		
1. Taking notes		
2. Assembling an annotated bibliography		
III. Planning the Report	10	0
A. Outlines		
1. Effective outlining		
2. Rules for formal outlines		
B. Abstracts and Introductory Summaries		
1. Types of abstracts		
2. Suggestions for writing abstracts		
IV. Writing Definitions	10	0
A. What Should be Defined		
1. Familiar words for unfamiliar things		
2. Unfamiliar words for familiar things		

	Student Contact Hours	
	Class	Laboratory
B. How Definitions are Constructed		
1. Informal		
2. Formal		
a. Class.		
b. Distinguishing characteristics		
c. Summary of formal usage		
d. Additional suggestions for formal usage		
3. Amplified definitions		
C. Where Definitions Should be Placed		
V. Describing a Mechanism	10	0
A. Definitions and Overview		
B. Description of a Mechanism		
1. Some potential problems		
2. Specifications		
VI. Describing a Process	10	0
A. Definitions and Overview		
B. Problems Encountered in Describing a Process		
C. Types of Processes		
D. Writing Instructions for a Process		
VII. Putting Skills Into Practice: Writing a Formal Technical Report	10	0
A. Writing the Rough Draft		
1. Prefatory pages		
2. Body of the report		
3. Appendix		
B. Editing the Rough Draft		
C. Producing the Final Copy		
VIII. Presenting an Oral Technical Report	10	0
A. Oral and Visual Aspects of Technical Communications		
B. Oral Presentations and Activities		
1. Oral reports and presentations		
2. Leading conferences and group discussions		
C. Visual Illustrations		
1. What illustrations can do		
2. Types of illustrations		
D. Presenting the Oral Report		

STUDENT COMPETENCIES

At the conclusion of this course, in the appropriate course areas indicated, the student will be able to:

- Apply technical speaking/writing to the job as required.
- Use appropriate reference materials in preparing a technical report.
- Write a formal and an informal outline for a technical report.

- Write an abstract for a technical report.
- Write appropriate definitions of technical terminology.
- Describe logically and effectively the characteristics and components of mechanisms.
- Describe logically and effectively the characteristics and components of processes.
- Prepare a formal technical report in accordance with accepted formats and style.
- Deliver a technical presentation with the help of visual aids.

SUGGESTED REFERENCE TEXTS

Andrews, D.C. and Blickle, M.D. Technical Writing: Principles and Forms. New York: Macmillan Publishing Co., Inc., 1978.

Center for Occupational Research and Development. Technical Communications. Waco, TX: 1980.

Fear, D.E. Technical Communications. Glenview, IL: Scott, Foresman and Co., 1977.

Lannon, J.M. Technical Writing. Boston: Little, Brown, and Co., 1979.

Mills, G.H. Technical Writing. 4th ed. New York: Holt, Rinehart and Winston, 1979.

Monroe, A.H. and Ehninger, D. Principles of Speech Communications, Seventh Brief Edition. Glenview, IL: Scott, Foresman and Co., 1974.

COMPUTER BASICS

This course will provide students with the knowledge and skills to use the microcomputer as a tool to solve engineering technology problems typically encountered throughout their programs. Topics taught will include microcomputer architecture, programming concepts, branching, looping, arrays, functions, subroutines, data files, graphics and applications.

COURSE OUTLINE

	Student Contact Hours	
	Class	Laboratory
I. Introduction to the Microcomputer	2	3
A. Hardware		
B. Terminology		
C. Execution Modes		
D. Programs		
II. Introductory Concepts of Programming	4	6
A. Flowcharting		
B. Variable Types		
C. Operations and Formulas		
D. Simple BASIC Programming		
E. Program Comments		
F. Storage and Retrieval of Programs		
III. Branching and Looping	3	4
A. Relational Operations		
B. Logical Operations		
C. Conditional Branching		
D. Multiple Branching		
E. The Stop Statement		
F. Loops		
G. Nested Loops		
IV. Arrays	3	4
A. Lists and Tables		
B. Subscripted Variables		
C. Defining Arrays		
V. Functions and Subroutines	3	4
A. Library Functions		
B. User Functions		
C. Defining		
D. Random Numbers		
E. Defining Subroutines		
F. Referencing Subroutines		
VI. Data Files	3	4
A. Creating Sequential Data Files		
B. Using Sequential Data Files		

	Student Contact Hours Class	Laboratory
C. Random Data Files		
D. File Specifications		
VII. Graphics	3	4
A. Drawing Bar Charts		
B. Graphing Functions		
C. Computer-Generated Imagery		
VIII. Engineering Applications	3	12
A. Electronic Technology Problems		
B. Electromechanical Technology Problems		
C. Mechanical Technology Problems		
IX. Other Microcomputer Applications	3	4
A. Word Processing		
B. Computer Games		
C. Computer-Generated Experiments		
D. Interfacing		

STUDENT LABORATORIES

- Execute instructor-supplied simple programs.
- Develop, debug, and execute simple BASIC programs.
- Save, retrieve, and execute a previously developed BASIC program.
- Create a data file, develop a program that will manipulate the file, and produce an acceptable output.
- Given a typical engineering problem including all necessary equations and data, develop programs that will solve the problems and produce acceptable outputs.

STUDENT COMPETENCIES

At the conclusion of this course, in the appropriate course areas indicated, the student will be able to:

- Identify microcomputer hardware and define the associated terms.
- Execute simple demonstration programs.
- Write, save, retrieve, and execute simple p ~~ams in BASIC.
- Write BASIC programs using branching and looping statements.
- Write BASIC programs manipulating data using arrays.
- Write BASIC programs using library functions.
- Develop functions and subroutines and incorporate them into BASIC programs.
- Write programs that use and manipulate data files.
- Solve selected technology problems using the microcomputer.

RECOMMENDED TEXTS

Bent, Robert J. and Sethares, George C. BASIC: An Introduction to Computer Programming. 2nd ed. Monterey, CA: Brooks/Cole Publishing Co., 1982.

Shelly, Gary B., and Cashman, Thomas J. Introduction to BASIC Programming. Brea, CA: Anaheim Publishing Co., 1982.

ECONOMICS IN TECHNOLOGY

Economics in Technology develops the techniques necessary to evaluate the economic impact and advantages of different production methods. It is a course designed to familiarize the student with analysis techniques that are necessary for accurate cost evaluation of specific projects. The conceptual format enables the student to apply the appropriate tools to a diversity of cost-related decisions.

COURSE CONTENT

	Student Contact Hours	
	Class	Laboratory
I. Fundamentals of Cost Analysis	6	0
A. Business Firms and Engineering Costing		
1. Profit, Revenue, and Cost		
2. Measurement of Project Costs		
3. Individuals and Nonprofit Organizations		
B. Types of Costs		
C. Economic Efficiency		
D. Determinants of Price		
1. Supply		
2. Market Supply		
3. Demand		
4. Market Demand		
5. Market Price		
6. Additional Factors that Influence Price		
E. Marginal Analysis		
1. Marginal Cost and Marginal Cost Savings		
2. How to Use Marginal Analysis		
II. Financial Parameters of Engineering Economics	6	0
A. Principal and Interest		
B. Time Value of Money		
C. Future Value of a Fixed Amount		
1. Compounding Process		
2. Future Value of $1		
3. Future Value of Amounts Greater Than $1		
4. How to Read the Future Value of $1 Table		
5. Observations Concerning the Future Value of a Fixed Amount		
6. Cost Escalation		
7. Conclusion		

	Student Contact Hours Class	Laboratory
D. Present Value of a Fixed Amount		
1. Derivation of a Formula for Present Value		
2. How to Read the Present Value of $1 Table		
3. Present Value of Amounts Greater Than $1		
4. Observations Concerning the Present Value of a Fixed Amount		
E. Shorter Time Periods		
III. Financial Techniques of Cost Analysis	6	0
A. Cost of an Annuity		
1. Accumulation of an Annuity		
2. Sum of an Annunity of $1 Formula		
3. The Sum (Future Value) of an Annuity of $1 Table		
4. Sum of an Annuity of More Than $1 Per Year		
B. Present Value of an Annuity		
1. Calculation of the Present Value of an Annuity		
2. Present Value of an Annuity of $1		
3. The Present Value of an Annuity of $1 Table		
4. Present Value of Annuities Larger Than $1		
C. Analysis of Projects, Using Present Value of an Annuity		
D. Present Value of an Irregular Flow of Cost Savings		
1. Cost Escalation and Present Value		
2. Conclusion		
IV. Economics of Engineering Alternatives	6	0
A. Finances of an Investment		
B. Taxes		
1. Corporations and Taxes		
2. Tax Credits		
C. Life of an Investment		
D. Life-Cycle Costing		
V. Engineering Cost Analysis	6	0
A. Replacement Projects and Original Projects		
B. Mutually-Exclusive Projects		
C. Net Cost Savings per Year		
D. Payback Period		
E. Capital Recovery Factor		
F. Benefit-Cost Analysis		

Student Contact Hours

Class | Laboratory

G. Net Present Value (NPV) Method
   1. Definition of Net Present Value
   2. Calculation of Net Present Value
   3. Usefulness of the Net Present Value Method
   4. Shortcomings of the NPV Method

H. Internal Reate of Return (IRR) Method
   1. Definition of Internal Rate of Return
   2. Calculation of the Internal Rate of Return
   3. IRR and an Irregular Flow of Cost Savings
   4. Use of IRR and Evaluation of Mutually-Exclusive Projects

I. Comparison of Methods for Evaluating Energy Projects

STUDENT COMPETENCIES

Upon completion of this course, the student should be able to:

- Describe the relationship between cost, revenue, and profit.
- Calculate the cost of a manufactured product.
- Determine the time value of money.
- Calculate the estimated future value of $1.
- Read and interpret interest tables.
- Compare simple and compound interest.
- Determine the cost of an annuity.
- Calculate the value of an annuity.
- Determine payback period for an investment in capital equipment.
- Compare Net Present Value method with Internal Rate of Return method for analyzing cost/benefits.

RECOMMENDED TEXTS

As far as we know, no single text covering all of these topics has yet been written. Each of the textbooks and references listed below covers some part of the outline.

Center for Occupational Research and Development. Energy Economics. Waco, TX: 1980.

Dubrin. Career and Personal Success.

Dubrin. Human Relations: A Job-Oriented Approach.

Hamilton, David. Technology, Man, and the Environment.

INDUSTRIAL RELATIONS

This course includes the study of the basis of human relations and the organization of individual and group behavior. Leadership, organizational and social environments (including labor unions), career development, communications and group processes as well as selected operating activities are covered. Appropriate case problems are reviewed and discussed. Special emphasis is placed on typical industrial and business relationships in everyday situations.

COURSE OUTLINE

	Student Contact Hours Class	Laboratory
I. Fundamentals of Organizational Behavior	3	0
A. Working With People		
B. Mainsprings of Motivation		
C. Social Systems		
D. Morale Information and its Use		
E. Developing a Sound Behavioral Climate		
II. Leadership and Its Development	4	0
A. The Leadership Role		
B. Effective Supervision		
C. Development of Participation		
D. Human Relations Training		
III. Organizational Environment	4	0
A. Organizational Structures		
B. Organizational Dynamics		
C. The Individual in the Organization		
D. Informal Organization		
IV. Career Development in Organizations	4	0
A. Understanding Career Motivation		
B. Making Career Choices		
C. Attitudes and Advancement		
D. Career Development and Management Practices		
V. Social Environment	3	0
A. Labor Unions		
B. Working With Unions		
C. Employment Discrimination		
D. Managing Scientific and Professional Employees		
E. Managing Employees in International Operations		
VI. Communications and Group Prosesses	5	0
A. Communication With Employees		
B. Communication Groups		
C. Counseling and Interviewing		
D. Group Dynamics		
E. Managing Change		

	Student Contact Hours Class	Laboratory
VII. Operating Activities	3	0
A. Appraising and Rewarding Performance		
B. Using Economic Incentive Systems		
C. Integrating Work Systems With People		
D. Understanding Automation		
E. Organizational Behavior in Perspective		
VIII. Interviewing for A Job	2	0
A. Resume		
B. Personal Appearance		
C. Presentation of Yourself		
IX. Case Problems in Technical Organizations	2	0

STUDENT COMPETENCIES

At the conclusion of this course, in the appropriate course areas indicated, the student will be able to:

- List and describe five fundamental components of a sound organizational environment.
- Explain the critical role of leadership in developing an organizational climate.
- Describe the characteristics of an effective leader.
- List four basic types of organizational structures.
- Diagram an organizational structure and label components.
- Develop a personal career objective and explain the rationale for the choice.
- Discuss and evaluate the impact of unionization on the U.S. economy.
- Explain the importance of interpersonal communication in an organization.
- List and describe the various types of communication that are important at work.
- Describe at least three common problems encountered by many workers in getting along with the following people on the job: supervisors, co-workers, subordinates.
- Describe three steps involved in job hunting.
- Explain the possible impact of automation on the people in an organization.
- Effectively formulate solutions to organizational problems presented by the instructor.

SUGGESTED REFERENCE TEXTS

Armine, et al. Manufacturing Organization and Management. Englewood Cliffs, NJ: Prentice-Hall, 1982.

Everand and Shilt. Business Principles and Management. Southwestern Publishing, 1979.

Yodar and Standohar. Personnel Management and Industrial Relations. Englewood Cliffs, NJ: Prentice-Hall, 1982.

FUNDAMENTALS OF ELECTRICITY AND ELECTRONICS

This course provides the foundations for the principles of electricity and magnetism required for further study in electricity and electronics. Topics discussed include basics of electricity and magnetism, electrical charge in motion, dc circuit analysis, ac circuit analysis, magnetic circuits and devices, reactance, and impedance.

COURSE OUTLINE

	Student Contact Hours Class	Laboratory
I. Basics of Electricity and Magnetism	3	6
A. Electricity		
1. Atomic structure and electrical charge		
2. The direction of electric forces		
3. The magnitude of electric forces		
B. Magnetism		
1. Natural or permanent magnets		
2. Ferromagnetic materials		
3. Magnetic field around a wire		
II. Electrical Charge in Motion	3	6
A. Electric Current		
B. Electromotive Force		
C. Production of Electron Flow		
1. The generator		
2. The battery		
3. Thermoelectric pumps		
4. Photoelectric pumps		
5. Piezoelectric pumps		
D. Resistance		
1. Important factors		
2. Resistance of wires		
E. Types of Resistors		
1. Fixed resistors		
2. Variable resistors		
3. Special resistors		
F. Ohm's Law		
III. Direct Current Through Series and Parallel Resistors	5	6
A. Series and Parallel Circuits		
1. Kirchoff's voltage law		
2. Kirchoff's current law		
B. Series-Parallel Combinations		
C. Mesh Current Analyses		

	Student Contact Hours Class	Laboratory
D. Superposition Theorem		
E. Thevenin's Theorem		
F. Wheatstone Bridge		
IV. AC Circuit Analysis	6	8
A. Alternating Current		
1. Frequency		
2. Generation of alternating current		
B. Practical AC Generators		
1. Armature coil size		
2. Field magnet		
3. Rotation of field coils		
4. Three-phase ac		
5. Phase between voltage and current		
6. Adding ac currents or voltages		
C. Power in AC Circuits		
D. Alternating Current and Voltage Values		
1. Instantaneous		
2. Average		
3. Effective or RMS value		
E. Rectifiers and Power Supplies		
1. AC source		
2. Transformer		
3. Rectifier		
4. Half-wave rectifier		
5. Full-wave rectifier		
6. Filter		
7. Voltage divider		
8. Voltage regulator		
V. Magnetic Circuits and Devices	5	6
A. Magnetism		
1. Magnetic poles/magnetic forces		
2. Electromagnetism		
3. Left-hand rule		
B. Magnetic Circuits		
1. Magnetomotive force		
2. Magnetic flux		
3. Reluctance and permeability		
4. Classification of magnetic substances		
5. The B-H curve		
6. Hysteresis		
C. Magnetic Devices		
1. Relays		
2. Relay circuits		
3. Transformers		

	Student Contact Hours	
	Class	Laboratory
D. Input/Output Voltage Phase		
1. Transformers used as impedance matching devices		
2. Transformer losses and efficiency		
3. The power transformer		
4. The audio transformer		
5. The radio-frequency transformer		
E. Motor Action		
1. Forces on charge in motions		
2. Mechanical torque		
3. Basic dc motor operation		
F. Magnetic Shielding		
VI. Reactance and Impedance	8	8
A. Inductors		
1. Electrical basis for inductance		
2. Induced current		
3. Mutual induced current		
4. Self-induced current		
B. Inductance		
1. Factors affecting inductance		
2. Phase relationship in an inductor		
C. Inductive Reactance		
1. Inductors in series		
2. Inductors in parallel		
D. Typical Inductors		
1. Power-frequency inductors		
2. Audio-frequency inductors		
3. Radio-frequency inductors		
E. Testing Inductors		
F. Capacitors		
1. Electrical basis for capacitance		
2. Factors affecting capacitance		
G. Phase Relationships in a Capacitor		
H. Capacitive Reactance		
1. Capacitors in series		
2. Capacitors in parallel		
I. Types of Capacitors		
J. Testing Capacitors		
K. Impedance in RL and RC Circuits		
1. Definition of impedance		
2. Vector concepts		
a. Addition of vectors		
b. Multiplication of vectors		
c. Division of vectors		
3. Impedance in RL and RC circuits		
L. Power Factor		
M. Time Constants		

STUDENT LABORATORIES

I. Learn wire sizes and color codes; obtain hands-on laboratory experience with soldering; splicing; insulation stripping of single, standard, enameled, and co-axial wires and cables; prepare clip leads; install plugs and co-ax connectors.

II. Set up simple dc circuits. Measure current, voltage and resistance, and verify Ohm's law. Calculate resistance of a given length of nichrome wire and compare this value with resistance obtained from Ohm's law and an appropriate dc circuit.

III. Connect resistors in series, parallel, and series-parallel circuits; calculate and measure appropriate current and voltage drops in these circuits. Compare the calculated and measured values with the help of Ohm's law. Set up Thevenin equivalent circuits and demonstrate equality.

IV. Connect transformers, resistors, rectifier diodes and capacitors in appropriate circuits. Use ac voltmeter and oscilloscope to study/analyze the voltage waveform across selected parts of the circuit. Plot the waveforms and specify peak voltages, period and frequency.

V. Set up circuits with step-down transformers and resistors and calculate power delivered to load resistors.

- Design a circuit which sounds an alarm if a "valuable" magnetic object is removed from a display case.
- Observe the effect of a magnetic field on a reed relay.
- Design, set up and evaluate an impedance-matching transformer circuit.
- Design, set up and evaluate a magnetic circuit which contains a horseshoe magnet.
- Design, build and test a simple iron core transformer circuit which demonstrates transformer action.

VI. Set up a suitable dc RC circuit with appropriate combination of resistors and capacitances. Determine circuit time constants.

- Calculate and measure total capacitance for capacitors arranged in parallel.
- Set up suitable ac RC and RL circuits and apply 1000-Hz square wave inputs. With aid of an oscilloscope determine and account for the voltage waveforms appearing across R, L, and C components.

STUDENT COMPETENCIES

At the conclusion of this course, in the appropriate course areas indicated, the student will be able to:

- Demonstrate suitable electrical fabrication skills including splicing, insulation stripping, soldering, clip-lead preparation, and installation of plugs and co-axial cable connectors.
- Identify wire sizes and use electrical color code.
- Calculate the resistance of any common form of wire.

