Engineering Technology Core Instructor Guide

An Engineering Technology Curriculum Guide

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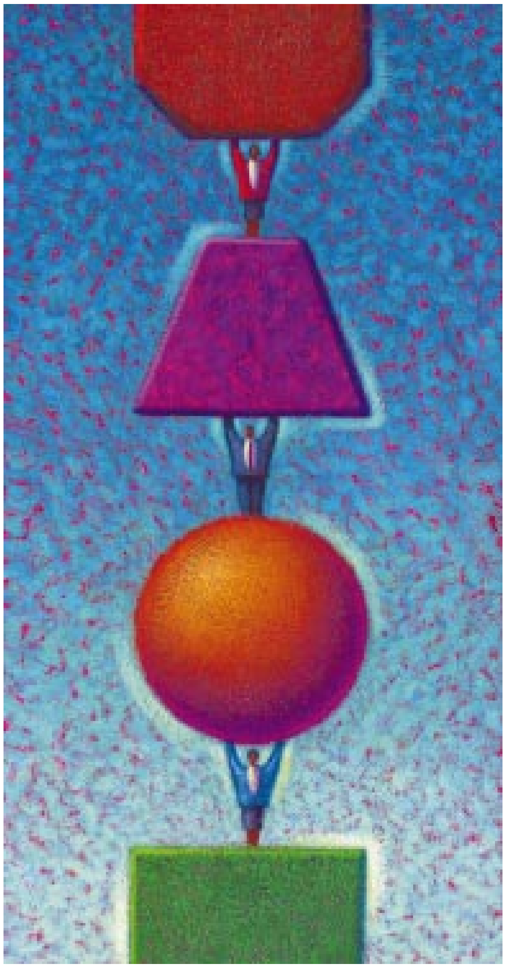

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An Engineering Technology Curriculum Guide

Preparing students to be successful in engineering technology majors

2001

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Introduction to *Engineering Technology Core*

What is Engineering Technology Core or ET Core?

The Engineering Technology Core (ET Core) is an integrated, problem-based course of study that models the workplace through the use of industrial-type problems and student and faculty teams. The ET Core provides the general education component for any engineering technology major.

Physics, mathematics, communications, and engineering technology courses are taught concurrently in the context of solving 16 workplace-related problems. A problem scenario is the centerpiece of each of the 16 modules. These modules can be taught over the course of three semesters or in other groupings or time frames. ET Core modules investigate six physical systems (electrical, mechanical, fluids, thermal, optics, and materials) relevant to the study of engineering technology.

Desired outcomes for students are:

- Students will complete the general education requirements in physics, mathematics, and English to enable them to have the requisite skills for their chosen major in engineering technology.
- Students will acquire and be able to apply problem-solving skills in classrooms that model the workplace.
- Students will develop and use workplace communication and teaming skills to solve workplace-related problems.
- Students will be able to apply communication, calculation, analytical, and technology skills to solve workplace-related problems.
- Through development of abilities to integrate content knowledge and skills with problem-solving strategies, students will be prepared for success in engineering technology major courses.

The intent of the ET Core curriculum approach is to:

- Recruit, retain, and graduate more highly skilled technicians.
- Support the success of a diverse population of students, including students traditionally under-represented in engineering technology programs.
- Provide an instructional approach and a curriculum that have been validated by industry. This validation has occurred through industry focus groups and endorsement of and involvement in the SC ATE Scholars education-industry partnership initiative.
- Use open-ended problem scenarios that reflect workplace/industry problems as closely as possible while, at the same time, covering the appropriate subject matter content. Problem scenarios provide a context and purpose for learning.
- Integrate and concurrently teach the courses of mathematics, physics, technology, and communications to show relationships between subjects and to help answer student questions: Why do I need to learn this? How is it relevant? How will I use it?

- Incorporate research-based teaching methodologies and concepts shown to be effective in improving student learning (i.e., collaborative learning/active learning, coaching, and multiple intelligences theory).
- Provide more opportunities for hands-on, inquiry-based learning, thus enabling students to immediately apply what they are learning.
- Use student teams to solve problems, which creates an additional support system for learning and encourages student participation and retention.
- Provide additional instructor support for students because instructors are part of a teaching team.
- Reinforce the use of effective teaching methods for faculty, and create a learning community where teaching team members assume a shared responsibility for student success in all courses.
- Support technology applications for data collection and analysis, research, problem solving, and presentations.

Who should consider using the ET Core?

The ET Core is available for use in any institution offering associate or baccalaureate degrees in engineering technology.

How does the integrated, problem-based approach work?

Interdisciplinary faculty team members coach student teams through a structured problem-based learning process that includes the following phases: preparing students to meet the problem; leading a "what do we know, what do we need to know" discussion; gathering and sharing information; generating solutions; and performing assessments. After students are introduced to a loosely structured problem, they identify what they know, how they know it (opinion versus scientific knowledge), and what information and skills they need to solve the problem. Faculty-guided workshops help students gain content-specific knowledge and master course competencies. Student team recommendations for solving problems are presented in written form or oral presentations.

ET Core classrooms should closely model the workplace environment. For example, student team workspace may be equipped with computer stations and tables for team meetings and tools such as whiteboards, where a team's work may be posted throughout a module. Student teams remain in their workspace while instructors come and go to coach and deliver "just-in-time" instruction.

What is the intent of the ET Core curriculum materials?

ET Core curriculum materials provide a framework through which faculty teaching teams can create lessons. Materials provide a framework for the four disciplines (physics, mathematics, communications, and technology). Open-ended problems provide a vehicle to teach concepts that meet local academic program and employer needs. The workplace-related problems are designed to teach basic problem-solving and content concepts, not to teach one solution to a specific problem.

The ET Core is designed to give instructor teams and their colleges as much flexibility as possible. Instructors determine the level of proficiency that is required of students. While student handouts of the problem scenarios are included with the instructor's guide, instructors determine textbooks and other resources for students. Textbooks are used as resources to reinforce topics covered in the ET Core modules and support concept development among the four disciplines.

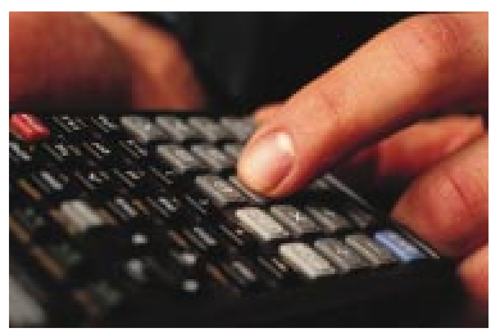
Other local college decisions include: how the curriculum will be taught at an individual college, including scheduling and teaching assignments; development of course syllabi, scope and sequence, and lesson plans; assessment and grading procedures; and technology resources.

How are ET Core modules sequenced?

ET Core modules are presented in the order in which they were developed, pilot tested, and initially implemented. This order deviates from the traditional physics sequencing to help accommodate concurrent learning of mathematics and physics. The scope and sequence for mathematics, technology, and communications were established to develop student learning of these disciplines in a "just-in-time" manner as physics concepts are introduced.

Over time, teaching teams have found that modifications of these modules can be made. For example, not all of the modules need to be presented to cover the appropriate content. In the electrical section, Modules 2 and 3 could be consolidated by using the problem scenario of Module 3 and combining the objectives and workshops of 2 and 3. Likewise, in the mechanical section, Modules 3 and 5 could be combined by using a modification of scenario 3 that adds a flywheel to extend motion during a power outage.

Faculty also have discovered that the modules on thermal, fluids, and optics can be presented at various times throughout the sequence. Following a more traditional physics sequence with mechanical modules being taught first would require changes in the scope and sequence charts for mathematics, technology, and communications. These modifications need to ensure that appropriate sequence of skill development in each discipline is considered. (See alternate sequence chart on page 9).



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What resources are available to support instructors?

A number of resources are available in this instructor guide to assist in implementing the ET Core curriculum. These resources include:

- Objectives and instructor notes with each module.
- Suggested student workshop activities.
- Content strands in each module.
- Print resources.
- Non-print resources, including web sites.
- A problem-based learning "Know/Need-to-Know Chart" template.
- Student competencies for each module and a master competency list.
- A master equipment list.
- Student handouts. Additional copies of these student handouts may be printed from the SC ATE Center of Excellence web site (http://scate.org).

Additional information may be found on the SC ATE web site or by contacting SC ATE at 803-896-5407 or scate@sctechsystem.com. The following South Carolina technical colleges piloted the SC ATE ET Core curriculum and may be contacted as resources. When calling, please request the college's Engineering Technology Division.

Florence-Darlington Technical College
P.O. Box 100548
Florence, SC 29501-0548
843-611-8324

Piedmont Technical College
P.O. Drawer 1467
Greenwood, SC 29648-1467
864-941-8324

Tri-County Technical College
P.O. Box 587
Pendleton, SC 29670-0587
864-646-8361

ET Core Modules —

Alternative sequences scheduled over three semesters in physics, mathematics, communications, and engineering technology courses

Original design
As pilot tested—Electrical modules scheduled first
(16 modules)

Semester 1

- Resistance, *Conduit Wiring*
- Current, *Trailer Fuse*
- Voltage, *Series/Parallel Circuits*
- Capacitance, *Timing Circuits*
- Impedance, *Power Factor for Electrical Installations*
- Thermal Expansion, *Assembling Metal Plate and Shaft*

Semester 2

- Displacement/Velocity, *Assembly Line Layout*
- Forces, *Assembly Line Chute*
- Energy, *Bucket Elevator*
- Equilibrium, *Weight Distribution in a Flatbed Trailer*
- Rotation, *Chipper Brake*
- Fluids, *Safety Shower*

Semester 3

- Geometrical Optics, *Projection System*
- Physical Optics, *Micro-Measurement – A Case Study*
- Physical and Chemical Properties of Materials, *Testing Paper Quality*
- Mechanical Properties of Materials, *Hydraulic Press*

Alternate Sequence #1
Mechanical modules scheduled first
(16 modules)

Semester 1

- Displacement/Velocity, *Assembly Line Layout*
- Forces, *Assembly Line Chute*
- Energy, *Bucket Elevator*
- Equilibrium, *Weight Distribution in a Flatbed Trailer*
- Rotation, *Chipper Brake*
- Fluids, *Safety Shower*

Semester 2

- Resistance, *Conduit Wiring*
- Current, *Trailer Fuse*
- Voltage, *Series/Parallel Circuits*
- Capacitance, *Timing Circuits*
- Impedance, *Power Factor for Electrical Installations*
- Thermal Expansion, *Assembling Metal Plate and Shaft*

Semester 3

- Geometrical Optics, *Projection System*
- Physical Optics, *Micro-Measurement – A Case Study*
- Physical and Chemical Properties of Materials, *Testing Paper Quality*
- Mechanical Properties of Materials, *Hydraulic Press*

Alternate Sequence #2
Combined to make fewer modules
(13 modules)

Semester 1

- Resistance, *Conduit Wiring*
- Voltage/Current, *Series/Parallel Circuits*
- Capacitance, *Timing Circuits*
- Impedance, *Power Factor for Electrical Installations*
- Thermal Expansion, *Assembling Metal Plate and Shaft*

Semester 2

- Displacement/Velocity, *Assembly Line Layout*
- Forces, *Assembly Line Chute*
- Energy/Rotation, *Bucket Elevator*
- Equilibrium, *Weight Distribution in a Flatbed Trailer*
- Fluids, *Safety Shower*

Semester 3

- Geometrical/Physical Optics, *Projection System*
- Physical and Chemical Properties of Materials, *Testing Paper Quality*
- Mechanical Properties of Materials, *Hydraulic Press*

Alternate Sequence #3
Mechanical first, combined to make fewer modules
(13 modules)

Semester 1

- Displacement/Velocity, *Assembly Line Layout*
- Forces, *Assembly Line Chute*
- Energy/Rotation, *Bucket Elevator*
- Equilibrium, *Weight Distribution in a Flatbed Trailer*
- Fluids, *Safety Shower*

Semester 2

- Resistance, *Conduit Wiring*
- Voltage/Current, *Series/Parallel Circuits*
- Capacitance, *Timing Circuits*
- Impedance, *Power Factor for Electrical Installations*
- Thermal Expansion, *Assembling Metal Plate and Shaft*

Semester 3

- Geometrical/Physical Optics, *Projection System*
- Physical and Chemical Properties of Materials, *Testing Paper Quality*
- Mechanical Properties of Materials, *Hydraulic Press*

Problem-Based Learning
Know/Need-To-Know (KNK) Chart

What do we know?	What do we need to know?	How do we find out?

Physics — Scope and Sequence Chart

Engineering Technology Core Modules

	Electrical					Thermal	Mechanical					Fluids	Optics		Materials	
	Resistance	Current	Voltage	Capacitance	Impedance	Thermal expansion	Displacement/ velocity	Forces	Energy	Equilibrium	Rotation	Fluids	Geometrical optics	Physical optics	Physical & chemical props. of materials	Mech. properties of materials
Topics																
Atomic structure	✔														✔	
Resistance physical properties	✔															
Resistance electrical properties		✔	✔	✔	✔											
Heat	✔					✔									✔	
Power	✔	✔	✔	✔	✔											
Ohm's Law		✔	✔	✔	✔											
Kirchhoff's Law		✔	✔	✔	✔											
Magnetism			✔		✔											
Faraday's Law			✔													
Power sources			✔	✔	✔											
Lasers			✔													
Capacitance physical properties				✔												
Capacitance electrical properties				✔	✔											
Inductance					✔											
Impedance					✔											
RLC circuits					✔											
Electrical phase relationship					✔											
Thermal expansion						✔								✔		
Heat transfer						✔								✔		
One-dimension motion							✔					✔				
Two-dimension motion							✔	✔								
Vectors							✔	✔		✔						
Newton's Laws (linear)								✔		✔						
Frictional forces								✔		✔		✔				
Kinetic energy						✔			✔	✔		✔				
Potential energy									✔			✔				
Conservation of energy			✔			✔			✔	✔		✔				
Linear equilibrium										✔						✔
Rotational equilibrium										✔	✔					✔
Torque										✔	✔					✔
Center of mass										✔	✔					✔
Moment of inertia											✔					✔
Newton's Laws (rotational)											✔					
Pressure												✔				
Reflection													✔			
Refraction													✔			
Waves														✔		
Superposition														✔		
Physical properties of materials															✔	
Chemical properties of materials															✔	
Stress																✔
Strain																✔
Shear																✔
Bending																✔
Deflection																✔

Mathematics — Scope and Sequence Chart

Engineering Technology Core Modules

	Electrical					Thermal	Mechanical					Fluids	Optics		Materials	
Topics	Resistance	Current	Voltage	Capacitance	Impedance	Thermal expansion	Displacement/ velocity	Forces	Energy	Equilibrium	Rotation	Fluids	Geometrical optics	Physical optics	Physical & chemical props. of materials	Mech. properties of materials
Linear relationships	✔	✔														
Linear formulas		✔				✔										
Solving linear equations	✔	✔		✔		✔	✔	✔								
Cartesian graphing	✔		✔				✔									
Graphing linear equations	✔	✔				✔	✔									
Area	✔			✔		✔		✔					✔			✔
Direct and inverse variation	✔	✔		✔							✔					
Resistance formulas	✔		✔		✔											
Laws of exponents		✔				✔						✔				
Systems of equations			✔					✔		✔	✔					
Right triangle trigonometry			✔		✔		✔	✔					✔	✔		
Graphing sine functions			✔		✔									✔		
Graphing cosine functions					✔											
Exponential and logarithmic equations				✔	✔	✔										
Radical expressions					✔											
Polar coordinates					✔						✔					
Rate of change							✔				✔					
Vector addition							✔	✔								✔
Similar triangles							✔	✔					✔			
Quadratic equations								✔	✔			✔				
Scalar product									✔							
Vector product										✔						
Volume						✔			✔	✔		✔				
Lines and angles								✔					✔	✔		
Sine wave addition														✔		
Reciprocal formulas		✔	✔										✔			
Maximum/minimum					✔											✔
Definite integrals																✔
Area under a curve							✔									✔
Derivatives							✔								✔	✔
Statistics			✔						✔						✔	

Technology — Scope and Sequence Chart

Engineering Technology Core Modules

Topics	Electrical					Thermal	Mechanical					Fluids	Optics		Materials	
	Resistance	Current	Voltage	Capacitance	Impedance	Thermal expansion	Displacement/ velocity	Forces	Energy	Equilibrium	Rotation	Fluids	Geometrical optics	Physical optics	Physical & chemical props. of materials	Mech. properties of materials
MEASUREMENTS																
Linear	✔					✔	✔	✔	✔	✔				✔		
Area	✔					✔										
Volume									✔		✔					
Voltage			✔		✔											
Current		✔	✔		✔											
Resistance	✔		✔	✔	✔											
Capacitance				✔												
Inductance					✔											
Temperature	✔					✔									✔	
Mass								✔	✔	✔	✔				✔	✔
Velocity							✔	✔	✔		✔	✔				
Force								✔	✔	✔	✔	✔				
Acceleration							✔	✔			✔					
Angles								✔			✔		✔			
Time				✔			✔	✔	✔		✔					
Pressure												✔				✔
Color codes			✔													
SCHEMATICS		✔	✔	✔	✔											
MANUFACTURING PROCESSES																
Assembly line							✔									
Manufacturing types						✔	✔									
Planning and installation	✔				✔			✔	✔							
Product design		✔						✔	✔		✔	✔				✔
Product modification			✔	✔							✔					✔
Quality control													✔	✔	✔	
Computer-aided design (CAD)							✔			✔						

Communications — Scope and Sequence Chart

Engineering Technology Core Modules

	Electrical					Thermal	Mechanical					Fluids
	Resistance	Current	Voltage	Capacitance	Impedance	Thermal expansion	Displacement/ velocity	Forces	Energy	Equilibrium	Rotation	Fluids
Topics												
TECHNICAL DOCUMENTS												
Memos	✔			✔	✔		✔	✔				
Letters			✔				✔					
Short reports	✔	✔		✔	✔	✔	✔	✔	✔	✔	✔	
E-mail messages			✔									
Collaborative reports	✔											✔
Proposals/recommendations					✔				✔	✔	✔	
Pre-employment porfolios											✔	
Document design			✔	✔			✔					
RESEARCH TECHNIQUES												
Internet sources			✔	✔							✔	✔
Print sources			✔	✔								
Interviews			✔				✔		✔			
Documentation			✔	✔			✔		✔			
WRITING PROCESS												
Audience analysis		✔					✔					
Technical description	✔						✔			✔		
Comparison and contrast								✔				
Process analysis		✔	✔									
Causal analysis						✔						✔
Persuasion							✔		✔		✔	✔
Peer editing	✔	✔		✔	✔							
Visuals	✔			✔			✔				✔	
Mechanics	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	
ORAL PRESENTATIONS												
Audience analysis			✔	✔					✔			✔
Presentation techniques			✔	✔	✔	✔		✔	✔		✔	
Persuasion techniques			✔									✔
Visuals			✔	✔				✔			✔	
Citing sources			✔	✔	✔							✔
Professionalism			✔	✔								✔

Engineering Technology Core Student Competencies

Electrical Competencies

Integrated Curriculum: Physics, Mathematics, Communications, Technology

B.1 Electrical resistance.

- B.1.1 Use physical properties to describe resistance.
  - B.1.1.1 Demonstrate a conceptual understanding of conductors, insulators, and semiconductors by using the basic structure of matter and electron motion to distinguish between each.
  - B.1.1.2 Graphically analyze temperature dependence of resistance data to deduce the functional relationship of temperature and resistance.
  - B.1.1.3 Apply algebraic operations to the temperature dependence of resistance to find unknown quantities.
  - B.1.1.4 Graphically analyze the direct and inverse relationships of the effect of length, cross-sectional area, and type of material on the value of resistance.
  - B.1.1.5 Calculate conductance from resistance values and vice versa.
  - B.1.1.6 Calculate the resistance given the material, length, and cross-sectional area.
- B.1.2 Use notation to determine resistance.
  - B.1.2.1 Apply standard color code to determine resistance and tolerance.
  - B.1.2.2 Use exponents, scientific notation, and engineering and prefix notation to express values of resistance.
- B.1.3 Determine resistance of combinations of resistors.
  - B.1.3.1 Determine resistance for series, parallel, and series-parallel network of resistors.
  - B.1.3.2 Apply algebraic operations to series and parallel resistance equations for equivalent resistance to obtain unknown quantities.

B.2 Current.

- B.2.1 Relate change to current.
  - B.2.1.1 Demonstrate the conceptual understanding of current as the rate of flow of charge.
- B.2.2 Apply currents in circuits.
  - B.2.2.1 Demonstrate a conceptual understanding of DC and AC current.
  - B.2.2.2 Apply Kirchhoff's current law to circuits with multiple current paths.

B.3 Voltage.

- B.3.1 Solve voltage source problems.
  - B.3.1.1 Demonstrate a conceptual understanding of DC and AC voltage by proper use of sources in electrical circuits.
  - B.3.1.2 Apply Lenz's law and sine wave characteristics to describe AC voltage and generation.
  - B.3.1.3 Apply the concept of electrical potential and electrical potential difference to differentiate between voltage with respect to ground and voltage across a device.
  - B.3.1.4 Differentiate between AC and DC voltage.
- B.3.2 Apply Ohm's law.
  - B.3.2.1 Graphically analyze voltage-current data for ohmic resistors to determine resistance.
  - B.3.2.2 Write a linear equation to express the current-voltage-resistance relationship.
  - B.3.2.3 Solve Ohm's law problems by algebraically manipulating Ohm's law equation for unknown quantities.
- B.3.3 Apply Kirchhoff's voltage law.
  - B.3.3.1 Determine the equivalent voltage for multiple voltage sources and apply to solve network problems.
  - B.3.3.2 Relate Kirchhoff's law to the conservation of energy and apply to solve network problems.
  - B.3.3.3 Apply systems of equations to solve multiple source circuits problems.

B.4 Impedance.

B.4.1 Characterize capacitance.

B.4.1.1 Demonstrate an understanding of capacitance by relating capacitance to its physical properties, and describe as an energy storage device.

B.4.1.2 Determine the time constant and charging rate for capacitors, and relate to graphic data.

B.4.1.3 Express charging and discharging in a capacitor as exponential growth and decay.

B.4.1.4 Calculate capacitive reactance and phase shift for ideal/real capacitors.

B.4.2 Characterize inductance.

B.4.2.1 Demonstrate an understanding of inductance as related to physical properties of the device.

B.4.2.2 Determine the time constant for an inductor, and relate to graphic data.

B.4.2.3 Determine inductive reactance and phase shift for ideal/real inductor.

B.4.3 Solve RLC circuits problems.

B.4.3.1 Determine the impedance of an RLC circuit and the phase relationship of voltage and current to each component.

B.4.3.3 Apply a maximum-minimum condition to solve RLC circuits for resonance.

B.4.3.4 Use complex algebra to solve an RLC circuit.

B.5 Power.

B.5.1 Solve for power in electrical systems.

B.5.1.1 Demonstrate an understanding of power as the rate of change of energy in an electrical circuit by calculating the power dissipated in electrical components.

B.5.1.2 Solve power relationships for an unknown quantity.

B.5.1.3 Apply energy conservation to determine efficiency.

B.6 Instrumentation.

B.6.1 Apply measurement techniques.

B.6.1.1 Use appropriate instruments (voltmeter, ampmeter, ohmmeter, multimeter, oscilloscope, etc.) to measure resistance, inductance, capacitance, and DC and AC voltage and current.

B.6.1.2 Determine the accuracy and precision of measuring devices.

B.6.1.3 Compare and contrast systematic and random errors for electrical measurements.

B.6.2 Use schematics.

B.6.2.1 Use appropriate electrical symbols to create electronic schematics.

B.6.2.2 Interpret schematic diagrams to identify electronic components and construct electrical circuits.

B.7 Electromagnetism.

B.7.1 Characterize electric fields.

B.7.1.1 Describe an electric field in terms of charge(s) and distance from the charge(s).

B.7.1.2 Relate electric fields to potential difference and determine electric fields via measurements of potential differences.

B.7.1.3 Differentiate between positive and negative electric charges.

B.7.1.4 Calculate the amount of electrical field energy contained in a capacitor.

B.7.1.5 Describe the force exerted on an electric charge by an electric field.

B.7.1.6 Express electric fields in SI[1] units.

B.7.2 Characterize magnetic fields.

B.7.2.1 Describe a magnetic field in terms of moving charge(s) and distance from the moving charge(s).

B.7.2.2 Determine magnetic field direction by use of magnetic compasses.

B.7.2.3 Differentiate between north and south poles of a magnet.

B.7.2.4 Calculate the amount of magnetic field energy contained in an inductor.

B.7.2.5 Describe the force exerted on a moving electric charge by a magnetic field.

B.7.2.6 Express magnetic fields in SI units.

B.7.3 Characterize interactions of electricity and magnetism.

B.7.3.1 Describe how a changing magnetic field gives rise to an electric field (Faraday's law).

B.7.3.2 Describe how a changing electric field gives rise to a magnetic field (Ampere's law).

B.7.3.3 Use transformers to change voltages and electric currents.

B.7.3.4 Examine a generator to witness how a changing magnetic field creates an electromotive force.

[1]Systeme International d'Unites, the international system of units now recommended for most scientific purposes.

B.8 Waves.

B.8.1 Relate frequency.