- Use Ohm's law to define the relationship between current, voltage, and resistance in an electrical circuit.
- Calculate power used by a resistive device.
- Design, build and troubleshoot simple dc series circuits.
- Design, build and troubleshoot simple ac circuits.
- Apply Thevenin's theorem and superposition theorem circuit analysis to dc circuits.
- Apply mesh current analysis to dc circuits.
- Discuss the operation of power supplies with the following: half-wave rectifiers, full-wave rectifiers, voltage regulation, filters, and voltage dividers.
- Describe the generation of a magnetic field, and define the following terms: magnetic poles, laws of attraction and repulsion, electromagnetism, magnetomotive force, magnetic flux, field strength and concentration (flux density), reluctance, permeability, magnetic saturation, diamagnetic, paramagnetic, ferromagnetic, hysteresis, residual magnetism, retentivity, and magnetic shielding.
- Use and operate the following magnetic devices: relays, transformers, and motors.
- Measure and calculate the value of capacitors in series and parallel.
- Measure and calculate the value of inductors in series and parallel.
- Determine capacitive reactance in an ac circuit.
- Determine inductive reactance in an ac circuit.
- Determine the impedance in an RC circuit.
- Determine the impedance in an RL circuit.
- Define RC and RL circuit time constants.
- Obtain and analyze voltage waveforms in RC and RL circuits.

SUGGESTED TEXTS

Boylestad, Robert D. Introductory Circuit Analysis. 4th ed. Merrill Publishing Co.

Center for Occupational Research and Development. Fundamentals of Electricity and Electronics. Waco, TX, 1980.

Crozier, Patrick. Introduction to Electronics. North Scituate, MA: Breton Publishers, 1983.

Faber, Rodney B. Applied Electricity and Electronics for Technology. New York: John Wiley and Sons, 1978.

Jackson, Herbert W. Introduction to Electric Circuits. 5th ed. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Marcus, Abraham. Basic Electronics. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1964.

DIGITAL ELECTRONICS

This course will present the student with the common digital circuits such as: multivibrators, counters, shift registers and memories. The students will examine and work with bus structures, data transmission techniques, and interfacing.

COURSE OUTLINE

	Student Contact Hours Class	Laboratory
I. Review Truth Tables, Gates and Flip-flops	3	4
A. Boolean Algebra and Truth Tables		
B. Gate Structures and Operation		
C. Flip-flop		
II. Multivibrators	3	4
A. One Shot		
B. Monostable		
C. Free-running		
III. Counters	6	10
A. Types and Designs		
B. Construction		
C. Applications		
IV. Shift Registers	6	8
A. Serial In/Serial Out		
B. Serial In/Parallel Out		
C. Parallel In/Serial Out		
D. Parallel In/Parallel Out		
E. Bidirectional and Dynamic Registers		
V. Memories	6	8
A. RAMs, ROMs		
B. PROMs and EPROMs		
C. Mass Storage Systems		
VI. Interfaces and Buses	3	6
A. Address Bus		
B. Data Bus		
C. Control Bus		
D. RS232C, S-100, ... Types		
E. "Handshaking"		

STUDENT LABORATORIES

- Measure the propagation delay for a flip-flop circuit and identify techniques for minimizing this delay.
- Construct a multivibrator circuit employing a 555 IC and operate at four different specified frequencies and duty cycles by calculating and connecting values of external R and C.

- Construct and operate model 16 and model 32 asynchronous counters using J-K flip-flops.
- Construct and operate various 7400 devices as different types of counters.
- Construct a digital clock using appropriate counter circuitry.
- Construct different types of shift registers using 74000 series devices.
- Use J-K flip-flops to construct a ten-stage ring counter.

STUDENT COMPETENCIES

Upon completion of this course, the student should be able to:

- Explain the difference between a latch and a flip-flop.
- Explain the operation and write the truth table for an S-R flip-flop.
- Explain the operation and write the truth table for a master/slave S-R flip-flop.
- Explain the function of the "preset" and "clear" inputs of an integrated-circuit flip-flop.
- Explain the operation and write the truth table for the D flip-flop.
- Explain the operation and write the truth table for the master/slave J-K flip-flop, and show the time between input and output.
- Define propagation delay for the flip-flop, and give its significance.
- Explain the operation of a one-shot multivibrator.
- Explain the operation of a free-running multivibrator.
- Draw a timing diagram for a four-stage binary counter.
- Give the difference between synchronous and asynchronous counters.
- Draw the logic diagrams for a four-stage synchronous and a four-stage asynchronous counter.
- Demonstrate the operation of cascaded counters.
- Give the definition and use of a shift register.
- Define the term "RAM."
- Define the term "address" as it applies to memory.
- Define "byte," "word," "nibble," "read," "write," as they apply to memory.
- Give the difference between static RAM and dynamic RAM.
- Define the term "ROM."
- Describe the operation of a diode matrix ROM.
- Define the term "PROM" and list several types.
- Explain the terms "FIFO" and LIFO" and give examples where each is used.
- Give an explanation of the theory of operation of the magnetic bubble memory.
- Give several examples of magnetic mass storage techniques.
- Distinguish between R2, NR2, biphase, Manchester and Kansas City standard magnetic recording formats.
- Give the meaning of "track" and "sector" as they apply to floppy disk storage.
- Describe the theory of operation of magnetic core memory.
- Define "address bus," "data bus," "control bus."
- Describe the operation of the tri-state buffer, and how these devices are used in the control of a bus.

- Give similarities and differences between several types of standard buses (GPIB, multibus, S-100).
- Define "handshaking," and explain how this is accomplished in the transmission of data between a CPU and an input device.

SUGGESTED REFERENCE TEXTS

Malvino, Albert Paul and Leach, Donald P. Digital Principles and Applications. 3rd ed. New York: McGraw-Hill, 1981.

Porat, D.I. and Barna, A. Introudction to Digital Techniques. New York: John Wiley & Sonns, 1979.

ANALOG CIRCUITS AND ACTIVE DEVICES

This course will expose the student to the most common circuit applications for analog devices. Amplifiers, oscillators and other circuits employed in industrial measurements and control are examined as well as the theory of opertaion behind AM, FM and SSB.

COURSE OUTLINE

	Student Contact Hours	
	Class	Laboratory
I. Amplifier Circuits	6	10
A. Transistor Amplifiers		
B. Classes of Amplifiers		
C. Operational Amplifiers		
II. Oscillator Circuits	6	8
A. Types		
B. Characteristics		
C. Construction		
D. Operation		
III. Amplifier Types	4	6
A. Audio Amplifiers		
B. Radio-Frequency Amplifiers		
C. Video Amplifiers		
D. Instrument Amplifiers		
E. Differential Amplifiers		
IV. Applications	5	8
A. Temperature-Measuring Systems		
B. Position-Measuring Analog System		
C. Variations of Temperature Measurement and Display		
1. Light as temperature display		
2. Sound as a temperature display		
3. Indirectly-heated sensor		
D. Transmitter Circuits		
E. Receiver Circuits		
V. Troubleshooting Analog Systems	6	8
A. Techniques		
B. Tools and Instruments		
C. Use of Data Books and References		

STUDENT LABORATORIES

- Design, build, and operate BJT, unijunction, and FET amplifiers in Class A, B, A-B, and C modes.
- Construct various circuits using one operational amplifier to demonstrate operation as a noninverting amplifier, inverting amplifier, oscillator, and differential amplifier.
- Design, construct, and test a regulated filtered power supply.
- Design, build, and identify the characteristics of a position-measuring system and a temperature-measuring system based upon a common 7400 family op amp.
- Design an AM demodulator circuit. Draw its input and output. Use the circuit to generate the AM signal input.
- Construct an analog bridge amplifier that amplifies changes in strain gages, photoresistors, and thermistors.
- Troubleshoot and repair a temperature-measuring system that has an instructor inserted fault.
- Modify a Class A MOSFET amplifier circuit to a class C circuit.
- Modify a non-inverting operational amplifier circuit to a differential amplifier circuit.
- Design, construct, and test an isolation circuit.

STUDENT COMPETENCIES

Upon completion of this course, the student should be able to:

- Construct, test and explain the Colpitts, Hartley, Clapp, crystal, and Wein bridge oscillators.
- Construct, test and explain the monostable and bistable multivibrators.
- Construct, test and explain the operation of a regulated power supply.
- Construct, test, troubleshoot and repair a wave-shaping circuit using a Schmitt trigger.
- Construct, test, and explain the unijunction oscillator circuit.
- Troubleshoot and repair an FM receiver circuit.
- Construct a video modulator circuit.
- Align an IF fitter string in a super heterodyne receiver.
- Define the following electronic devices and systems:
  - class A, B, C amplifiers
  - digital switches/gates
  - variable-voltage input/output devices
  - variable-resistance input/output devices
  - variable-capacitance input/output devices
  - variable-inductance input/output devices
  - audio amplifier
  - AM radio receiver
  - digital counter
  - digital computer
- Explain the operation of an AM radio receiver.
- Outline an industrial process that uses an analog circuit to control a measured parameter such as temperature.
- Describe how basic position measurements are made and processed.

SUGGESTED REFERENCE TEXTS

Faber, R.B. Applied Electricity and Electronics of Technology. New York: John Wiley & Sons, 1982.

Grob, Bernard. Electronic Circuits and Applications. Hightstown, NJ: McGraw-Hill, 1982.

GRAPHICS

An introductory course that provides the technician with basic skills and techniques used to communicate information and ideas graphically. Topics include: an introduction to freehand sketching; basic drafting techniques and procedures; schematic drawing; descriptive geometry; and computer graphics.

COURSE OUTLINE

	Student Contact Hours	
	Class	Laboratory
I. Technical Sketching	1	6
A. Sketching Lines, Circles, and Arcs		
B. Using the Box Construction Technique		
C. Sketching Isometric Views		
D. Sketching Oblique Views		
II. Drafting Fundamentals	1	10
A. Use of Instruments		
B. Lettering		
C. Alphabet of Lines		
D. Drawing Reproduction		
E. Scale		
F. Dimensioning and Tolerancing		
G. Geometric Construction Techniques		
III. Orthographic Projection	2	12
A. Third-Angle Projection Drawing		
B. Section Drawing		
IV. Pictorial Drawing	1	6
Drawing Objects in Isometric Form		
V. Schematic Drawing and Symbols	2	12
A. Drawing Electronic Schematic Diagrams		
B. "Tape-Up" of Printed Circuit Board Designs		
C. Drawing Electrical Wiring Diagrams		
D. Piping Diagrams		
E. Flow Diagrams		
F. Hydraulic Schematics		
VI. Descriptive Geometry	2	12
A. True Length, Slope, and Bearing		
B. Auxiliary Views		
C. Developments		
VII. Computer Graphics	0	2
A. Drawing on CRT		
B. Introduction to CAD		
VIII. Overview of Engineering Graphics	1	0
Drawing in Industry		

STUDENT LABORATORIES

- Prepare isometric and oblique sketches.
- Use drafting instruments to make simple drawings involving geometric construction techniques.
- Prepare orthographic drawings of objects.
- Prepare isometric drawings of simple objects.
- Prepare schematic drawings and "tape-ups."
- Find true length, slope, and bearing of lines.
- Draw surfaces in true size.
- Prepare developments of objects.
- Display data graphically on CRT.

STUDENT COMPETENCIES

At the conclusion of this course, the student will be able to:

- Make simple freehand sketches that will describe an object or a process in three dimensions.
- Use drafting instruments to make simple engineering drawings.
- Draw and interpret objects in orthographic projection.
- Draw and interpret simple objects in isometric graphic form.
- Prepare and interpret schematic drawings.
- Graphically find the true length, slope, and bearing of a line.
- Determine true shapes and sizes of surfaces from alternative views using the line and plan methods of descriptive geometry.
- Make simple development drawings of objects.
- Use a microcomputer to display data graphically.

SUGGESTED REFERENCE TEXTS

French, T.E. and Vierck, C.J. Engineering Drawings and Graphics Technology. New York: McGraw-Hill Book Co., 1978.

Luzadder, Warren J. Fundamentals of Enginee Drawing. Englewood Cliffs, NJ: Prentice-Hall, 1981.

PROPERTIES OF MATERIALS

A quantitative survey and description of the physical, chemical, mechanical, thermal, electrical, magnetic, acoustical and optical properties of materials. The course identifies and uses resource tables and handbooks extensively. Laboratory exercises provide the student with a broad exposure to the measurement of typical material properties.

COURSE OUTLINE

	Student Contact Hours	
	Class	Laboratory
I. Physical and Mechanical Properties	6	12

I. Physical and Mechanical Properties
   A. Hardness
      1. Hardness scale--how hardness is determined
      2. Metals
      3. Alloys
      4. Other composites
   B. Tensile Strength--Its Importance
      1. Definition of the stages before tensile break
      2. Elongation (Hooke's law)
      3. Elasticity (Young's modulus) and resilience
      4. Ductility
         a. Gold to cast iron
         b. How it is a valuable asset
         c. How it can contribute to mechanical failures
   C. Compression or Crushing Strength
      1. Metals
      2. Concrete
      3. Other composites
   D. Porosity
      1. Definition
      2. Measurement of porosity
      3. Importance in some types of applications
         a. Silica gel
         b. Activated carbon
   E. Flexural Strength
      1. Definition and relationship
      2. Importance in design
      3. Application to metals
      4. Application to plastics
      5. Application to composites

	Student Contact Hours	
	Class	Laboratory
F. Brittleness		
1. Definitions		
2. Fault in high-hardness products		
3. How composites are often used to obtain the best balance of properties		
G. Shear Strength		
1. Definitions and relationships		
2. Examples of the importance of shear strength		
3. Composites		
H. Fatigue Strength		
1. Definition		
2. Causes		
3. Metals		
4. Plastics		
II. Chemical Properties	4	6
A. Corrosion in Air		
1. Determining factors		
2. Preventive measures		
a. Selecting the right material		
b. Coating		
c. Anodizing		
d. Humidity effect		
B. Corrosion in Solution		
1. The electromotive force series--indicator for corrosion in aqueous solutions		
2. Protecting the surface		
3. Adding inhibitors		
C. Plastics and Their Uses		
1. Criteria for picking a plastic		
2. Limitations		
D. Alloys Designed for the Job		
E. Hygroscopicity--Definition		
1. Severe effects it can have		
a. Optics		
b. Corrosion		
2. Some good factors		
III. Thermal and Electrical Properties	4	0
A. Parallelism in the Equations for Thermal and Electrical Conduction		
B. Thermal and Electrical Conduction in Metals		
1. Conductors		
2. Insulators		
3. Semiconductors		

	Student Contact Hours Class	Laboratory
C. Differences in Thermal and Electrical Conduction		
D. Thermal Properties of Some Composites		
1. High-temperature alloys		
2. Ablative materials		
E. Insulation		
1. Glass		
2. Rock wool		
3. Foamed materials		
IV. Magnetic Properties	2	6
A. What is a Magnet?		
1. How magnetic forces arise		
2. Basic equations relating forces to magnetic fields		
B. Soft Iron-Type Magnets		
C. Ferrites		
D. Permanent Magnets		
E. Electromagnets		
1. How they work		
2. Applications		
F. Magnetic Tapes and Discs		
1. How they work		
2. Applications--limitations		
3. Role in advancing technology		
V. Optical and Acoustical Properties	3	6
A. Light and Its Characteristics		
1. Wave character		
2. Absorption		
3. Refraction		
4. Reflection		
5. Diffraction		
6. Interference		
7. Polarization		
B. How Different Materials Affect Light		
1. Absorption		
2. Refraction		
3. Reflection		
4. Diffraction		
5. Polarization		
C. Applications		
1. Camera		
2. Eyeglasses		
3. Analytical spectrophotometers		
D. Newer Optical Phenomena		
1. Laser materials		
2. Fiber optics		

	Student Contact Hours	
	Class	Laboratory
E. Sound and Its Characteristics 1. Interaction of sound with gases 2. Interaction of sound with liquids 3. Sound absorption characteristics with different materials 4. Reverberations in rooms with different type walls	1	0

STUDENT LABORATORIES

I. Determine Young's modulus, the stress-strain range where Hooke's law applies, the yield point, and ultimate tensile strength of three types of metal bars--steel, stainless steel, and copper. This laboratory requires a tension tester.

II. Test the compressive and tensile breaking strength of two concrete blocks to demonstrate the dramatic differences in strength of concrete under these two load conditions. This laboratory will require a tension and compression tester.

III. Determine the bulk porosity of silica gel and activated carbon by weighing them in their regenerated state and again when their pores have been saturated. Only simple laboratory equipment is required.

IV. Show differences in corrosivity of several metals in several environments and with some use of protective agents. Exposure to the environments will occur for at least one week.

V. Using a constant light source, a light meter, several filters, a quartz prism, and two light polarizers, the absorption, spectral, and polarizable characteristics of light will be made apparent. The use of dextro-glucose will demonstrate optical rotation. Some simple optical equipment will be used.

VI. Learn how selected metals can be magnetized and demagnetized easily. Build and make tests on electromagnets, with several metals to demonstrate their different magnetic properties.

STUDENT COMPETENCIES

At the conclusion of this course, in the appropriate course areas indicated, the student will be able to:

- Demonstrate a wide exposure to the different types of properties of materials. The student should know that properties such as hardness, tensile strength, and compressive strength are important to some material applications, be able to measure them, and make selections for an application.
- Assess the corrosivity of a material in a particular environment and make suggestions for decreasing the corrosivity.
- Use thermal and electrical resistivities--or conductance--and assess the importance of these in selecting materials for certain types of applications.

- Assess the importance of magnetic characteristics of materials being used in a particular application.
- Measure and evaluate the importance of light absorbance, refractivity, and reflectivity in the materials application at hand.

SUGGESTED TEXTS AND REFERENCES

Applied Optics and Optical Engineering. New York: Academic Press, 1965.

CRC Handbook of Chemistry and Physics. Boca Raton, FL: CRC Press, Inc.

Kirk-Othner Encyclopedia of Chemical Technology. New York: Wiley-Interscience.

Langes Handbook of Chemistry. New York: McGraw-Hill Book Co.

Marks Standard Handbook for Mechanical Engineers. New York: McGraw-Hill Book Co., Inc.

The Metals Handbook. Metals Park, OH: American Society of Metals.

Perry and Chilton. Chemical Engineering Handbook. New York: McGraw-Hill Book Co., Inc.

White, Frederick A. Our Acoustic Environment. New York: Wiley-Interscience Publishers.

MECHANICAL DEVICES AND SYSTEMS

Mechanical Devices and Systems is a study of principles, concepts, and applications of various mechanisms encountered in industrial applications of engineering technology. Such mechanisms include belt drives, chain drives, linkages, valves, fans and blowers. The subject matter on mechanical components and systems covers operational principles, uses, maintenance, troubleshooting, and procedures for repair and replacement. The laboratory applications emphasize practical maintenance and installation of equipment and selection and specification of proper replacement components from manufacturers' catalogs.

COURSE OUTLINE

	Student Contact Hours	
	Class	Laboratory
I. Introduction		
A. Overview of Mechanical Devices and Systems		
B. Types of Components and Systems		
C. The Role of the Technician		
II. Belt Drives	3	4
A. Mechanical Drives		
B. Flat Belt Drives		
1. Length measurement and calculation		
2. Belt-speed calculation		
3. The positive-drive belt		
C. Maintenance of Flat Belt Drives		
1. Splicing of flat belts		
2. Troubleshooting of flat belts		
D. V-Belt Drives		
1. Design variations		
2. Variable-speed belt drives		
3. V-Belt sizes and matching numbers		
4. Pulley size		
5. V-belt drive selection		
E. Maintenance of V-Belt Drives		
1. Sheave alignment in V-belt drives		
2. V-belt installation		
3. Belt tension		
4. Troubleshooting of V-belts		
III. Chain Drives	2	4
A. Characteristics of Chain Drives		
B. Types of Chains		
C. Chain Length		
D. Sprockets		
1. Types of sprockets		
2. Sprocket speed		

	Student Contact Hours	
	Class	Laboratory
3. Sprocket position		
4. Idler sprockets		
5. Selection of chain drives		
E. Maintenance		
1. Alignment		
2. Chain installation		
3. Chain tension and sag		
4. Lubrication		
5. Sprocket inspection		
F. Troubleshooting of Chain Belts		
G. Chain Storage		
IV. Gear Drives	4	6
A. Mechanical Basics		
B. Gear Basics		
C. Terminology		
D. Types of Gears		
1. Parallel-axes gears		
2. Intersecting-axes gears		
3. Nonintersecting, nonparallel-axes gears		
4. Moving-axes gears		
E. Gear Trains		
F. Maintenance		
1. Lubrication		
2. Adjustment		
3. Inspection and troubleshooting		
G. Selection of Gear Drives		
V. Drive Train Components I	3	6
A. Shafts and Keyways		
1. Shaft spacing		
2. Turned-down shafting		
3. Flexible shafts		
4. Shaft expansion		
5. Alignment		
6. Metalizing of shafts		
7. Bent shafts		
8. Shaft selection		
9. Shaft keys and keyseats		
B. Plain Bearings		
1. Mounted plain bearings		
2. Lubrication		
C. Antifriction Bearings		
1. Radial bearings		
2. Thrust bearings		
3. Combination bearings		
4. Mounted bearings		
5. Shaft alignment		
6. Belt tension		
7. Shock loads		

	Student Contact Hours	
	Class	Laboratory
8. Bearing installation		
9. Vibration		
10. Current through bearings		
11. Lubricants		
12. Troubleshooting		
13. Selection of antifriction bearings		
VI. Drive Train Components II	2	6
A. Seals		
1. Static seals--gaskets and O-rings		
2. Dynamic seals		
3. Mechanical seals		
B. Couplings		
1. Definitions		
2. Rigid couplings		
3. Flexible couplings		
4. Universal joints		
5. Selection of couplings		
C. Clutches		
1. Definitions		
2. Friction clutches		
3. Magnetic clutches		
4. Jaw clutches		
5. Dry fluid clutches		
6. Hydraulic clutches		
VII. Linkages	2	4
A. Terms and Definitions		
B. Types of Linkages		
1. Links/cranks		
2. Four bar		
3. Geneva mechanism		
VIII. Cams		
A. Terms and Definitions		
B. Types of Cams		
C. Types of Followers		
IX. Fans and Blowers	2	6
A. The Two Fan and Blower Types		
1. Axial-flow fans and blowers		
2. Centrifugal fans and blowers		
3. Materials of construction		
4. Accessories		
B. Testing and Airflow Measurements		
C. Anemometers		
D. Maintenance		
E. Fan Selection		

	Student Contact Hours	
	Class	Laboratory
F. General Information and Terms		
1. Pressure increases		
2. Fan laws		
3. Fan wheel diameter		
4. Pressure and pressure difference		
5. Air horsepower		
6. Air density		
7. Efficiency		
X. Valves	2	4
A. Components and Operation Principles		
B. Uses of Valves		
C. Valve Types		
D. Materials for Valves		
E. Valve Codes and Markings		
F. Valve Actuators		
G. When Automatic Controllers are Used		
H. Valve Maintenance		

STUDENT LABORATORIES

I. Identify and correct defects in operating motor and belt drive system.

II. Identify and correct defects in operating motor and chain drive system.

III. For a geared transmission with each gear numbered, disassemble, label each gear as to type, inspect each for visible wear, and label power flow from input to output shaft.

IV. Disassemble drive chain assembly, identify bearings removed, clean and inspect for damage, lubricate properly, and reassemble.

V. Disassemble a sealed system such as a hydraulic pump; identify type of seal, couplings, clutches; clean, inspect and replace as necessary; and reassemble system.

VI. Upon examination of two or more machines from a given list, identify types of linkages and cams used. Sketch and describe each mechanism's movement with arrows to show force input and output.

VII. Set up fan/air duct systems; measure air pressure at five concentric locations in the duct and power consumption of fan; and calculate efficiency rating, volume flow rate, and fan horsepower.

VIII. Disassemble given valves; sketch and identify parts; relubricate and repack as necessary; reassemble each of the various valves.

STUDENT COMPETENCIES

At the conclusion of this course, in the appropriate course areas indicated, the student will be able to:

- List applications, advantages, disadvantages, and design characteristics of various types of belts.
- Calculate belt length, belt velocity, and pulley diameter.

- Install and properly adjust a belt.
- Describe how improperly maintained belts lose energy.
- Identify and cite possible causes of defects in belts and belt systems.
- Identify various types of chains, including applications, parts labeling, and maintenance.
- Calculate chain length and slack; calculate sprocket speed.
- Describe how alterations in size, number of teeth, and speed affect energy balance and life of a chain-drive system.
- Explain alignment and adjustments for chain drives.
- Install and properly adjust a chain.
- Use applicable formulas to calculate quantities for a gear-drive system.
- Identify various gear types; cite use, distinguishing characteristics, advantages, and disadvantages.
- Describe various gear trains; cite distinguishing characteristics and applications.
- Given a geared transmission, disassemble, label each gear as to type, inspect and detect visible wear, and label power flow from input to output shaft.
- Explain the function of shafts and keyways.
- Identify and explain the use of common plain bearings.
- Discuss effects of friction in plain and antifriction bearings.
- Describe the function of bearings in relation to shafts and discuss maintenance and operating characteristics.
- Select and utilize proper gaskets appropriately for a given drive train.
- Explain the use of seals, couplings, and packing in drive trains.
- Explain uses and operating characteristics of common clutches in drive systems.
- Identify and describe the operational characteristics and major components of common mechanical linkages.
- List and describe the uses and operational characteristics of common cams and cam systems.
- List and describe the operation of common fans and blowers.
- Distinguish between uses of fans and uses of blowers.
- Identify common problems and their solution in the implementation of fan and blower systems.
- Identify major components of valves.
- List functions and distinguishing operating characteristics of principal types of valves.
- Select proper valve type for a given set of requirements.
- Identify and describe basic types of actuators.
- Explain procedures for inspecting and maintaining valves.

SUGGESTED TEXTS

Machinery Handbook.

Center for Occupational Research and Development. Mechanical Devices and Systems. Waco, TX: 1980.

Millwright and Mechanics Guide. Audel.

FLUID POWER

The course in Fluid Power is designed to provide the student with an overview of fluid power technology and a working knowledge of each of the components used in fluid power circuits. Hydraulic and pneumatic systems will be discussed. Topics presented will include fundamentals of fluid dynamics, conventional fluid circuits and fluid power components.

COURSE OUTLINE

	Student Contact Hours	
	Class	Laboratory
I. Introduction and Fundamentals of Fluid Power	4	3
A. Introduction to Fluid Power		
1. Overview and applications of fluid power		
2. Advantages and disadvantages of fluid power		
3. How fluid power works		
B. Basic Fluid Power Systems		
1. Hydraulic systems		
2. Pneumatic systems		
C. Review of Physics Fundamentals		
1. Potential and kinetic energy		
2. Force and pressure		
3. Work done by a fluid		
4. Fluid power		
D. Basic Principles of Fluid Behavior		
1. Continuity equation		
2. Bernoulli's theorem		
3. Torricelli's theorem		
4. Ideal gas laws		
E. Basic Fluid Symbols		
1. Hydraulic circuit		
2. Pneumatic circuit		
F. Summary		
II. Properties of Hydraulic and Pneumatic Fluids	3	3
A. Properties of Hydraulic Fluids		
1. Viscosity index		
2. Lubrication		
3. Rust and corrosion prevention		
4. Oxidation stability		
5. Resistance to foaming		
6. Flash and fire points		
B. Types of Hydraulic Fluids		
1. Water		

	Student Contact Hours	
	Class	Laboratory
2. Petroleum oils		
3. Water-oil emulsions		
4. Water-glycol fluids		
5. Synthetic fluids		
C. Properties of Pneumatic Fluids		
D. Summary		
III. Fluid Storage, Conditioning, and Maintenance	4	4
A. Reservoirs and Tanks		
1. Hydraulic reservoirs		
2. Pneumatic tanks		
B. Temperature Control		
1. Cooling in hydraulic systems		
2. Cooling in pneumatic systems		
C. Filters and Strainers		
1. Types of hydraulic filters		
2. Location of hydraulic filters		
3. Pneumatic filters		
4. Air pressure regulators		
5. Air-line lubricators		
6. FRL units		
D. Sealing Devices		
1. Compression packings		
2. O-rings		
3. V-rings		
4. Piston cup packings		
5. Piston rings		
6. Water rings		
7. Seal materials		
E. Summary		
IV. Pumps and Compressors	4	4
A. Theory of Pumps		
1. Positive-displacement pumps		
2. Characteristics of positive-displacement liquid pumps		
3. Variable-displacement pumps		
B. Hydraulic Pumps		
1. Vane pumps		
2. Piston pumps		
3. Pressure-compensated/flow-compensated pumps		
4. Selection of hydraulic pumps		
5. Pump maintenance		
C. Air Compressors		
1. Reciprocating compressors		
2. Rotary compressors		
3. Screw compressors		
4. Compressor maintenance		

	Student Contact Hours Class	Laboratory
E. Vacuum Pumps		
F. Summary		
V. Fluid Power Actuators and Motors	4	4
A. Actuators		
1. Construction of hydraulic cylinders		
2. Cylinder operating characteristics		
3. Construction of air cylinders		
4. Mounting and application of cylinders		
5. Special cylinder types		
6. Rotary actuators		
7. Causes of cylinder failure		
8. Cylinder maintenance		
B. Motors		
1. Hydraulic motor types		
2. Hydraulic motor performance		
3. Air motors		
C. Summary		
VI. Fluid Distributor and Control Devices	4	4
A. Accumulators		
1. Accumulator types		
2. Accumulator applications		
3. Accumulator unloading valves		
B. Pressure Intensifiers		
C. Fluid Conductors and Connectors		
1. Rigid pipes		
2. Semirigid tubing		
3. Flexible hoses		
4. Thermoplastic tubing		
D. Fluid Control Devices		
1. Directional control valves		
2. Servo valves		
3. Pressure control valves		
4. Flow control valves		
5. Other control valves		
E. Summary		
VII. Fluid Circuits	4	4
A. Fluid Power Symbols		
B. Basic Hydraulic Circuits		
1. Cylinder circuits		
2. Motor circuits		
3. Speed control		
C. Basic Pneumatic Circuits		
1. Cylinder circuits		
2. Motor circuits		
3. Speed control		
4. Multi-pressure circuits		
D. Synchronous Motion		
1. Hydraulic cylinders in series		
2. Fluid motors as synchronizers		
3. Air cylinders		

	Student Contact Hours	
	Class	Laboratory
4. Hydraulic motors		
E. Actuator Speed		
1. Pneumatic circuits		
2. Hydraulic circuits		
VIII. Troubleshooting Fluid Circuits	3	4
A. Maintenance and Troubleshooting in Fluid Power Systems		
1. Causes of failure Dirt, heat, misapplication, improper fluids or poor fluid maintenance, faulty installation poor maintenance, improperly designed circuits, improper installation of hose/tube fittings		
2. Symptoms of failure		
B. Troubleshooting Hydraulic Circuits		
1. Measuring equipment		
2. Troubleshooting procedures		
C. Troubleshooting Pneumatic Circuits		
D. Safety Considerations		
1. Safety circuits		
2. Safety procedures and regulations		
E. Summary		

STUDENT LABORATORIES

I. Draw appropriate schematic diagrams for operating one single-acting cylinder. Show all components and connections of the necessary hydraulic and pneumatic circuits. Build the appropriate fluid circuits and operate them in the laboratory.

II. Construct and operate fluid circuits for single-acting and double-acting hydraulic cylinders. Compare characteristics and operation of the cylinders.

III. Remove and inspect the following fluid power components.

a. Sump strainer
b. Line filter
c. FRL unit
d. Hydraulic reservoir
e. Compression packing
f. O-ring seal
g. V-ring seal
h. Piston cup packing
i. Piston ring seal

Make a sketch of each and discuss its condition and operation.

IV. Measure volumetric efficiency of a hydraulic pump, overall efficiency of a hydraulic power system, and delivery rate of an air compressor.

V. Construct and operate fluid power circuits for operation of hydraulic and pneumatic motors.

VI. Construct and operate a circuit, including an accumulator, to power a pressure intensifier and a circuit to sequence the operation of hydraulic cylinders.

VII. Construct two hydraulic circuits for powering the same load--one using a pressure-relief valve and the other using a pump unloading valve. Determine the energy consumption and efficiency of each circuit during a full cycle and compare the two.

VIII. Troubleshoot a typical hydraulic system which contains design faults and/or inoperative components.

STUDENT COMPETENCIES

At the conclusion of this course, in the appropriate course areas indicated, the student will be able to:

- Identify components and describe the function of basic hydraulic and pneumatic power systems.
- Identify and correct hydraulic system problems (rust, corrosion, oil viscosity, oil oxidation).
- Explain operation, advantages, and disadvantages of various hydraulic filters and filter locations.
- Explain operation of each element in a pneumatic filter-regulator-lubricator unit.
- Diagram and explain operating characteristics and applications of various types of pumps and compressors.
- Operate reciprocating compressors and positive-displacement and non-positive-displacement rotary air compressors.
- Measure volumetric efficiency of a hydraulic pump, overall efficiency of a hydraulic power system, and delivery rate of an air compressor.
- Diagram and explain operation of common types of fluid actuators.
- Troubleshoot damaged cylinders.
- List common types of control valves, their importance, and their operating characteristics.
- Explain design demands and control characteristics important in construction of fluid circuits, including actuator speed limits, flow control characteristics, synchronous motion, cylinder speed.
- Design, build, and operate fluid circuits for single-acting and double-acting hydraulic cylinders.
- Disassemble and reassemble key fluid power components including strainers, filters, reservoirs, seals, valves and packings.
- Build and operate fluid power circuits for operation of hydraulic and pneumatic motors.
- Build and operate a fluid power circuit containing an accumulator to power a pressure intensifier.
- Build and operate a fluid power circuit to sequence the operation of hydraulic cylinders.
- Build and operate a hydraulic circuit with a pressure-relief valve.
- Build and operate a hydraulic circuit with a pump unloading valve.
- Maintain and troubleshoot hydraulic circuits.
- Maintain and troubleshoot pneumatic circuits.

SUGGESTED TEXTS

Center for Occupational Research and Development. Fluid Power Systems. Waco, TX: 1980.

Sullivan, James A. Fluid Power Theory and Application. Reston Publishing Company, Inc., 1982.

Vickers. Mobil Hydraulics Manual.

INSTRUMENTATION AND CONTROLS

Instrumentation and Controls is designed to provide the student with practical knowledge and skills in the specification, use and calibration of measuring devices and the principles and applications of automatic control processes for electrical power production, heating, air conditioning and manufacturing.

COURSE OUTLINE

	Student Contact Hours	
	Class	Laboratory
I. Principles of Process Control	2	4
A. Instrumentation and Control: The Concept		
1. Open-loop control		
2. Closed-loop control		
3. Negative feedback in the control system		
B. Valve Operation and Fail-Safe Conditions		
C. Controller Action		
D. Valve and Controller Selection		
E. Process Dynamics--Capacity Versus Capacitance		
F. Pressure Control		
G. Dead Time and Lag Time		
II. Instruments for Fluid Measurements--Pressure and Level	3	4
A. Control Quality of the System		
1. Measurement theory		
2. Accuracy		
3. Pressure measurement		
4. Liquid manometers		
5. Reference values for pressure measurement		
Bourdon tubes and pressure elements, strain gages		
6. Calibration of pressure transmitters and gages		
B. Liquid Level Measurements		
1. Float-operated devices		
2. Head-type (or pressure) devices		
3. Capacitance devices		
4. Conductance electrodes		
5. Ultrasonic detectors		
6. Radiation detectors		
7. Displacers		

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	Student Contact Hours Class	Laboratory
III. Fluid Flow Measurement	3	4
A. Flow Rate Calculations		
B. Velocity of Flowing Fluid		
C. Head Flow Measurement		
1. Calculation principles		
2. Flow equations		
3. Differential producers Orifice plate, venturi tubes, flow nozzle, target meters		
4. Pressure tap locations Vena contracta tap locations, pipe or full-flow tap locations, flange tap locations		
5. Viscosity correction Turbulent and laminar flow		
6. Practical Considerations Applications of head-flow meters		
D. Non-Head-Type Flow Meters		
1. Turbine flow meters		
2. Magnetic flow meters		
3. Ultrasonic flow meters		
E. Square Root Extractors		
1. Input		
2. Output		
3. Calibration		
IV. Instruments for Temperature Measurement	3	4
A. Temperature Scales		
B. Temperature Measurement		
1. Electrical temperature transducers Thermocouples, thermocouple applications, read-out device (millivolt measurement), thermocouple reference junction compensation, special thermocouple applications		
2. Resistance-temperature devices (RTD)		
3. Optical temperature transducers		
C. Mechanical Temperature Transducers		
1. Filled thermal systems Capillary tubes of the filled system, error and compensation in the system		
2. Bimetallic elements		

	Student Contact Hours	
	Class	Laboratory
V. Instruments for Mechanical Measurement	3	4
A. Control Practices		
B. Transducers and Transmitters		
1. Motion detectors--linear		
Linear potentiometer--linear motion-to-electrical transducers, linear motion variable inductor, linear variable differential transformer (LVDT), variable capacitance for linear movement		
2. Motion detectors--rotary		
Rotary potentiometers, rotary variable differential transformer (RVDT), synchro systems, flyball governor		
3. Velocity measurement--rotary tachometers		
C. Force Sensors		
1. Strain gage		
2. Piezoelectric crystal		
D. Proximity and Limit Detectors		
1. Contact-type limit detectors		
2. Noncontact-type proximity detectors		
E. Applications		
VI. Pneumatic Controls	3	4
A. Pneumatic Transmitters--Force Balance Type		
1. Flapper nozzle		
Relay, feedback		
2. Force balance differential pressure transmitter		
B. Pneumatic Controllers--Force Balance Type		
1. Proportional control mode		
2. Proportional-plus-reset control		
3. Proportional-plus-derivative control		
4. Controller action		
5. Controller specifications		
C. Motion Balance Pneumatic Instruments		
D. Signal Transducers		
1. Current-to-pressure transducers		
2. Pressure-to-current transducers		
E. General Applications of Pneumatic Instruments		
1. Transmission lag		
2. Volume boosters		
3. Valve positioners		
F. Conclusion		

	Student Contact Hours	
	Class	Laboratory
VII. Automatic Control Systems	3	6

A. Closed-Loop Controls vs. Open-Loop Controls
1. Closed-loop or automatic feedback control and control modes
2. On-off control
3. Proportional control
    Proportional output and gain

STUDENT LABORATORIES

- Construct and test a flow and level control system.
- Calibrate pressure gages.
- Calibrate flow metering devices.
- Measure temperature with thermocouple and RTD.
- Operate LVDT differential pressure transducer.
- Operate a d/P cell with a variable capacitor.
- Calibrate and operate a pneumatic d/P cell.
- Bench check a pneumatic controller.
- Construct and operate an open-loop control system.
- Tune a flow controller.
- Tune a level controller.

STUDENT COMPETENCIES

Upon successful completion of this course, in the appropriate course areas indicated, the student will be able to:

- Define the following terms:
    - Process
    - Process control
    - Open-loop control
    - Closed-loop control
    - Feedback
    - Error signal
    - Closed-loop control components
        - Measuring means
        - Controlling means
        - Final control element
- List the advantages and limitations of the following:
    - Open-loop control
    - Closed-loop control
- Explain the objective and purpose of process measurement.
- Describe the operating principles, theory, and units of instruments that perform measurement processes.
- Define inferred measurement.
- Perform a calculation that relates pressure to level measurement.
- Calibrate representative instruments used in measuring processes.
- Explain operating principles (include descriptions, characteristics, and applications) of various differential pressure sensing flowmeters.