B.8.1.1 Define the frequency and angular frequency of a wave.
B.8.1.2 Define the wavelength of a wave.
B.8.1.3 Define the amplitude of a wave.
B.8.1.4 Define the wave speed of a wave and relate it to the frequency and wavelength of a wave.

B.8.2. Solve wave equations.

B.8.2.1 Define sine, cosine, and tangent functions.
B.8.2.2 Graph sine and cosine waves as a function of angle.
B.8.2.3 Convert units between radians and degrees.
B.8.2.4 Describe the phase change both physically and mathematically.
B.8.2.5 Write and/or read a wave equation and determine the wave's properties from the equation.

B.9 Effective team and communication skills.

B.9.1 Demonstrate the ability to work in teams.

B.9.1.1 Employ problem solving skills to solve a team task.
B.9.1.2 Use appropriate human relations skills.
B.9.1.3 Demonstrate various listening skills.
B.9.1.4 Apply small group dynamics/teamwork skills.
B.9.1.5 Apply large group dynamics/teamwork skills.
B.9.1.6 Work in teams to make oral presentations
B.9.1.7 Work in teams to collaborate on assignments.

B.9.2 Gather appropriate information

B.9.2.1 Use various media to obtain information.
B.9.2.2 Demonstrate engineering technology-appropriate computer skills.
B.9.2.3 Demonstrate ability to conduct primary/secondary research.
B.9.2.4 Collaborate with others to obtain information.
B.9.2.5 Correctly document research information.
B.9.2.6 Demonstrate ability to conduct interviews/surveys.

B.9.3 Organize written information.

B.9.3.1 Format appropriate documents (letters, memos, manuals, and reports).
B.9.3.2 Demonstrate the four C's of writing: clear, concise, correct, complete.
B.9.3.3 Revise written material.
B.9.3.4 Use appropriate organizational patterns.
B.9.3.5 Use appropriate engineering technology terminology.
B.9.3.6 Collaborate on the creation of written material.
B.9.3.7 Correctly document written material.
B.9.3.8 Use computer programs to create/revise written material.

B.9.4 Organize oral information.

B.9.4.1 Apply appropriate organizational patterns (informative, persuasive).
B.9.4.2 Practice key workplace interpersonal skills.
B.9.4.3 Create various means of visual support (slides, PowerPoint, graphs).
B.9.4.4 Correctly cite information.
B.9.4.5 Use computers to organize presentations.

B.9.5 Present written and oral information.

B.9.5.1 Demonstrate professional delivery skills.
B.9.5.2 Use computers to make written and oral presentations.
B.9.5.3 Analyze audiences (setting, demographics, size).
B.9.5.4 Define the purpose of presentations.
B.9.5.5 Support presentation with appropriate visuals.

Engineering Technology Core Student Competencies

Thermal Competencies

Integrated Curriculum: Physics, Mathematics, Communications, Technology

E.1 Energy in thermal systems.

- E.1.1 Apply sensible heat to solve thermal problems.
  - E.1.1.1 Demonstrate a conceptual understanding of temperature, heat, and energy by distinguishing between them.
  - E.1.1.2 Use appropriate devices to measure temperature in Celsius and Fahrenheit systems and convert between the two.
  - E.1.1.3 Explain the application of conservation of energy to thermal processes.
  - E.1.1.4 Use algebraic operations to determine the unknown quantity in the heat loss–heat gained equation.
  - E.1.1.5 Graphically analyze cooling/heating curves to deduce the functional relationship between time, temperature, and rate.
- E.1.2 Apply latent heat to solve thermal problems.
  - E.1.2.1 Demonstrate a conceptual understanding of latent heat by relating phase changes to energy loss or gain.
  - E.1.2.2 Calculate the energy associated with a phase change.
  - E.1.2.3 Describe evaporation, condensation, and sublimation.

E.2 Thermal expansion.

- E.2.1 Apply linear expansion to solve problems.
  - E.2.1.1 Use appropriate data acquisition devices to obtain linear expansion measurements.
  - E.2.1.2 Plot linear expansion data and write a linear function for the relationship between temperature and length.
  - E.2.1.3 Solve the linear equation of temperature and length for unknown quantities.
- E.2.2 Apply area expansion to solve problems.
  - E.2.2.1 Determine the coefficient of area expansion from linear expansion coefficient.
  - E.2.2.2 Determine area expansion.
- E.2.3 Apply volume expansion to solve problems.
  - E.2.3.1 Determine the coefficient of volume expansion from linear expansion coefficient.
  - E.2.3.2 Determine deferential volume expansion for a fluid in a solid container.

E.3 Heat transfer.

- E.3.1 Solve thermal conduction problems.
  - E.3.1.1 Demonstrate a conceptual understanding of thermal conduction by distinguishing between thermal conductors and thermal insulators.
  - E.3.1.2 Graphically analyze the relationship of the effect of length, cross-sectional area, and type of material on thermal resistance.
  - E.3.1.3 Apply algebraic operations to determine the unknown quantity in the thermal conduction equation.
  - E.3.1.4 Use the R-factor to describe the relative relationship of thermal insulator.
- E.3.2 Solve thermal convection problems.
  - E.3.2.1 Demonstrate conceptual understanding of thermal convection by relating surface characteristics, shape, and orientation to convection properties.
  - E.3.2.2 Differentiate between natural and forced convection.
- E.3.3 Solve thermal radiation problems.
  - E.3.3.1 Demonstrate a conceptual understanding of thermal radiation by describing black body radiation.
  - E.3.3.2 Use the Stefan-Boltzmann equation to determine radiation energy from an object.
  - E.3.3.3 Use appropriate devices to obtain temperature from radiating objects.

E.4 Effective team and communication skills.

- E.4.1. Gather appropriate information.
  - E.4.1.1 Demonstrate ability to conduct primary/secondary research.
  - E.4.1.2 Collaborate with others to obtain information.
  - E.4.1.3 Correctly document research information.
- E.4.2 Organize oral information.
  - E.4.2.1 Apply appropriate organizational patterns (informative, persuasive).
  - E.4.2.2 Create various means of visual support (slides, PowerPoint, graphs).
- E.4.3 Present written and oral information.
  - E.4.3.1 Demonstrate professional delivery skills.
  - E.4.3.2 Define the purpose of presentations.
  - E.4.3.3 Support presentation with appropriate visuals.

Engineering Technology Core Student Competencies

Mechanical Competencies

Integrated Curriculum: Physics, Mathematics, Communications, Technology

C.1 Rate in linear systems.

- C.1.1 Use time measurements.
  - C.1.1.1 Demonstrate an understanding of time and time measurement devices.
- C.1.2 Solve problems involving displacement.
  - C.1.2.1 Demonstrate a conceptual understanding of distance by expressing measurements in SI and customary US units.
  - C.1.2.2 Compare and contrast distance and displacement by using vectors and scalars.
  - C.1.2.3 Use scientific, engineering, and prefix notations with the concept of exponents, decimals, and fractions to convert between and with units systems.
  - C.1.2.4 Use appropriate data acquisition devices to obtain linear measurement.
  - C.1.2.5 Add vectors graphically.
- C.1.3 Solve problems involving velocity.
  - C.1.3.1 Demonstrate a conceptual understanding of velocity as a rate of change, and distinguish between velocity and speed.
  - C.1.3.2 Determine velocity and speed graphically and analytically.
  - C.1.3.3 Apply the equation of displacement.
  - C.1.3.4 Solve linear equations of motion and solve formulas for unknown quantities.
  - C.1.3.5 Determine average and instantaneous velocity graphically and analytically.
  - C.1.3.6 Use appropriate data acquisition devices to measure/calculate and store data in electronic files.
- C.1.4 Solve problems involving acceleration.
  - C.1.4.1 Demonstrate a conceptual understanding of acceleration by solving problems of uniform motion.
  - C.1.4.2 Solve quadratic equations of motion with uniform acceleration for unknown quantities.
  - C.1.4.3 Use appropriate data acquisition devices to produce graphic data of uniform acceleration for solutions to motion problems.
  - C.1.4.4 Analyze uniform data using the concept of slope and area under the curve to determine displacement, velocity, and acceleration.

C.2 Forces in linear systems.

- C.2.1 Solve problems on statics (concurrent/coplanar).
  - C.2.1.1 Demonstrate a conceptual understanding of forces and static equilibrium problems.
  - C.2.1.2 Apply Newton's laws of motion to describe translational equilibrium.
  - C.2.1.3 Calculate the mass/weight of an object from density and volume and determine the center of mass.
  - C.2.1.4 Construct free body diagrams and apply vector techniques for solutions to static problems.
  - C.2.1.5 Apply trigonometric principles including the law of sines and cosines to solve vector problems.
- C.2.2 Solve dynamics problems.
  - C.2.2.1 Demonstrate a conceptual understanding of force in kinetic friction problems.
  - C.2.2.2 Apply Newton's law of motion, free body diagrams, and vector techniques to predict how forces affect the motion of objects.
  - C.2.2.3 Apply systems of equations to solve equations of motion for more than one object.

C.3 Conservation principles.

- C.3.1 Solve energy/work problems.
  - C.3.1.1 Demonstrate a conceptual understanding of work and energy by calculating and measuring kinetic and potential energy for gravitational and spring systems.
  - C.3.1.2 Apply the conservation of mechanical energy principle to solve problems with conservative and non-conservative forces.
  - C.3.1.3 Determine power for mechanical systems and apply to solve mechanical system problems.

C.4 Rate in rotational systems.

- C.4.1 Solve angular displacement problems.
  - C.4.1.1 Demonstrate a conceptual and analytical understanding of rotational displacement by expressing measurements in different units.
  - C.4.1.2 Use appropriate data acquisition devices to measure angular displacement.
  - C.4.1.3 Convert between angular and linear displacements.
- C.4.2 Solve angular velocity problems.
  - C.4.2.1 Demonstrate a conceptual and analytical understanding of rotational displacement by expressing measurements in different units.
  - C.4.2.2 Use appropriate data acquisition devices to measure angular acceleration.
  - C.4.2.3 Use appropriate data acquisition devices to measure rotational rates and store data in electronic files.
- C.4.3 Solve angular acceleration problems.
  - C.4.3.1 Demonstrate a conceptual and analytical understanding of angular acceleration.

C.5 Torque in rotational systems.

- C.5.1 Solve rotational static problems (non-concurrent/coplanar).
  - C.5.1.1 Demonstrate a conceptual and analytical understanding of torque/moments.
  - C.5.1.2 Determine center of mass of objects, and apply to solutions of rotational static problems.
  - C.5.1.3 Apply rotational equilibrium conditions and free body diagrams to static problems.
  - C.5.1.4 Apply rotational and translational equilibrium conditions to analyze structural arrangements.
  - C.5.1.5 Use systems of equations to solve equilibrium problems.
- C.5.2 Solve rotational dynamics problems.
  - C.5.2.1 Demonstrate a conceptual and analytical understanding of moment of inertia.
  - C.5.2.2 Apply the rotational version of Newton’s Second Law to the solution of rotational problems.

C.6 Conservation concepts in rotational systems.

- C.6.1 Solve rotational energy/work problems.
  - C.6.1.1 Demonstrate a conceptual and analytical understanding of work and energy by calculating rotational kinetic energy.
  - C.6.1.2 Apply the conservation of energy principle to the transfer of energy between linear and rotational systems.

C.7 Effective team and communications skills.

- C.7.1 Demonstrate the ability to work in teams.
  - C.7.1.1 Employ problem solving skills to solve a team task.
  - C.7.1.2 Use appropriate human relations skills.
  - C.7.1.3 Demonstrate various listening skills.
  - C.7.1.4 Apply small group dynamics/teamwork skills.
  - C.7.1.5 Apply large group dynamics/teamwork skills.
  - C.7.1.6 Work in teams to make oral presentations.
  - C.7.1.7 Work in teams to collaborate on assignments.
- C.7.2 Gather appropriate information.
  - C.7.2.1 Use various media to obtain information.
  - C.7.2.2 Demonstrate engineering-technology-appropriate computer skills.
  - C.7.2.3 Demonstrate ability to conduct primary/secondary research.
  - C.7.2.4 Collaborate with others to obtain information.
  - C.7.2.5 Correctly document research information.
  - C.7.2.6 Demonstrate ability to conduct interviews/surveys.

- C.7.3 Organize written information.
  - C.7.3.1 Format appropriate documents (letters, memos, manuals, reports).
  - C.7.3.2 Demonstrate the four C's of writing: clear, concise, correct, complete.
  - C.7.3.3 Revise written material.
  - C.7.3.4 Use appropriate organizational patterns.
  - C.7.3.5 Use appropriate engineering technology terminology.
  - C.7.3.6 Collaborate on the creation of written material.
  - C.7.3.7 Correctly document written material.
  - C.7.3.8 Use computer programs to create/revise written material.
- C.7.4 Organize oral information.
  - C.7.4.1 Apply appropriate organizational patterns (informative, persuasive).
  - C.7.4.2 Practice key workplace interpersonal skills.
  - C.7.4.3 Create various means of visual support (slides, PowerPoint, graphs).
  - C.7.4.4 Correctly cite information.
  - C.7.4.5 Use computers to organize presentations.
- C.7.5 Present written and oral information.
  - C.7.5.1 Demonstrate professional delivery skills.
  - C.7.5.2 Use computers to make written and oral presentations.
  - C.7.5.3 Analyze audiences (setting, demographics, size).
  - C.7.5.4 Define the purpose of presentations.
  - C.7.5.5 Support presentation with appropriate visuals.

Engineering Technology Core Student Competencies

Fluids Competencies

Integrated Curriculum: Physics, Mathematics, Communications, Technology

D.1 Density.

- D.1.1 Demonstrate conceptual understanding of the basic properties of solids, liquids, and gases.
  - D.1.1.1 Compare and contrast properties of solids, liquids, and gases.
- D.1.2 Apply density calculations.
  - D.1.2.1 Calculate density using measurements of mass and volume.
  - D.1.2.2 Express density in appropriate units.

D.2 Pressure.

- D.2.1 Convert units of pressure.
  - D.2.1.1 Calculate pressure using force and area.
  - D.2.1.2 Define absolute pressure, gauge pressure, and atmospheric pressure.
  - D.2.1.3 Express pressure in units of Pascal, atmosphere, millimeters of mercury, etc.
- D.2.2 Calculate pressure, depth, and density.
  - D.2.2.1 Verify pressure is independent of the area or shape of the container.
  - D.2.2.2 Calculate pressure in a fluid given height and density of the fluid.
  - D.2.2.3 Measure fluid pressure.
- D.2.3 Apply Pascal's principle to solve problems in hydraulics.
  - D.2.3.1 State and apply Pascal's law to solve problems involving hydraulic pressure.

D.3 Archimedes' principle.

- D.3.1 State Archimedes' principle.
  - D.3.1.1 Describe the operation of a physical device in terms of Archimedes' principle.
- D.3.2 Apply Archimedes' principle to determine buoyant force.
  - D.3.2.1 Draw a free-body diagram including buoyant forces.
- D.3.3 Apply Archimedes' principle to determine density.
  - D.3.3.1 Determine the density of a fluid using Archimedes' principle.

D.4 Fluid flow.

- D.4.1 Describe fluid flow.
  - D.4.1.1 Explain the components of Bernoulli's equation.
  - D.4.1.2 Explain/describe the operation of a venturi tube.
- D.4.2 Apply the continuity equation to fluid problems.
  - D.4.2.1 Determine the flow and velocity of a fluid in a pipe using the continuity equation.
- D.4.3 Apply Bernoulli's equation to fluid problems.
  - D.4.3.1 Calculate the velocity and pressure of a fluid in a pipe using Bernoulli's equation.

D.5 Advanced fluid concepts.

- D.5.1 Identify advanced fluid terminology.
  - D.5.1.1 Define/describe viscosity.

D.6 Effective team and communication skills.

- D.6.1. Organize written information.
  - D.6.1.1 Format appropriate documents (letters, memos, manuals, and reports).
  - D.6.1.2 Use appropriate organizational patterns.
- D.6.2 Organize oral information.
  - D.6.2.1 Apply appropriate organizational patterns (informative, persuasive).
  - D.6.2.2 Create various means of visual support (slides, PowerPoint, graphs).
  - D.6.2.3 Correctly cite information.
  - D.6.2.4 Use computers to organize presentations.
- D.6.3 Present written and oral information.
  - D.6.3.1 Demonstrate professional delivery skills.
  - D.6.3.2 Use computers to make written and oral presentations.
  - D.6.3.3 Support presentation with appropriate visuals.

Engineering Technology Core Student Competencies

Optics Competencies

Integrated Curriculum: Physics, Mathematics, Communications, Technology

F.1 Reflection.

F.1.1 Apply the law of reflection.

- F.1.1.1 Draw a tangent and normal to plane and spherical surfaces.
- F.1.1.2 Draw an incident and reflected ray.
- F.1.1.3 Determine the focal point of a spherical mirror by calculation and construction.

F.1.2 Apply mirror equation.

- F.1.2.1 Determine image and object distance for a converging mirror by calculation and construction.
- F.1.2.2 Determine and describe the optical characteristics of an image formed by a converging mirror.
- F.1.2.3 Apply the properties of parallel and transverse lines.
- F.1.2.4 Apply the properties of similar triangles.

F.2 Refraction.

F.2.1 Apply the law of refraction (Snell's law)

- F.2.1.1 Determine the angle of refraction.
- F.2.1.2 Draw an incident and refractive ray.
- F.2.1.3 Determine the focal point of a thin convex lens by calculation and construction.
- F.2.1.4 Determine the critical angle for total internal reflection.

F.2.2 Apply the lens equation.

- F.2.2.1 Determine image and object distance for converging lens by calculation and construction.
- F.2.2.2 Determine and describe the optical characteristics of an image formed by a converging lens.

F.3 Diffraction/Interference.

F.3.1 Define and apply the physical characteristics of waves.

- F.3.1.1 Describe the relationship between wave length, frequency, and speed.
- F.3.1.2 Calculate the energy content of a light wave.
- F.3.1.3 Determine physical characteristics of a wave from a wave equation.
- F.3.1.4 Write the wave equation given the physical characteristics.

F.3.2 Describe the results of superposition of waves.

- F.3.2.1 Determine the phase difference between two waves at a given point.
- F.3.2.2 Use the phase differences to describe constructive and destructive interference.
- F.3.2.3 Describe the dispersion of a laser beam.

Engineering Technology Core Student Competencies

Materials Competencies

Integrated Curriculum: Physics, Mathematics, Communications, Technology

G.1 Materials.

- G.1.1 Describe materials properties.
  - G.1.1.1 Identify and classify materials based on physical properties.
  - G.1.1.2 Identify chemical and physical properties of given materials.
- G.1.2 Define and apply stress/strain principles.
  - G.1.2.1 Determine stress in an object subjected to applied forces.
  - G.1.2.2 Determine strain in an object subjected to applied forces.
  - G.1.2.3 Apply Hook's Law to determine the Young modulus of elasticity.
  - G.1.2.4 Use elastic limit and yield point to determine load limitations.
- G.1.3 Use principles of shear stress and bending moments.
  - G.1.3.1 Construct a shear stress diagram for a loaded beam.
  - G.1.3.2 Construct a bending moment diagram for a loaded beam.
  - G.1.3.3 Determine maximum shear stress for a loaded beam.
  - G.1.3.4 Determine maximum bending moment for a beam.
  - G.1.3.5 Integrate a polynomial function.
  - G.1.3.6 Use definite integral to calculate the area of a curve.

Engineering Technology Core Equipment List*

Electrical Module #1
Spools of wire — several lengths and diameters (i.e., 8-, 10-, and 12-gauge)
Calipers
Digital multimeter
Computer
Calculator
Software — word-processing, spreadsheet, CAD
Resistance as function of temperature apparatus
CBL/MBL (calculator-based or microcomputer-based laboratory) temperature probe
Data logger

Electrical Module #2
Light bulbs (5 watt and 7 watt)
Sockets for lights
Resistors
Power supply DC/AC
Digital multimeter (DMM)
CBL/MBL voltage & current probes
Software — electrical circuit simulation

Electrical Module #3
Resistors
Power supply DC/AC
Digital multimeter
CBL/MBL voltage and current probes
Laser pointer
Software – electrical circuit simulation

Electrical Module #4
Capacitors
Resistors
Power supply DC/AC
Function generator
Oscilloscope
Digital multimeter

Electrical Module #5
Capacitors
Inductors
Resistors
Power supply
Function generator
Motor
Oscilloscope

Thermal Module #1
Thermal expansion apparatus
Thermometers (Fahrenheit and Celsius)
CBL/MBL temperature probes
Hot plate
Beakers
Specific heat masses
Mass scales

Mechanical Module #1
CBL/MBL interface devices
Position probes for CBL/MBL
Related computer software
Interactive physics software
Timing devices
Air tracks and carts
Meter sticks
Protractors

Mechanical Module #2
CBL/MBL interface devices
Force probes for CBL/MBL
Position probes for CBL/MBL
Timing devices
Spring force measuring devices
Air tracks and carts
Force tables
Friction blacks
Interactive physics software
Set of weights
Scales
Inclined plane

Mechanical Module #3
CBL/MBL interface devices
Force probes for CBL/MBL
Linear measuring devices (meter stick, caliper, etc.)
Set of weights
Interactive physics software
Gear trains
Scales

Engineering Technology Core Equipment List*, continued

Mechanical Module #4
CBL/MBL interface devices
Force probes for CBL/MBL
Linear measuring devices (meter sticks)
Scales
Lever system
Boom system
Set of weights
Interactive physics software

Mechanical Module #5
CBL/MBL interface devices
Force probes for CBL/MBL
Moment of inertia system
Timing devices
Scales
Set of weights
Interactive physics software

Fluids Module
CBL/MBL interface devices
Pressure probes for CBL/MBL
Pressure gauges
Flow meters
Linear measuring devices
Fluid flow trainer

Optics Module #1
Lens and mirror set
Plane glass plates
Linear measuring devices
Protractors
Light sources
Lasers

*Per student workstation

Optics Module #2
Optical flats
Single and double slits
Diffraction grating
Gauge block set
Oscilloscope
Monochromatic light source
Laser
Linear measuring devices

Materials Module #1
Force probes for paper strength test
Micrometers and calipers to measure paper thickness.
Scale (0-100 grams)
Litmus paper (pH test)
Magnifying glass(search for dirt, etc.)
Spreadsheet software
Technical publications/specifications
Light source (opacity, brightness)
Photometers
Food coloring, Ink
Blender (for making paper)
Screen wire
Dishpans
Gloves
Appropriate MSDS (Material Safety Data Sheets)
Flat iron
Chlorine bleach
Paper, pulp
Copies of periodic table
Noncombustible container for ash test
Matches
Material samples (paper, metals, wood, plastics

Materials Module #2
CBL/MBL interface devices
Force probes for CBL/MBL
Pressure probes for CBL/MBL
Hydraulic press
Stress/strain system
Beam deflection system

Engineering Technology Core
Electrical Module #1

Resistance

Conduit Wiring

Problem Scenario for the Student

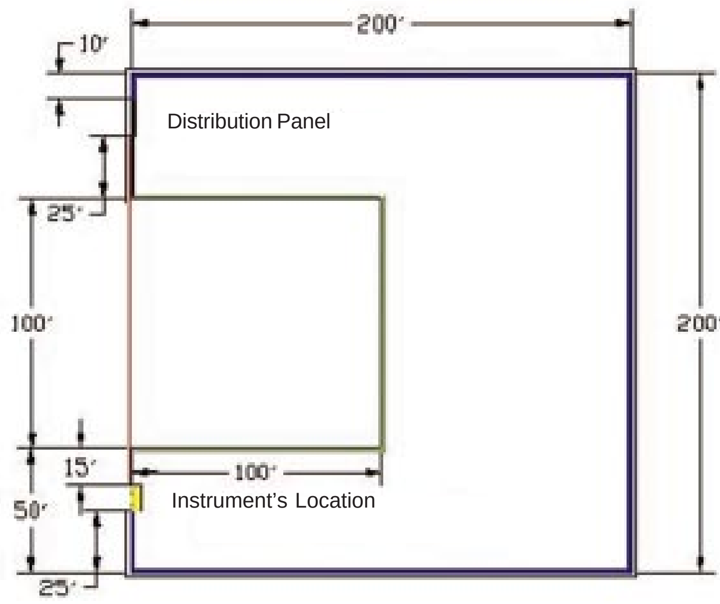
You have been on your co-op job at the AOP Company for three weeks and have just been assigned to a maintenance team in the instrumentation department. Your team leader, aware that you have just completed a section of study on resistance, has come to you with a wiring problem to be solved. Since you have only limited knowledge of voltages and current, your team leader explains that she has done some calculations related to the current and voltage requirements for the equipment.

She explains that the voltage at the instrument station will be less than the voltage at the distribution panel. When current flows through the wire connecting the panel to the instruments, there will be a voltage drop related to the current and resistance. She has determined that there is a maximum allowable resistance in the wiring leading to each instrument so that each instrument will have the proper operating voltage. She has given you the following table:

Instrument	Maximum Resistance	Current
Electrical furnace	0.35	22
Electronic test station with computer, power supply, function generator, oscilloscope, and DMM	0.71	12
Soldering station	0.92	8.0

You also have been given a diagram of the available conduit to pull the connecting wires through. The red conduit has space for a pair of wires and the green and blue conduits each have room for two pairs of wire. (Note that when you make electrical connections, you will need a pair of wires for each instrument.) A check of the stock room reveals that you have three different spools of wire: 800 ft. of AWG #8; 1,800 ft. of AWG #10; and 3,000 ft. of AWG #12. You also have been told that the temperature in the room the lines run through may rise to 99°F and that the temperature of the wires themselves may rise another 13 degrees.