- Sketch a typical differential-pressure flow-sensing device and transmission channel.
- Install an orifice plate and a venturi tube in pipes; measure pressure drops as functions of flow; calculate flows, based on nominal discharge coefficients, for each device.
- Calibrate an orifice plate and a venturi tube by preparing a plot of differential pressure versus flow; calculate discharge coefficient.
- List and define four classes of filled thermal systems.
- Define the term "inferential measurement" and explain why temperature measurement is based on this principle.
- Measure temperature using the following types of electrical temperature measuring devices:

  Thermocouple
  Resistance (RTD)
  Optical
- Explain how thermocouple, resistance and optical devices can be used to make the following measurements:

  Displacement:
  1. Linear
  2. Angular

  Velocity
  Force
- Explain how a pneumatic transmitter measures the following variables:

  Temperature
  Level
  Flow
  Pressure
- Identify the parts of a pneumatic transmitter.
- Calibrate and align a pneumatic transmitter.
- Implement the operation of a closed-loop control system by performing the following:

  Install closed-loop control components on a combination level-flow process.
  Connect the instruments to perform closed-loop control functions.
  Make instrument adjustments to provide optimum process control.
- Describe a method of control quality evaluation and relate the effect of each control-loop component on the quality of the process. This includes a definition and explanation of the following terms:

  Gain
  1. Process
  2. Instrument

  Capacity
  Dead time
  Lag time
  Process stability
  Process disturbance

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RECOMMENDED TEXTS

Center for Occupational Research and Development. Instrumentation and Controls. Waco, TX: 1980.

Fribance, Austin. Industrial Instrumentation Fundamentals. McGraw-Hill.

Kirk and Rimboi. Instrumentation. American Technical Publishers.

COMPUTER APPLICATIONS

This course provides an introduction to the hardware and software architecture of microprocessor systems used in applications of signal processing and control. Specifically, the course covers techniques for processing both analog and digital information into and out of microcomputers and applies these techniques to real-world control problems.

COURSE OUTLINE

	Student Contact Hours	
	Class	Laboratory
I. Assembly Language Programming	10	18
A. Registers, Accumulators, Binary Arithmetic Review		
B. Flags, Program Counters		
C. Addressing Modes		
1. Direct		
2. Indirect		
3. Indexed		
D. Arithmetic Instructions		
E. Logical Instructions		
F. Shift and Rotate Instructions		
G. Decrement/Increment Instructions		
H. Compare Instructions		
I. Bit Test Instructions		
J. Data Transfer Instructions		
K. Unconditional Jump Instructions		
L. Conditional Branch Instructions		
M. Subroutines		
1. Multibyte arithmetic		
2. Editor/assembler operation		
N. Writing a Program		
II. Input/Output Devices and Techniques	4	6
A. Parallel/Serial Transmission		
B. Synchronous/Asynchronous Communication		
C. Interrupts		
D. I/O Busing		
E. I/O Hardware		
F. Switches		
G. Display		
H. I/O Coding		
I. I/O Storage Devices		
III. Analog/Digital Conversion	4	6
A. Mechanical Conversion Devices		
B. Electrical Conversion Techniques		
1. Digital-to-analog computer		
2. Analog-to-digital conversion		

	Student Contact Hours Class	Student Contact Hours Laboratory
3. Resolution		
4. Counter-comparator		
5. Successive approximation		
6. Simultaneous conversion		
7. Microprocessor-controlled conversions		
IV. Signal Interfaces	4	6
A. TTC		
B. CMOS		
C. RS232		
V. Bus Systems	4	6
A. Characteristics of a Bus		
1. Signals		
Address lines, data lines, control lines		
2. Motherboard		
3. Comparison of busing systems		
B. Timing and Synchronization		
C. Bus Interfacing		
1. Bus connectors		
2. Physical dimensions		
VI. Troubleshooting Microcomputer Components	4	8
A. Introduction to Troubleshooting Equipment		
1. Current tracer		
2. Logic clips and comparators		
3. Oscilloscopes		
4. Logic analyzers		
B. Troubleshooting Techniques		

STUDENT LABORATORIES

- Use a microcomputer system to solve math problems and code conversions supplied by instructor.
- Interface and operate devices using A-to-D, and D-to-A converters.
- Use the PIA furnished by the instructor and interface with the outside world.
- Construct a circuit that uses an integrated circuit to convert TTL Logic to RS232 and vice-versa.
- Interface and control a stepper-motor with a microcomputer.

STUDENT COMPETENCIES

At the conclusion of this course, the student should be able to:

- Convert decimal number to binary, octal, hexadecimal BCD, and grey code; divide and multiply binary and multiple-precision numbers.
- Understand and design basic I/O and interfacing devices.
- Analyze circuits pertaining to programmable peripheral chips.
- Design a VART-based interfacing circuit to convert TTL data to RS232.
- Interface a microcomputer to a stepping motor with feedback.

RECOMMENDED TEXT

Goody, Roy W. The Intelligent Microcomputer. Science Research Associates.

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ELECTROMECHANICAL DEVICES

Electromechanical Devices provides the student with a working knowledge of control elements in electrical circuits, transformers, motors and generators. Topics presented include switches, circuit breakers, relays, fuses, transformers, dc and ac motors and generators.

COURSE OUTLINE

	Student Contact Hours Class	Laboratory
I. Electromechanical Devices--An Introduction A. Magnetic Forces and Fields B. The Origin of Magnetism C. Magnetic Fields of Electric Currents D. Forces on Charged Particles Moving Through Magnetic Fields E. Generator Action F. Motor Action G. Transformers	3	3
II. Control Elements in Electrical Circuits A. Switches B. Testing and Maintenance of Switches C. Relays D. Testing and Maintenance of Relays E. Relay Circuits F. Fuses G. Checking and Replacing Fuses H. Circuit Breakers I. Checking Circuit Breakers	4	4
III. Transformers A. The Basic Transformer B. Power Losses in Transformers C. Power Transformers D. Autotransformers E. Other Transformers F. Troubleshooting Transformers	4	4
IV. Generators and Alternators A. The Simple DC Generator B. Construction of DC Generators C. Field Coil Connections in DC Generators D. Operation of DC Generators E. The Alternator F. Automobile Alternators G. Large Alternators H. Operation of Alternators I. Maintenance	4	4

	Student Contact Hours Class	Laboratory
V. DC Motors and Controls	5	5
A. The Simple DC Motor		
B. Construction of DC Motors		
C. DC Motor Controls		
D. Motor Efficiency		
E. Motor Maintenance and Troubleshooting		
VI. AC Motors and Controls	5	5
A. Three-Phase AC Motors		
1. Rotating magnetic fields		
2. Synchronous motors		
3. Induction motors		
4. Power factor in ac motors		
B. Synchronous Motors		
1. Rotor construction		
2. Field excitation and power factor		
3. Starting synchronous motors		
4. Applications of synchronous motors		
C. Three-Phase Induction Motors		
1. Rotor construction		
2. Starting three-phase induction motors		
3. Applications of three-phase induction motors		
4. Wound rotor motors		
D. Single-Phase Induction Motors		
1. Capacitor-start motors		
2. Permanent-capacitor motors		
3. Repulsion-induction motors		
4. Shaded-pole motors		
5. Speed control of single-phase induction motors		
E. Universal Motors		
VII. Synchromechanisms	5	5
A. The Synchro Transmitter		
B. The Synchro Receiver		
C. Differential Synchro Transmitters and Receivers		
D. The Synchro Control Transformer		
E. Classification of Synchromechanisms		
F. Application of Synchromechanisms		

STUDENT LABORATORIES

- Diagram the magnetic fields of permanent magnets and electromagnets.
- Construct common control circuits using switches and relays.
- Construct circuits and measure efficiency of a power transformer.
- Set up a generator and an alternator and measure the output characteristics.

- Construct a motor control circuit and measure the output characteristics of a shunt motor.
- Set up, operate, and determine the characteristics of synchronous induction, and universal motors.

STUDENT COMPETENCIES

Upon successful complecion of this course, in the appropriate course areas indicated, the student should be able to:

- Diagram and explain the components and relationships of basic magnetic and electromagnetic systems.
- Determine direction of force on a conductor or a current-carrying conductor in a magnetic field.
- Determine loop rotation of wire in a magnetic field.
- Identify, diagram, and explain the characteristics of basic types of switches used in electrical circuits.
- Identify, diagram, and explain the characteristics of basic types of relays used in electrical circuits.
- Identify, diagram, and explain the function of basic fuses and circuit breakers used in electrical circuits.
- Construct a relay control circuit.
- Diagram, label, and explain the characteristics and components of basic types of transformers.
- Determine primary voltage and current, secondary voltage and current, input power, output power and efficiency of a transformer.
- Test transformers for continuity of windings and shunted windings.
- Diagram, label, and explain the characteristics and components of basic alternators.
- Diagram, label, and explain the characteristics of basic generators.
- Operate a dc generator and alternator and determine their operating characteristics.
- Diagram, label, and explain the components and characteristics of common types of dc motors.
- Specify appropriate types of motors for a given mechanical load.
- Diagram, label, and explain the components and characteristics of common motor control circuits.
- Construct, test, and plot the curve of a dc motor control circuit.
- Diagram, label, and explain the components and characteristics of common types of ac motors.
- Given necessary data, determine the number of magnetic poles, synchronous speed, operating speed, slip speed of common ac motors.
- Operate universal motor, shaded-pole motor, capacitor start motor.
- Diagram, label, and explain the characteristics of synchronous electromechanical systems.
- Determine magnetic polarity, electrical zero, rotation rate and direction of input/output for synchronous systems.
- Identify appropriate class of synchronous mechanism for specified situations.
- Construct common synchro-control circuits and evaluate their operating characteristics.

RECOMMENDED TEXTS

Alevich, Walter N. Electric Motor Control. New York: Van Nostrand Publishing Co., 1975.

Anderson, Edwin P. Electric Motors. Indianapolis, IN: Theodore Aide and Co., 1969.

Center for Occupational Research and Development. Electromechanical Devices. Waco, TX: 1981.

Fitzgerald, A.E. and Kirply, Charles J. Electric Machinery. New York: McGraw-Hill Book Co., Inc., 1952.

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INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT

This course deals with the source, distribution and use of electrical power in industrial plants. The first part of the course describes ac electrical power as it arrives at the plant substation and the electrical equipment needed to transform it to useful voltages, distribute it effectively and protect it from overcurrent conditions. Equipment typically includes transformers, switchgear, fuses and relays. The second part of the course deals with the electromechanical equipment which is required to convert electrical power into useful, rotational mechanical energy. Equipment typically includes ac and dc motors, motor controllers and synchromechanisms.

COURSE OUTLINE

	Student Contact Hours	
	Class	Laboratory
I. Polyphase AC Circuits	4	10
A. Review of Single-Phase, AC Circuits		
1. Current, voltage, reactance, impedance		
2. Vector diagram representation of current and voltage, phase lag		
3. Apparent power, real power, power factor		
B. Three-Phase, Four-Wire Circuit		
C. Balanced Y-Connected Leads		
D. Polyphase Vector Diagrams		
E. Unbalanced Y-Connected Leads		
F. Delta-Connected Leads		
G. Measurement of Power in Three-Phase Systems		
H. Three-Phase Ratings		
I. Power Factor Correction		
II. Electromechanical Devices--An Introduction	3	0
A. Magnetic Forces and Fields		
B. The Origin of Magnetism		
C. Magnetic Fields of Electric Currents		
D. Forces on Charged Particles Moving Through Magnetic Fields		
E. Generator Action		
F. Motor Action		
G. Transformers		
III. Control Elements in Electrical Circuits	3	4
A. Switches		
B. Testing and Maintenance of Switches		
C. Relays		
D. Testing and Maintenance of Relays		
E. Relay Circuits		

	Student Contact Hours Class	Laboratory
F. Fuses		
G. Checking and Replacing Fuses		
H. Circuit Breakers		
I. Checking Circuit Breakers		
IV. Transformers	3	4
A. The Basic Transformer		
B. Power Losses in Transformers		
C. Power Transformers		
D. Autotransformers		
E. Other Transformers		
F. Troubleshooting Transformers		
V. Power Distribution--Industrial (Purchased Power)	4	12

A. Voltage Levels
B. Switching and Distribution
  1. Controls
  2. Metering
C. Industrial and Commercial Circuits
  1. Voltage levels
  2. Metering
  3. Rate Schedules
    a. Usage
    b. Demand
    c. Fuel adjustment
D. Distribution
  1. Conduit and cable
  2. Metering control and protection
    a. kWh--watt--volt--(indicating and recording)
    b. Overload--short circuit--ground fault
    c. Demand--PF correction
  3. Transformers (13.8 kV/2300 V)
    a. Primary-disconnect, fusible
    b. Metering
  4. Transformers (13.8 kV/460 V)
    a. Low-voltage breakers
    b. Distribution bus
  5. Low-voltage motor control centers
  6. Special circuits
    a. Welding
    b. Heating
    c. Air conditioning
  7. Lighting and receptacles
    Main breaker--transformer--distribution panel

	Student Contact Hours Class	Laboratory
VI. Generators and Alternators	3	4
A. The Simple DC Generator		
B. Construction of DC Generators		
C. Field Coil Connections in DC Generators		
D. Operation of DC Generators		
E. The Alternator		
F. Automobile Alternators		
G. Large Alternators		
H. Operation of Alternators		
I. Maintenance		
VII. DC Motors and Controls	2	4
A. The Simple DC Motor		
B. Construction of DC Motors		
C. DC Motor Controls		
D. Stepper Motors		
E. Solenoids		
F. Motor Efficiency		
G. Motor Maintenance and Troubleshooting		
VIII. AC Motors and Controls	4	6
A. Three-Phase AC Motors		
1. Rotating magnetic fields		
2. Synchronous motors		
3. Induction motors		
4. Power factor in ac motors		
B. Synchronous Motors		
1. Rotor construction		
2. Field excitation and power factor		
3. Starting synchronous motors		
4. Applications of synchronous motors		
C. Three-Phase Induction Motors		
1. Rotor construction		
2. Starting three-phase induction motors		
3. Applications of three-phase induction motors		
4. Wound rotor motors		
D. Single-Phase Induction Motors		
1. Capacitor-start motors		
2. Permanent-capacitor motors		
3. Repulsion-induction motors		
4. Shaded-pole motors		
5. Speed control of single-phase induction motors		
E. Universal Motors		
IX. Synchromechanisms	4	6
A. The Synchro Transmitter		
B. The Synchro Receiver		
C. Differential Synchro Transmitters and Receivers		

Student Contact Hours	
Class	Laboratory

D. The Synchro Control Transformer
E. Classification of Synchromechanisms
F. Applications of Synchromechanisms

STUDENT LABORATORIES

- Examine the electrical distribution and switchgear system at the school (or one building at the school) and draw a schematic to accurately represent this system, identifying major components and locations.
- Using a circuit analyzer (instrument panel), connect a three-phase motor load. Vary the load (from no-load to full-load) on the motor (with prony brake) and record data on current, voltage, power, bus, power factor. Plot curves of the variables and calculate efficiency; verify power factor readings by calculations.
- Analyze the electrical supply and controls of a heating, lighting, and cooling system for a building. Draw schematic and identify all components.
- Hook up single-phase transformer, connect load, record input and output current, voltage, and power. Calculate step-down ratio and transformer losses and efficiency.
- Hook up three-phase transformer, connect load, record input and output current, voltage, and power. Calculate step-down ratio and transformer losses and efficiency.
  a. Δ - Δ
  b. Δ - Y
  Vary reactance loads on each phase. Measure voltage, current, power. Sketch phase-angle relationships for each phase.
- Set up a generator and an alternator and measure the output characteristics.
- Construct a motor control circuit and measure the output characteristics of a shunt motor.
- Set up, operate, and determine the operating characteristics of synchronous, induction, and universal motors.

STUDENT COMPETENCIES

Upon completion of this course, in the appropriate course areas indicated, the student will be able to:

- List and explain the purpose of basic components of electric power transmission systems from generating plant to user.
- Describe in proper terminology the application of required metering, capacity, and control of electric power distribution systems.
- Draw a schematic (elementary) diagram using proper electrical symbols of an electrical power distribution system as employed in utilities and industry.
- Define synchronizing (paralleling), phase rotation, true power, reactive (VAR) power, power factor correction.

- Describe methods for PF correction on polyphase circuits with capacitor banks and synchronous machines to meet utility standards and increase line-load capacity; measuring amps, watts, VARs, and PF.
- Examine the electrical distribution and switchgear system at the school and draw a schematic to accurately represent this system, identifying the major components and locations.
- Examine an operating bus duct system and draw a representative schematic, identifying all components and locations.
- Using a circuit analyzer (instrument panel), connect a three-phase motor load. Vary the load (from no-load to full-load) on the motor (with prony brake) and record data on current, voltage, power, bus, power factor. Plot curves of the variables and calculate efficiency and verify power factor readings by calculations.
- Analyze the electrical supply and controls of a building heating, lighting, and cooling system.
- Hook up single-phase transformer, connect load, record input and output current, voltage, and power. Calculate step-down ratio and transformer losses and efficiency.
- Hook up three-phase transformer, connect load, record input and output current, voltage, and power. Calculate step-down ratio and transformer losses and efficiency.
  a. Δ - Δ
  b. Δ - Y

  Vary reactance loads on each phase. Measure voltage, current, power. Sketch phase-angle relationships for each phase.
- Identify, diagram and explain the operating characteristics of typical switches, relays, fuses and circuit breakers used in electrical circuits.
- Determine the operating characteristics of a dc generator and alternator.
- Diagram, label, and explain the components and functioning characteristics of common types of dc motors.
- Specify appropriate types of motors for a given mechanical load.
- Diagram, label, and explain the components and functions of common motor control circuits.
- Construct, test, and plot the curve of a dc motor control circuit.
- Diagram, label, and explain the components and operating characteristics of common types of ac motors.

SUGGESTED TEXTS

Wildi, T. Electrical Power Technology. New York: John Wiley and Sons, Inc., 1981.

MANUFACTURING PROCESSES

This course provides a background in manufacturing materials and manufacturing methods employed in cold working processes. Through lecture, demonstration, and practical applications the student becomes familiar with various types of machine tools, tooling, measuring, and inspection procedures. Automation and numerical control for machine tools are introduced.

COURSE OUTLINE

	Student Contact Hours	
	Class	Laboratory
I. Introduction to Production Processes	2	4
A. Course Objectives		
B. Production Design and Process Selection		
1. Product specifications		
2. Production design		
3. Production process		
4. Inspection		
5. Marketing		
II. Principles of Metal Cutting	2	4
A. Mechanics of Metal Cutting		
B. Metal Cutting Tools		
III. Metal Cutting Tools	8	14
A. Turning Lathes		
1. Types		
2. Construction and design		
3. Operation		
B. Turret and Automatic Lathes		
1. Types		
2. Construction and design		
3. Operation		
4. Multiple tooling		
C. Screw Machines		
1. Types		
2. Construction and design		
3. Operation		
D. Drilling Machines		
1. Types		
2. Construction and design		
3. Operation		
E. Boring Machines		
1. Types		
2. Construction and design		
3. Operation		

	Student Contact Hours: Class	Student Contact Hours: Laboratory
IV. Special Cutting Tools	4	4

F. Planers and Shapers
   1. Types
   2. Construction and design
   3. Operation

G. Milling Machines
   1. Types
   2. Construction and design
   3. Operation

H. Broaching Machines
   1. Types
   2. Construction and design
   3. Operation

I. Sawing Machines
   1. Types
   2. Construction and design
   3. Operation

J. Grinding Machines
   1. Types
   2. Construction and design
   3. Operation

K. Gear Cutter Machines
   1. Types
   2. Construction and design
   3. Operation

IV. Special Cutting Tools — Class: 4, Laboratory: 4

A. Chemical Milling Machines
   1. Processes
   2. Applications
   3. Operation

B. Electrical Discharge Machines
   1. Processes
   2. Applications
   3. Operation

C. Electrochemical Machines
   1. Processes
   2. Applications
   3. Operation

D. Laser Beam Machines
   1. Processes
   2. Applications
   3. Operation

E. Ultrasonic Machines
   1. Processes
   2. Applications
   3. Operation

	Student Contact Hours	
	Class	Laboratory
F. Electron Beam Machines 1. Processes 2. Applications 3. Operation G. Automatic Machines 1. Definition 2. Application H. Numerical Control Machines 1. Definition 2. Computers 3. Control concepts 4. Application 5. Operation		
V. Metal Forming Machines A. Processes B. Operations 1. Stamping 2. Piercing 3. Bending 4. Drawing 5. Rolling 6. Squeezing	6	0
VI. Measuring, Gaging, and Inspection Techniques A. Visual Inspection B. Direct Measurement C. Comparative Measurement D. Precision Measurement E. Measuring Standards F. Tolerances G. Optical Measuring	6	4
VII. Finishing A. Surface Finishing 1. Types 2. Processes B. Cleaning and Coating 1. Mechanical cleaning 2. Chemical cleaning 3. Organic coating 4. Inorganic coating 5. Metallic coating 6. Conversion coating	2	0

STUDENT LABORATORIES

- Conduct a tour of the school shop facilities to include machine shop, tool and die shop and welding shop. List and describe all tools/ machines examined.