With this information, your team must determine the correct gauge wire to run through which conduit and to which instrument. Your team also must draw a wiring diagram of your results.



Setting the Stage

Electricity and electronics are diverse technological fields with applications that touch all aspects of our lives. From simple applications such as wiring and lighting to complex computer and communications systems, electrical concepts and components form the building blocks for each device. This section begins with some basic concepts and characteristics of materials that comprise electrical circuits and devices.

Under normal conditions, all materials have resistance to electrical current in a circuit. Electrical resistance is measured in units of ohms, and electrical current is measured in amperes. The opposition of the flow of current is not unlike the frictional opposition of motion in a mechanical system. Just like mechanical friction that produces heat, such as warming your hands by rubbing them together, the collision of electrons with atoms converts electrical energy into heat. This heat produces a temperature rise in the material carrying the current. Therefore, the resistance of a substance depends on four physical factors: type of material, length, cross-sectional area, and temperature.

Each material, because of its unique structure, reacts differently to current. Conductors are said to have "free" electrons and permit a large flow of charge with low resistance. Insulators, with "bound" electrons, permit little or no flow and have large resistance. A third class of materials, semiconductors, falls between conductors and insulators.

Because of their low resistance, conducting metals such as copper wire are used to supply electrical power from a source to devices. Since these wires do have resistance, there will be a voltage drop along the wire when a current is flowing through it. Consequently, several factors must be considered when selecting wiring to supply a power source to devices. The total resistance must be low enough to keep the voltage at a proper level, the cross-sectional area must be large enough to safely handle the current, and the cost of the wire should be as low as possible.

Content Strands

Physics

Atomic structure
Resistance
Resistance, heat, and power

Mathematics

Cartesian coordinates
Area
Direct and inverse variation
Solution of equations

Technology

DMM and computers
Measuring resistance
Excel
Elecrtrical symbols

Communications

Writing effective paragraphs
Memos
Peer editing
Technical description

Notes to the Instructor

1. Introduce teaming, problem-based learning (see Know/Need-to-Know chart template on next page), and an integrated curriculum.
2. Model integration of content by using an activity that cuts across all disciplines.
3. Give a mini-lecture and/or have a guest speaker on teams in industry.
4. Using this project, demonstrate the integration of the disciplines. Electrical instruments, their application, and measurement techniques can be taught in the technology component, data collection in the physics, processing of data and graphing in the math, data analysis in physics/technology, and presentation of the solution in communications.
5. In this project, the student may have to be guided through the problem-solving process. First, give students the student handout and discuss the problem and background information. Students should work in teams to complete a Know/Need-to-Know chart about the problem. Through a directed discussion, students should participate in the workshops or activities that will lead to a solution of the problem. One activity might include the development of a concept map, such as the one provided.
6. Determine students' learning styles by using Richard Felder's resource material (http://www.ncsu.edu/effective_teaching) or another learning styles inventory.
7. Determine students' multiple intelligences' (MI) strengths, and use these strengths to determine initial student teams.
8. A good teaming environment provides students with tables to work on and easel pads, whiteboards, or other devices for organizing and recording team collaboration efforts.
9. Students can be introduced to the concept of resistance through a kinesthetic activity.
10. Students can be given a basic introduction to manual drafting and sketching by diagramming their solutions for the final report.

Continued on next page

Objectives

- Construct an effective wiring diagram to solve a specific wiring problem.
- Evaluate the benefits of working in teams to produce a team solution to a problem.
- Analyze the effect of length, cross-sectional area, type of material, and temperature on electrical resistance.
- Use computer application software such as CAD, Excel, and Word to explain, analyze, and report a proposed team solution to a problem.
- Outline an effective written technical description.
- Write an effective memo.

11. Students should be given an introduction to computer operations.
    A. With the wiring diagram, students could be introduced to simple operations in a CAD package. This instruction would cover opening the application, loading a file, creating straight line drawings, saving a file, and printing a drawing.
    B. A spreadsheet package such as Excel can be introduced by having students open the application, load a file, enter data into a table to calculate resistance, save the file, and print the table.
    C. A word-processing package such as Word can be introduced by having students open the application, load a file, type in documents, save the document, and print.
12. Form students into teams of three to explore the dependence of resistance on length, area, type of material, and temperature. This exploration can be done as a jigsaw with a member from each team collecting data. The data can be generated through a calculator-based laboratory (CBL) or microcomputer-based laboratory (MBL). The data can be stored in a spreadsheet and plotted to determine direct or inverse dependence. Students then can select the proper equations for the functional relationship for length, area, type of material, and temperature.
13. Introduction to measurement of voltage and current should include analog and digital measuring techniques. Data collection with CBL or MBL systems will reinforce computer usage.
14. In many plants, an engineer rather than a technician would solve a wiring problem such as this. Also, the solution to the problem would not be obtained by calculating the resistance from resistivity, length, and area, but would be done by using a wire gage table and the National Electrical Code. In fact, once students have an understanding of calculation of resistance from these parameters, they could use a wire gage to arrive at the solution. The temperature effect would need to be calculated.
15. Data for the various measurements of resistance dependence can be used to create graphs using appropriate scales. These graphs can be used to investigate direct and inverse relationships and methods of interpreting graphs.
16. Journal entries are an effective means of reflecting on what is being learned in the project.
17. Classroom resources:

Hewitt, Paul G. (1991). *Scaling*. Menlo Park, CA: Addison-Wesley. (30-minute videocassette).

Laws, Priscilla. (1997). *Workshop Physics Activity Guide*. New York: John Wiley & Sons.

Loyd, David H. (1997). *Physics Laboratory Manual*. 2nd edition. Fort Worth, TX: Saunders College Publications.

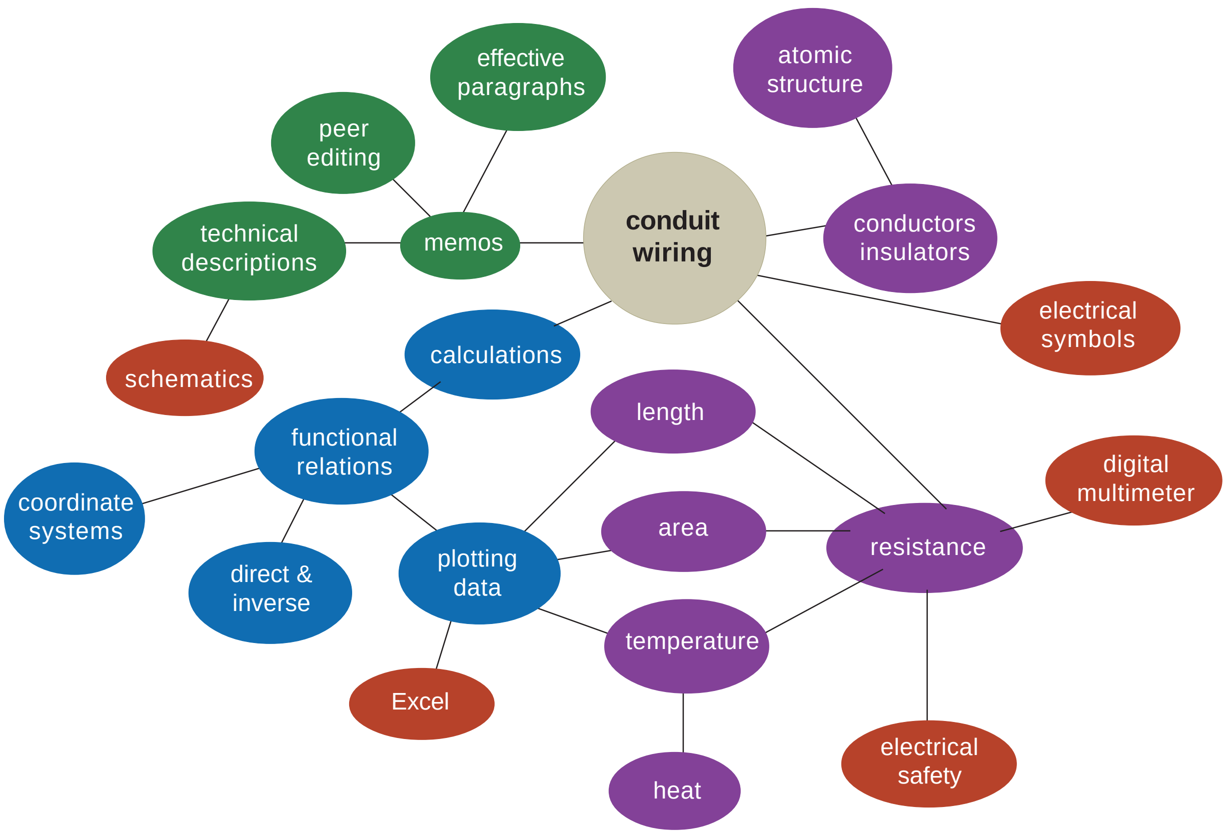
Student Workshop Activities

- Atomic structure and resistance
- Physical properties of resistors
- Graphing and interpreting data (direct and inverse relationships)
- Scientific/Engineering notation; significant digits and prefix notation
- Formula evaluation
- Listening
- Audience and purpose
- Technical description
- Memo writing
- Peer editing
- The writing process
- Characteristics of effective paragraphs
- DMM (digital multimeter)
- Computer operations, Excel, and Word
- E-mail
- Sketching
- Electrical symbols
- Safety and housekeeping
- Estimating
- Units

Problem-Based Learning
Know/Need-to-Know Chart

What do we know?	What do we need to know?	How do we find out?

Concept Map


effective paragraphs
atomic structure
peer editing
conduit wiring
conductors insulators
technical descriptions
memos
electrical symbols
schematics
calculations
length
functional relations
digital multimeter
coordinate systems
area
resistance
direct & inverse
plotting data
temperature
Excel
electrical safety
heat

Student Competencies

B.1.1.1 Demonstrate a conceptual understanding of conductors, insulators, and semiconductors by using the basic structure of matter and electron motion to distinguish between each.
B.1.1.2 Graphically analyze temperature dependence of resistance data to deduce the functional relationship of temperature and resistance.
B.1.1.3 Apply algebraic operations to the temperature dependence of resistance to find unknown quantities.
B.1.1.4 Graphically analyze the direct and inverse relationships of the effect of length, cross-sectional area, and type of material on the value of resistance.
B.1.1.5 Calculate conductance from resistance values and vice versa.
B.1.1.6 Calculate the resistance given the material, length, and cross-sectional area.
B.1.1.7 Work in teams to collaborate on assignments.
B.9.1.1 Employ problem solving skills to solve a team task.
B.9.1.2 Use appropriate human relations skills.
B.9.1.3 Demonstrate various listening skills.
B.9.2.1 Use various media to obtain information.
B.9.2.2 Demonstrate engineering-technology-appropriate computer skills.
B.9.2.3 Demonstrate ability to conduct primary/secondary research.
B.9.2.4 Collaborate with others to obtain information.
B.9.3.1 Format appropriate documents (letters, memos, manuals, and reports).
B.9.3.2 Demonstrate the four Cs of writing: clear, concise, correct, complete.
B.9.3.3 Revise written material.
B.9.3.4 Use appropriate organizational patterns.
B.9.3.5 Use appropriate engineering technology terminology.
B.9.3.6 Collaborate on the creation of written material.
B.9.3.8 Use computer programs to create/revise written material.
B.9.5.2 Use computers to make written and oral presentations.
B.9.5.3 Analyze audiences (setting, demographics, size).
B.9.5.4 Define the purpose of presentations.

Integrated Skills

Teaming
Problem solving
Data collection
Data analysis
Computer skills
Calculator skills
Unit conversion

Student Assessment

- Faculty teams will assess the technical accuracy of wiring diagrams and the quality of written technical descriptions, including data analysis, produced by student teams.
- Faculty will assess individual student performance in discipline-specific workshops, labs, and activities.
- Teaming skills and problem-solving skills will be evaluated by faculty, peer, and student self-assessments.

Engineering Technology Core
Electrical Module #1 — Student Handout

Resistance

Conduit Wiring

Problem Scenario

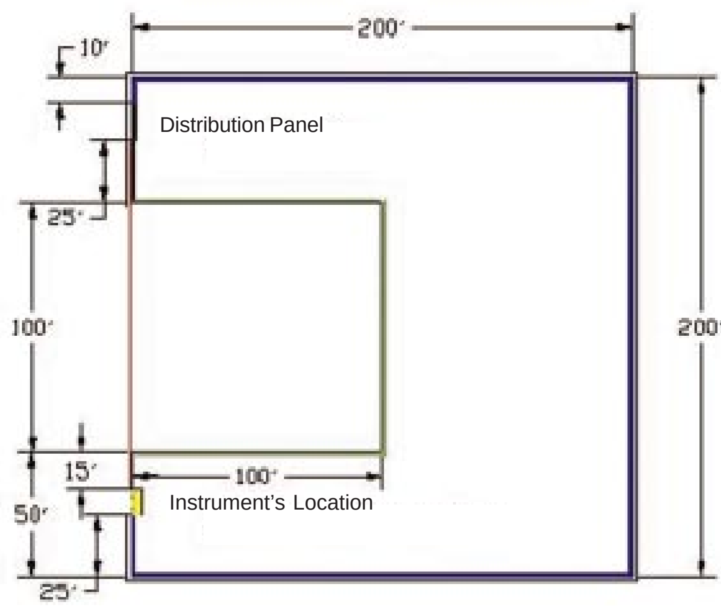
You have been on your co-op job at the AOP Company for three weeks and have just been assigned to a maintenance team in the instrumentation department. Your team leader, aware that you have just completed a section of study on resistance, has come to you with a wiring problem to be solved. Since you have only limited knowledge of voltages and current, your team leader explains that she has done some calculations related to the current and voltage requirements for the equipment.

She explains that the voltage at the instrument station will be less than the voltage at the distribution panel. When current flows through the wire connecting the panel to the instruments, there will be a voltage drop related to the current and resistance. She has determined that there is a maximum allowable resistance in the wiring leading to each instrument so that each instrument will have the proper operating voltage. She has given you the following table:

Instrument	Maximum Resistance	Current
Electrical furnace	0.35	22
Electronic test station with computer, power supply, function generator, oscilloscope, and DMM	0.71	12
Soldering station	0.92	8.0

You also have been given a diagram of the available conduit to pull the connecting wires through. The red conduit has space for a pair of wires and the green and blue conduits each have room for two pairs of wire. (Note that when you make electrical connections, you will need a pair of wires for each instrument.) A check of the stock room reveals that you have three different spools of wire: 800 ft. of AWG #8; 1,800 ft. of AWG #10; and 3,000 ft. of AWG #12. You also have been told that the temperature in the room the lines run through may rise to 99°F and that the temperature of the wires themselves may rise another 13 degrees.

With this information, your team must determine the correct gauge wire to run through which conduit and to which instrument. Your team also must draw a wiring diagram of your results.



Setting the Stage

Electricity and electronics are diverse technological fields with applications that touch all aspects of our lives. From simple applications such as wiring and lighting to complex computer and communication systems, electrical concepts and components form the building blocks for each device. This section begins with some basic concepts and characteristics of materials that comprise electrical circuits and devices.

Under normal conditions, all materials have resistance to electrical current in a circuit. Electrical resistance is measured in units of ohms, and electrical current is measured in amperes. The opposition of the flow of current is not unlike the frictional opposition of motion in a mechanical system. Just like mechanical friction that produces heat, such as warming your hands by rubbing them together, the collision of electrons with atoms converts electrical energy into heat. This heat produces a temperature rise in the material carrying the current. Therefore, the resistance of a substance depends on four physical factors: type of material, length, cross-sectional area, and temperature.

Each material, because of its unique structure, reacts differently to current. Conductors are said to have “free electrons” and permit a large flow of charge with low resistance. Insulators, with bound electrons, permit little or no flow and have large resistance. A third class of materials, semiconductors, fall between conductors and insulators.

Because of their low resistance, conducting metals, such as copper wire, are used to supply electrical power from a source to devices. Since these wires do have resistance, there will be a voltage drop along the wire when a current is flowing through it. Consequently, several factors must be considered when selecting wiring to supply a power source to devices. The total resistance must be low enough to keep the voltage at a proper level, the cross-sectional area must be large enough to safely handle the current, and the cost of the wire should be as low as possible.

Performance Expectations

- ❑ Students will be evaluated individually and in teams. The evaluation will include problem-solving and teaming skills used by students and student teams.
- ❑ Students will have opportunities for self evaluation, peer evaluation, and team evaluation.
- ❑ Individual instructors will test and grade students individually on the content of workshops and activities.
- ❑ The team-generated solution will be evaluated and graded by the faculty team. The solution should include a wiring diagram, technical description, and cover memo.

Objectives

- Construct an effective wiring diagram to solve a specific wiring problem.
- Evaluate the benefits of working in teams to produce a team solution to a problem.
- Analyze the effect of length, cross-sectional area, type of material, and temperature on electrical resistance.
- Use computer application software such as CAD, Excel, and Word to explain, analyze, and report a proposed team solution to a problem.
- Outline an effective written technical description.
- Write an effective memo.

Engineering Technology Core
Electrical Module #2

Current

Trailer Fuse

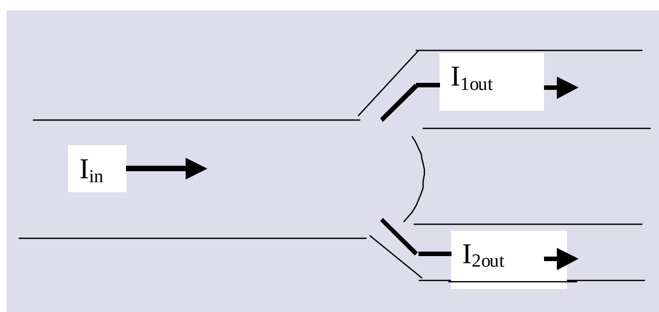
Problem Scenario for the Student

The Vulcan New Metals fabrication shop has just hired you. The company wants to expand its product line from metal containers to trailer systems. The trailer's lighting system will be connected to the towing vehicle. Most vehicles' electrical fuse systems, however, are not designed to handle a trailer. Therefore, you must change the parking light fuse when adding a trailer, as well as recommend to the owner the modifications to a vehicle's electrical system to accommodate the trailer's lighting system. Your technician team has been asked to do the following:

1. Determine the additional current load placed on a vehicle's circuit by a standard trailer lighting system. The trailer lighting system includes four side marker lamps and two tail lamps.
2. Propose an amendment to the section of the vehicle's manual that deals with trailer towing.
3. Compose a written explanation to the design team.

Setting the Stage

The fuse is one of the most basic circuit elements. It is used to protect electrical equipment in the home, in automobiles, in industry, and elsewhere. The fuse, a bimetallic conductor through which current passes, is the connection between the equipment and its power source. If the equipment does not work properly and draws excessive current, the fuse "blows," disconnecting the equipment from the power source and preventing further damage. In other words, as the current increases, the metal in a fuse heats and begins to melt if the current exceeds the rated value.

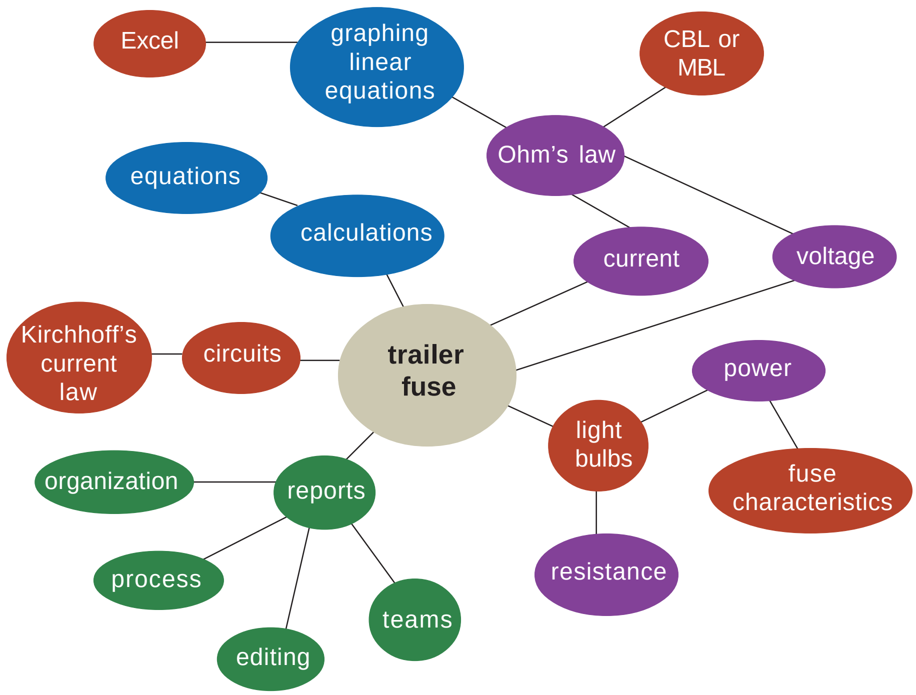


A fuse plays an important role in electrical circuits because it ensures that the current does not exceed a safe level. In industrial plants and homes, power must be limited to ensure that the current through the lines is within rated values. Therefore, fuses and circuit breakers are installed where power enters the installation. In the case of industrial plants and homes, circuit breakers have replaced fuses for this control and can be reset when the breaker has been tripped. However, fuses are still in wide use for the protection of circuits because of the low cost of the fuse compared with the high cost of the circuit breaker.

Another important concept for electrical circuits is the rule concerning the flow of current from a single path into more than one path. Consider a wire that splits in two paths (see the figure above). The current flowing into the junction (I_{in}) equals the sum of the currents (ΣI_{out}) leaving the junction.

This rule is known as Kirchhoff's current rule (KCR) or Kirchhoff's current law (KCL), and it allows technicians to determine the amount of current in parallel circuits.

Concept Map



Content Strands

Physics

Ohm's law
Kirchhoff's law
Resistance
Power

Mathematics

Linear relations
Graphing linear equations
Using a scientific/graphing calculator

Technology

Introduction to MathCAD
Using DMM measures for Ohm's law and Kirchhoff's law
Interpreting technical data
Electrical safety

Communications

Process instructions
Peer editing
Team roles
Organizing body of a report

Notes to the Instructor

1. Use the evaluations of a student's performance in Electrical Module 1 to establish placement in a permanent team for the remaining modules.
2. Teaming skills need to be enhanced. "Jigsaw" on team roles.
3. This project as stated is "ill structured," similar to one that might be given by a supervisor. The students must request or research several pieces of information on the types of bulbs used in a trailer system. This requirement adds to the problem-solving process of identifying what students know and what they need to know.

Problem-Based Learning Know/Need-to-Know Chart

What do we know?	What do we need to know?	How do we find out?

4. The students can discover Kirchhoff's current law (KCL) using an exercise with several different light bulbs in parallel and with CBL/MBL measurements. Once the rule is discovered, it can be reinforced with a circuit simulation program. Demonstration of KCL with water gives visual learners a good visual representation.
5. Students can discover Ohm's law using the CBL/MBL systems.

Objectives

- Construct an effective wiring diagram to solve a specific wiring problem.
- Use calculators and algebra to solve Kirchhoff's current law problems.
- Explain team roles and how they are used to develop a team solution.
- Write a well-organized, well-developed, and grammatically and mechanically acceptable procedure.

Continued on next page

Notes to the Instructor, continued

6. If students attempt to find the current by measuring the resistances as in Electrical Module 1 and applying Ohm's law, they will arrive at an incorrect answer. They have measured the "cold" resistance of the light sources. They can not use an ohmmeter to determine resistance in this case. They must make a dynamic measurement using Ohm's law. Therefore, this project can be used to reinforce the concepts of resistance and temperature found in Electrical Module 1.
7. The students can use Ohm's law data and graphics to understand the relationship between slope and resistance.
8. Operations with scientific and English notation can be used to show factor analysis and the laws of exponents.
9. Students can build circuits in physics or technology and write a procedure on how to build the circuits.

Student Workshop Activities

- Ohm's law
- Algebraic manipulations and graphics
- Parallel circuits
- Reading schematics/data sheets and interpreting graphics
- Preparation of a written proposal
- Elements of teams and team roles
- Writing instructions and procedures
- Organizational principles
- Peer editing
- Computer productivity tools
- KCR/KCL
- Operations involving exponents
- Operations with scientific/ engineering notation

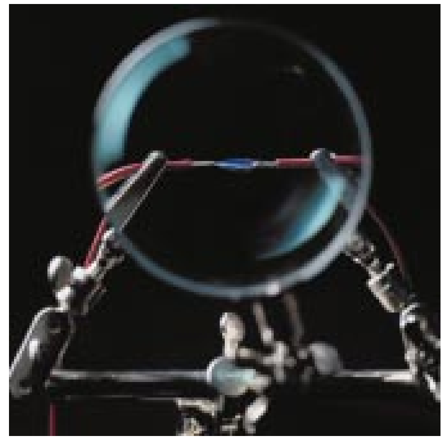
Student Assessment

- Faculty teams will evaluate the technical accuracy of written team reports on the electrical impact of a trailer lighting system.
- Faculty will assess individual student performance in discipline-specific workshops, labs, and activities.
- Teaming skills and problem-solving skills will be evaluated by faculty, peers, and students' self-assessments.

Integrated Skills

Data collection
Data analysis
Computer skills
Calculator skills
Teaming skills
Problem solving
Unit conversion

Student Competencies



B.1.1.5 Calculate conductance from resistance values and vice versa.
B.1.2.2 Use exponents, scientific notation, and engineering and prefix notation to express values of resistance.
B.2.1.1 Demonstrate the conceptual understanding of current as the rate of flow of charge.
B.2.2.2 Apply Kirchhoff's current law to circuits with multiple current paths.
B.3.1.3 Apply the concept of electrical potential and electrical potential difference to differentiate between voltage with respect to ground and voltage across a device.
B.3.2.1 Graphically analyze voltage-current data for ohmic resistors to determine resistance.
B.3.2.3 Solve Ohm's law problems by algebraically manipulating Ohm's law equation for unknown quantities.
B.5.1.2 Solve power relationships for an unknown quantity.
B.6.2.1 Use appropriate electrical symbols to create electronic schematics.
B.6.2.2 Interpret schematic diagrams to identify electronic components and construct electrical circuits.
B.9.1.1 Employ problem-solving skills to solve a team task.
B.9.1.2 Use appropriate human relations skills.
B.9.1.3 Demonstrate various listening skills.
B.9.1.7 Work in teams to collaborate on assignments.
B.9.2.1 Use various media to obtain information.
B.9.2.2 Demonstrate engineering technology-appropriate computer skills.
B.9.2.3 Demonstrate ability to conduct primary/secondary research.
B.9.2.4 Collaborate with others to obtain information.
B.9.3.1 Format appropriate documents (letters, memos, manuals, reports).
B.9.3.2 Demonstrate the four C's of writing: clear, concise, correct, complete.
B.9.3.3 Revise written material.
B.9.3.4 Use appropriate organizational patterns.
B.9.3.5 Use appropriate engineering technology terminology.
B.9.3.6 Collaborate on the creation of written material.
B.9.3.8 Use computer programs to create/revise written material.
B.9.5.2 Use computers to make written and oral presentations.

Engineering Technology Core
Electrical Module #2 — Student Handout

Current

Trailer Fuse

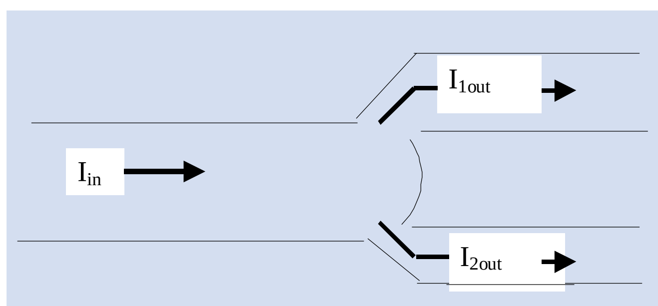
Problem Scenario

The Vulcan New Metals fabrication shop has just hired you. The company wants to expand its product line from metal containers to trailer systems. The trailer's lighting system will be connected to the towing vehicle. Most vehicles' electrical fuse systems, however, are not designed to handle a trailer. Therefore, you must change the parking light fuse when adding a trailer, as well as recommend to the owner the modifications to a vehicle's electrical system to accommodate the trailer's lighting system. Your technician team has been asked to do the following:

1. Determine the additional current load placed on a vehicle's circuit by a standard trailer lighting system. The trailer lighting system includes four side marker lamps and two tail lamps.
2. Propose an amendment to the section of the vehicle's manual that deals with trailer towing.
3. Compose a written explanation to the design team.

Setting the Stage

The fuse is one of the most basic circuit elements. It is used to protect electrical equipment in the home, in automobiles, in industry, and elsewhere. The fuse, a bimetallic conductor through which current passes, is the connection between the equipment and its power source. If the equipment does not work properly and draws excessive current, the fuse "blows", disconnecting the equipment from the power source and preventing further damage. In other words, as the current increases, the metal in a fuse heats and begins to melt if the current exceeds the rated value.



A fuse plays an important role in electrical circuits because it ensures that the current does not exceed a safe level. In industrial plants and homes, power must be limited to ensure that the current through the lines is within rated values. Therefore, fuses and circuit breakers are installed where power enters the installation. In the case of industrial plants and homes, circuit breakers have replaced the use of fuses for this control, and they can be reset when the breaker has been tripped. However, fuses are still in wide use for the protection of circuits because of the low cost of the fuse compared to the high cost of the circuit breaker.

Another important concept for electrical circuits is the rule concerning the flow of current from a single path into more than one path. Consider a wire that splits in two paths (see the figure above). The current flowing into the junction (I_{in}) equals the sum of the currents (ΣI_{out}) leaving the junction.

This rule is known as Kirchhoff's current rule (KCR) or Kirchhoff's current law (KCL), and it allows us to determine the amount of current in parallel circuits.

Objectives

- Construct an effective wiring diagram to solve a specific wiring problem.
- Use calculators and algebra to solve Kirchhoff's current law problems.
- Explain team roles and how they are used to develop a team solution.
- Write a well-organized, well-developed, and grammatically and mechanically acceptable procedure.

Performance Expectations

- ❑ Students will be evaluated individually and in teams. The evaluation will include problem-solving and teaming skills used by students and student teams.
- ❑ Students will have opportunities for self evaluation, peer evaluation, and team evaluation.
- ❑ Individual instructors will test and grade students individually on the content of workshops and activities.
- ❑ Team products will be evaluated by faculty teams.

Engineering Technology Core
Electrical Module #3

Voltage

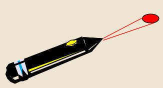
Series/Parallel Circuits

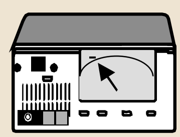
Problem Scenario for the Student

You are a technician at the Quick Snap Cable Company which makes flat flexible cable used in laser jet printers. The cable has electrical contacts crimped onto each end by a 10-ton press. The cable also has a blue indicator line on one side of the cable, which indicates the pin number of the cable. This cable must slide into the press with the blue line on the left side.

A customer has complained because he has received improperly assembled parts. You have received a copy of the complaint (see complaint letter, page 48) and must outline the points to be discussed in your initial communication with the client as a measure of goodwill. Before communicating with this customer, your team must also develop a proposed solution to the customer's problem.

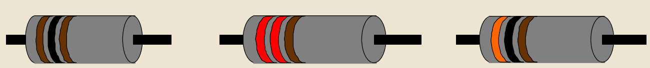
Additionally, a machine operator has suggested that your team place a laser onto the press, making the blue line more visible to the operator. Your team leader would like to test the feasibility of using a laser to improve operations before installing a permanent system on each press. Your budget is limited and you will need to use available materials to test the new process. In the stock room you find the following items:

A battery operated laser pointer 

Single power supply 

5V, 100 ma

Three values of resistors

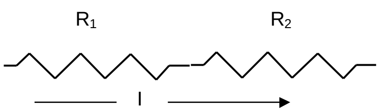


Your team must modify the laser pointer to accomplish the job. You should research and take into consideration any safety requirements for the use of the laser pointer. The system must have an on/off switch, a fuse, and a power-on indicator. Work with your team to design and build this test circuit. Your team also must prepare a written response to the customer's complaint, detailing all aspects of the solution to the problem. This response must have your supervisor's approval.

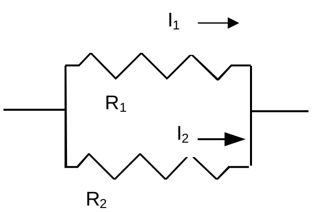
For training purposes, prepare a safety bulletin on the use of lasers and present this information orally with accompanying visual aids. As a final measure, provide written documentation of all proposed machine changes, including any appropriate schematics and a cost estimate.

Setting the Stage

In Electrical Modules 1 and 2, we determined the characteristics of resistance and current. We saw the need for a "driving force," i.e., voltage causing a current to flow through a resistor. We also investigated the basic relationship between voltage, current, and resistance, a relationship known as Ohm's law. Most electrical circuits, however, do not consist of a voltage source and a single element connected to that source; instead, several elements are connected in a circuit that is series, parallel, or a combination of the two. The diagram below shows a simple series and a simple parallel combination of resistors.



Series Circuit



Parallel Circuit

A circuit that has several elements connected one after the other so that the same current flows through each element is called a series circuit. A circuit that splits the current from a single path into several paths is called a parallel circuit. This kind of circuit was investigated in Electrical Module 2.

All electronic devices require power to operate and, therefore, need a power supply to provide voltage. Power supplies may be DC or AC and of various voltage and current capacities. In many cases, the required voltage and/or current rating for a device may not be readily available and some type of circuit must be constructed to provide the proper voltage. One means of obtaining the required voltage is to use a higher-than-needed source in series with a voltage-dropping resistor.

Notes to the Instructor

1. Students will construct both series and parallel circuits. They will measure the equivalent resistance for the different combinations of resistors and thus deduce the relationship for equivalent resistance. Simulation software can also be used to investigate resistor combinations.
2. Students will construct various series and parallel circuits to develop an understanding of Kirchhoff's voltage law. Simulation software allows for a greater number of circuits to be investigated.
3. Students can solve Kirchhoff's laws using systems of equations and can verify the solutions with simulation software.
4. Students can investigate laser safety on the Internet and produce a safety bulletin.
5. Students should continue writing technical descriptions.

Continued on next page

Content Strands

Physics
Magnetism
Faraday's law
DC/AC sources
Laser and light sources

Mathematics
Systems of equations
Percent error calculations
Sine waves
Right triangle trigonometry

Technology
Measuring devices
Color codes
Kirchhoff's voltage law
Prototypes
Oscilloscopes

Communications
Maintenance logs
E-mail
Research on lasers and safety/bulletin
Response letter
Oral reports

Objectives

- Adapt an existing laser device and power supply to facilitate observation in a cable assembly process.
- Construct series, parallel, and series-parallel circuits, and relate measured and calculated equivalent resistance.
- Prepare a well-developed written response to a customer complaint letter.
- Deliver an effective procedure speech.

Concept Map

Student Workshop Activities

- Resistors (color codes, power ratings, type, and percent error)
- Kirchhoff's voltage law
- Laser/light sources
- Document design (bulletins, letters, memos, and visual aids)
- Telephone etiquette
- Research citation
- Prototypes
- DC/AC source
- Sine waves
- Letter writing
- Visual/verbal support in oral reporting
- Team decision making
- Systems of equations
- Right triangle trigonometry

Notes to the Instructor, *continued*

6. Students should give oral presentations:
   - A. Present solutions to the project
   - B. Present process speeches to reinforce the concepts of presenting instructions/ processes.

Problem-Based Learning Know/Need-to-Know Chart		
What do we know?	What do we need to know?	How do we find out?

Student Assessment

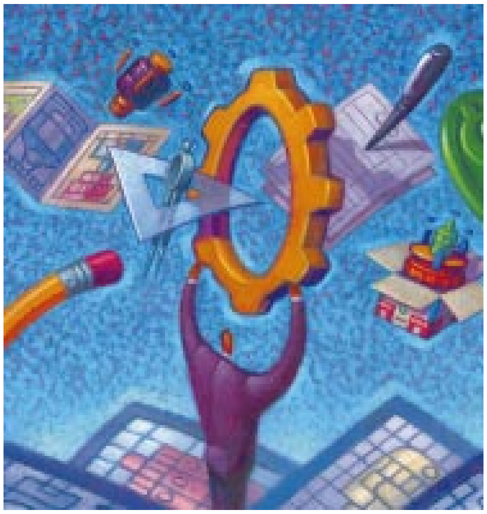
- Faculty teams will evaluate the written response to a customer complaint letter and the design, safety, and effectiveness of a test circuit that powers a laser pointer.
- Faculty will assess knowledge, skills, and performance in discipline-specific workshops, labs, and activities.
- Teaming skills and problem-solving skills will be evaluated by faculty, peers, and students' self-assessments.

Student Competencies

B.1.2.1 Apply standard color code to determine resistance and tolerance.
B.1.2.2 Use exponents, scientific notation, and engineering notation and prefix notation to express values of resistance.
B.1.3.1 Determine resistance for series, parallel, and series-parallel network of resistors.
B.1.3.2 Apply algebraic operations to series and parallel resistance equations for equivalent resistance to obtain unknown quantities.
B.2.2.2 Apply Kirchhoff's current law to circuits with multiple current paths.
B.3.1.1 Demonstrate a conceptual understanding of DC and AC voltage by proper use of sources in electrical circuits.
B.3.1.2 Apply Lenz's law and sine wave characteristics to describe AC voltage and generation.
B.3.1.3 Apply the concept of electrical potential and electrical potential difference to differentiate between voltage with respect to ground and voltage across a device.
B.3.1.4 Differentiate between AC and DC voltage.
B.3.2.3 Solve Ohm's law problems by algebraically manipulating Ohm's law equation for unknown quantities.
B.3.3.2 Relate Kirchhoff's voltage law to the conservation of energy and apply to solve network problems.
B.3.3.3 Apply systems of equations to solve multiple source circuits problems.
B.5.1.1 Demonstrate an understanding of power as the rate of change of energy in an electrical circuit by calculating the power dissipated in electrical components.
B.5.1.2 Solve power relationships for an unknown quantity.
B.6.1.1 Use appropriate instruments (voltmeter, ammeter, ohmmeter, multimeter, oscilloscope, etc.) to measure DC and AC voltage, current, and resistance, inductance, and capacitance.
B.6.2.1 Use appropriate electrical symbols to create electronic schematics.
B.6.2.2 Interpret schematic diagrams to identify electronic components and construct electrical circuits.
B.9.1.1 Employ problem solving skills to solve a team task.
B.9.1.2 Use appropriate human relations' skills.
B.9.1.3 Demonstrate various listening skills.
B.9.2.1 Use various media to obtain information.
B.9.2.2 Demonstrate engineering technology-appropriate computer skills.
B.9.2.3 Demonstrate ability to conduct primary/secondary research.
B.9.2.4 Collaborate with others to obtain information.
B.9.3.1 Format appropriate documents (letters, memos, manuals, reports).
B.9.3.2 Demonstrate the four C's of writing: clear, concise, correct, complete.
B.9.3.3 Revise written material.
B.9.3.4 Use appropriate organizational patterns.
B.9.3.5 Use appropriate engineering technology terminology.
B.9.3.6 Collaborate on the creation of written material.
B.9.3.7 Document written material.
B.9.3.8 Use computer programs to create/revise written material.
B.9.4.1 Apply appropriate organizational patterns (informative, persuasive).
B.9.4.2 Practice key workplace interpersonal skills.
B.9.4.3 Create various means of visual support (slides, PowerPoint, graphs).
B.9.4.5 Use computers or organize presentations.
B.9.5.1 Demonstrate professional delivery skills.
B.9.5.2 Use computers to make written and oral presentations.
B.9.5.3 Analyze audiences (setting, demographic, size).
B.9.5.5 Support presentation with appropriate visuals.

Integrated Skills

Data collection
Data analysis
Computer skills
Calculator skills
Teaming skills
Problem solving
Unit conversion



Engineering Technology Core
Electrical Module #3 — Student Handout

Voltage
Series/Parallel Circuits

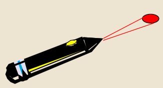
Problem Scenario

You are a technician at the Quick Snap Cable Company which makes flat flexible cable used in laser jet printers. The cable has electrical contacts crimped onto each end by a ten-ton press. The cable also has a blue indicator line on one side of the cable, which indicates the pin number of the cable. This cable must slide into the press with the blue line on the left side.

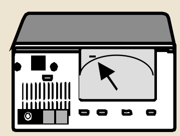
A customer has complained because he has received improperly assembled parts. You have received a copy of the complaint (see complaint letter, page 48) and must outline the points to be discussed in your initial communication with the client as a measure of goodwill. Before communicating with this customer, your team must also develop a proposed solution to this problem.

Additionally, a machine operator has suggested that your team place a laser onto the press, making the blue line more visible to the operator. Your team leader would like to test the feasibility of using a laser to evaluate the improvement in operations before installing a permanent system on each press. Your budget is limited and you will need to use available materials to test the new process. In the stock room you find the following items:

A battery operated laser pointer

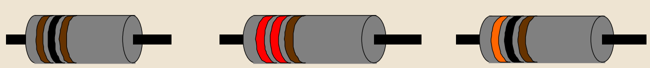


Single power supply



5V, 100 ma

Three values of resistors

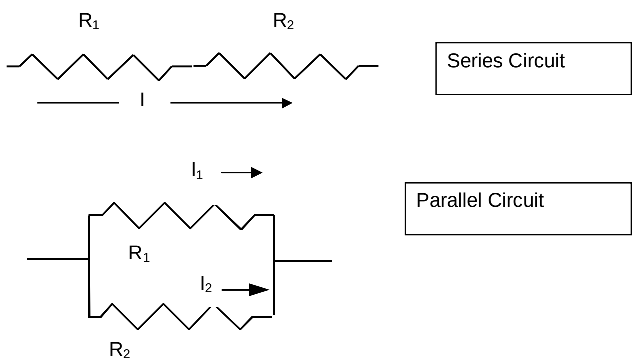


Your team must modify the laser pointer to accomplish the job. You should research and take into consideration any safety requirements for the use of the laser pointer. The system must have an on/off switch, a fuse, and a power-on indicator. Work with your team to design and build this test circuit. Your team also must prepare a written response to the customer's complaint, detailing all aspects of the solution to the problem. This response must have your supervisor's approval.

For training purposes, prepare a safety bulletin on the use of lasers and present this information orally with accompanying visual aids. As a final measure, provide written documentation of all proposed machine changes, including any appropriate schematics and a cost estimate.

Setting the Stage

In Electrical Modules 1 and 2, you determined the characteristics of resistance and current. You saw the need for a "driving force," i.e., voltage causing a current to flow through a resistor. You also investigated the basic relationship between voltage, current, and resistance, a relationship known as Ohm's law. Most electrical circuits, however, do not consist of a voltage source and a single element connected to that source; instead, several elements are connected in a circuit that is series, parallel, or a combination of the two. The diagram below shows a simple series and a simple parallel combination of resistors.



A circuit that has several elements connected one after the other so that the same current flows through each element is called a series circuit. A circuit that splits the current from a single path into several paths is called a parallel circuit. This kind of circuit was investigated in Electrical Module 2.

All electronic devices require power to operate and, therefore, need a power supply to provide voltage. Power supplies may be DC or AC and of various voltage and current capacities. In many cases, the required voltage and/or current rating for a device may not be readily available and some type of circuit must be constructed to provide the proper voltage. One means of obtaining the required voltage is to use a higher-than-needed source in series with a voltage-dropping resistor.

Objectives

- Adapt an existing laser device and power supply to facilitate observation in a cable assembly process.
- Construct series, parallel, and series-parallel circuits, and relate measured and calculated equivalent resistance.
- Prepare a well-developed written response to a customer complaint letter.
- Deliver an effective procedure speech.

Performance Expectations

- Students will be evaluated individually and in teams. The evaluation will include problem-solving and teaming skills used by students and student teams.
- Students will have opportunities for self evaluation, peer evaluation, and team evaluation.
- Individual instructors will test and grade students individually on the content of workshops and activities.
- Team products, such as response letter, safety bulletin, oral presentation, documentation, and schematics will be evaluated by faculty teams.

Complaint Letter

RAPID COMPUTER SYSTEMS
ONE TECHNOLOGY DRIVE
ATLANTA, GA 42356
October 30, 2001

J.F. COX
Operations Manager
SCATE Cable, Inc.
Highway 76
Pendleton, SC 29670

Dear Ms. Cox:

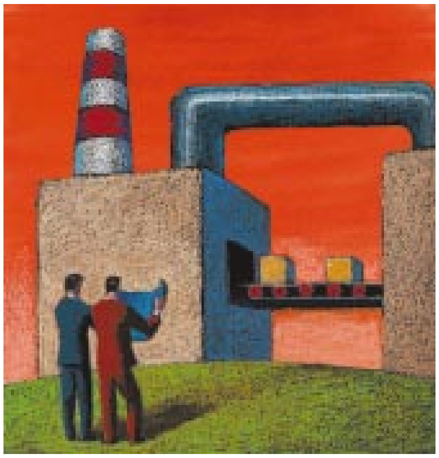
We are having a problem with your manufactured cable assemblies. We have had several of our computer systems fail our in-house functional tests. Inspection of those systems revealed that the cables were installed backward. We further determined that the cables were installed backward because they were assembled backward at your manufacturing facility.

This problem is continuing and shows no apparent pattern. There are a few backward cables randomly appearing from shipment to shipment. As a result, we have been forced to have our personnel inspect each cable before installing it. This additional task has caused a considerable slowdown in our production.

I need to know why this problem is occurring and how you plan to correct the problem. We cannot afford to delay production and will have no other choice but to end our contract with you if the problem is not resolved immediately.

Sincerely,

M. J. Holbrook
Purchasing Manager



Engineering Technology Core
Electrical Module #4

Capacitance

Timing Circuits

Problem Scenario for the Student

The section of the production line that attaches the anti-tamper shrink-wrap to the bottles containing contact lens cleaning solution has a visual inspection system. This visual system verifies that the cap on the bottle is completely closed before the wrap is applied to the cap. The system uses a video camera to capture a “still” picture of the bottle moving on the production line. To obtain a “still” picture, a strobe is flashed to illuminate the bottle and cap for a fraction of a second and the strobe gives the video the impression that the bottle is stationary. This picture is then digitized and compared to a properly capped bottled image.

The third-shift technician has discovered that the strobe unit is broken and has left you the memo below. All the accompanying documentation, however, is in Japanese. The schematic must be redrawn and a problem/solution documented to guide technicians in future repairs. (Use caution: A xenon bulb requires lethal power levels to perform properly.)

To: First Shift
From: Sara Jones
Subject: Broken Strobe

The production line is down, and I have found that the problem is a melted capacitor in the timing circuit for the strobe on the visual system. The strobe is from Japan, and a new one will take six (6) weeks to be made and shipped to the U. S.

I have removed the capacitor from the strobe unit. I could not read the value of the capacitor. I have repaired the problem that caused the capacitor to melt but did not have time to finish. Please finish repairing the strobe unit.

The strobe needs to flash at 1-second intervals.

Although the operation manual does not say much on safety with a xenon light, I hear that you need to be careful. Maybe you should check out the safety requirements.

Setting the Stage

In the first three projects, we have looked at measurements in an electrical circuit that is constant or steady state and does not have time dependence. In this project, we will investigate an electrical device that will have a time dependent voltage when a DC voltage is applied across the device. A capacitor is such a device. In a circuit, you can consider the capacitance of a circuit as the ratio between the charging current and the rate of change of voltage with time.

The most basic timing circuit used in industrial electronics is the capacitor/resistor combination. This circuit forms the basis for such functions as timing relays for motor starters, windshield wiper delay units, camera flash units, and capacitive sensors.

The time dependent characteristics of the voltage in a DC circuit can be used as a simple means of creating a timing device. This is one of the most basic timing circuits in industry.

Notes to the Instructor

1. To prepare students for solving a problem that includes timing, students should create a list of devices that use some type of timing in their operation. This listing can be done as a think-pair-share exercise. As a follow-up exercise, a list for the entire class can be created. The class also can be led to identify devices that use simple, inexpensive methods for timing and can discuss how the timer is created. Students should recognize that it is not necessary that all devices use digital timers.

2. Demonstrate a strobe to obtain stop action. After the demonstration, give the teams a description of the manufacturing operation and discuss the operation of a visual system. Then, give the students the memo from the third-shift technician and lead them through the "Know/Need to Know" chart. Items to be available during the introduction should include the following:
   a. Statement of job duties.
   b. Memo from third-shift technician.
   c. Company procedure on reporting repairs.
   d. Manual of operation for the strobe (minimal information on safety should be included).

Problem-Based Learning Know/Need-to-Know Chart

What do we know?	What do we need to know?	How do we find out?

3. Lead teams to develop a problem statement.

   Possible problem statement or definition:
   We, as first-shift technicians, must:
   - *Determine the value of a capacitor so that the strobe will flash every second.*
   - *Revise the operation manual to reflect changes.*
   - *Write about using xenon light sources safely.*

4. Students can discover the physical and electrical characteristics through experimental exploration. Graphing and mathematical analysis of exponential and logarithmic functions will help the students understand the physical and electrical characteristics. Students should have a brief introduction to electric fields in a parallel plate capacitor to aid in the understanding of the properties of capacitors.

5. Data from electrical circuits can be graphed and used to investigate exponential and logarithmic functions so that the time constant equation for voltage with a capacitor can be determined.

6. The focus of this project is to understand capacitors and to develop a safety report on high voltage and xenon lights. Students can be introduced to the technique of looking at the strobe as a black box that needs voltage to rise to the value that the xenon light fires in one second. They need only develop a simple resistance-capacitor combination for the voltage source to reach operating voltage in one second.

7. Students should use the Web to research safety of xenon lights and high voltage and prepare a safety document to be supplied with the repaired device.

Content Strands

Physics
Physical characteristics of capacitors
Electrical characteristics of capacitors
Capacitors in series and parallel

Mathematics
Exponential and logarithmic functions
Linear equations

Technology
Xenon lights
RC circuits
Schematics

Communications
Internet research — xenon light safety, high voltage
Document preparation

Objectives

- Determine the value of a capacitor so that a strobe will flash at 1-second intervals.
- Research and write a safety report on high voltage and xenon lights.