- Conduct a tour of a local manufacturing industry which might include machine shops, foundries, fabrication shops, etc. List and describe all tools/machines identified and indicate all manufacturing processes.
- Given a hypothetical machine-piece part, design and describe a manufacturing process to produce it. Include a design of the overall system, necessary equipment, and processes performed.
- Perform proper metal cutting procedures on selected piece-parts on the following metal cutting tools:
  - Lathe
  - Milling machine
  - Drill press
  - Planer and shaper
  - Saw
  - Grinder
- For a CNC milling machine, take a simple piece-part, develop a program to cut two holes, program the machine and run the part.
- Given selected machined parts, select the proper measuring device, perform and report measurements for each.

STUDENT COMPETENCIES

Upon successful completion of this course, in the appropriate course areas indicated, the student will be able to:

- Discuss elements used in selection and design of the processes used in manufacturing.
- Name and describe principal cutting tools.
- Explain the purpose of cutting fluids.
- Define the terms "speed" and "feed" and explain how they are related to lathe work.
- Define the following lathe terms:
  - Plane or straight turning
  - Facing
  - Parting
  - Chamfering
  - Knurling
  - Swing
  - Headstock
  - Tailstock
  - Coinage
  - Bed
- Explain operation of an engine lathe.
- Describe the most common lathe accessories and attachments.
- List ways to cut tapers on a lathe.
- Contrast major differences among a bench lathe, a tool lathe, and a speed lathe.
- Discuss important features of a horizontal turret lathe and describe the nature of work performed.
- Describe a screw machine.

- Define the following terms:
  - Drilling
  - Core drilling
  - Counterdrilling
  - Step drilling
  - Boring
  - Counterboring
  - Spot-facing
  - Countersinking
  - Reaming
- Name the two types of boring machines.
- Describe the difference between peripheral milling and face milling.
- Describe a hole broach and name its principal elements.
- Give a practical tolerance for production grinding operations.
- Name the three classes of gear cutting methods.
- Compare similarities and differences of ECM and EDM.
- Explain why a CO_2 laser is particularly effective for machining non-metals.
- List important factors that control the quality of surface finish obtained by ultrasonic machines.
- Define an electron beam and how it is used as a special cutting tool.
- Prepare a sketch illustrating how five axes of machine motion might be applied to manufacturing operations on a machine part.
- Set up and run a simple cutting task on a CNC milling machine.
- Give an example of the machines and tools used for stamping, piercing, bending, drawing and rolling.
- Explain differences between inspection, quality control, and statistical quality control.
- Define the following measurement terms:
  - Tolerance
  - Allowance
  - Clearance
  - Basic size
  - Standard size
  - Nominal size
- Given a number of direct-measurement, comparative-measurement, and precision-measurement instruments, perform and record results of an inspection of various parts to determine if the parts conform to appropriate measuring standards.
- Using a table of typical surface finish values, compare the ranges of surface-roughness-height values of drilling, grinding, and polishing.
- Explain why honing cannot be used as a method to improve errors of hole location or alignment on a workpiece.
- List some limitations of abrasive blasting.
- Discuss the major advantages of ultrasonic cleaning.
- Explain why alkaline cleaning of aluminum, zinc, brass, or tin workpieces is not recommended.
- Explain the function of organic coating and inorganic coating.
- Compare metallic coating with conversion coating.

SUGGESTED TEXTS

Doyle, L.E. Manufacturing Processes and Materials for Engineers. 2nd ed. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1969.

Yankee, H.W. Manufacturing Processes. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1979.

APPENDIX B

SECTION 2: COURSE DESCRIPTIONS/COMPETENCIES FOR SPECIALTY COURSES AND MODULE OUTLINES

Fundamentals of Robotics and Automated Systems

Controllers for Robots and Automated Systems

Automated Systems and Support Components

Robotics and Automated Systems Interfaces

Robotics/Automated Systems at Work

Automated Work Cell Integration

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FUNDAMENTALS OF ROBOTICS AND AUTOMATED SYSTEMS
Classroom/Lab hrs/wk 2/3

COURSE DESCRIPTION

This course introduces the student to robotics and automated systems and their operating characteristics. Topics to be covered include robotics principles of operation and work envelopes. Students will learn the various coordinate systems and how hydraulic, pneumatic and electromechanical systems function together as a system. Other subjects to be covered include servo and nonservo controls, system capabilities and limitations, and safety. Robot tooling will be investigated including welders, grippers, magnetic pickups, vacuum pickups, compliance devices, adhesive applicators, and paint sprayers.

COURSE OUTLINE

	Student Contact Hours Class	Laboratory
I. Introduction to Robotics and Automated Systems	2	3
A. Description of a System		
B. Definitions		
1. Robots		
2. Automation		
C. Elements of Automation		
1. CAD (CADD)		
2. CAM		
3. CAD/CAM		
4. CAE		
5. CIM		
D. Robot Components		
1. Manipulator		
2. Power supply		
3. Controller		
4. Transducers		
II. Robotics/Automated Systems Hazards and Safety Requirements	2	
A. Three Axioms		
B. Three Laws		
C. Robot Hazards (risk identification)		
D. Regulations		
1. NFPA		
2. OSHA		
3. NEMA		
4. JIC		
5. NMTBA		
6. IEEE		
7. NEC		
8. ANSI		

	Student Contact Hours	
	Class	Laboratory
E. Mental Attitude		
1. Cleanliness		
2. Neatness		
III. Robotic Operating Parameters	4	6
A. Interpreting Manufacturer's Specifications		
1. Accuracy/repeatability		
2. Coordinate system		
3. Speed		
4. Arm geometry		
B. Degrees of Freedom		
1. Definition		
2. Robot/arm		
3. Wrist/tool		
C. Payload		
1. Mass		
2. Limitations		
3. Radius (cg distance from mount surface)		
4. Moment of inertia		
IV. Robot Programming Characteristics	4	6
A. Reference Planes of Motion		
1. Tool control path		
2. Robot's coordinate system		
B. Programming Characteristics		
1. Language		
2. High/med/low technology		
C. Path Control		
1. Point-to-point		
2. Controlled path		
3. Continuous path		
V. Robot Structural Systems	2	3
A. Mechanical		
1. Support		
2. Structural		
3. Arm-motion control		
B. End-of-Arm Tooling		
1. Tooling		
2. Compliance devices		
3. Applications		
C. Grippers		
1. Parallel motion		
2. Angular motion		
3. Special		
VI. Robot Drive Systems	2	6
A. Electrical		
1. Power		
2. Control		
3. Servo		
4. Stepper motors		

	Student Contact Hours Class	Laboratory
B. Hydraulic		
1. Pumps		
2. Actuators		
3. Valves		
C. Pneumatic		
1. Pumps		
2. Actuators		
3. Valves		
VII. Robot Control and Feedback Systems	4	6
A. Control		
1. Open loop		
2. Closed loop		
B. Transducers		
1. Discrete		
2. Analog		
C. Relative and Absolute Positioning		

STUDENT LABORATORIES

I. Measure Robot Physical Characteristics
Coordinate systems
Speed of operation
Payloads
Work envelope

II. Identify Robot's Path Control Characteristics and Reference Planes
Point-to-point
Control path
Continuous path

III. Program Robots and Automated Systems
Teach pendant
Lead through
Off line
Post processor

IV. Program/Operate End-of-Arm Tooling
Grippers
Vacuum pickups
Magnetic pickups

V. Describe and Operate Drive System
Mechanical
Electrical
Hydraulic/pneumatic

VI. Identify Major Systems

- Mechanical
- Electrical
- Hydraulic
- Pneumatic
- Controls
- Sensors
- Servos/nonservos
- End-of-arm tooling

STUDENT COMPETENCIES

Upon completion of this course students will be able to:

1. Measure robot performance (distance, positioning, accuracy and repeatability).
2. Specify the robot coordinate system.
3. Operate the following equipment.
   a. End-of-arm tooling
   b. Grippers
   c. Magnetic pickups
   d. Vacuum pickups
   e. Compliance devices
4. Identify major systems of a robot.
5. Describe robot drive system operation.
6. Describe mobility of an industrial robot.
7. Identify a robot's work envelope.
8. Be conversant in robot technology.
9. Demonstrate knowledge of safety requirements for working around robots.
10. Specify safety con' 'lerations for personnel, work area, operations and machines.

FUNDAMENTALS OF ROBOTICS AND AUTOMATED SYSTEMS

MODULE FR-01 Introduction to Robotics and Automated Systems

INTRODUCTION

This module introduces the students to the concepts of robotics and automation. They will learn that systems and subsystems work together as part of a total robotic/automated system.

MODULE OUTLINE

I. Description of a System
   Breakdown System into Subsystems

II. Definitions
   A. Robots
      1. RIA
      2. JIRA
   B. Automation

III. Elements of Automation
   A. CAD(CADD)
   B. CAM
   C. CAD/CAM
   D. CAE
   E. CIM

IV. Robot Components
   A. Manipulator
      1. Arm
      2. Tooling
   B. Power Supply
      1. Electric
      2. Hydraulic
      3. Pneumatic
   C. Controller
      1. Nonservo
      2. Servo
   D. Sensors
      1. Contact
      2. Noncontact

INSTRUCTIONAL OBJECTIVES

Upon completion of this module students will be able to:

1. Describe how several subsystems function together as part of a total system.
2. Define a robot (RIA and JIRA).
3. Describe the function of a robot arm.
4. Define the following terms:

arm	pneumatic
contact sensor	servo
noncontact sensor	nonservo
memory	CAD/CAM
hydraulic	

5. Identify the major components of a hydraulic system.
6. Identify the major components of a pneumatic system.
7. Describe the concept of automation.

FUNDAMENTALS OF ROBOTICS AND AUTOMATED SYSTEMS

MODULE FR-02 Robotics/Automated Systems Hazards and Safety Requirements

INTRODUCTION

Students in this module learn the ideals of safety. They are shown the hazards involved with robots and normal production facilities. As part of the lab, students will assemble and operate simple safety and warning systems.

MODULE OUTLINE

I. Three Axioms
   - A. If the robot is not moving, do not assume it is not going to move.
   - B. If the robot is repeating a pattern, do not assume it will continue.
   - C. Maintain respect for what a robot is and what it can do.

II. Three Laws (Asimov's)
   - A. A robot must not harm a human being, nor through inaction allow one to come to harm.
   - B. A robot must always obey human beings, unless that is in conflict with the first law.
   - C. A robot must protect itself from harm, unless that is in conflict with the first and/or second law.

III. Robot Hazards (risk identification)
   - A. Speed of Operation
   - B. Pinch Points
   - C. Safety Shields
   - D. Warning Labels

IV. Regulations/Codes
   - A. NFPA
   - B. OSHA
   - C. NEMA
   - D. JIC
   - E. NMTBA
   - F. AGMA
   - G. IEEE
   - H. NEC
   - I. ANSI

V. Mental Attitude
   - A. Cleanliness
   - B. Neatness

INSTRUCTIONAL OBJECTIVES

Upon completion of this module students will be able to:

1. Identify six safety hazards associated with robots.
2. State three axioms of safety for working around robots.
3. State Asimov's three laws of robot safety.
4. List two examples of regulations for each of the following:

NFPA	OSHA	NEMA	JIC	ANSI
NMTBA	AGMA	IEEE	NEC	

LAB ACTIVITIES

1. Design, assemble, and operate an electrical safety circuit that will interrupt a robot power supply when a gate is opened.
2. Design safety barriers for three industrial robots.

FUNDAMENTALS OF ROBOTICS AND AUTOMATED SYSTEMS

MODULE FR-03 Robotic Operating Parameters

INTRODUCTION

This module describes the geometric and operational characteristics of a robot. Students will learn four coordinate systems, degrees of freedom and payload parameters.

MODULE OUTLINE

I. Manufacturer's Specifications
   A. Accuracy/Repeatability
   B. Coordinate System
      1. Cartesian
      2. Spherical
      3. Cylindrical
      4. Jointed spherical
      5. Tool center point
   C. Power Supply
      1. Electric
      2. Hydraulic
      3. Pneumatic
   D. Motion
      1. Speed
      2. Momentum
      3. Acceleration
   E. Arm Geometry
      1. Telescopic
      2. Articulated

II. Degrees of Freedom
   A. Definition
   B. Robot/Arm
   C. Wrist/Tooling

III. Payload
   A. Mass
   B. Limitations
   C. Radius (cg distance from mount surface)
   D. Moment of Inertia

INSTRUCTIONAL OBJECTIVES

Upon completion of this module the student will be able to:

1. Identify and explain the four coordinate systems that describe robot movements.
2. Describe the degrees of freedom of a robot.

3. Calculate payload limitations.
4. Given a robot, identify its degrees of freedom and coordinate system.
5. Compare and evaluate manufacturer's specification for selected robots.

LAB ACTIVITIES

1. Measure the relative positions of three points in space (using one as the origin) using cartesian, cylindrical, and spherical coordinates.
2. List the degrees of freedom of five different robots.
3. Plot a curve showing payload mass versus distance from mounting surface.

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FUNDAMENTALS OF ROBOTICS AND AUTOMATED SYSTEMS

MODULE FR-04 Robot Programming Characteristics

INTRODUCTION

This module introduces the student to the concept of reference planes, the characteristics of programming robot motion, and the paths of motion of a robot arm. Students will do limited programming and operating of robots.

MODULE OUTLINE

I. Reference Planes of Motion
   A. Tool Control Path
   B. Robot's Coordinate System
II. Programming Characteristics
   A. Introduction to Languages
      1. VAL
      2. APT
      3. COMPACT II
      4. Other
   B. Programming Methods
      1. Off-line
      2. Teach pendant
      3. Walk through
      4. Lead through
   C. High/med/low technology
      1. Servo/nonservo
      2. Path of motion
III. Path Control
   A. Point-to-Point
      1. Controlled path
      2. Noncontrolled path
   B. Continuous Path

INSTRUCTIONAL OBJECTIVES

Upon completion of this module students will be able to:

1. Define reference plane.
2. Describe the purpose of a (machine) program.
3. List and describe the three types of robot arm-movement
4. Create simple programs for robot arm motion control paths.
5. Explain the term "tool control path."
6. Describe the difference between high, medium, and low technology as applied to industrial robots.

LAB ACTIVITIES

1. Program robots that use cartesian, cylindrical, or spherical coordinates.
2. Program a robot using the tool path pointing system.
3. Program a robot using a teach pendant.
4. Program robots using point-to-point, control path, and continuous path.

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FUNDAMENTALS OF ROBOTS AND AUTOMATED SYSTEMS

MODULE FR-05 Robot Structural Systems

INTRODUCTION

This module describes the mechanical and structural characteristics of a robot. Students will learn the mechanical aspects of various support and operational systems and end-of-arm tooling.

COURSE OUTLINE

I. Mechanical
   A. Support
   B. Structural
   C. Arm-Motion Control

II. End-of-Arm Tooling
   A. Tooling
      1. Welders
      2. Painters
      3. Nut-drivers
      4. Special
   B. Compliance Devices
      1. Active
      2. Passive
   C. Applications
      1. Magnetic pickups
      2. Vacuum pickups
      3. Mandrels
      4. Pneumatic fingers

III. Grippers
   A. Parallel Motion
   B. Angular Motion
   C. Special

INSTRUCTIONAL OBJECTIVES

Upon completion of this module students will be able to:

1. Describe and sketch the operation of a four-bar linkage.
2. Program and operate robot arms that are equipped with either welders or painters.
3. Program and operate vacuum and magnetic pickups.
4. Describe the difference between parallel and angular grippers.
5. Explain the difference between active and passive compliance devices.
6. Determine the maximum weight that can be lifted with a specific vacuum or magnetic pickup.
7. Identify the applications which should use parallel gripper motion.
8. Identify the applications which should use angular gripper motion.

LAB ACTIVITIES

1. Sketch and diagram the operating elements of a robot.
2. Mount a welder or paint gun to a robot arm.
3. Install/remove a remote center compliance device.

FUNDAMENTALS OF ROBOTICS AND AUTOMATED SYSTEMS

MODULE FR-06 Robot Drive Systems

INTRODUCTION

This module describes robot drive systems and their control. Students will operate electrical, pneumatic, and hydraulic power and control systems.

MODULE OUTLINE

I. Electrical
   A. Power
   B. Control
   C. Servo
      1. AC
      2. DC
   D. Stepper Motors

II. Hydraulic
   A. Pumps
      1. Fixed displacement
      2. Variable displacement
   B. Actuators
      1. Linear
      2. Rotary
   C. Valves

III. Pneumatic
   A. Pumps
      1. Fixed displacement
      2. Variable displacement
   B. Actuators
      1. Linear
      2. Rotary
   C. Valves

INSTRUCTIONAL OBJECTIVES

Upon completion of this module the student will be able to:

1. Describe the operation of servo motors and stepper motors in robot drive systems.
2. Describe the function of each component in a hydraulic and/or pneumatic system of a robot.
3. Operate robot drive systems.
4. Calculate the mechanical advantage and speed ratio of gear trains.
5. Explain the difference between fixed- and variable-displacement pumps.
6. Explain the function/purpose of a relief valve in a hydraulic or pneumatic system.
7. List the advantages and disadvantages of electric, hydraulic, and pneumatic drive systems.

LAB ACTIVITIES

1. Operate robots equipped with servo control systems.
2. Operate robots equipped with stepper motors.
3. Operate robots equipped with hydraulic cylinders and motors.

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MODULE FR-07 Robot Control and Feedback Systems

INTRODUCTION

This module describes the methods used to sense robot positions and how this information is fed back to the controller. Students will observe how fed-back information affects controller operation.

MODULE OUTLINE

I. Control
  A. Open Loop
  B. Closed Loop

II. Sensors
  A. Discrete
    1. Thermistor
    2. Photodiode
    3. Limit switch
    4. Hall effect
    5. Encoder
  B. Analog
    1. Piezoelectric
    2. Thermistor
    3. Phototransistor
    4. Strain gage rosette
    5. Thermocouple
    6. Acoustic
    7. Eddy current
    8. Potentiometer
    9. Resolver
    10. Tachometer generator

INSTRUCTIONAL OBJECTIVES

Upon completion of this module students will be able to:

1. Describe two methods of controlling robot motion.
2. Identify five types of sensors in robotic systems
3. Describe the difference between servo and nonservo systems
4. Explain the purpose of feedback systems.
5. Explain the difference between open and closed loop.
6. Describe the following sensors:

Thermistor	Photodiode	Limit switch
Hall effect	Piezoelectric	Phototransistor
Thermocouple	Acoustic	Strain gage rosette
Eddy current	Potentiometer	Tachometer generator
Resolver		

7. Describe an open-loop control system.
8. Describe a closed-loop control system.

LAB ACTIVITIES

1. Operate open-loop control systems.
2. Operate closed-loop control systems.
3. Observe discrete device performance characteristics.
4. Observe analog device performance characteristics.
5. Identify the sensors installed on a robot.