Concept Map

Student Workshop Activities

- Capacitance (physical and electrical)
- Capacitor in series and parallel
- Electrical fields
- RC circuits
- Xenon light characteristics and safety
- Linear equations — revisited
- Exponential and logarithmic functions
- Graphing calculators
- Internet use
- Follow-up letters
- Documentation
- Library orientation
- Document design

Student Assessment

- Faculty teams will evaluate safety reports produced by teams.
- Faculty will assess team solutions, including calculations and schematics.
- Faculty will assess knowledge, skills, and performance in discipline-specific workshops, labs, and activities.
- Teaming skills and problem-solving skills will be evaluated through faculty, peer, and student self-assessments.

Student Competencies

B.2.1.1 Demonstrate the conceptual understanding of current as the rate of flow of charge.
B.3.1.3 Apply the concept of electrical potential and electrical potential difference to differentiate between voltage with respect to ground and voltage across a device.
B.3.2.3 Solve Ohm's law problems by algebraically manipulating Ohm's law equation for unknown quantities.
B.3.3.2 Relate Kirchhoff's voltage law to the conservation of energy and apply to solve network problems.
B.4.1.2 Determine the time constant and charging rate for capacitors, and relate to graphic data.
B.4.1.3 Express charging and discharging in a capacitor as exponential growth and decay.
B.6.1.1 Use appropriate instruments (voltmeter, ammeter, ohmmeter, multimeter, oscilloscope, etc.) to measure DC and AC voltage, current, and resistance, inductance, and capacitance.
B.6.2.1 Use appropriate electrical symbols to create electronic schematics.
B.6.2.2 Interpret schematic diagrams to identify electronic components and construct electrical circuits.
B.7.1.1 Describe an electric field in terms of charge(s) and distance from the charge(s).
B.7.1.2 Relate electric fields to potential difference and determine electric fields via measurements of potential differences.
B.7.1.3 Differentiate between positive and negative electric charges.
B.7.1.4 Calculate the amount of electrical field energy contained in a capacitor.
B.7.1.5 Describe the force exerted on an electric charge by an electric field.
B.7.1.6 Express electric fields in SI units.
B.9.1.1 Employ problem solving skills to solve a team task.
B.9.1.2 Use appropriate human relations skills.
B.9.1.3 Demonstrate various listening skills.
B.9.2.1 Use various media to obtain information.
B.9.2.2 Demonstrate engineering-technology-appropriate computer skills.
B.9.2.3 Demonstrate ability to conduct primary/secondary research.
B.9.2.4 Collaborate with others to obtain information.
B.9.2.5 Document research information.
B.9.3.1 Format appropriate documents (letters, memos, manuals, reports).
B.9.3.2 Demonstrate the four C's of writing: clear, concise, correct, and complete.
B.9.3.3 Revise written material.
B.9.3.4 Use appropriate organizational patterns.
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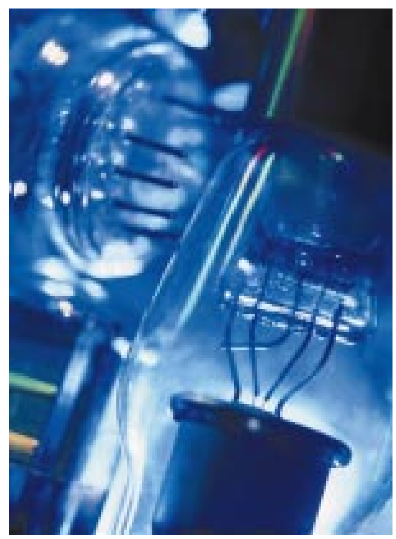
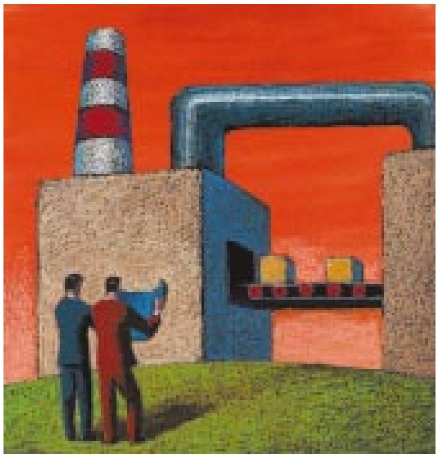
B.9.3.6 Collaborate on the creation of written material.
B.9.3.7 Document written material.
B.9.3.8 Use computer programs to create/revise written material.
B.9.5.2 Use computers to make written and oral presentations.
B.9.5.3 Analyze audiences (setting, demographic, size).
B.9.5.4 Define the purpose of presentations.
B.9.5.5 Support presentation with appropriate visuals.

Integrated Skills

Data collection
Data analysis
Computer skills
Calculator skills
Teaming skills
Problem solving
Unit conversion





Engineering Technology Core
Electrical Module #4 — Student Handout

Capacitance
Timing Circuits

Problem Scenario

The section of the production line that attaches the anti-tamper shrink-wrap to the bottles containing contact lens cleaning solution has a visual inspection system. This visual system verifies that the cap on the bottle is completely closed before the wrap is applied to the cap. The system uses a video camera to capture a “still” picture of the bottle moving on the production line. To obtain a “still” picture, a strobe is flashed to illuminate the bottle and cap for a fraction of a second and the strobe gives the video the impression that the bottle is stationary. This picture is then digitized and compared to a properly capped bottled image.

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Although the operation manual does not say much on safety with a xenon light, I hear that you need to be careful. Maybe you should check out the safety requirements.

Setting the Stage

In the first three projects, you have looked at measurements in an electrical circuit that is constant or steady state and does not have time dependence. In this project, you will investigate an electrical device that will have a time dependent voltage when a DC voltage is applied across the device. A capacitor is such a device. In a circuit, you can consider the capacitance of a circuit as the ratio between the charging current and the rate of change of voltage with time.

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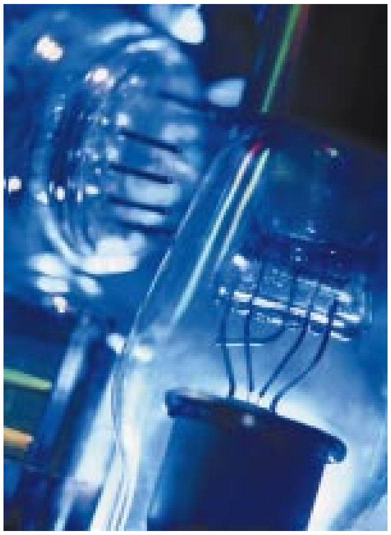
Performance Expectations

- Students will be evaluated individually and in teams. The evaluation will include problem-solving and teaming skills used by students and student teams.
- Students will have opportunities for self evaluation, peer evaluation, and team evaluation.
- Individual instructors will test and grade students individually on the content of workshops and activities.
- Team products, such as cover memo, description of problem/solution, circuit schematics, and calculations will be evaluated by faculty teams.



Objectives

- Determine the value of a capacitor so that a strobe will flash at 1-second intervals.
- Research and write a safety report on high voltage and xenon lights.

Engineering Technology Core
Electrical Module #5

Impedance

Power Factor for Electrical Installations

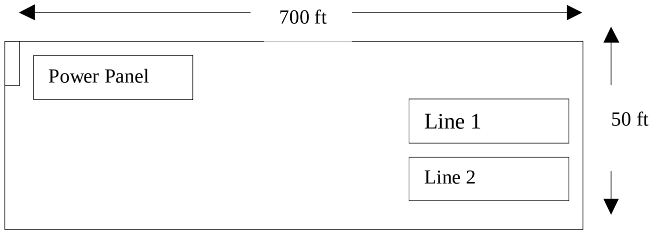
Problem Scenario for the Student

You are a technician at a plant that builds cabinets for electronic equipment. The manufacturing process involves shearing sheet metal, stamping openings for insertion of meters and other electronic equipment, bending the sheet metal, and assembling the equipment into the cabinet.

In the past, your company has had two plants assembling the cabinets: your plant and the Western Range plant located near the West Coast. Because of increased production efficiency and better transportation, your company has decided to consolidate the operation at a single location as a cost-saving move.

Your plant has been selected to be the one remaining in operation. The equipment from the other plant is to be moved to your plant to increase production. Your team has been asked to develop plans for the installation of the 20 stamping machines (punch motor) that will include electrical installation. Not all of the machines will be used continuously because of different production levels on each shift.

You also have been told the location of the lines in the plant and that you need to have a power factor of 90 percent or better. The location in the plant will be 750 feet from the main distribution panel. The only additional information that you have been given is this small sketch of the assembly line. You will need to contact the technician in the other plant and obtain the information needed to determine the cabling requirements and how to correct the power factor if necessary.



Setting the Stage

Resistors, conductors, and capacitors exhibit different frequency responses when alternating current flows through them. The response of a circuit containing resistors, inductors, and capacitors to a sinusoidal voltage has a special relationship of an "opposing" characteristic of each element.

This "opposing" action is a result of the inductor and capacitor, in contrast to the resistor, being sensitive to the frequency of the applied voltage. As seen in the last module, the voltage and the current flow through a capacitor are not in phase with each other.

This shift in the relationship of the voltage and current has an effect on the power consumption and power supplied to a device that has inductive or capacitive reactions. For maximum power to be delivered, it is desirable to have the voltage and current in phase at the device.

In a manufacturing production line, the motors are inductive and thus create a power factor problem that needs to be corrected. The work in this project will investigate the correction of power factors for production lines.

Notes to the Instructor

1. Prepare the students for this project by giving them the hourly power demands for a local power company on a heavy demand day. The teams should discuss the company's production rate and how it meets peak demands. Students should be told that the power companies want to operate their plants at a constant load. Discuss how they meet peak load demands.
2. Give the students a bill from a local power company. The students should determine which electrical quantity is being billed.
3. Introduce the project by role playing a plant announcement for the moving of the operation. Tell the class that teams have been assigned to plan the installation of several operations. They are to plan the installation of the stamping operation. Teams are to ensure that the power factor will be 90 percent or greater. They will be given some information on the motors, but it may not be complete. Give them the specifications for punch motor 1.
4. In this project, students must determine the information needed to complete the calculations and request that information. From the table below, students will be given what is known. The table includes data for the whole line. Students are to be assigned only one motor from the list. This would allow each team to work with different data. Student will be given only data that is requested by specific name, i.e., what is the current, what is the power, etc.

Line 1

	Conveyer Motor	Bending Motor	Shear Motor
Voltage (V)	440	440	440
Phase	3	3	3
Horsepower	20	60	100
Current (amps)	23	72	96
Code	C	J	A
Z (ohms)			4.583
X_L (ohms)	11.873	3.513	
R (ohms)	15	5	
Power Factor			87%

Line 2

	Punch Motor 1	Punch Motor 2	Conveyor Motor
Voltage (V)	440	440	440
Phase	3	3	3
Horsepower	125	185	10
Current (amps)	115	185	42
Code	J	A	B
Z (ohms)	3.83		10.476
X_L (ohms)			
R (ohms)	2	2.5	5.42
Power Factor		80%	

Problem-Based Learning Know/Need-to-Know Chart

What do we know?	What do we need to know?	How do we find out?

Content Strands

Physics
Magnetism
Impedance
Inductors
Phase shift

Mathematics
Right triangle trigonometry
Sine waves
Complex numbers
Maximum of a function

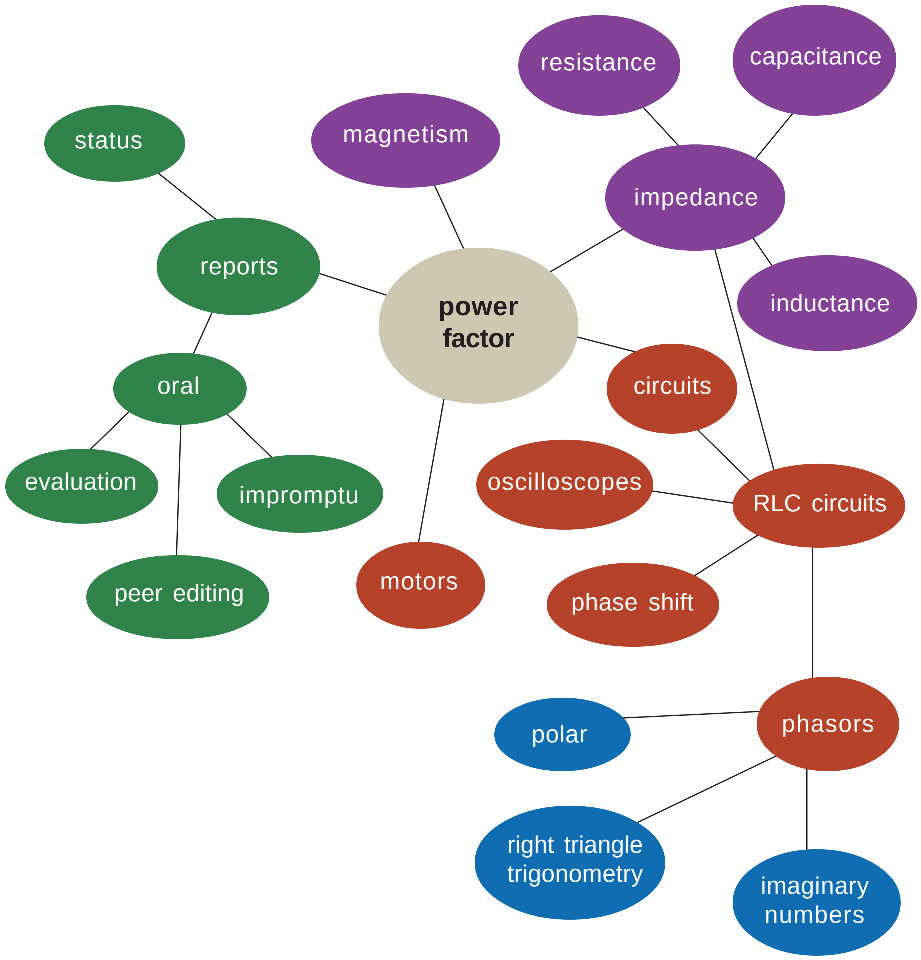
Technology
Motors
Oscilloscopes
RLC circuits
Input devices
Circuit emulators and schematics

Communications
Status reports
Oral reports incorporating visuals
Oral peer editing
Impromptu speaking
Evaluating presentations

Objectives

- Develop a plan for the electrical installation of 20 stamping machines on a production line.
- Develop an effective informative speech by incorporating and correctly citing source material.

Concept Map



Student Workshop Activities

- Right triangle trigonometry
- Complex numbers
- AC and sine waves
- Phase shift
- Motors
- Oscilloscopes
- Circuit emulators and schematics
- Characteristics of inductors
- Magnetism
- Impedance
- RLC circuits
- Progress reports
- Peer evaluations of presentations

Student Assessment

- Faculty teams will evaluate electrical installation plans produced by teams.
- Faculty teams will evaluate written documentation and oral presentations.
- Teaming skills and problem-solving skills will be evaluated by faculty, peers, and students' self-assessments.

Student Competencies

B.1.2.2 Use exponents, scientific notation, and engineering notation and prefix notation to express values of resistance.
B.4.2.1 Demonstrate an understanding of inductance as related to physical properties of the device.
B.4.2.3 Determine inductive reactance and phase shift for ideal/real inductor.
B.4.3.1 Determine the impedance of an RLC circuit and the phase relationship of voltage and current to each component.
B.5.1.2 Solve power relationships for unknown quantity.
B.6.1.1 Use appropriate instruments (voltmeter, ammeter, ohmmeter, multimeter, oscilloscope, etc.) to measure DC and AC voltage and current, resistance, inductance, and capacitance.
B.6.2.1 Use appropriate electrical symbols to create electronic schematics.
B.6.2.2 Interpret schematic diagrams to identify electronic components and construct electrical circuits.
B.7.1.2 Relate electric fields to potential difference and determine electric fields via measurements of potential differences.
B.7.2.1 Describe a magnetic field in terms of moving charge(s) and distance from the moving charge(s).
B.7.2.2 Determine magnetic field direction by use of magnetic compasses.
B.7.2.3 Differentiate between north and south poles of a magnet.
B.7.2.4 Calculate the amount of magnetic field energy contained in an inductor.
B.7.2.5 Describe the force exerted on a moving electric charge by a magnetic field.
B.7.2.6 Express magnetic fields in SI units.
B.7.3.1 Describe how a changing magnetic field gives rise to an electric field (Faraday's Law).
B.7.3.2 Describe how a changing electric field gives rise to a magnetic field (Ampere's Law).
B.7.3.3 Use transformers to change voltages and electric currents.
B.7.3.4 Examine a generator to witness how a changing magnetic field creates an electromotive force.
B.8.1.1 Define the frequency and angular frequency of a wave.
B.8.1.2 Define the wavelength of a wave.
B.8.1.3 Define the amplitude of a wave.
B.8.1.4 Define the wave speed of a wave and relate it to the frequency and wavelength of a wave.
B.8.2.1 Define sine, cosine, and tangent functions.
B.8.2.2 Graph sine and cosine waves as a function of an angle.
B.8.2.3 Convert units between radians and degrees.
B.8.2.4 Describe the phase change both physically and mathematically.
B.8.2.5 Write and/or read a wave equation and determine the wave's properties from the equation.
B.9.1.1 Employ problem solving skills to solve a team task.
B.9.1.2 Use appropriate human relations skills.
B.9.1.3 Demonstrate various listening skills.
B.9.2.1 Use various media to obtain information.
B.9.2.2 Demonstrate engineering-technology-appropriate computer skills.
B.9.2.3 Demonstrate ability to conduct primary/secondary research.
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B.9.4.5 Use computers to organize presentations.
B.9.5.1 Demonstrate professional delivery skills.
B.9.5.2 Use computers to make written and oral presentations.
B.9.5.3 Analyze audiences (setting, demographics, size).
B.9.5.4 Define the purpose of presentations.

Integrated Skills

Data collection
Data analysis
Computer skills
Calculator skills
Teaming skills
Problem solving
Unit conversion

Engineering Technology Core
Electrical Module #5 — Student Handout

Impedance
Power Factor for Electrical Installations

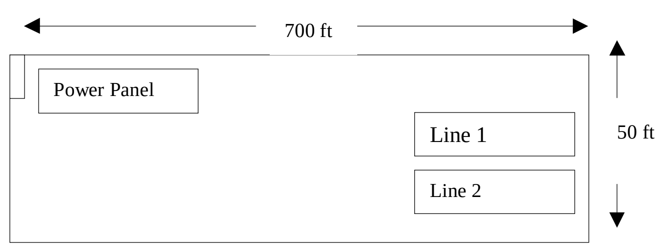
Problem Scenario

You are a technician at a plant that builds cabinets for electronic equipment. The manufacturing process involves shearing sheet metal, stamping openings for insertion of meters and other electronic equipment, bending the sheet metal, and assembling the equipment into the cabinet.

In the past, your company has had two plants assembling the cabinets: your plant and the Western Range plant located near the West Coast. Because of increased production efficiency and better transportation, your company has decided to consolidate the operation at a single location as a cost-saving move.

Your plant has been selected to be the one remaining in operation. The equipment from the other plant is to be moved to your plant to increase production. Your team has been asked to develop plans for the installation of the 20 stamping machines (punch motor) that will include electrical installation. Not all of the machines will be used continuously because of different production levels on each shift.

You also have been told the location of the lines in the plant and that you need to have a power factor of 90 percent or better. The location in the plant will be 750 feet from the main distribution panel. The only additional information that you have been given is this small sketch of the assembly line. You will need to contact the technician in the other plant and obtain the information needed to determine the cabling requirements and how to correct the power factor if necessary.



Setting the Stage

Resistors, conductors, and capacitors exhibit different frequency responses when alternating current flows through them. The response of a circuit containing resistors, inductors, and capacitors to a sinusoidal voltage has a special relationship of an "opposing" characteristic of each element.

This "opposing" action is a result of the inductor and capacitor, in contrast to the resistor, being sensitive to the frequency of the applied voltage. As seen in the last project, the voltage and the current flow through a capacitor are not in phase with each other.

This shift in the relationship of the voltage and current has an effect on the power consumption and power supplied to a device that has inductive or capacitive reactions. For maximum power to be delivered, it is desirable to have the voltage and current in phase at the device.

In a manufacturing production line, the motors are inductive and thus create a power factor problem that needs to be corrected. The work in this project will investigate the correction of power factors for production lines.

Performance Expectations

- Students will be evaluated individually and in teams. The evaluation will include problem-solving and teaming skills used by students and student teams.
- Students will have opportunities for self evaluation, peer evaluation, and team evaluation.
- Individual instructors will test and grade students individually on the content of workshops and activities.
- Team products, such as cover memo, installation plan, circuit schematics, and calculations will be evaluated by faculty teams.

Objectives

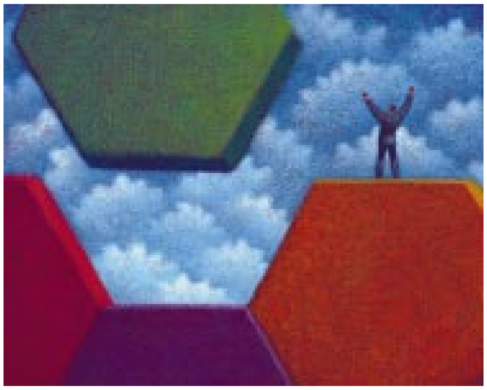
- Develop a plan for the electrical installation of 20 stamping machines on a production line.
- Develop an effective informative speech by incorporating and correctly citing source material.

Line 1

	Conveyer Motor	Bending Motor	Shear Motor
Voltage (V)	440	440	440
Phase	3	3	3
Horsepower	20	60	100
Current (amps)	23	72	96
Code	C	J	A
Z (ohms)			4.583
X_L (ohms)	11.873	3.513	
R (ohms)	15	5	
Power Factor			87%

Line 2

	Punch Motor 1	Punch Motor 2	Conveyor Motor
Voltage (V)	440	440	440
Phase	3	3	3
Horsepower	125	185	10
Current (amps)	115	185	42
Code	J	A	B
Z (ohms)	3.83		10.476
X_L (ohms)			
R (ohms)	2	2.5	5.42
Power Factor		80%	



Engineering Technology Core
Thermal Expansion Module

Thermal Expansion

Assembling Metal Plate & Shaft

Problem Scenario for the Student

A local job shop has just been awarded a contract to supply a lawn mower plate and axle assembly during peak times, and the company's owner is seeking advice from your team on planning the assembly operation and modification of a storage space to do the assembly. The operation will require an operator to be present at all times.

There are CAD drawings of the plate and axle assembly and of the floor plans for the job shop. The team is asked to consider:

- How to assemble the axle to the plate.
- How to produce 400 units per day.
- That the process in the job shop is a batch process.
- That the local plant uses a thermal process to insert the axle into the plate.
- That the local plant uses a continuous flow furnace to heat the plate for up to 350^o C.
- That the storage room has an air supply that now maintains the room at 80^o F with an air supply of 2,000 CFM with an exit temperature of 60^o F.

The team also is expected to provide a report of the findings, including a detailed technical description of the process for assembly and drawings as necessary.

Setting the Stage

The concept of temperature is difficult to explain. Although we all know that it is cold in the winter and hot in the summer and we know what feels hot or cold to us, this does not explain temperature. We do know that temperature is a measure of the "hotness" or "coldness" of a substance, but this is not a physical definition of temperature. In order to understand temperature we must turn to atomic theory of matter.

As energy is added to a substance, kinetic energy of the atoms is increased and we sense that the substance is hotter or that the temperature has increased. Therefore, we conclude that temperature is related to the energy of the atoms. More exactly, temperature is defined as the average kinetic energy of the molecules of the object. For a gas or liquid this kinetic energy results in a random atomic or molecular motion and for a solid this energy results in a vibration of the atom or molecule about a fixed position.

Heat on the other hand is the energy that flows to or from an object. Heat then flows from a higher temperature substance to a lower temperature substance. If we speak of the heat in a substance, we are then referring to total kinetic energy of the substance.

When substances are heated and the motion increases this causes other physical property changes. For a gas, this may result in an increase in pressure or volume depending on the nature of the container. Generally, for liquids and solids the result is an increase in the volume. This thermal expansion is used in many devices that are used to measure temperature. The common liquid-in-glass thermometer uses the larger expansion of the liquid to increase the height of the column in the glass container. Other thermometers use changes in physical properties to indicate temperatures. Because thermometers use a change in a physical property they must be calibrated according to a set of rules.

Notes to the Instructor

1. To orient the student to the problem, assign teams to do a jigsaw on classifications of manufacturing industries (i.e., project, job shop, repetitive, etc.) with the number of types depending on the number of team members. Be sure to include job shop as one of the classifications. Students can investigate the changing work environment in the past century and the EPA and OSHA regulations related to the work environment.

2. The problem may be introduced by having an industry representative play the role of a manufacturing engineer and give students the instructions for the work that the team will be charged to do. The introduction could be via a videotape taken in an industry with the representative describing how the job shop operates and then giving the instructions. The restatement of the problem (see the following page) may be used. A description of the ways other companies are attaching the plate is needed. The following material should be made available to the teams.

   CAD drawing of plant
   CAD drawing of assembly
   Scale model of parts
   Manufacturing engineering process sheet
   Data on HVAC in the room

.

   For future questions, the manufacturing engineer (this could be a member of the teaching team) could be "contacted" by fax or e-mail . Students may question why they were asked to look at alternate methods to attach the plate. There are several reasons that might be given, such as:
   1) It is always good to consider alternate methods and to think "outside the box" to see if there is a better way to solve the problem.
   2) They should ask how others have solved the problem.
   3) Looking at alternate methods that do not work will help them understand why the selected method was chosen.
   4) Students will not question the method nor complain that they know a better way.

Continued on next page

Content Strands

Physics

Temperature and temperature scales
Sensible and latent heat
Thermal expansion
Heat transfer

Mathematics

Linear equations
Solving formulas
Exponents
Exponential decay

Technology

Manufacturing facilities
Heat loading
Introduction to HVAC
Manufacturing process

Communications

Informative speeches
Jigsaw on thermal elements
Reports on research results

Objectives

- Apply thermal properties of matter to a metal plate and shaft assembly.
- Determine coefficients of linear, area, and volume expansion.
- Describe characteristics of manufacturing systems or types, such as job shop, project, repetitive, line, and continuous.
- Determine impact of heating processes on room temperature and HVAC (heating, ventilation, and air conditioning) systems.
- Research and report thermal properties of materials.

3. Students should construct a Know/Need-to-Know (KNK) chart. Below is a possible chart that they may construct.

What do we know ?	How do we know it?	What you think you know?	What do we need to know?
Material of parts	Engineering drawing		Safety requirement
Dimension of parts	Engineering drawing		Comfort level
Dimension of room	Plant layout		Who are the operators?
Production rate	Management team criteria	You need to heat the plate	How do we attach the plate to the axle?
		Parts cannot be redesigned	What can change comfort level?
			How do we maintain comfort level?
			What does design mean?

Possible problem statement or definition:

How can we as engineering technicians propose/design a place and process to attach a metal plate to a wheel axle in such a way that:

- It meets production rate (number to be produced per unit of time).
- It uses existing space.
- It maintains comfort and safety levels for operators.
- It eliminates internal residual machine stresses.
- Parts are not redesigned.
- It meets budget limitations.

4. Student teams can be assigned a jigsaw exercise to investigate the three thermal properties (sensible/latent, linear expansion, and heat transfer by conduction) needed for the solution to the problem. After each team has completed its investigation, each will instruct the other teams so that all students understand these concepts as they relate to solving the problem.

5. The time allotted for this project does not permit students to experimentally determine all the information needed to solve the problem. Once they arrive at using thermal expansion to attach the plate, they can be given data (temperature to heat, time to leave in the furnace, and how long to cool) from other sites that are attaching the plate.

Furnace temperature	200 to 500^{o} C
Soak time	15 minutes
Production rate	400 per day

6. During or after workshops, teams should revisit and refine the KNK chart and the concept map to move toward the solution.

7. Students can calculate the additional heat load in the room resulting from the furnaces and supply the values to the company's maintenance personnel to determine change in the cooling. If this is done, they could be shown the possible solutions and discuss the options. If time permits, they could do the HVAC calculations.

Comments:

Plate Assembly Solution

1. Students may first focus on the mechanism or procedure for the insertion of the shaft into the plate. If so, then they should be guided to understand that once inserted, the shaft will not remain in the plate unless clamped in some manner. Also, they should understand that before they can decide on the mechanism or procedure, they need to know how the shaft will be held in the plate.
2. They should know from the drawing that they will have to force the shaft into the plate or modify the plate/shaft to make it easy to insert.
3. They can brainstorm methods on how to make the shaft easy to insert into the plate or they may know that the size of the shaft and plate can be modified by a temperature change. Since this is an operation that is being done in another plant, the students should be led to ask: "**How is the shaft being inserted now**?"
4. Students can be given several workshops on thermal properties of matter.

Suggested Workshop Topics:

PHYSICS
Temperature and temperature scales
Temperature and Heat Jigsaw on:
- Sensible and latent heat
- Thermal expansion
- Heat transfer – conduction measurements, discussion of convection and radiation

TECHNOLOGY
Manufacturing facilities
Heat Loading
HVAC (introduction)
Manufacturing process

MATHEMATICS
Solving linear equations
Graphing and reading graphs
Solving formulas
Literal equations
Exponential decay
Conversion between systems
Exponents
Natural logs

COMMUNICATIONS
Informative speeches
Jigsaw on thermal elements
Reports on research results

A. The definitions of the major temperature scales can be used to determine a linear equation from two points and develop the conversion formula between Celsius and Fahrenheit.
B. By using various masses of water at various temperatures, the difference between heat and temperature can be investigated.
C. The determination/deduction of the effect of specific heat can be used to lead to the functional relationship of heat, specific heat, mass, and temperature change.
D. Data on the linear thermal expansion can be collected and then graphically and mathematically analyzed to determine the relationship between expansion and temperature. Different materials can be used to relate the coefficient of linear expansion to the type of material.
E. Students can determine the coefficient of area and volume expansion from linear expansion.
F. Investigation of the heat loss of water in a styrofoam cup can be used to study the thermal conduction and surface area of a conic section.
G. CBL/MBL experiments on Newton's cooling law will give the students an understanding of the cooling of the plate once it is removed from the oven. Students could investigate the cooling curve to mathematically model the cooling and process discuss asymptotes, exponential decay, and natural logarithms.
H. Investigation of heat transfer by convection and radiation is difficult to understand and could be presented in a mini-lecture.
I. Students can apply the knowledge gained to determine the necessary temperature for heating the plate or cooling the shaft.

5. Students can now arrive at the conclusion that the optimal operation is to heat a plate. They may determine from a machinist that they need only the diameter to be one- to two-thousandth oversized to make a fit. (Students could be given a series of plates with different diameter holes to make this determination.) The plates are to be heated in a batch process and can be heated in an oven (a high temperature oven is not needed). It will require modification of the HVAC system for the room. They will not have time to determine the changes. It could be stated that this information would be given to another team to determine the modifications.
6. Students need to see that there should be a jig to insert the shaft so that the shaft is aligned as shown and is perpendicular to the plate. They may design the jig to ensure proper registration.
7. Students should understand that the solution of how to insert the shaft leads to other problems such as proper alignment and the comfort of the room.

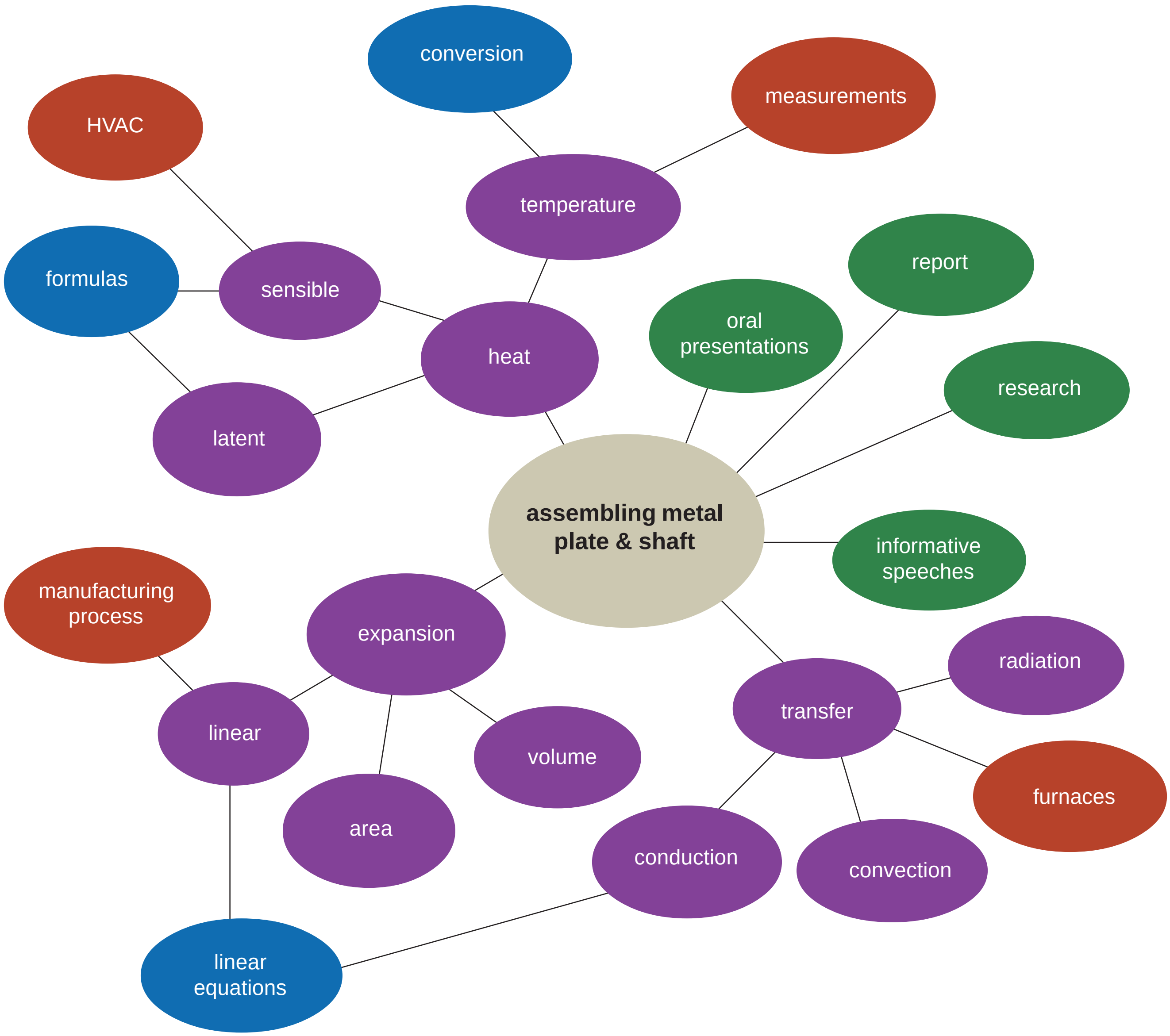
Student Competencies

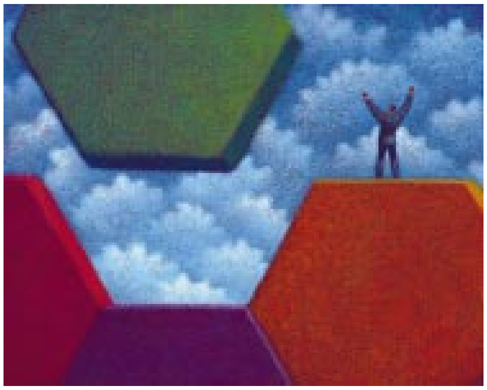
E.1.1.1 Demonstrate a conceptual understanding of temperature, heat, and energy by distinguishing between them.
E.1.1.2 Use appropriate devices to measure temperature in Celsius and Fahrenheit systems and convert between the two.
E.1.1.3 Explain the application of conservation of energy to thermal processes.
E.1.1.4 Use algebraic operations to determine the unknown quantity in the heat loss–heat gained equation.
E.1.1.5 Graphically analyze cooling/heating curves to deduce the functional relationship between time, temperature, and rate.
E.1.2.1 Demonstrate a conceptual understanding of latent heat by relating phase changes to energy loss or gain.
E.1.2.2 Calculate the energy associated with a phase change.
E.1.2.3 Describe evaporation, condensation, and sublimation.
E.2.1.1 Use appropriate data acquisition devices to obtain linear expansion measurements.
E.2.1.2 Plot linear expansion data and write a linear function for the relationship between temperature and length.
E.2.1.3 Solve the linear equation of temperature and length for unknown quantities.
E.2.2.1 Determine the coefficient of area expansion from linear expansion coefficient.
E.2.2.2 Determine area expansion.
E.2.3.1 Determine the coefficient of volume expansion from linear expansion coefficient.
E.2.3.2 Determine deferential volume expansion for a fluid in a solid container.
E.3.1.1 Demonstrate a conceptual understanding of thermal conduction by distinguishing between thermal conductors and thermal insulators.
E.3.1.2 Graphically analyze the relationship of the effect of length, cross-sectional area, and type of material on thermal resistance.
E.3.1.3 Apply algebraic operations to determine the unknown quantity in the thermal conduction equation.
E.3.1.4 Use the R-factor to describe the relative relationship of thermal insulator.
E.3.2.1 Demonstrate conceptual understanding of thermal convection by relating surface characteristics, shape, and orientation to convection properties.
E.3.2.2 Differentiate between natural and forced convection.
E.3.3.1 Demonstrate a conceptual understanding of thermal radiation by describing black body radiation.
E.3.3.2 Use the Stefan-Boltzmann equation to determine radiation energy from an object.
E.3.3.3 Use appropriate devices to obtain temperature from radiating objects.
E.4.1.1 Demonstrate ability to conduct primary/secondary research.
E.4.1.2 Collaborate with others to obtain information.
E.4.1.3 Document research information.
E.4.2.1 Apply appropriate organizational patterns (informative, persuasive).
E.4.2.2 Create various means of visual support (slides, PowerPoint, graphs).
E.4.3.1 Demonstrate professional delivery skills.
E.4.3.2 Define the purpose of presentations.
E.4.3.3 Support presentation with appropriate visuals.

Integrated Skills

Data collection
Data analysis
Computer skills
Calculator skills
Teaming skills
Problem solving
Unit conversion

Concept Map


conversion
measurements
HVAC
temperature
report
formulas
sensible
oral presentations
heat
research
latent
assembling metal plate & shaft
informative speeches
manufacturing process
expansion
radiation
transfer
linear
volume
furnaces
area
conduction
convection
linear equations



Engineering Technology Core
Thermal Expansion Module — Student Handout

Thermal Expansion

Assembling Metal Plate & Shaft

Problem Scenario

A local job shop has just been awarded a contract to supply a lawn mower plate and axle assembly during peak times, and the company's owner is seeking advice from your team on planning the assembly operation and modification of a storage space to do the assembly. The operation will require an operator to be present at all times.

There are CAD drawings of the plate and axle assembly and of the floor plans for the job shop. The team is asked to consider:

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- How to produce 400 units per day.
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- That the local plant uses a continuous flow furnace to heat the plate for up to 350° C.
- That the storage room has an air supply that now maintains the room at 80° F with an air supply of 2,000 CFM with an exit temperature of 60° F.

The team also is expected to provide a report of the findings, including a detailed technical description of the process for assembly and drawings as necessary.

Performance Expectations

- ❑ Instructors will evaluate student teams and students individually, including problem solving and teaming skills.
- ❑ Students will have opportunities for self evaluation, peer evaluation, and team evaluation.
- ❑ Instructors will test and evaluate individual student performance on the content of workshops and participation in class activities.
- ❑ Team products will be evaluated by faculty teams.

Objectives

- ◆ Apply thermal properties of matter to a metal plate and shaft assembly.
- ◆ Determine coefficients of linear, area, and volume expansion.
- ◆ Describe characteristics of manufacturing systems or types, such as job shop, project, repetitive, line, and continuous.
- ◆ Determine impact of heating processes on room temperature and HVAC systems.
- ◆ Research and report thermal properties of materials.

Campbell Machining Company
PO Box 5482, Columbia, SC 24612
803-555-6111 fax: 803-555-6217 www.campbellco.com

February 9, 2001

Engineering Support Consultants
1200 W. Evans Street
Florence, SC 29501

Dear Mr. Hui:

Campbell Machining Company, a midsize job shop specializing in industrial assembly, has just received a contract and would like for your team of technicians to assist us in developing an assembly process that our company would use.

The contract requires us to machine and assemble a plate and shaft assembly for a local lawn mower manufacturer during their peak production time so that they do not have to add a second shift operation. We will be providing manufacturing outsourcing for up to 400 assemblies per day once a month over a three-month period. The orders will be on short notice and the turn around time would be two days.

We have the equipment to machine the parts. However, as we gear up for this new contract, we would request that your team make recommendations on assembly equipment, the assembly process that would be best for the insertion procedure, and the conversion of a storage area into the assembly space.

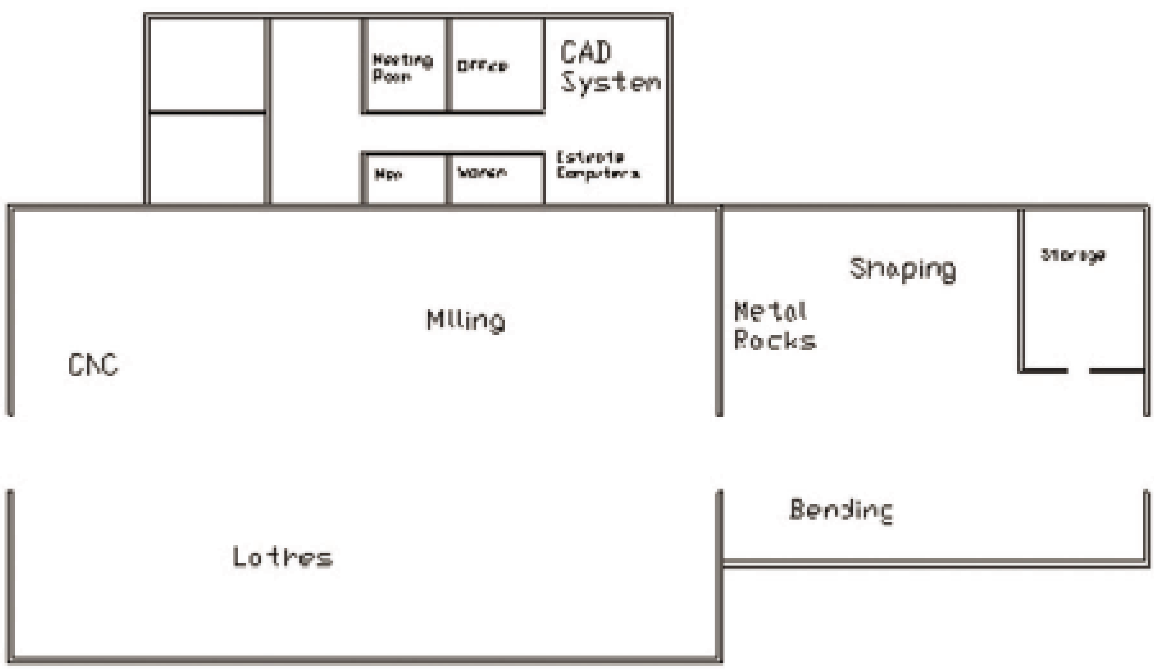
Please call me at 803-555-6111 to set up a time when you can meet with me on site to see our current operation and to discuss this project.

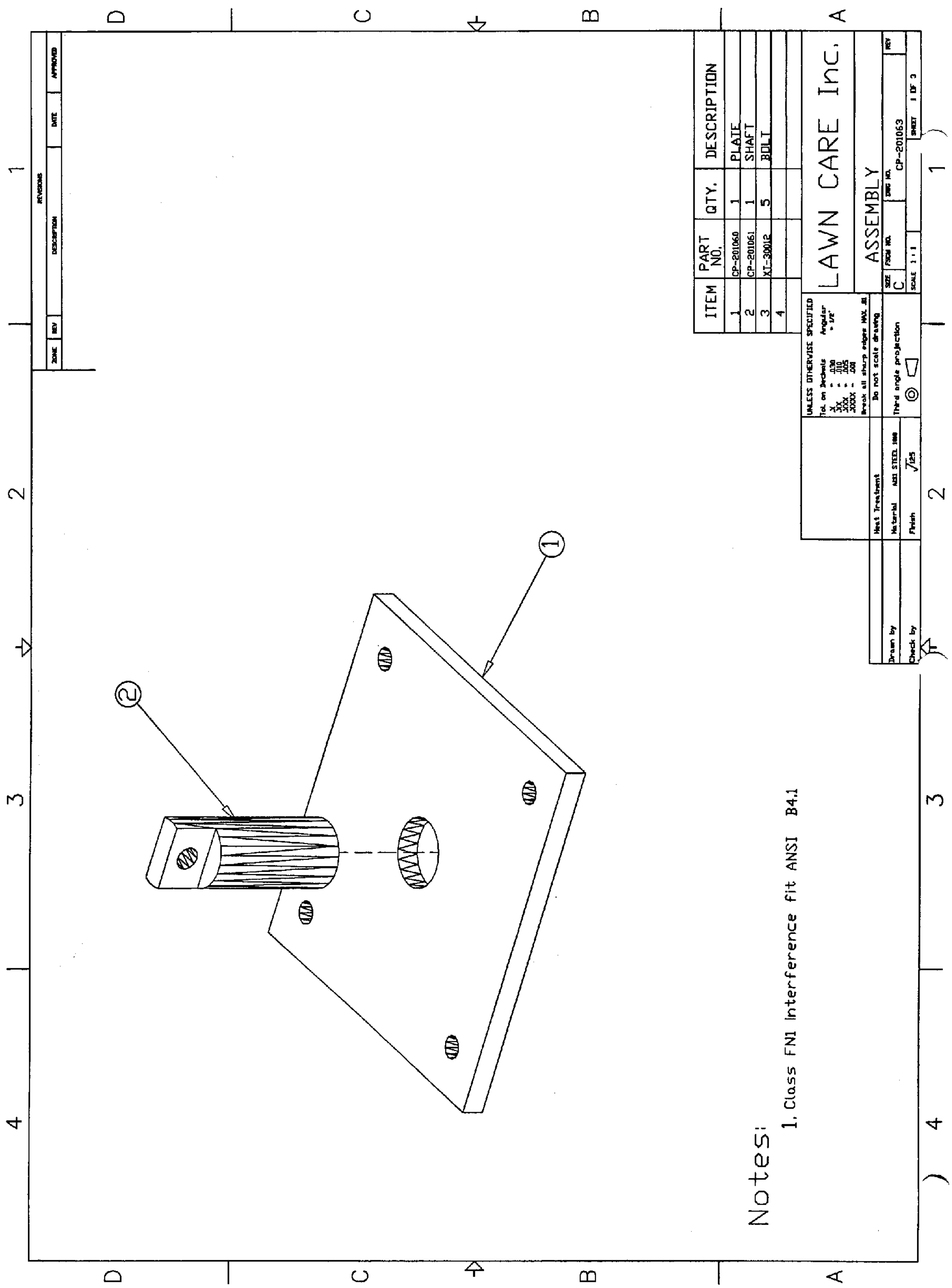
Sincerely,

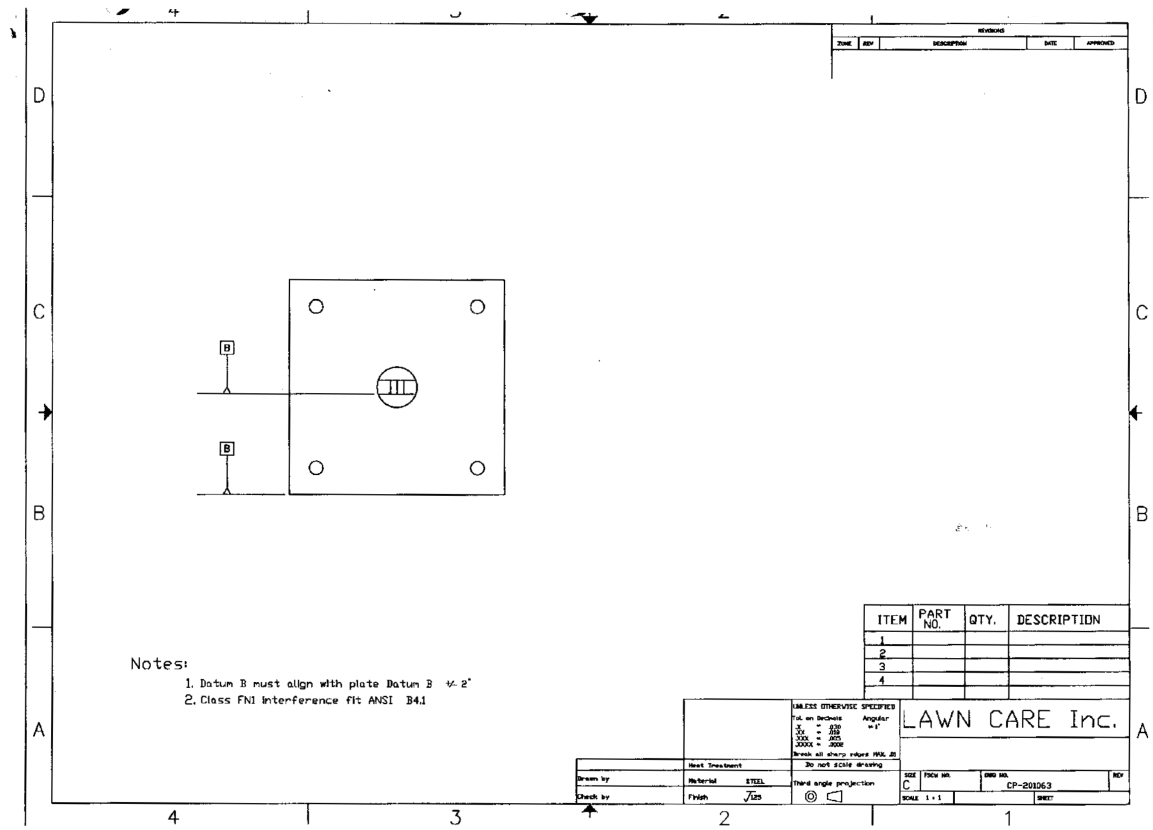
John Burns
CEO, Campbell Machining Company