CONTROLLERS FOR AUTOMATED SYSTEMS

Classroom/Laboratory hrs/wk 2/6

COURSE DESCRIPTION

Students will learn the principles of control systems and how they are applied to a production system to achieve automation. Systems included in the course are drum controllers, stepper motors, programmable logic controllers, microprocessors, computers, feedback systems and robot controllers.

COURSE OUTLINE

	Student Contact Hours Class	Laboratory
I. Introduction to Controllers A. Purpose/Function of Controllers B. Open-Loop Controllers C. Closed-Loop Controllers	2	
II. Fixed Sequence A. Ladder Diagrams B. Drum Controllers/Timer C. Stepper Relays	8	18
III. Programmable Logic Controllers (PLCs) A. Sequence Controller B. Process Controller C. Components/Architecture of PLC	3	12
IV. Feedback Sensors A. Discrete Signals/Sensors B. Analog Signals/Sensors C. Contact Sensors D. Noncontact Sensors E. Output Signal Uses	3	15
V. Robot Controllers A. Definition of a Manufacturing Operation B. Sensing C. Controller Programming D. Operation E. Robot Controller Programming--A Case Study	4	15

STUDENT LABORATORIES

I. Set Up, Program and Operate Drum Controllers

II. Set Up, Program and Operate Stepper Motors/Relays

III. Set Up, Program and Operate Open- and Closed-Loop Programmable Logic Controllers

IV. Set Up, Calibrate and Operate Feedback Sensors and Control Devices Including Encoders and Resolvers

V. Set Up and Operate Robot Controllers using:
   Teach pendants
   Walk through
   Off line
   Post process

STUDENT COMPETENCIES

Upon completion of this course, the student will be able to:

1. Install, adjust, troubleshoot and repair or replace control devices to manufacturer's specifications.
2. Program stepper relays.
3. Program and/or reprogram PLCs (drum, relay and microprocessor types) for specific sequence of events.
   a. Prepare a flow chart for a specific sequence of events in performing a given application.
   b. Enter instructions into control unit.
   c. Run program to see if it executes properly.
   d. Edit or debug program as necessary.
   e. Download and upload programs.
   f. Recognize and resolve hardware/software impedance matching problems.
4. Draw logic diagrams.
5. Read, understand and comply with requirements of service bulletins.
6. Use teaching pendant for testing, editing and setup.
7. Adjust feedback loops that include:
   a. Encoders
   b. Optical sensors
   c. Electronic sensors
   d. Microprocessors
   e. Optoelectronics
   f. Hall-effect devices
   g. Velocity sensors
   h. Position detectors
8. Install a programmable controller and its input/output devices.
9. Perform electrical adjustments on servo power amplifiers.
10. Perform zeroing of encoders.
11. Define axis control and feedback specifications.

CONTROLLERS FOR AUTOMATED SYSTEMS

MODULE CA-01 Introduction to Controllers

INTRODUCTION

This module introduces students to the concept of devices/systems that control or sequence the operation of several pieces of equipment. It is the proper sequencing that is important to the successful operation of an automated system. Both open-loop (without feedback) and closed-loop (with feedback) controllers will be assembled and operated.

MODULE OUTLINE

I. Purpose/Function of Controllers

II. Open-Loop Control Principles
- A. Drum
- B. Stepper Motors
- C. Programmable Logic Controllers

III. Closed-Loop Control Principles
- A. Programmable Logic Controllers
- B. Proportional Robot Controller
  - 1. AC/DC servo
  - 2. Hydraulic
- C. Sensors
  - 1. Discrete
    - a. Thermistor
    - b. Photodiode
    - c. Limit switch
    - d. Hall effect
    - e. Encoder
  - 2. Analog
    - a. Piezoelectric
    - b. Thermistor
    - c. Phototransistor
    - d. Strain gage rosette
    - e. Thermocouple
    - f. Acoustic
    - g. Eddy current
    - h. Potentiometer
    - i. Resolver
    - j. Tachometer generator

OBJECTIVES

Upon completion of this module students will be able to:

1. Describe the operation and the difference between open- and closed-loop controllers.
2. Identify the types of controllers in open-loop and closed-loop systems.

3. Describe the importance of sensors in a closed-loop control system.
4. Explain the function of a proportional robot controller.
5. List advantages and disadvantages of open-loop and closed-loop controllers.
6. Set up and operate an open-loop system that does not utilize sensors.
7. Set up and operate a closed-loop system with sensing.

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CONTROLLERS FOR AUTOMATED SYSTEMS

MODULE CA-02 Open-Loop Controller Applications Fixed Sequence

INTRODUCTION

This module discusses open-loop controllers--those without feedback. Students will study, program and operate drum controllers, and stepper motors.

MODULE OUTLINE

I. Ladder Diagrams
   - A. Logic Expressions
   - B. Design

II. Drum Controller/Timer
   - A. Programming
   - B. Operations
   - C. System Connection
   - D. Reset/Start-up

III. Stepper Relay
   - A. Relay Logic
   - B. Inputs
   - C. Programming
   - D. Reset/Start-up
   - E. System Connection

OBJECTIVES

Upon completion of this module students will be able to:

1. Program and operate drum controllers.
2. Describe typical devices and systems controlled by open-loop controllers.
3. Draw and interpret ladder diagrams.
4. Program and test a drum controller.
5. Install, replace, troubleshoot, repair or adjust to manufacturers' specifications, open-loop control devices.
6. Program and operate a stepper relay control.
7. Stop, reset and restart a system controlled by a stepper relay and/or drum controller.
8. Convert a ladder diagram into a drum controller program.
9. Explain relay logic.

LAB ACTIVITIES

1. Program and test a drum controller.
2. Install, adjust, troubleshoot and repair or replace open-loop control devices to manufacturer's specifications.
3. Program and operate a stepper relay control.
4. Stop, reset and restart a system controlled by a stepper relay and/or drum controller.
5. Draw ladder diagrams and convert them into drum controller programs.

CONTROLLERS FOR AUTOMATED SYSTEMS

MODULE CA-03 Programmable Logic Controller

INTRODUCTION

Students will learn what programmable logic controllers (PLCs) are and how they are applied to controlling automated systems. Both sequence and process applications will be studied along with programming and interfacing the PLCs.

MODULE OUTLINE

I. Sequence Controller
   A. Programming
   B. Output Signals

II. Process Controller
   A. Programming
   B. I/O Signals

III. Components/Architecture of PLCs
   A. Processor
   B. Power Supply
   C. Memory
   D. I/O

OBJECTIVES

Upon completion of this module students will be able to:

1. Describe the difference between a sequence controller and a process controller.
2. Install, program and operate PLCs (sequence controller) by:
   a. Preparing a flow chart
   b. Entering instructions into control unit
   c. Running program
   d. Editing/debugging program
   e. Downloading/uploading program
   f. Recognizing and resolving hardware/software impedance matching problems
3. Install, program and operate PLCs (process controller) by:
   a. Preparing a flow chart
   b. Entering instructions into control unit
   c. Running program
   d. Editing/debugging program
   e. Downloading/uploading program
   f. Recognizing and resolving hardware/software impedance matching problems

4. Draw logic diagrams.
5. Explain how a programmable logic controller is used to control an automated system.
6. Interchange programmable logic controllers between machines.

LAB ACTIVITIES

1. Interchange programmable logic controllers between machines.
2. Program/reprogram PLCs for a specific sequence of events by:
    a. Preparing a flow chart
    b. Entering instructions into control unit
    c. Running program
    d. Editing/debugging program
    e. Downloading/uploading programs
    f. Recognizing and resolving hardware/software impedence matching problems

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CONTROLLERS FOR AUTOMATED SYSTEMS

MODULE CA-04 Feedback Sensors and Control

INTRODUCTION

This module describes closed-loop control systems including feedback. The students will study and apply feedback (discrete) signals to controllers. Other items to be studied include encoders and resolvers.

MODULE OUTLINE

I. Discrete Signals/Sensors
   A. Signal Characteristics
   B. Input versus Output
   C. Sensor Output

II. Analog Signals/Sensors
   A. Signal Characteristics
   B. Input versus Output
   C. Sensor Output

III. Contact Sensors
   A. Operation
   B. Limitation

IV. Noncontact Sensors
   A. Operation
   B. Limitation

V. Output Signal Uses

OBJECTIVES

Upon completion of the module students will be able to:

1. Define feedback and its purpose.
2. Describe the operation of resolvers and encoders.
3. Adjust feedback loops that include:
   a. Encoders
   b. Optical sensors
   c. Electronic sensors
   d. Microprocessors
   e. Optoelectronics
   f. Hall-effect devices
   g. Velocity sensors
   h. Position detectors
4. Compare the advantages and disadvantages of contact and noncontact sensors.
5. Calibrate encoders and resolvers.
6. Install and calibrate noncontact sensors.
7. Install and calibrate contact sensors.

LAB ACTIVITIES

1. Calibrate encoders and resolvers.
2. Install, calibrate contact sensors.
3. Install, calibrate noncontact sensors.
4. Adjust feedback loops that include:
    a. Encoders
    b. Optical sensors
    c. Electronic sensors
    d. Microprocessors
    e. Optoelectronics
    f. Hall-effect devices
    g. Velocity sensors
    h. Position detectors

CONTROLLERS FOR AUTOMATED SYSTEMS

MODULE CA-05 Robot Controllers

INTRODUCTION

This module introduces students to controllers whose programs can be easily changed. Students will reprogram controllers that operate automated systems to accomplish a wide variety of tasks. Signals will be fed back so that students can observe the interactive principles of sensing and controlling systems.

MODULE OUTLINE

I. Define a Manufacturing Operation
   What Individual Tasks are Accomplished

II. Sensing
   A. Types of Sensors
   B. Information Sensed and Transmitted
   C. Robot Arm
      1. Position
      2. Velocity
   D. Work Cell
      1. Contact
      2. Noncontact
      3. Process

III. Controller Programming
   A. Architecture
   B. Fixed Logic (Fixed Sequence)
   C. Reprogrammable
   D. Languages
   E. Robot Programming--A Case Study

IV. Operation
   A. Mechanical
   B. Electrical
   C. Signals Sensed and Transmitted

V. Robot Controller Programming--A Case Study

OBJECTIVES

Upon completion of this module the student will be able to:

1. Draw ladder diagrams and construct working representative models.
2. Program robot controllers by:
   a. Preparing flow chart
   b. Entering instructions
   c. Running program
   d. Editing/debugging program
   e. Downloading/uploading program
   f. Resolving hardware/software problems

3. Program computers that control automated systems.
4. Program microprocessors that control automated systems.
5. Explain the advantage of being able to rapidly reprogram an automated system.
6. Explain the difference between microprocessors and computers.
7. Interchange robot controllers.
8. Determine input signals required for feedback.
9. Reprogram a controller so a robot performs a different function.
10. Adjust servo power amplifiers.
11. "Zero" an encoder.

LAB ACTIVITIES

1. Define input signals required (feedback) for an automated system controller.
2. Reprogram a controller so that a robot performs a different function.
3. Perform electrical adjustments on servo power amplifier.
4. Perform zeroing of an encoder.
5. Program controllers by:
   a. Preparing flow chart
   b. Entering instructions
   c. Running program
   d. Editing/debugging program
   e. Downloading/uploading program
   f. Resolving hardware/software problems

AUTOMATED SYSTEMS AND SUPPORT COMPONENTS
Classroom/Laboratory hrs/wk 2/6

COURSE DESCRIPTION

Students learn the concepts of production--mass production, batch processing, and job shopping. They also learn how identical support components are applied to different types of automated manufacturing. Proper orientation of parts will be examined in the laboratory. Also, sensor performance will be compared to manufacturer's data.

COURSE OUTLINE

	Student Contact Hours Class	Laboratory
I. Introduction to Types of Manufacturing	2	0
A. Mass Production		
1. Large volume		
2. Hard or fixed automation		
3. Single-purpose machines/transfer lines		
B. Batch Processing		
1. Small volumes		
2. Job shop		
3. Flexible automation		
4. Group technology		
C. Job Shopping		
1. Limited production		
2. Flexible manufacturing (if large or expensive items)		
II. Parts Movers	4	15
A. Parts Feeders		
1. Bowl feeders		
2. Hoppers		
3. Gravity feeders		
B. Material Handlers		
1. Conveyors		
2. Wire-guided vehicles		
3. Cranes		
4. Lift, carry, and shuttle-type transfer devices and systems		
5. Power-and-free versus synchronous		
6. Walking beams		
III. Jigs and Fixtures	4	12
A. Free-Effort Fixtures		
B. Parts Orientation		
C. Fixture Optimization		

	Student Contact Hours Class	Laboratory
IV. Positioners A. Electrical B. Pneumatic C. Hydraulic D. Index tables	4	15
V. Sensors (Direct Reading/Discrete [Single-Function] Devices) A. Limit Switches B. Position Indicators C. Level Indicators D. Tactile E. Pressure F. Temperature	4	18

STUDENT LABORATORIES

I. Observe and Describe Three Types of Manufacturing
   Take field trips and write reports describing observed manufacturing operations
   Separate ten parts according to common manufacturing operations (Group Technology)

II. Set Up Part Feeders
   Operate rotary hopper
   Operate bowl feeders
   Determine parts presentation requirements

III. Operate the Following Types of Material Handlers
- Conveyors
- Wire-guided vehicles
- Gravity feeders

IV. Evaluate the Following Types of Sensors
- Limit switch
- Photoelectric
- Tactile
- Proximity
- Temperature
- Pressure
- Flow

V. Operate the Following Positioners and Work Holders
- Hydraulic
- Electric
- Pneumatic
- Mechanical
- Index tables

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VI. Set Up and Operate the Following Energy Control Devices
- Switches
- Relays
- Valves
- Servo
- Nonservo

VII. Evaluate Applications of the Following Types of Actuators
- Cylinders
- Rotary devices
- Stepper motors
- Mechanical
- Springs
- Solenoids

VIII. Assemble and Study Mechanical Positioners Operated by the Following
- Four-bar linkages
- Geneva mechanisms
- Links
- Gears/pulleys
- Cam and follower
- Walking beams

STUDENT COMPETENCIES

Upon completion of this course, the student should be able to:

1. Program stepper motors.
2. Install, adjust, troubleshoot and repair or replace tactile and video sensors.
3. Describe the application of mechanical linkages/gears to a robotic work cell.
4. Perform electrical adjustments on servo power amplifiers.
5. Describe the application of hydraulic, electric or pneumatic positioners and sensors to a flexible cell.

AUTOMATED SYSTEMS AND SUPPORT COMPONENTS

MODULE AS-01 Types of Manufacturing

INTRODUCTION

This module presents the three basic methods used by manufacturers to produce goods--continuous (mass) production, batch processing, and job shopping. Students will learn the criteria used in selecting the correct process and the advantages and disadvantages of each.

MODULE OUTLINE

I. Mass Production
   A. Large Volume
   B. Hard or Fixed Automation
   C. Single-Purpose Machines/Transfer Lines

II. Batch Processing
   A. Small Volumes
   B. Flexible Automation
   C. Group Technology

III. Job Shop
   A. One or Two of a Kind
   B. Flexible Automation (if very expensive or large)

OBJECTIVES

Upon completion of this module students will be able to:

1. Describe the characteristics of continuous (mass) production, batch processing, and job shopping.
2. Evaluate a product and determine the correct manufacturing technique for it.
3. Draw a material flow diagram, from receiving to shipping, for one part produced in a factory using mass production techniques.
4. Define the term "flexible automation."
5. Explain the meaning of "group technology."
6. Describe a manufacturing operation using single-purpose machines and transfer lines.
7. List the advantages and disadvantages of mass production, batch processing, and job shop production.

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AUTOMATED SYSTEMS AND SUPPORT COMPONENTS

MODULE AS-02 Parts Movers

INTRODUCTION

This module introduces students to various types of equipment that supply parts/subassemblies to automated machine tooling. Students will evaluate methods of parts orientation to facilitate transfer to subsequent machines. Students will also learn the characteristics of systems that move large parts and/or large numbers of parts.

MODULE OUTLINE

I. Parts Feeders
   A. Bowl Feeders
   B. Vibratory Feeders
   C. Feed Rate
   D. Gravity Feeders

II. Material Handlers
   A. Conveyors
   B. Wire-Guided Vehicles
   C. Cranes
   D. Lift, Carry and Shuttle-type Transfer Devices/Systems
   E. Power-and-Free versus Synchronous
   F. Walking Beam

OBJECTIVES

Upon completion of this module students will be able to:

1. Set up equipment to supply parts to subsequent machines.
2. Set up a bulk feeder to supply parts at a specified rate.
3. List the operating characteristics/constraints of:
   a. Conveyors
   b. Wire-guided vehicles
   c. Gravity feeders
   d. Lift, carry and shuttle-type transfer devices/systems
4. Explain the difference between a "part" and a "subassembly."
5. Define the term "part orientation."
6. Explain the difference between "parts feeder" and "material handler."
7. Describe an appropriate application of a bowl feeder.
8. Describe an appropriate application of a vibratory feeder.
9. Define the term "feed rate."
10. Describe the operation of a wire-guided vehicle.
11. Describe an appropriate application of a "gravity feeder."
12. Define the term "conveyor."
13. Assemble a conveyor system used to supply parts to a robot.
14. Set up and operate a vibratory feeder.

LAB ACTIVITIES

1. Assemble parts feeders and/or material-handling devices to supply parts to a robot.
2. Set up and operate a vibratory feeder.
3. Build a fixture to hold a workpiece in a specified orientation.
4. Analyze and determine optimum fixturing for manufacturing two parts.

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AUTOMATED SYSTEMS AND SUPPORT COMPONENTS

MODULE AS-03 Jigs and Fixtures

INTRODUCTION

This module describes methods and equipment used to hold parts in a specific orientation. Students will assemble jigs and fixtures and use them to orient parts properly for subsequent operations.

MODULE OUTLINE

I. Free-Effort Fixtures
   A. Description
   B. Parts Orientation Determintion
   C. Part Holder

II. Parts Orientation
   A. Constraints of Part
   B. Constraints of Operation
   C. Part Design

III. Fixture Optimization
   A. Maximum Number of Parts
   B. Economic Considerations
   C. Position Optimization

OBJECTIVES

Upon completion of this module students will be able to:

1. Describe the purpose of jigs and fixtures.
2. Analyze fixtures for economic improvement.
3. Sketch parts in a specific orientation.
4. Sketch jigs/fixtures to hold a part in a specific orientation.

LAB ACTIVITIES

1. Design and assemble a fixture for holding parts to be welded.
2. Design and assemble a fixture to hold parts in the correct orientation for a robot to pick them up.
3. Design and assemble a fixture to receive parts from a robot.
4. Design a shipping fixture to maximize the number of parts stackable in one layer of a shipping carton.

AUTOMATED SYSTEMS AND SUPPORT COMPONENTS

MODULE AS-04 Positioners

INTRODUCTION

This module presents the concept of work positioners--devices that hold a workpiece in a specific orientation while it is being worked on. Students will operate positioners to hold workpieces in a specific orientation.

MODULE OUTLINE

I. Application of Positioners
   A. Welding
   B. Machining
   C. Painting
   D. Assembly

II. Electrical
   A. Stepper Motors
   B. Servo Motors
   C. Solenoids

III. Pneumatic
   A. Cylinders
   B. Motors
   C. Servos

IV. Hydraulic
   A. Cylinders
   B. Motors
   C. Servos

V. Mechanical
   A. Geneva Mechanisms
   B. Ball Screw
   C. Bell Crank
   D. Four-bar Linkage
   E. Cam and Follower
   F. Walking Beams

OBJECTIVES

Upon completion of this module students will be able to:

1. Sketch the correct way to hold a workpiece.
2. Identify and sketch the correct orientation for a specific part while it is being worked on.
3. Describe how actuators and mechanisms are used to accomplish 1 and 2.
4. Calculate the maximum force achievable by a cylinder.
5. Troubleshoot and repair servo and stepper motors.
6. Set up work holders to hold two pieces to be welded.