Electric Panelboards

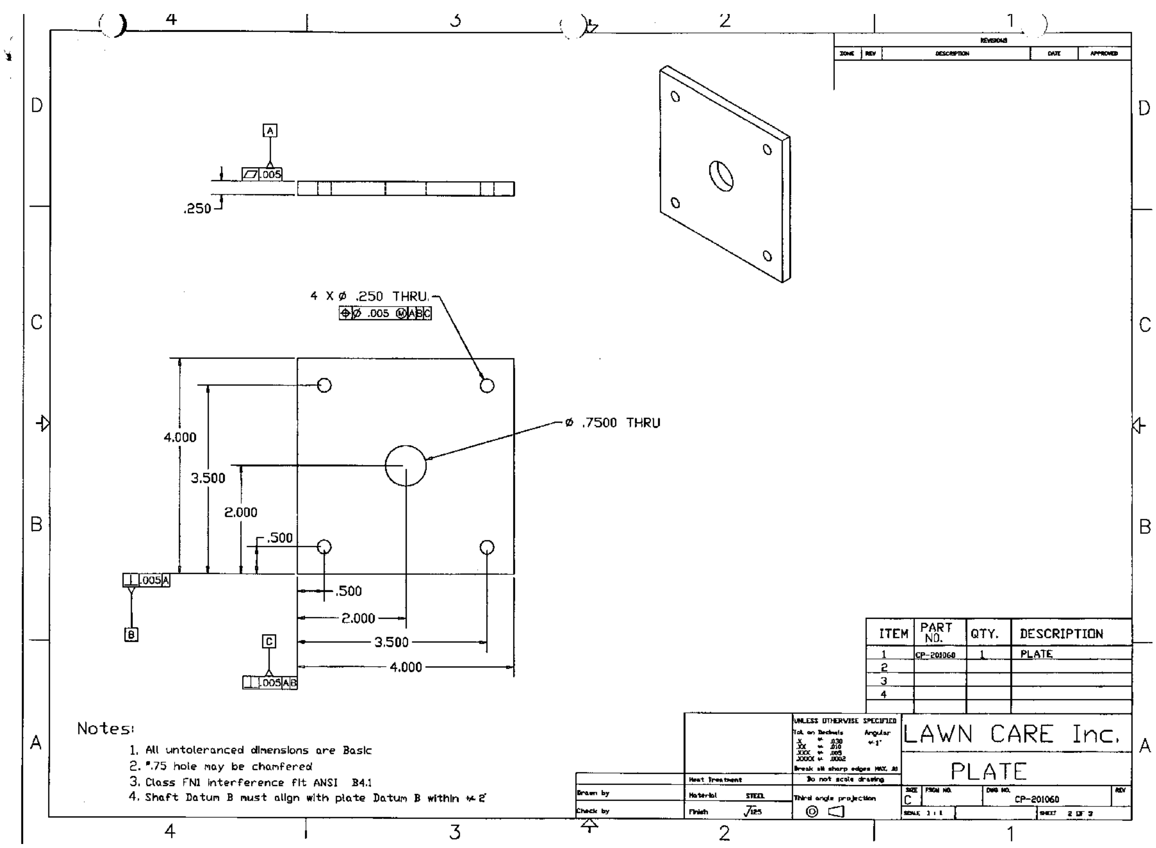
Panel No.	Location	Mains	Voltage Rating	No. of Circuits	Breaker Ratings	Poles	Purpose
P-1	Front Office	Breaker 100 A	208/120 V 3 ϕ , 4w	7 8 5	20 A 20 A 20 A	1 2 1	Lighting Receptacles Spares
P-2	Computer	Breaker 100 A	208/120 V 3 ϕ , 4w	2 5 2	20 A 20 A 20 A	1 2 1	Lighting Receptacles Spares
P-3	Mfg. Area E. Wall	Breaker 100 A	208/120 V 3 ϕ , 4w	5 7 2	50 A 20 A 20 A	1 1 1	Lighting Receptacles Spares
P-4	Mfg. Area W. Wall	Breaker 100 A	208/120 V 3 ϕ , 4w	5 7 2	50 A 20 A 20 A	1 1 1	Lighting Receptacles Spares
P-5	Mfg. Area E. Wall	Lugs only 600 A	208 3 ϕ , 3w	3 3	100 A 75 A	3 3	CNC Mills
P-6	Mfg. Area N. Wall	Lugs only 500 A	208 3 ϕ , 3w	4	100 A	3	Lathes
P-7	Mfg. Area W. Wall	Lugs only 700 A	208 3 ϕ , 3w	3 3 4	75 A 50 A 50 A	3	Shapers Screw Mach. Storage Area



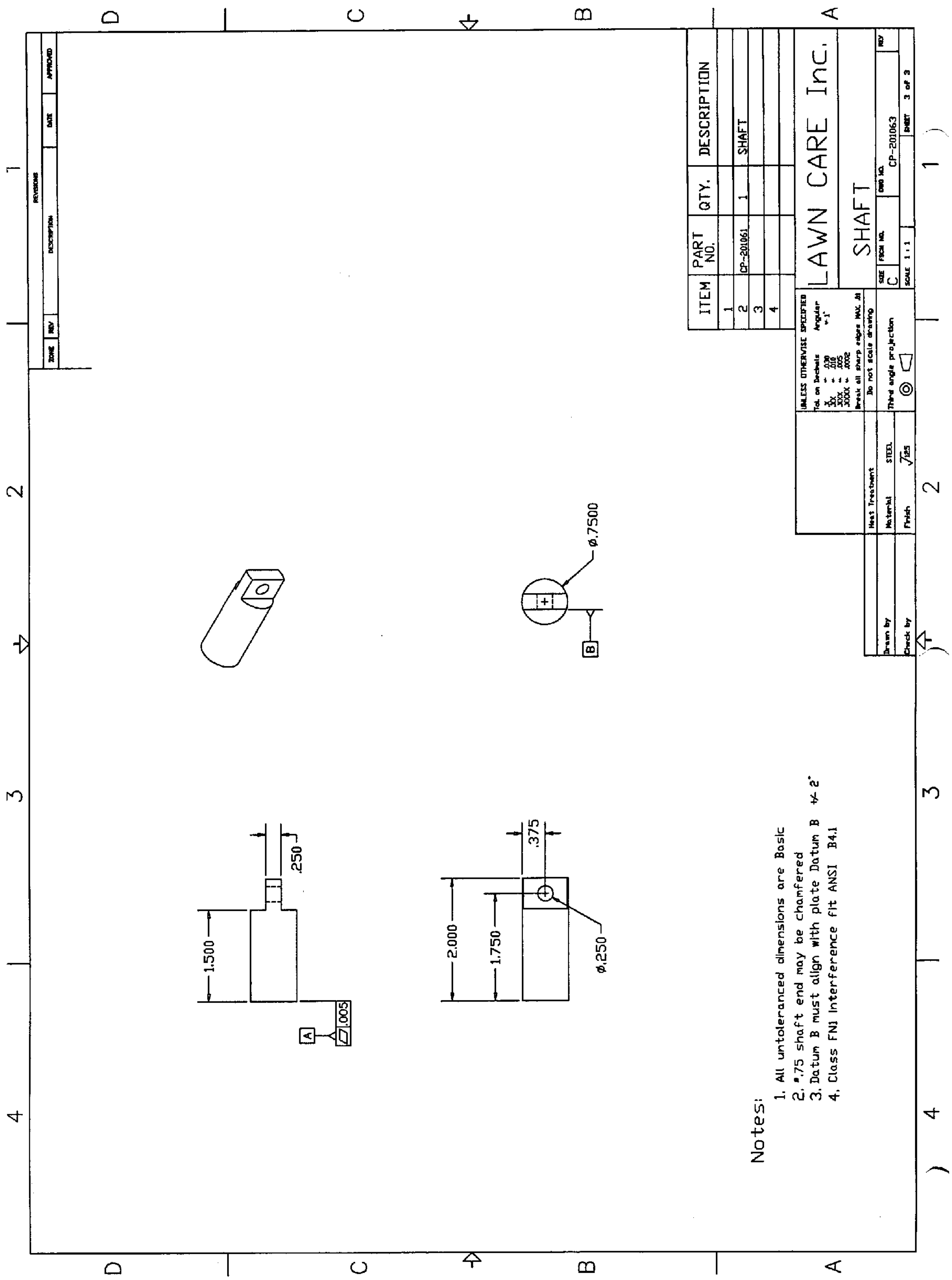

ITEM | PART NO. | QTY. | DESCRIPTION
1 | CP-201060 | 1 | PLATE
2 | CP-201061 | 1 | SHAFT
3 | XT-30012 | 5 | BOLT
4
LAWN CARE Inc.
ASSEMBLY
CP-201063
UNLESS OTHERWISE SPECIFIED
Break all sharp edges
Do not scale drawing
Third angle projection
Heat Treatment
Material
Finish
Drawn by
Check by
Notes:
1. Class FN1 Interference fit ANSI B4.1



Notes:
1. Datum B must align with plate Datum B +/- 2°
2. Class FN1 interference fit ANSI B4.1
ITEM
PART NO.
QTY.
DESCRIPTION
LAWN CARE Inc.
CP-201063



4 X ø .250 THRU.
ø .7500 THRU
4.000
3.500
2.000
.500
.250
Notes:
1. All untoleranced dimensions are Basic
2. *.75 hole may be chamfered
3. Class FN1 interference fit ANSI B4.1
4. Shaft Datum B must align with plate Datum B within +/- 2°
ITEM
PART NO.
QTY.
DESCRIPTION
PLATE
LAWN CARE Inc.
PLATE
CP-201060


ITEM
PART NO.
QTY.
DESCRIPTION
1
2
CP-201061
1
SHAFT
3
4
LAWN CARE Inc.
SHAFT
C
CP-201063
SCALE 1:1
SHEET 3 of 3
Third angle projection
Material
STEEL
Heat Treatment
Finish
Drawn by
Check by
ø.7500
B
.250
1.500
A
.005
.375
2.000
1.750
ø.250
Notes:
1. All untoleranced dimensions are Basic
2. ø.75 shaft end may be chamfered
3. Datum B must align with plate Datum B ± 2°
4. Class FN1 Interference fit ANSI B4.1

Engineering Technology Core
Mechanical Module #1

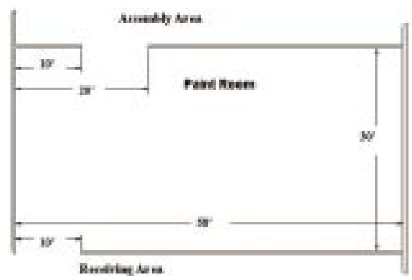
Displacement/Velocity

Assembly Line Layout

Problem Scenario for the Student

You work in a section of an assembly plant that assembles refrigerator doors. Because of a sales increase, your plant needs to add more production capacity. Your team is responsible for planning and installing a new section that paints, dries, and cools the exterior door and then inserts the plastic interior to the door. Both of these parts arrive from other sections of the plant in the same receiving space.

The process requires that the exterior door be loaded onto a conveyor system to move through the painting, drying, and cooling stations. It takes 30 seconds to move the door through a paint station that is 25 feet long. The door then moves through a drying oven for seven minutes and then cools for 15 minutes. After cooling, the plastic interior is assembled into the exterior door. The assembled door then moves to the next station where gaskets, handles, etc. are attached.



Your team has determined that a single material-handling robot can be used to place the exterior door and interior panel on the conveyor to move to the point at which they will be joined. This diagram shows the space that has been allotted for this operation. Your team must determine the placement of the painting station, drying oven, and cooling space. Your team also must determine how to get the exterior door and interior insert at the assembly point at the same time.

You will need to write a letter to a subcontractor who will install the assembly line, provide a technical description of the requirements with appropriate calculations, and create a CAD diagram of the floor plan.

Setting the Stage

Industrial technicians state that one of the most important technical concepts employed by entry-level technicians deals with the motion of material on or through the production line. In this section we will study several concepts related to motion. Kinematics is the study of relative motion without reference to the cause of motion. From our experience, we know a great deal about motion. We have observed objects speeding up, slowing down, moving in straight lines, and moving on curves. We have heard such terms as speed, velocity, and acceleration. From these observations, we have developed an intuitive understanding of motion in everyday life. However, if students are to reach intelligent conclusions about motion in an industrial environment, we will need to make a more careful analysis of motion using formulas, sensors, and computers.

In the analysis of motion, there are two general classifications of quantities. The first of these classifications is scalar. Scalar quantities are measured directly by a scale (hence **scalar**) such as a ruler, thermometer, or balance. Examples of scalars are mass, length, volume, temperature, and density. Therefore, a **scalar** is a quantity that has magnitude.

Other physical quantities can be described only when more information than magnitude is needed. For example, if students were told to go to a dinner that was 45 miles (**scalar**) from home, they would only know that the dinner was somewhere on a circle that was centered on their home and had a radius of 45 miles. They would need more information to easily find the dinner. If they were given the direction from home, they would be able to attend the dinner.

Continued on next page

Setting the Stage, continued

Therefore, it is necessary to specify some physical quantities with both magnitude and directions. Such quantities are called **vectors**. Examples of vectors are displacement, velocity, and acceleration.

On a production line, it is important to be able to analyze the motion of the product on the line. This analysis will require using computers to collect data, construct graphs of the data, and analyze the motion from the graph. Parts on an assembly line must arrive at the right place at the right time to prevent storage costs and delays. When students report their findings, it is essential that they use precise terminology and correctly use the terms distance, displacement, speed, velocity, or acceleration. This module will help students to clarify their understanding of such terms.

Objectives

- Write a clear, concise, technical description.
- Add vectors graphically and analytically.
- Solve one-dimensional kinematic problems.
- Produce CAD drawings.
- Apply distance, time, and velocity relationships to the layout of a conveyor system.

Notes to the Instructor

Construct a "Know/Need-to-Know" chart. The following is an example.

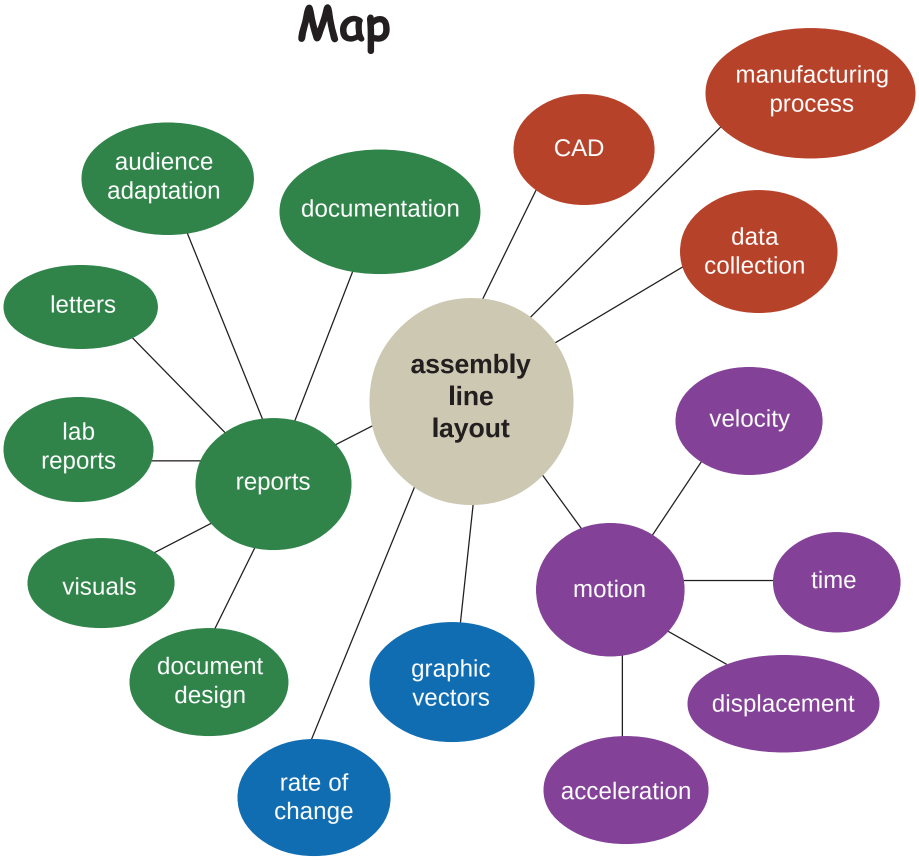
What do I know?	How do I know it?	What do I think I know?	What do I need to know?
Must assemble two parts. Same point start/end. The time and distance for painting. Drying/cooling time. Room dimensions. Time for insert. Reporting process.	Given in problem scenario. Given in problem scenario. Given. Given. Given a CAD drawing. Given. Given.	Conveyor has constant speed. Insert does not have same path.	Continuous conveyor or not? Dimensions of door? Definition of terms? Size of drying and cooling stations? Insert path? Space between stations? How to adapt report to audience? What visuals do I need?

1. Students can "role play" the workings of an assembly line by walking through the processes involved. Videotapes of actual plant assembly lines and conveyor systems will give students a visual image of the problem. If there is a local industry that uses similar conveyor systems in the area, a plant tour could be arranged for students to visit an assembly line site.
2. Provide a laboratory experience that demonstrates vectors and vector addition. Use a CAD system to graph vectors.
3. Give students documents intended for different audiences and have them compare and contrast them for design and content.
4. Collect real data from motion experiments and use the data to determine linear equations and the area under a curve. Excel spreadsheets can be used for data analysis. Require lab reports of motion experiments
5. Critique a variety of types of visual aids for presentation enhancement and impact.
6. Teaming skills should be revisited during this first project of the second semester.
7. Emphasize safety considerations related to conveyor systems and discuss potential hazards.
8. Provide CAD drawings—different dimensions for each student team.
9. Give students specifications on painting, drying, and cooling stations.

Student Assessment

- Faculty teams will evaluate the project outcome, student participation, and quality of written work.
- Faculty will assess knowledge, skills, and performance in workshops, labs, and activities.
- Teaming skills and problem-solving skills will be evaluated by faculty, peers, and students' self-assessments.

Concept Map



Content Strands

Physics

One-dimensional motion
Displacement
Velocity
Acceleration

Mathematics

Linear equations
Vectors
Right triangle trigonometry
Graphic analysis
Rate of change
Area under a curve

Technology

Computer-aided design (CAD)
Excel
Manufacturing process

Communications

Audience analysis
Technical description
Document design
Lab reports

Integrated Skills

Data collection
Computer skills
Calculator skills
Teaming skills
Problem solving
Dimensional analysis

Student Workshop Activities

- One-dimensional motion
- Preparing lab reports
- Letters and memos
- Vectors
- CAD
- Graphical analysis—rate of change, slope, area under a curve

Student Competencies

C.1.1.1 Demonstrate an understanding of time and time measurement devices.
C.1.2.1 Demonstrate a conceptual understanding of distance by expressing measurement in SI and customary US units.
C.1.2.2 Compare and contrast distance and displacement by using vectors and scalars.
C.1.2.4 Use appropriate data acquisition devices to obtain linear measurement.
C.1.2.5 Add vectors graphically.
C.1.3.1 Demonstrate a conceptual understanding of velocity as a rate of change and distinguish between velocity and speed.
C.1.3.2 Determine velocity and speed graphically and analytically.
C.1.3.3 Apply the equation of displacement.
C.1.3.4 Solve linear equations of motion and solve formulas for unknown quantities.
C.1.3.6 Use appropriate data acquisition devices to measure/calculate and store data in electronic files.
C.1.4.1 Demonstrate a conceptual understanding of acceleration by solving problems of uniform motion.
C.1.4.4 Analyze uniform data using the concept of slope and area under the curve to determine displacement, velocity, and acceleration.
C.7.1.1 Employ problem-solving skills to solve a team task.
C.7.1.2 Use appropriate human relations' skills.
C.7.1.3 Demonstrate various listening skills.
C.7.1.4 Apply small group dynamics/teamwork skills.
C.7.1.5 Apply large group dynamics/teamwork skills.
C.7.1.6 Work in teams to make oral presentations.
C.7.1.7 Work in teams to collaborate on assignments.
C.7.2.1 Use various media to obtain information.
C.7.2.2 Demonstrate engineering-technology-appropriate computer skills.
C.7.2.3 Demonstrate ability to conduct primary/secondary research.
C.7.2.4 Collaborate with others to obtain information.
C.7.2.5 Correctly document research information.
C.7.3.1 Format appropriate documents (letters, memos, manuals, reports).
C.7.3.2 Demonstrate the four C's of writing: clear, concise, correct, complete.
C.7.3.3 Revise written material.
C.7.3.4 Use appropriate organizational patterns.
C.7.3.5 Use appropriate engineering technology terminology.
C.7.3.6 Collaborate on the creation of written material.
C.7.3.7 Document written material.
C.7.3.8 Use computer programs to create/revise written material.
C.7.4.1 Apply appropriate organizational patterns (informative, persuasive).
C.7.4.2 Practice key workplace interpersonal skills.
C.7.4.3 Create various means of visual support (slides, PowerPoint, graphs).
C.7.4.4 Cite information.
C.7.4.5 Use computers to organize presentations.
C.7.5.1 Demonstrate professional delivery skills.
C.7.5.2 Use computers to make written and oral presentations.
C.7.5.3 Analyze audiences (setting, demographic, size).
C.7.5.4 Define the purpose of presentations.
C.7.5.5 Support presentation with appropriate visuals.

Engineering Technology Core
Mechanical Module #1 — Student Handout

Displacement/Velocity
Assembly Line Layout

Problem Scenario

You work in a section of an assembly plant that assembles refrigerator doors. Because of a sales increase, your plant needs to add more production capacity. Your team is responsible for planning and installing a new section that paints, dries, and cools the exterior door and then inserts the plastic interior to the door. Both of these parts arrive from other sections of the plant in the same receiving space.

The process requires that the exterior door be loaded onto a conveyor system to move through the painting, drying, and cooling stations. It takes 30 seconds to move the door through a paint station that is 25 feet long. The door then moves through a drying oven for seven minutes and then cools for 15 minutes. After cooling, the plastic interior is assembled into the exterior door. The assembled door then moves to the next station where gaskets, handles, etc. are attached.

Your team has determined that a single material-handling robot can be used to place the exterior door and the interior panel on the conveyor to move to the point at which they will be joined The diagram on the reverse side shows the space that has been allotted for this operation. Your team must determine the placement of the painting station and drying oven, and cooling space. Your team also must determine how to get the exterior door and interior insert at the assembly point at the same time.

You will need to write a letter to a subcontractor who will install the assembly line, provide a technical description of the requirements with appropriate calculations, and create a CAD diagram of the floor plan.

Performance Expectations

- ❑ Instructors will evaluate student teams, including problem-solving and teaming skills.
- ❑ Students will have opportunities for self evaluation, peer evaluation, and team evaluation.
- ❑ Instructors will test and evaluate individual student performance on the content of workshops, labs, and participation in class activities.
- ❑ Team-generated solutions will be evaluated and graded by the faculty team. Solutions should include a letter to a subcontractor, a technical description, calculations, and CAD drawings.

Objectives

- ◆ Write a clear, concise, technical description.
- ◆ Add vectors graphically and analytically.
- ◆ Solve one-dimensional kinematic problems.
- ◆ Produce CAD drawings.
- ◆ Apply distance, time, and velocity relationships to the layout of a conveyor system.

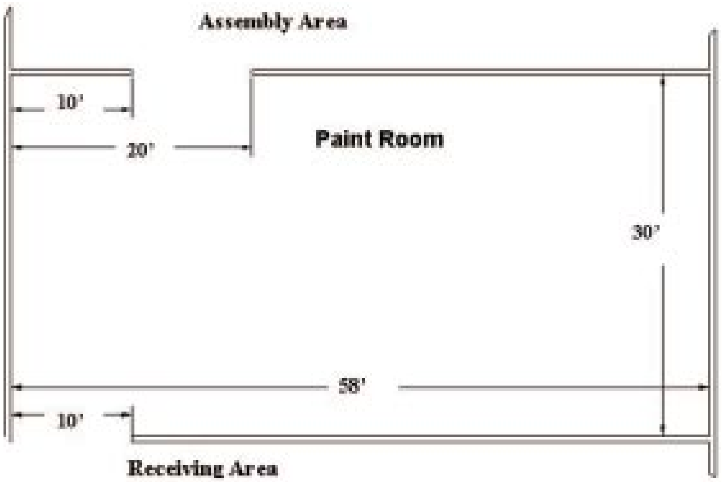
Setting the Stage

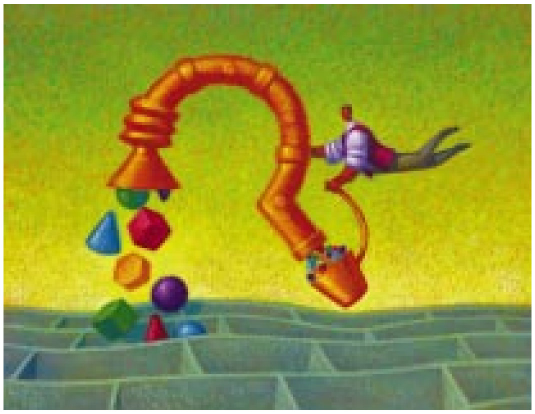
Industrial technicians state that one of the most important technical concepts employed by entry-level technicians deals with the motion of material on or through the production line. In this section you will study several concepts related to motion. Kinematics is the study of relative motion without reference to the cause of motion. From your experience you know a great deal about motion. You have observed objects speeding up, slowing down, moving in straight lines and moving on curves. You have heard such terms as speed, velocity, and acceleration. From these observations you have developed an intuitive understanding of motion in everyday life. However, if you are to reach intelligent conclusions about motion in an industrial environment, you will need to make a more careful analysis of motion using formulas, sensors, and computers.