7. Define the term "work positioner."
8. Explain the function performed by a servo motor.
9. Design, assemble and operate an electrically-operated work positioner.
10. Design, assemble and operate a hydraulically-operated work positioner.

LAB ACTIVITIES

1. Design, assemble and operate an electrically-operated work positioner.
2. Design, assemble and operate a hydraulically-operated work positioner.

MODULE AS-05 Sensors (Direct-Reading/Discrete [Single-Function] Devices)

INTRODUCTION

This module discusses seven discrete sensors used in robotics and automated systems. Students will test each type of sensor and compare its operating characteristics with manufacturer's specifications.

MODULE OUTLINE

I. Contact Sensors
   A. Tactile
   B. Limit Versus Proximity Switches

II. Noncontact Sensors
   A. Vision
   B. Magnetic
   C. Optoelectric
      1. Direct
      2. Retroreflective
      3. Diffused
      4. Specular
   D. Eddy Current

III. Process Sensors
   A. Pressure
   B. Temperature
   C. Level
   D. Flow

OBJECTIVES

Upon completion of this module students will be able to:

1. Identity the correct application of five different sensing devices.
2. Describe a discrete device.
3. Test and compare sensor performance with manufacturer's specifications.
4. Install, calibrate, adjust limit switches, level indicators, and pressure and temperature indicators.
5. Define the difference between direct- and indirect-reading sensors.
6. Calibrate sensors.
7. Measure the signal output of a sensor.
8. Define the following terms: limit switch, position indicator, level indicator, attitude indicator, tactile sensor, pressure sensor, temperature sensor.
10. Install and calibrate a sensor.
11. Interpret manufacturers' specifications.
12. Determine output signal characteristics for a variety of sensors.

LAB ACTIVITIES

1. Test seven types of sensors to determine output signal characteristics in relation to input signals.
2. Interpret manufacturers' specifications.
3. Install and calibrate thermal sensors in a heat transfer system.

ROBOTICS/AUTOMATED SYSTEMS INTERFACES
Classroom/Laboratory hrs/wk 2/6

COURSE DESCRIPTION

Students in this course will learn the principles of interconnecting (interfacing) controllers, sensors and actuators. They will study, set up and operate simple (discrete, binary) and complex (analog) sensors, tooling, controllers and network interfacing.

COURSE OUTLINE

COURSE OUTLINE	Student Contact Hours Class	Laboratory
I. Simple Sensor Interfaces (Discrete, Binary)	4	12
A. Sensors		
B. Controllers		
II. Control Signal Interfacing	4	12
A. Electrical Characteristics		
B. RS-232 Characteristics		
C. Data Transmission		
D. Terminology		
III. Mechanical Interfaces	4	12
A. Interchangeability		
B. Grippers		
C. Welders		
D. Applicators		
E. Grinders		
F. Lasers		
IV. Electrical Interfaces	4	12
A. Interchangeability		
B. Magnetic Pickups		
C. Grippers with Tactile Sensors		
D. Welders		
V. Networking	4	12
A. Data Exchange		
B. Control of Other Computers/Controllers		

STUDENT LABORATORIES

1. Interface Signals
   a. Measure sensor output and compare to manufacturer's specifications.
   b. Simulate signals input to controller and observe and measure the response.
   c. Compare and analyze RS-232C interconnections and determine requirements for compatibility.

2. Tooling Interfaces
   a. Mechanical
      1. Interchangeability
      2. Movements/clearances
      3. Special hardware/tools of installation
   b. Electrical
      1. Power supplied
      2. Control signals
      3. Actuator/sensor sensing
      4. Disconnects
   c. Pneumatic/hydraulic
      1. Disconnects
      2. Pressure/volume flow
      3. Sensing

STUDENT COMPETENCIES

Upon completion of this course, the student should be able to:

1. Use manual's troubleshooting charts to aid fault isolation/repair.
2. Use manufacturer's manuals as a guide to troubleshoot, repair, test and operate a failed machine.
3. Use manufacturer's manuals to determine a machine's normal operating characteristics.
4. Using a manual, identify operational/functional systems.
5. Disassemble, repair, test and return to service robots that have failed.
6. Install, adjust, troubleshoot, repair or replace:
   a. Industrial robots
   b. End-of-arm tooling
   c. Smart actuators
7. Coordinate the operation of several pieces of automatic equipment.
8. Adjust machines for accuracy and repeatability.
9. Start up and shut down an automated production system.
10. Follow troubleshooting procedures recommended by the manufacturer to diagnose, isolate and repair a robot/automated system.
11. Specify the robot-to-material interfaces.
12. Set up, program, troubleshoot a system comprised of a minimum of two transfer lines, one robot and at least one machining center.
13. Set up, and so forth, robot to either remove parts from a conveyor and palletize them or to depalletize parts and place them on a conveyor.
14. Configure a system for counting regular/irregular-shaped objects moving on an overhead track.
15. Operate the following equipment:
    a. End-of-arm tooling
    b. Grippers
    c. Magnetic pickups
    d. Vacuum pickups
    e. Compliance devices
16. Adapt the following to robotic application:
    a. Welder
    b. Adhesive applicators
    c. Paint sprayers
    d. Grinder

17. Adapt the following to work with automated systems:
    a. Conveyors
    b. Bulk feeders
18. Program a host computer to control several "lower-level" computers that in turn control portions of an automated system.
19. Interchange different open-loop controllers between systems.
20. Interchange different closed-loop controllers between systems.

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ROBOTICS/AUTOMATED SYSTEMS INTERFACES

MODULE RI-01 Simple Sensor Interfaces (Discrete/Binary)

INTRODUCTION

This module introduces students to the principles and procedures of (electrically) interfacing controllers and sensors. Students will set up and measure the characteristics of transmitted and received signals.

MODULE OUTLINE

I. Sensors
   A. Sensor Outputs
      1. On/off
      2. High/low
   B. Sensor Mountings
      1. Structural
      2. Thermal
      3. Electrical
   C. Sensor Calibration
      Positioning
   D. Interconnect/Cabling
      1. Conductors
      2. Nonconductors (for example, fiber optics)

II. Controllers
   A. Programmable Logic Controllers
      1. Power supply
      2. Input signal requirements/characteristics (from sensor)
      3. Output signal requirements/characteristics (to control)
      4. Programming
   B. Robot Input/Output
      1. Input signal requirements/characteristics (from sensor)
      2. Output signal requirements/characteristics (to control)
      3. Programming
   C. Interconnects/Cabling
      1. Conductors
      2. Nonconductors

OBJECTIVES

Upon completion of this module students will be able to:

1. Define a discrete signal.
2. Measure interfacing requirements for transmitting and receiving a signal.
3. Set up interfaces between discrete sensors and controllers.
4. Measure discrete sensor output.
5. Measure signal insertion loss in fiber-optic cabling.

ROBOTICS/AUTOMATED SYSTEMS INTERFACES

MODULE RI-02 Control Signal Interfacing

INTRODUCTION

This module describes the characteristics of RS-232 interfacing requirements. Students will measure the characteristics of transmitted and received signals across an RS-232 connector.

MODULE OUTLINE

I. Electrical Characteristics
   A. Data Transmission
      1. Parallel
      2. Serial
   B. Synchronous Transmission
   C. Asynchronous Transmission

II. RS-232 Characteristics
   A. Voltage Levels
   B. Pin Configurations

III. Data Transmission
   A. Without Handshaking
   B. With Handshaking

IV. Terminology
   A. Half Duplex
   B. Full Duplex

OBJECTIVES

Upon completion of this module students will be able to:

1. State the difference between serial and parallel transmission.
2. Recall the advantages of serial transmission and when it would be preferred over parallel data transmission.
3. Recall when parallel transmission of data would be preferred over serial data transmission.
4. Write the voltage specifications of RS-232.
5. State RS-232 handshaking capability availability.

LAB ACTIVITIES

1. By using a computer program, output an ASCII character using an endless loop:
   a. Observe and record the output waveform
   b. Observe and record voltage level
   c. Observe and record dc offset

d. Observe and record frequency
e. Observe and record stop bit/start bit

Change the ASCII character and repeat the above measurements.

2. Demonstrate capability to interface a printer to a host computer. By using the pin diagram of the computer and printer, identify each pin used and its function.
3. Repeat #2 using a computer terminal-keyboard/CRT.

ROBOTICS/AUTOMATED SYSTEMS INTERFACES

MODULE RI-03 Mechanical Interfaces

INTRODUCTION

This module describes the physical characteristics of mounting different tools on a robotic arm. Students will evaluate the mounting characteristics of several types of robot arms.

MODULE OUTLINE

I. Interchangeability
   A. Locating Devices
   B. Clearances
   C. Tolerances
   D. Parallel/Squareness
   E. Coordinate System, Reference

II. Grippers
   A. Parallel
   B. Nonparallel

III. Welders
   A. Resistance
   B. Arc
   C. MIG
   D. TIG

IV. Applicators
   A. Adhesive
   B. Paint

V. Grinders

VI. Lasers

OBJECTIVES

Upon completion of this module students will be able to:

1. Write specifications for mechanical interfaces.
2. Interpret manufacturer's data to determine if a tool is adaptable to a specific robot arm and define the difference if it is not adaptable.
3. Specify robot-to-material interfaces.

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LAB ACTIVITIES

1. Interchange the following equipment:
   - End-of-arm tooling
   - Grippers
   - Magnetic pickups
   - Vacuum pickups
   - Compliance devices
2. Adapt the following to robotic application:
   - Welders
   - Adhesive applicators
   - Paint sprayers
   - Grinders
3. Design and build mechanical alignment devices for use in mounting tooling on a robot arm.

ROBOTICS/AUTOMATED SYSTEMS INTERFACES

MODULE RI-04 Electrical Interfaces

INTRODUCTION

This module describes the characteristics required to electrically interchange robot tooling. Students will evaluate three types of connectors used in designing interchangeable connectors.

MODULE OUTLINE

I. Interchangeability
   A. Connector Configuration
   B. Pin Configuration
   C. Voltage and Current Restraints

II. Magnetic Pickups

III. Grippers with Tactile Sensors

IV. Welders

OBJECTIVES

Upon completion of this module students will be able to:

1. Write specifications for electrical connectors.
2. Describe the proper application of three different connectors.
3. Evaluate manufacturer's specifications of connectors.

LAB ACTIVITIES

1. Adapt welders to robotic application
2. Specify mating electrical plugs and receptacles.
3. Modify circular connectors to prevent undesired connections.

MODULE RI-05 Networking

INTRODUCTION

Students will interconnect microprocessors and computers so they can "talk" to each other. Computers will be interconnected forming a local area network. Methods of connecting a host computer to other computers that control portions of automated systems will be studied and simulated.

MODULE OUTLINE

I. Data Exchange
   A. RS-232 Interface
   B. Send/Receive

II. Control of Other Computers/Controllers
   A. Handshaking
   B. Control Signal Interchanging
   C. Use of Another Computer's Memory
   D. Hierarchy of Control
   E. Manufacturer's Automation Protocol (MAP)

OBJECTIVES

Upon completion of this module students will be able to:

1. Define the control systems necessary for computer-integrated manufacturing.
2. Coordinate the operation of several pieces of automatic equipment.

LAB ACTIVITIES

1. Program a host computer to control several "lower-level" computers.
2. Program several computers so they can address, input, and output information from the other computers.

ROBOTICS/AUTOMATED SYSTEMS AT WORK
Classroom/Laboratory hrs/wk 2/6

COURSE DESCRIPTION

This course provides students an opportunity to observe and study the application of robots and automated systems to manufacturing. Students will simulate in the lab several of the systems observed in industry. The laboratory exercises are aimed at evaluating current systems and attempting to improve them.

COURSE OUTLINE

	Student Contact Hours Class	Laboratory
I. Review Two Types of Automation A. Fixed B. Flexible	2	4 (field trips)
II. Flexible Automation A. Case Studies (Class) 1. Welding 2. Assembly 3. Material handling B. Case Study (Individual) Machine tending	10	42
III. Fixed Automation A. Case Studies (Class) 1. Bottlers 2. Transfer line 3. Photocopier B. Case Study (Individual) 1. Process control 2. Packaging	8	14

STUDENT LABORATORIES

1. Set up, debug, program, operate robots in two categories (electric, pneumatic, or hydraulic).
   a. Point-to-point, continuous path, control path
   b. Circular, spherical, cartesian, jointed spherical
   c. Drum, PLC, microprocessor, computer
2. Perform an analysis of an existing automated system.
3. Assemble prototype systems similar to existing production systems.

STUDENT COMPETENCIES

Upon completion of this course, the student should be able to:

1. Install, adjust, troubleshoot and repair or replace sensors for tactile sensing.
2. Identify and use appropriate lubricant.

3. Use manual's troubleshooting charts to aid fault isolation/repair.
4. Explain the difference between accuracy, precision and repeatability.
5. Install, adjust, troubleshoot, repair or replace:
   a. Industrial robots
   b. End-of-arm tooling
   c. Smart actuators
6. Interconnect robots and other equipment.
7. Analyze and select appropriate robot sensing requirements for certain manufacturing operations.
8. Start up and debug a robot system.
9. Analyze operating difficulties of installed robots; perform necessary corrective adjustments to return system to normal operation.
10. Perform field testing of a robot and check to assure that its performance is in accordance with specifications.
11. Specify the robot-to-material interfaces.
12. Set up, etc., robot to either remove parts from transfer line and palletize them or to depalletize parts and place then on a transfer line.
13. Design a system for counting regular/irregular-shaped objects moving on an overhead track.
14. Operate the following equipment.
    a. End-of-arm tooling
    b. Grippers
    c. Magnetic pickups
    d. Vacuum pickups
    e. Compliance devices
15. Adapt the following to robotic application:
    a. Welder
    c. Paint sprayers
    b. Adhesive applicators
    d. Grinders
16. Adapt the following to work with automated systems:
    a. Conveyors
    b. Bulk feeders

MODULE RS-01 Review the Types of Automation

INTRODUCTION

This module is a brief review of the types of automated production--fixed and flexible. Students will compare the SME and Japanese definitions of robots and learn how each is applied to automation.

MODULE OUTLINE

I. Fixed (Hard) Automation
   A. In Line
   B. Rotary

II. Flexible Automation
   A. High-Volume/Low-Mix Products
   B. Low-Volume (Each)/High-Mix Products

OBJECTIVES

Upon completion of this module students will be able to:

1. State both the SME and Japanese definitions of a robot.
2. Explain the difference between the definitions.
3. Describe fixed automation.
4. Describe flexible automation.

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MODULE RS-02 Flexible Welding

INTRODUCTION

Students will analyze a flexible welding system that is in use. One of the flexible production systems being investigated will be simulated in the laboratory. This will be a class project.

MODULE OUTLINE

CASE STUDY

- Company (where study is being done)
- System to be studied
- Equipment involved (include an overall sketch)

FOR EACH MAJOR PIECE OF EQUIPMENT

- Item (name, manufacturer, model, serial number)
- Major operations performed
- Task breakdown (identify tasks performed)
- Power source/size (electric, hydraulic, ?)
- Control system (drum, programmable logic controller, microprocessor, computer)
- Programming language
- Sensors incorporated (temperature, pressure, position, ?)
- Application/economic justification

FOR ROBOTS

- Specification
- Type/classification
- Mounting (fixed, track, ?)
- Method of installing program
- Load capacity

OBJECTIVES

Upon completion of this module students will be able to:

1. Analyze a flexible automated welding system.
2. Assemble a prototype welding system similar to the operating system.
3. Program and operate the prototype system.
4. Select, install, and calibrate sensors used on the prototype system.

LAB ACTIVITIES

1. Select power supplies, sensors, and transfer systems.
2. Design and assemble a controller system.
3. Program controllers.
4. Adjust, calibrate and operate the system.

ROBOTICS/AUTOMATED SYSTEMS AT WORK

MODULE RS-03 Flexible Assembly

INTRODUCTION

Students will analyze a flexible assembly system that is in use. One of the flexible production systems being investigated will be simulated in the laboratory. This will be a class project.

MODULE OUTLINE

CASE STUDY
- Company (where study is being done)
- System to be studied
- Equipment involved (include an overall sketch)

FOR EACH MAJOR PIECE OF EQUIPMENT
- Item (name, manufacturer, model, serial number)
- Major operations performed
- Task breakdown (identify tasks performed)
- Power source/size (electric, hydraulic, ?)
- Control system (drum, programmable logic controller, microprocessor, computer)
- Programming language
- Sensors incorporated (temperature, pressure, position, ?)
- Application/economic justification

FOR ROBOTS
- Specification
- Type/classification
- Mounting (fixed, track, ?)
- Method of installing program
- Load capacity

OBJECTIVES

Upon completion of this module students will be able to:

1. Analyze a flexible automated assembly system.
2. Assemble a prototype assembly system similar to the operating system.
3. Program and operate the prototype system.
4. Select, install, and calibrate sensors used on the prototype system.

LAB ACTIVITIES

1. Select power supplies, sensors, and transfer systems.
2. Design and assemble a controller system.
3. Program controllers.
4. Adjust, calibrate and operate the system.

ROBOTICS/AUTOMATED SYSTEMS AT WORK

MODULE RS-04 Flexible Material Handling

INTRODUCTION

Students will analyze a flexible material-handling system that is in use. One of the flexible production systems being investigated will be simulated in the laboratory. The system to be studied may be a large-scale system, such as a stacker, that includes wire-guided vehicles, or it may be a smaller-scale system that involves only one robot that palletizes/depalletizes parts. This will be a class project.

MODULE OUTLINE

CASE STUDY
- Company (where study is being done)
- System to be studied
- Equipment involved (include an overall sketch)

FOR EACH MAJOR PIECE OF EQUIPMENT
- Item (name, manufacturer, model, serial number)
- Major operations performed
- Task breakdown (identify tasks performed)
- Power source/size (electric, hydraulic, ?)
- Control system (drum, programmable logic controller, microprocessor, computer)
- Programming language
- Sensors incorporated (temperature, pressure, position, ?)
- Application/economic justification

FOR ROBOTS
- Specification
- Type/classification
- Mounting (fixed, track, ?)
- Method of installing program
- Load capacity

OBJECTIVES

Upon completion of this module students will be able to:

1. Analyze a flexible automated material-handling system.
2. Assemble a prototype material-handling system similar to the operating system.
3. Program and operate the prototype system.
4. Select, install, and calibrate sensors used on the prototype system.

LAB ACTIVITIES

1. Select power supplies, sensors, and transfer systems.
2. Design and assemble a controller system.
3. Program controllers.
4. Adjust, calibrate and operate the system.

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ROBOTICS/AUTOMATED SYSTEMS AT WORK

MODULE RS-05 Flexible Machine Tending

INTRODUCTION

Students will analyze a flexible machine-tending system that is in use. One of the flexible production systems being investigated will be simulated in the laboratory. This will be an individual project.

MODULE OUTLINE

CASE STUDY
- Company (where study is being done)
- System to be studied
- Equipment involved (include an overall sketch)

FOR EACH MAJOR PIECE OF EQUIPMENT
- Item (name, manufacturer, model, serial number)
- Major operations performed
- Task breakdown (identify tasks performed)
- Power source/size (electric, hydraulic, ?)
- Control system (drum, programmable logic controller, microprocessor, computer)
- Programming language
- Sensors incorporated (temperature, pressure, position, ?)
- Application/economic justification

FOR ROBOTS
- Specification
- Type/classification
- Mounting (fixed, track, ?)
- Method of installing program
- Load capacity

OBJECTIVES

Upon completion of this module students will be able to:

1. Analyze a flexible automated machine-tending system.
2. Assemble a prototype machine-tending system similar to the operating system.
3. Program and operate the prototype system.
4. Select, install, and calibrate sensors used on the prototype system.

LAB ACTIVITIES

1. Select power supplies, sensors, and transfer systems.
2. Design and assemble a controller system.
3. Program controllers.
4. Adjust, calibrate and operate the system.

ROBOTICS/AUTOMATED SYSTEMS AT WORK

MODULE RS-06 Fixed (Hard) Automation--Bottling Plant

INTRODUCTION

Students will determine the operating principles and characteristics for a bottling plant. This will be a class project.

MODULE OUTLINE

CASE STUDY
- Company (where study is being done)
- System to be studied
- Equipment involved (include an overall sketch)

FOR EACH MAJOR PIECE OF EQUIPMENT
- Item (name, manufacturer, model, serial number)
- Major operations performed
- Task breakdown (identify tasks performed)
- Power source/size (electric, hydraulic, ?)
- Control system (drum, programmable logic controller, microprocessor, computer)
- Programming language
- Application/economic justification

FOR ROBOTS
- Specification
- Type/classification
- Mounting (fixed, track, ?)
- Method of installing program
- Load capacity

OBJECTIVES

Upon completion of this module students will be able to:

1. Perform case studies on bottling plants.
2. Measure the performance of the power supplies, controllers and sensors in a fixed automation system.

LAB ACTIVITIES

1. Select power supplies, sensors, and transfer systems.
2. Design and assemble a controller system.
3. Program controllers.
4. Adjust, calibrate and operate the system.

MODULE RS-07 Fixed (Hard) Automation--Transfer Line

INTRODUCTION

Students will determine the operating principles and characteristics for a transfer line. This may involve either or both light-duty (light weight, small parts) or heavy-duty (heavy or large) lines. This will be a class project.

MODULE OUTLINE

CASE STUDY
- Company (where study is being done)
- System to be studied
- Equipment involved (include an overall sketch)

FOR EACH MAJOR PIECE OF EQUIPMENT
- Item (name, manufacturer, model, serial number)
- Major operations performed
- Task breakdown (identify tasks performed)
- Power source/size (electric, hydraulic, ?)
- Control system (drum, programmable logic controller, microprocessor, computer)
- Programming language
- Sensors incorporated (temperature, pressure, position, ?)
- Application/economic justification

FOR ROBOTS
- Specification
- Type/classification
- Mounting (fixed, track, ?)
- Method of installing program
- Load capacity

OBJECTIVES

Upon completion of this module students will be able to:

1. Perform case studies on transfer lines.
2. Measure the performance of the power supplies, controllers and sensors in a fixed automation system.

LAB ACTIVITIES

1. Select power supplies, sensors, and transfer systems.
2. Design and assemble a controller system.
3. Program controllers.
4. Adjust, calibrate and operate the system.

ROBOTICS/AUTOMATED SYSTEMS AT WORK

MODULE RS-08 Fixed (Hard) Automation--Photocopier

INTRODUCTION

Students will determine the operating principles and characteristics for a photocopier. This will be a class project.

MODULE OUTLINE

CASE STUDY
- Company (where study is being done)
- System to be studied
- Equipment involved (include an overall sketch)

FOR EACH MAJOR PIECE OF EQUIPMENT
- Item (name, manufacturer, model, serial number)
- Major operations performed
- Task breakdown (identify tasks performed)
- Power source/size (electric, hydraulic, ?)
- Control system (drum, programmable logic controller, microprocessor, computer)
- Programming language
- Sensors incorporated (temperature, pressure, position, ?)
- Application/economic justification

FOR ROBOTS
- Specification
- Type/classification
- Mounting (fixed, track, ?)
- Method of installing program
- Load capacity

OBJECTIVES

Upon completion of this module students will be able to:

1. Perform case studies on photocopiers.
2. Measure the performance of the power supplies, controllers and sensors in a fixed automation system.

LAB ACTIVITIES

1. Select power supplies, sensors, and transfer systems.
2. Design and assemble a controller system.
3. Program controllers.
4. Adjust, calibrate and operate the system.

ROBOTICS/AUTOMATED SYSTEMS AT WORK

MODULE RS-09 Fixed (Hard) Automation--Process Control System

INTRODUCTION

Students will determine the operating principles and characteristics for a process control system. This will be an individual project.

MODULE OUTLINE

CASE STUDY
- Company (where study is being done)
- System to be studied
- Equipment involved (include an overall sketch)

FOR EACH MAJOR PIECE OF EQUIPMENT
- Item (name, manufacturer, model, serial number)
- Major operations performed
- Task breakdown (identify tasks performed)
- Power source/size (electric, hydraulic, ?)
- Control system (drum, programmable logic controller, microprocessor, computer)
- Programming language
- Sensors incorporated (temperature, pressure, position, ?)
- Application/economic justification

FOR ROBOTS
- Specification
- Type/classification
- Mounting (fixed, track, ?)
- Method of installing program
- Load capacity

OBJECTIVES

Upon completion of this module students will be able to:

1. Perform case studies on process control systems.
2. Measure the performance of the power supplies, controllers and sensors in a fixed automation system.

LAB ACTIVITIES

1. Select power supplies, sensors, and transfer systems.
2. Design and assemble a controller system.
3. Program controllers.
4. Adjust, calibrate and operate the system.

ROBOTICS/AUTOMATED SYSTEMS AT WORK

MODULE RS-10 Fixed (Hard) Automation--Packaging

INTRODUCTION

Students will determine the operating principles and characteristics for a packaging operation.

MODULE OUTLINE

CASE STUDY
- Company (where study is being done)
- System to be studied
- Equipment involved (include an overall sketch)

FOR EACH MAJOR PIECE OF EQUIPMENT
- Item (name, manufacturer, model, serial number)
- Major operations performed
- Task breakdown (identify tasks performed)
- Power source/size (electric, hydraulic, ?)
- Control system (drum, programmable logic controller, microprocessor, computer)
- Programming language
- Sensors incorporated (temperature, pressure, position, ?)
- Application/economic justification

FOR ROBOTS
- Specification
- Type/classification
- Mounting (fixed, track, ?)
- Method of installing program
- Load capacity

OBJECTIVES

Upon completion of this module students will be able to:

1. Perform case studies on packaging operations.
2. Measure the performance of the power supplies, controllers and sensors in a fixed automation system.

LAB ACTIVITIES

1. Select power supplies, sensors, and transfer systems.
2. Design and assemble a controller system.
3. Program controllers.
4. Adjust, calibrate and operate the system.

AUTOMATED WORK CELL INTEGRATION
Classroom/Laboratory hrs/wk 1/8

COURSE DESCRIPTION

Students, working in teams and under the instructor's supervision, will assemble and operate an automated production system. The students will select equipment, write specifications, design fixtures and interconnects, integrate system/provide interfaces, and make the assigned system operational. This is a laboratory class.

COURSE OUTLINE

	Student Contact Hours Class	Laboratory
The instructor will assign a project similar to those described on the following pages. Students will analyze the requirements, write specifications and assemble, program, debug and operate a prototype or demonstration work cell.	10	80

STUDENT COMPETENCIES

Upon completion of this course, the student should be able to:

1. Interconnect robots and other equipment.
2. Program a host computer that controls the operation of several pieces of equipment.
3. Set up, operate, troubleshoot, maintain and repair automated systems.
4. Use manual's troubleshooting charts to aid fault isolation/repair.
5. Disassemble, repair, test and return to service robots that have failed.
6. Install, adjust, troubleshoot, repair or replace:
   a. Industrial robots
   b. End-of-arm tooling
   c. Smart actuators
7. Coordinate the operation of several pieces of automatic equipment.
8. Adjust machines for accuracy and repeatability.
9. Set up machine vision system.
10. Analyze and select appropriate robot sensing requirements for certain manufacturing operations.
11. Start up and shut down an automated production system.
12. Follow troubleshooting procedures recommended by the manufacturer to diagnose, isolate and repair a robot/automated system.
13. Perform field testing of a robot and check to assure that its performance is in accordance with specifications.
14. Develop material handling specifications for a work cell.
15. Set up, program, troubleshoot a system comprised of a minimum of two transfer lines, one robot and at least one machining center.
16. Set up, and so forth, robot to either remove parts from transfer line and palletize them or to depalletize parts and place them on a transfer line.
17. Program a host computer to control several "lower-level" computers that in turn control portions of an automated system.
18. Write material handling specifications for a work cell.

AUTOMATED WORK CELL INTEGRATION

INTRODUCTION

Students will work in small teams on assigned projects that include the design, specification writing, assembly, programming, debugging, and operation of assigned work cells. Students will then reprogram the controller and make other necessary adjustments so the same physical equipment will perform a different task.

MODULE OUTLINE

The instructor will assign one or more of the following projects. Students will analyze the requirements, write specifications, and assemble, program, debug and operate a prototype or demonstration work cell.

OBJECTIVES

Upon completion of this course students will be able to:

1. Convert work assignments into written specifications.
2. Design and assemble a reprogrammable work cell.
3. Program, debug, and operate the work cell.
4. Reprogram the work cell to accomplish different tasks.

LAB ACTIVITIES

The lab activities are outlined as projects on the following pages.

AUTOMATED WORK CELL INTEGRATION

TEAM MEMBER ASSIGNMENT

Students in each team will be rotated so that each has an opportunity to do all of the following jobs.

LEADER:	Directs efforts of team members Directs assembly of equipment
RECORDER:	Assists assembly Records decisions Sketches setups and parts Writes project report
SUPPLIER:	Obtains needed parts Assists assembly Designs needed parts
PROGRAMMER:	Assists assembly Writes/coordinates the programming Selects sensors Selects interconnecting cabling

PROJECT 1 PARTS PRODUCTION

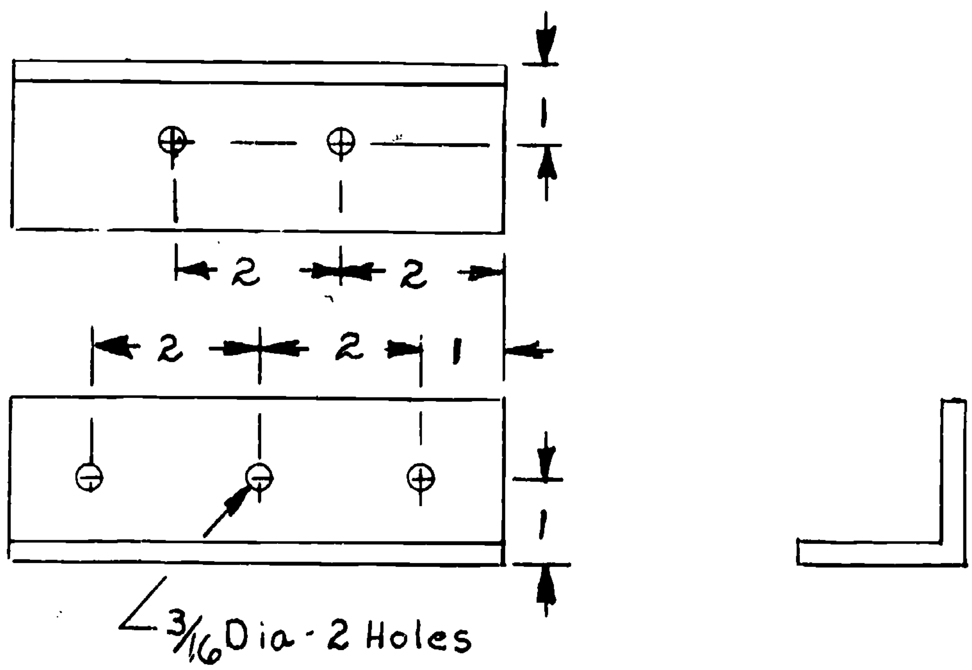
ASSIGNMENT

Automate the production of the part shown in the sketch. The major tasks to be accomplished are:

1. Load a 20' piece of 2x2x1/4 angle on an automatic cut-off saw.
2. Cut the angle into 6" lengths.
3. Drill holes per sketch.
4. Palletize the finished parts.

SUGGESTED EQUIPMENT TO BE AUTOMATED

1. Cut-off saw
2. One or two drill presses
3. Conveyor(s)



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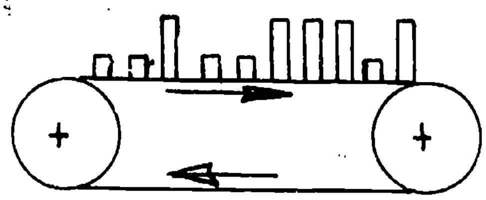
PROJECT 2 INSPECTION

ASSIGNMENT

Automate the separation of pieces of round bar stock according to length. Two lengths of parts will be supplied randomly. This project should not use vision.

SUGGESTED EQUIPMENT TO BE AUTOMATED

1. Conveyor
2. Inspection System
3. Palletizing



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PROJECT 3 HEAT TREAT

ASSIGNMENT

Design, assemble, and operate an automated Heat Treating Work Cell. The major tasks to be accomplished include:

1. Remove the untreated part from the pallet.
2. Place part in heat treating oven.
3. When t = 850 degrees, remove the part from the oven.
4. Quench the part.
5. Place part on pallet.

SUGGESTED EQUIPMENT TO BE AUTOMATED

1. Conveyors
2. Oven
3. Pallets
4. Quenching

PROJECT 4 PALLETIZING

ASSIGNMENT

Automate the packaging of one-gallon paint cans in a cardboard box. Paint cans (empty) weigh approximately eight ounces. They will be supplied at a rate of four per minute.

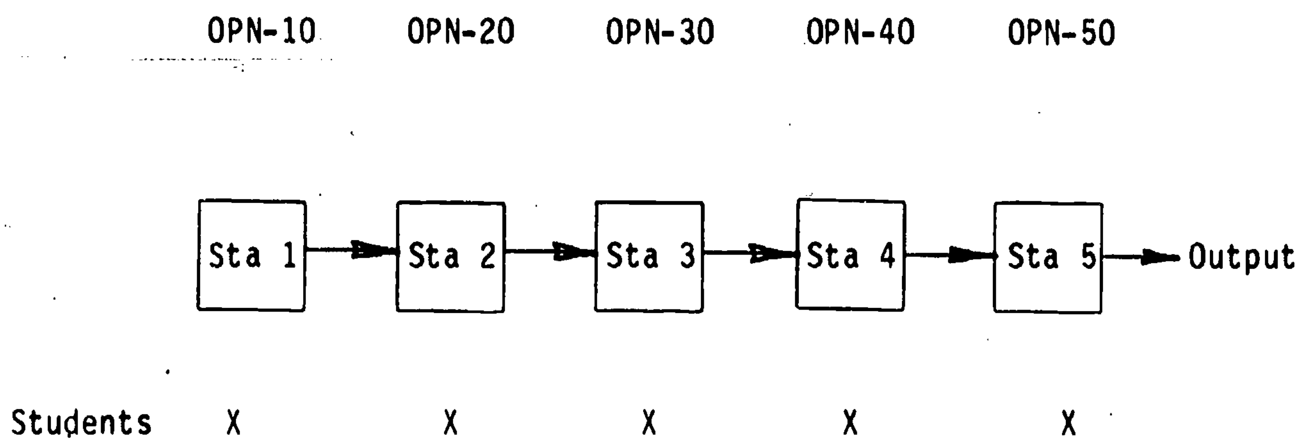
SUGGESTED EQUIPMENT TO BE AUTOMATED

1. Conveyor
2. Pick and place robot
3. Method to remove full boxes
4. Supply of boxes to be filled.

PROJECT 5 ASSEMBLY

ASSIGNMENT

Assemble a semicomplex product. Assembly (electric motor, etc.) of at least 15 different parts in a specified period of time to demonstrate the theory of mass production by allocating work to different assembly stations to attain the required production rate of "X" jobs per hour.



OBJECTIVE

1. To demonstrate task breakdown to attain a specific production rate.
2. To demonstrate the practicality of replacing manual labor with fixed or flexible automation.
3. As an added benefit to explain the justification parameters for replacing manual effort with mechanical devices.

Note: OPN-10 indicates oeprations to be conducted at Station 1.

APPENDIX C

PHYSICS MODULES TO BE MODIFIED OR WRITTEN

PHYSICS MODULE CHANGES

1F3 LINEAR ACTUATOR CYLINDER

Change: Add cylinder

The hydraulic cylinder is a device commonly used to move heavy objects. It uses the principle of transforming controlled hydraulic pressure into linear force. In this module, the student will be introduced to operating principles of hydraulic cylinders and the interrelated role of hydraulic pressure and force in the operation of cylinders.

2F1 WORK BY FLUID PUMPS

Change: Add hydraulic pumps

Students review the principles of work and energy as they apply to fluids and electricity. Values for work and energy involving fluids and electricity are determined both experimentally and by calculation. In the laboratory, students measure electrical power input and hydraulic power output of a motor/pump.

3M7 SPHERICAL MOTION

New module

Students will expand their previous study of motion in two dimensions into three dimensions. Linear and rotational motion (velocity and acceleration) will be evaluated as they occur in normal working environments. Students will measure and calcuate relative positions of points in spherical coordinates.

4M1 ANGULAR MOMENTUM

Change: Revise to add single mass

In this module, the student will examine the concept of angular momentum. Angular momentum of several rotating systems will be calculated. In the laboratory, the angular momentum of a flywheel and a single mass will be measured by two techniques and the results compared.

5M1 FRICTION

Change: Add gripper experiment

This module explains some of the factors that influence friction. It also includes a demonstration of a method to calculate frictional forces between one or two pairs of surfaces in contact.

7F4 ENERGY CONVERSION IN FLUID SYSTEMS

Change: Add application

Energy has been defined as the capacity to do work. Also, energy cannot be created, but energy may be transferred from one form to another within a system.

Potential energy, the capacity to do work because of position, may be transferred to kinetic energy, the capacity to do work because of motion. This module will demonstrate this energy transfer in fluid systems.

8M1 LEVERS

Change: Add application

The lever is one of the simplest and most common mechanical force transformers. Depending upon its configuration, the lever may be used to amplify either force or displacement, or to change their directions.

In this module, the student will investigate the lever as a force transformer. In the laboratory, the student will measure and calculate the mechanical advantages of several levers.

9F5 VACUUM PUMPS

Change: Add application

A number of different pumps are used to produce a vacuum in enclosed chambers. These pumps include rotary mechanical pumps, diffusion pumps, sputter-ion pumps, and cryogenic pumps. The pressure ranges that can be covered vary from one pump type to another. In common practice, a mechanical pump is used to pump down from atmospheric pressure to medium vacuum; and then a second pump is switched on to reach high or ultrahigh vacuum.

In the laboratory, the student will use at least two different pump types to evacuate a vacuum system and will measure the pressure in the system during pump-down.

9E6 PRECISION CONTROL MOTORS

New module

This module introduces students to electric motors whose movement is controlled by input pulses--stepper motors. Rotor position is controlled by the number of input pulses, allowing accurate positioning of mechanisms operated by the motors.

10E2 HALL-EFFECT DEVICES

New module

Students will learn how changes in magnetic fields can be used to sense the position or attitude of various items. A change in magnetic field, or the introduction of a magnetic field, will be evaluated as a control for other electronic circuitry.

10E3 PIEZOELECTRIC DEVICES

New module

There are materials that, when acted upon physically or thermally, generate electrical signals that can be detected, amplified and used to sense various parameters. Students will study the operating characteristics of piezoelectric devices in the laboratory.

11M3 VIBRATION ISOLATION

New application

Mechanical vibrations are produced by almost every kind of machinery. Electric motors, internal combustion engines, air compressors, vacuum pumps, printing and manufacturing presses, and fans all produce unwanted vibrations. If these vibrations are not eliminated or reduced to an acceptable level, they can destroy the machinery or limit its proper operation.

In this module the characteristics of steady-state vibrations will be illustrated, and the methods used to eliminate or reduce these vibrations in various kinds of machinery will be discussed. In the laboratory, the student will measure the acceleration of a vibrating system and its support to determine transmission of vibration.

13L18 ENCODERS/RESOLVERS

New module

Students will study the concept of controlling electric motor speed and rotor position by counting photoelectric signal pulses. Position sensing of this type is being used as part of control systems in robotics and automated systems to monitor the operation of various machines.