In the analysis of motion, there are two general classifications of quantities. The first of these classifications is scalar. Scalar quantities are measured directly by a scale (hence **scalar**) such as a ruler, thermometer, or balance. Examples of scalars are mass, length, volume, temperature, and density. Therefore, a **scalar** is a quantity that has magnitude.

Other physical quantities can be described only when more information than magnitude is needed. For example, if you were told that you were to go to a dinner that was 45 miles (**scalar**) from your home, you would only know that the dinner was somewhere on a circle that was centered on your home and that had a radius of 45 miles. You would need more information to easily find the dinner. If you were given the direction from your home, you would be able to attend the dinner. Therefore, it is necessary to specify some physical quantities with both magnitude and directions. Such quantities are called **vectors**. Examples of vectors are displacement, velocity, and acceleration.

On a production line, it is important to be able to analyze the motion of the product on the line. This analysis will require using computers to collect data, construct graphs of the data, and analyze the motion from the graph. Parts on an assembly line must arrive at the right place at the right time to prevent storage costs and delays. When you report your findings, it is essential that you use precise terminology and correctly use the terms distance, displacement, speed, velocity, or acceleration. This project will help you to clarify your understanding of such terms.





Engineering Technology Core
Mechanical Module #2

Forces

Assembly Line Chute

Problem Scenario for the Student

Your company's engineering design team is in the process of designing an automated flexible manufacturing production line. This line is to assemble four different models of radios (am/fm stereo, am/fm/cassette, am/fm/CD, and am/fm/cassette/CD) for different supply houses. An order for a single supply house may consist of a combination of each model.

To simplify manufacturing, all models will have the same basic exterior design with the differences being only the components that are inserted into the box. At the end of the manufacturing line, several orders will be queued before packing. Multiple queues will allow for rework on a defective product. In the packing queue, the design team wishes to be able to queue up to five orders. They have decided that they will be able to direct the boxes into one of five chutes for queuing.

The design team has requested that your technician team make an oral and written report on the construction of the chute to include type of material and the slope. Your team must use the following criteria:

- The chute should be made of stainless steel or aluminum.
- The drop of the chute from the assembly line to the packing station is four meters.
- The chute must be at least five meters long for sufficient numbers to be queued.
- The final velocity of the box at the bottom of the chute should be less than two meters per second to prevent damage to the components.
- You are to build a table model prototype and extrapolate the data from this prototype to the full-scale model.
- The report should contain results based on theory and empirical data.

Setting the Stage

In Mechanical Module 1, we studied kinematics and described the relationship between time, displacement, velocity, and acceleration. In this module, we will explore dynamics (the study of motion) and the cause of motion. Observations show that forces come in various forms. Mechanical forces are seen as a push or pull, electrical or magnetic forces as attractions or repulsion, and fluid forces are related to pressure. We will, in this module, move from the understanding of a mechanical force as a push or pull that causes a change in motion to a more precise qualitative definition that relates force and the resulting change in motion.

Newton was the first to explain, in a series of laws, the effect that a push or pull (force) had on an amount of material (mass) and the motion (displacement, velocity, or acceleration). This ability to quantitatively describe motion caused by force allows us to predict how objects will move. This ability to predict will help us design manufacturing operations and systems.

Applying a force will cause a change in the motion of the object if there are no other forces that balance the applied force. Two types of change in motion can occur. The speed can increase/decrease, or the direction of the motion can change.

Objectives

- Solve quadratic equations.
- Solve two-dimension dynamic problems.
- Build prototypes.
- Design an assembly line chute based on Newton's laws.
- Compare and contrast in written and oral forms.

Notes to the Instructor

1. Students should be given a CAD diagram of the manufacturing line and the space required for a chute to be in the shipping area.
2. A plant tour of an assembly line would help students understand the product flow of such an operation.
3. Use CBL/MBL for electronic data acquisition to study the motion of "boxes" down a prototype chute.
   a. Measure displacement
   b. Measure position vs. time
   c. Measure motion as function of angle
   d. Measure the effect of material on motion
4. Develop free body diagrams to investigate the forces acting on the "boxes."
5. Use spreadsheets to enter data and to graph relationships. Use graphic analysis to determine the coefficient of friction and to investigate the relation of velocity and acceleration on an inclined plane.
6. Support graphical analysis through mathematical investigation of Newton's Laws.
   a. Slope
   b. Area under the curve
   c. Maximum/minimum functions
   d. Vectors
   e. Quadratic functions
7. Develop prototypes using common materials such as wooden boards, tilted file cabinets, sheet metal gutters, etc.

Problem-Based Learning Know/Need-to-Know Chart		
What do we know?	**What do we need to know?**	**How do we find out?**

Student Assessment

- Faculty will assess the technical content of the problem solution and the quality of presentations given by the teams. Each student will evaluate his/her own work and the work of each student in his/her team.
- Individual student assessments will be conducted through written tests of the physics and mathematical concepts presented in the unit.
- Faculty will evaluate oral presentations (based on chute design, a CAD drawing of the design, technical description of the chute) and a cover memo.

Content Strands

Physics

Newton's laws of motion
Friction
Normal force
Weight

Mathematics

Similar triangles
Quadratic equations
Resolve vector components
Systems of equations

Technology

Prototypes
Free body diagrams

Communications

Technical reports
Comparison and contrast
Oral presentations

Student Workshop Activities

- Data acquisition of displacement, velocity, and acceleration.
- Determine equations of motion through graphical analysis.
- Investigate equations of motion through slopes, areas under the curve, and quadratic functions.
- Newton's laws of motion, friction, and inclined planes.
- Trigonometric functions used to analyze free body diagrams.
- Investigate geometry involved in an inclined plane.
- Organize information and present orally.
- Conservation of energy.

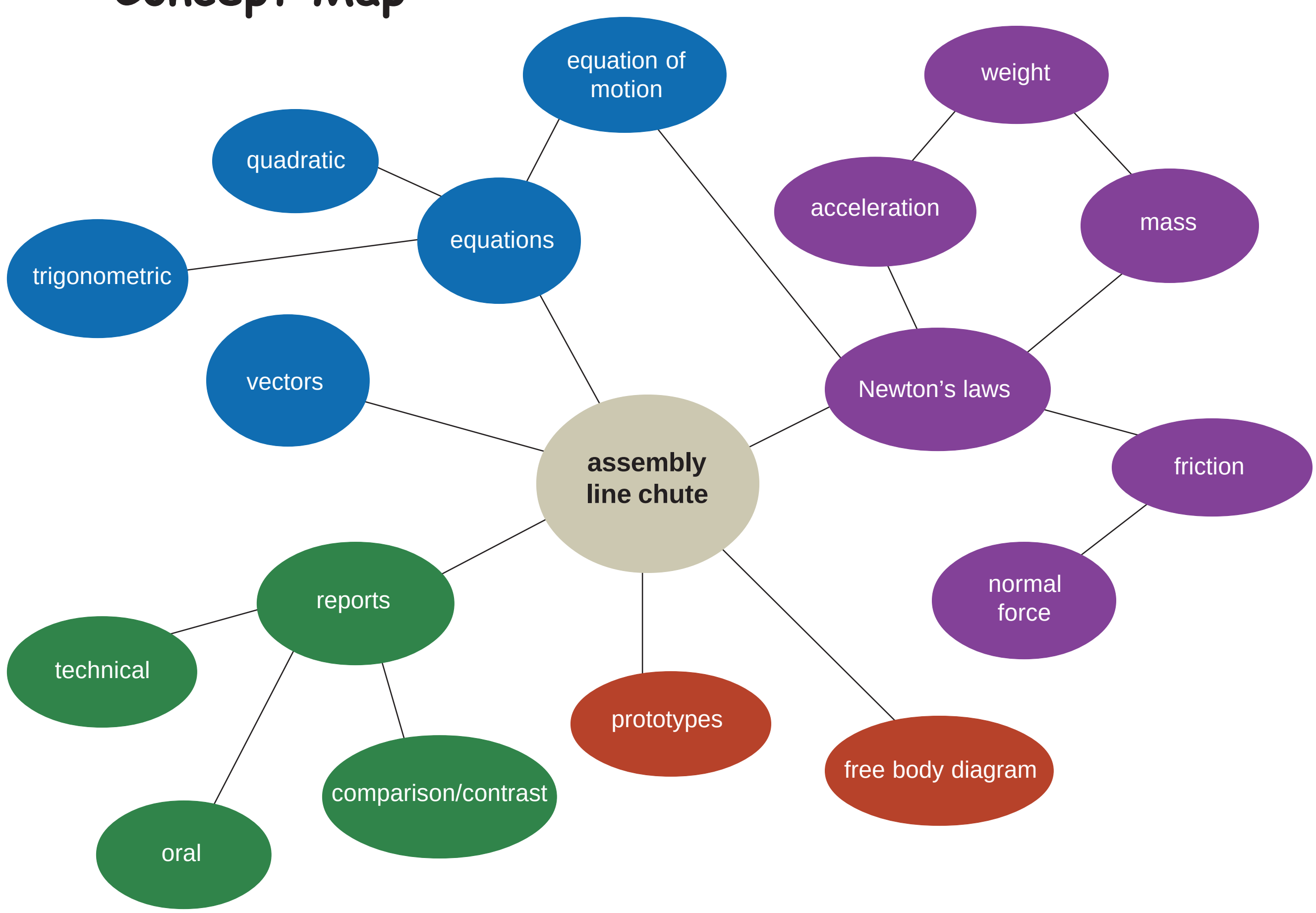
Student Competencies

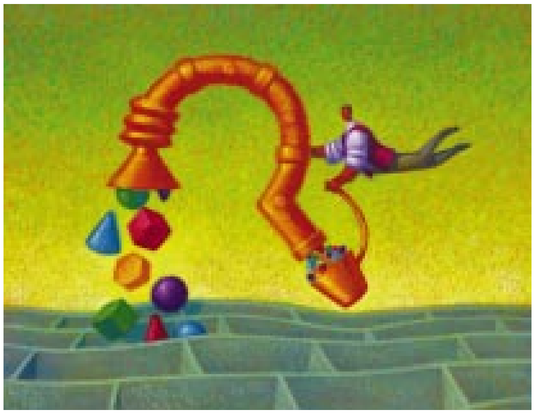
C.1.4.1 Demonstrate a conceptual understanding of acceleration by solving problems of uniform motion.
C.1.4.2 Solve quadratic equations of motion with uniform acceleration for unknown quantities.
C.1.4.3 Use appropriate data acquisition devices to produce graphic data of uniform acceleration for solution to motion problems.
C.1.4.4 Analyze uniform data using the concept of slope and area under the curve to determine displacement, velocity, and acceleration.
C.2.2.1 Demonstrate a conceptual understanding of force in kinetic friction problems.
C.2.2.2 Apply Newton's laws of motion, free body diagrams, and vector techniques to predict how forces affect the motion of objects.
C.7.1.1 Employ problem-solving skills to solve a team task.
C.7.1.6 Work in teams to make oral presentations.
C.7.3.2 Demonstrate the four C's of writing: clear, concise, correct, complete.
C.7.4.3 Create various means of visual support (slides, PowerPoint, graphs).
C.7.4.4 Cite information.
C.7.5.2 Use computers to organize presentations.

Integrated Skills

Data collection
Computer skills
Calculator skills
Basic statistics
Teaming skills
Problem solving
Dimensional analysis

Concept Map





Engineering Technology Core
Mechanical Module #2 — Student Handout

Forces
Assembly Line Chute

Problem Scenario

Your company's engineering design team is in the process of designing an automated flexible manufacturing production line. This line is to assemble four different models of radios (am/fm stereo, am/fm/cassette, am/fm/CD, and am/fm/cassette/CD) for different supply houses. An order for a single supply house may consist of a combination of each model.

To simplify manufacturing, all models will have the same basic exterior design with the differences being only the components that are inserted into the box. At the end of the manufacturing line, several orders will be queued before packing. Multiple queues will allow for rework on a defective product. In the packing queue, the design team wishes to be able to queue up to five orders. They have decided that they will be able to direct the boxes into one of five chutes for queuing.

The design team has requested that your technician team make an oral and written report on the construction of the chute to include type of material and the slope. Your team must use the following criteria:

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- You are to build a table model prototype and extrapolate the data from this prototype to the full-scale model.
- The report should contain results based on theory and empirical data.

Setting the Stage

In Mechanical Module 1, you studied kinematics and described the relationship between time, displacement, velocity, and acceleration. In this module, you will explore dynamics (the study of motion) and the cause of motion. Observations show that forces come in various forms. Mechanical forces are seen as a push or pull, electrical or magnetic forces as attractions or repulsion, and fluid forces are related to pressure. You will, in this module, move from the understanding of a mechanical force as a push or pull that causes a change in motion to a more precise qualitative definition that relates force and the resulting change in motion.

Newton was the first to explain, in a series of laws, the effect that a push or pull (force) had on an amount of material (mass) and the motion (displacement, velocity, or acceleration). This ability to quantitatively describe motion caused by force allows you to predict how objects will move. This ability to predict will help you design manufacturing operations and systems.

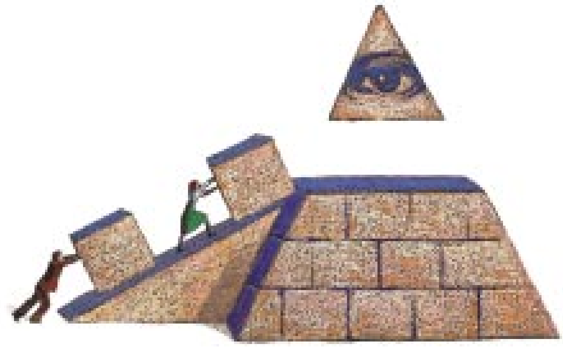
Applying a force will cause a change in the motion of the object if there are no other forces that balance the applied force. Two types of change in motion can occur. The speed can increase/decrease, or the direction of the motion can change.

Objectives

- Solve quadratic equations.
- Solve two-dimension dynamic problems.
- Build prototypes.
- Design an assembly line chute based on Newton's laws.
- Compare and contrast in written and oral forms.

Performance Expectations

- Each student will be evaluated on the technical content of the team solution and the quality of the team presentation.
- Instructors will test and evaluate individual student performance on the content of workshops and participation in class activities.
- Oral presentations are expected to include a chute design, CAD drawing of the design, technical description of the chute, and a cover memo.
- Students will have opportunities for self-evaluation, peer evaluation, and team evaluation.



Engineering Technology Core
Mechanical Module #3

Energy

Bucket Elevator

Problem Scenario for the Student

You are employed at the Ceres grain processing plant. There is a rumor that the plant will be expanding, and your team has been discussing the impact that this expansion will have on the plant operations and your job.

Currently grain is brought into the unloading area by truck and dumped into a hopper that feeds the grain onto a continuous conveyer system that extends from the hopper at ground level to the storage bins on the roof of the building. This conveyor is three feet wide and moves two feet per second carrying grain that is four inches deep. The conveyor has a slope of 7 percent to prevent the grain from sliding down the conveyor. As can be expected, these conveyors take up a large amount of space to reach the top of the building.

The plant manager announces that indeed there will be a plant expansion. Because of the limited property owned, much of the expansion will be in the present area used to unload and transport the grain to the storage bins.

Your supervisor assembles your team and asks that you look at the problem caused by the new expansion. He suggests that a bucket elevator move grain from the hopper station at ground level to the storage tank, 85 feet above the ground. Buckets, placed every foot (on 1-foot centers) along the elevator belt, are to move the grain to the storage tank at the same rate as the present conveyor system. The supervisor has diagrams of the proposed new unloading area and the placement of the hoppers. The bucket conveyor has a head pulley (which also is the drive pulley) that is three feet in diameter. The selected drive will be coupled directly to the head pulley drive shaft.

You are to select a bucket size, a drive, a gear reducer, and an electric motor from vendor catalogs that will move the conveyor at the maximum rated speed of seven feet per second.

Setting the Stage

Industries often need to move quantities of bulk materials like corn, soy beans, fertilizer, wood chips, cement, etc. to an elevated position. A vertical conveyor, either belt or chain, can have buckets attached to lift the materials. This type of conveyor is called a bucket elevator.

Typically an electric motor drives a gear box that then drives a drum at the top of the conveyor. The top drum is called a head drum.

The gear box could be directly coupled to a shaft that supports and drives the head drum or could drive the shaft by being coupled through sprockets and chains just like on a bicycle. The top or head drum turns the belt or chain and also is adjustable to take up slack in the chain or belt. Material is scooped up at the bottom of the conveyor and discharged at the top.

Notes to the Instructor

1. Depending on time available for this project, instructors may place constraints on the problem and make the solution as simple as finding the power required to lift the grain. It is suggested that students be allowed to work on as broad a problem as possible.
2. Students could do preliminary reports in memo or e-mail format. The final report should include recommendations, purchase requisitions, documentation, and calculations with a cover memo.
3. Student teams also may be required to make oral presentations explaining their work.
4. Students will need access to catalogs for gear reducers, motors, and, possibly, chains and sprockets.
5. Instructors should provide diagrams of the proposed new unloading areas and the placement of the hoppers.
6. Students will measure the mass of a given volume of grain, conduct multiple measurements, determine the average density, and calculate the standard deviation of density.

Problem-Based Learning Know/Need-to-Know Chart

What do we know?	What do we need to know?	How do we find out?

Objectives

- Solve work/energy problems.
- Calculate scalar products of vectors.
- Write a clear, concise recommendation report.
- Locate and select products from vender information.
- Use conservation of energy to select a drive for a bucket elevator.

Student Assessment

- Faculty will assess the technical content of the problem solution and the quality of presentations given by the teams. Each student will evaluate his/her own work and the work of each student in his/her team.
- Individual student assessments will be conducted through written tests of the physics and mathematical concepts presented in the unit.

Content Strands

Physics
Density
Potential energy
Kinetic energy
Conservation of energy

Mathematics
Averages
Volume
Standard deviation
Scalar product of vectors

Technology
Measurements
Equipment evaluation and selection

Communications
Trip reports
Oral presentation
Recommendation report/proposal

Integrated Skills

Data collection
Computer skills
Calculator skills
Basic statistics
Teaming skills
Problem solving
Research
Unit conversion
Dimensional analysis

Student Competencies

C.4.1.1 Demonstrate a conceptual and analytical understanding of rotational displacement by expressing measurements in different units.
C.4.1.2 Use appropriate data acquisition devices to measure angular displacement.
C.5.1.1 Demonstrate a conceptual and analytical understanding of torque/moments.
C.6.1.1 Demonstrate a conceptual and analytical understanding of work and energy by calculating rotational kinetic energy.
C.6.1.2 Apply the conservation of energy principle to the transfer of energy between linear and rotational systems.
C.7.1.1 Employ problem-solving skills to solve a team task.
C.7.1.2 Use appropriate human relations skills.
C.7.1.3 Demonstrate various listening skills.
C.7.1.4 Apply small group dynamics/teamwork skills.
C.7.1.5 Apply large group dynamics/teamwork skills.
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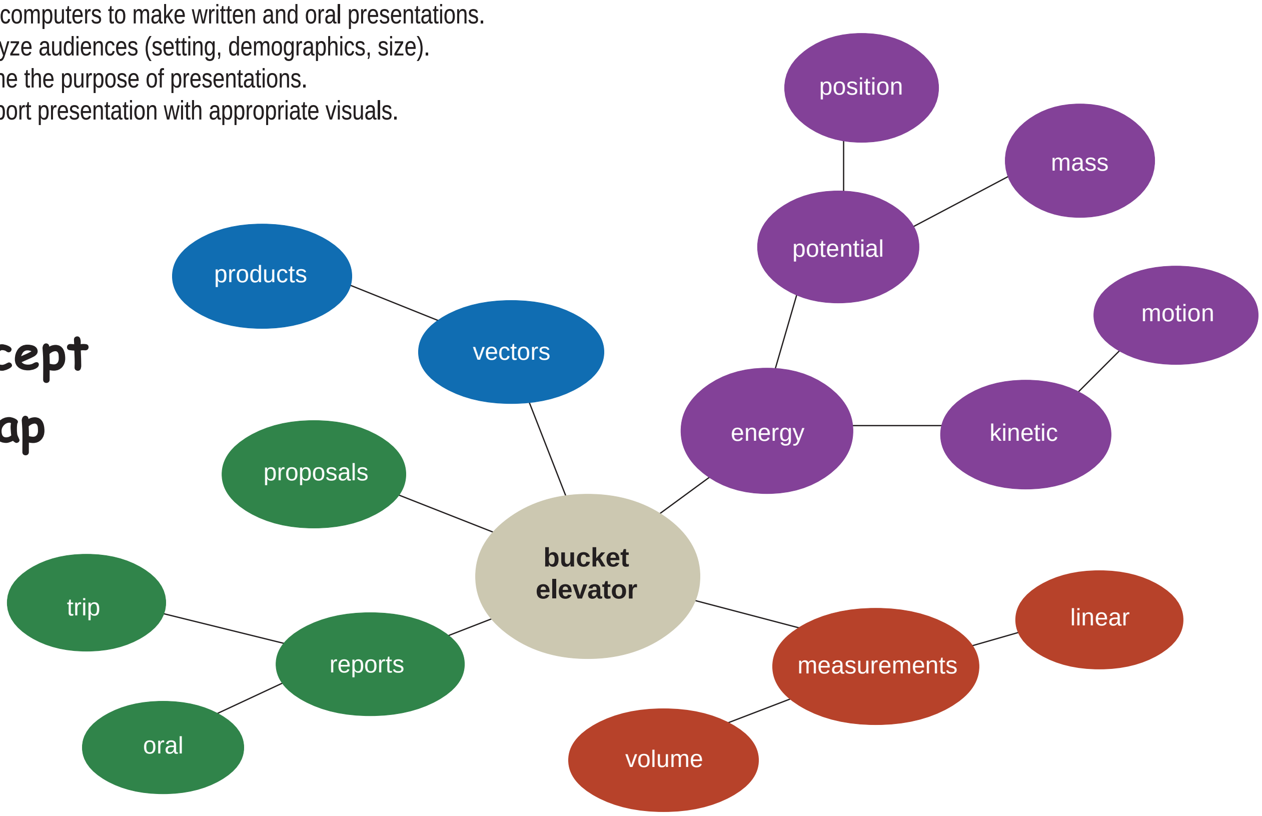
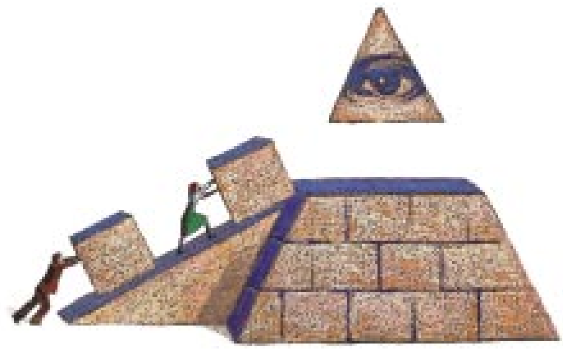
C.7.5.3 Analyze audiences (setting, demographics, size).
C.7.5.4 Define the purpose of presentations.
C.7.5.5 Support presentation with appropriate visuals.

Student Workshop Activities

- Potential energy
- Kinetic energy
- Vectors and scalar products
- Volume measurements
- Conveyor systems
- Bucket elevators
- Writing proposals
- Effective oral presentations
- Creating cover memos

Concept Map





Engineering Technology Core
Mechanical Module #3 — Student Handout

Energy
Bucket Elevator

Problem Scenario

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Currently grain is brought into the unloading area by truck and dumped into a hopper that feeds the grain onto a continuous conveyer system that extends from the hopper at ground level to the storage bins on the roof of the building. This conveyor is three feet wide and moves two feet per second carrying grain that is four inches deep. The conveyor has a slope of 7 percent to prevent the grain from sliding down the conveyor. As can be expected, these conveyors take up a large amount of space to reach the top of the building.

The plant manager announces that indeed there will be a plant expansion. Because of the limited property owned, much of the expansion will be in the present area used to unload and transport the grain to the storage bins.

Your supervisor assembles your team and asks that you look at the problem caused by the new expansion. He suggests that a bucket elevator move grain from the hopper station at ground level to the storage tank, 85 feet above the ground. Buckets, placed every foot (on 1-foot centers) along the elevator belt, are to move the grain to the storage tank at the same rate as the present conveyor system. The supervisor has diagrams of the proposed new unloading area and the placement of the hoppers. The bucket conveyor has a head pulley (which also is the drive pulley) that is three feet in diameter. The selected drive will be coupled directly to the head pulley drive shaft.

You are to select a bucket size, a drive, a gear reducer, and an electric motor from vendor catalogs that will move the conveyor at the maximum rated speed of seven feet per second.

Setting the Stage

Industries often a need to move quantities of bulk materials like corn, soy beans, fertilizer, wood chips, cement, etc. to an elevated position. A vertical conveyor, either belt or chain can have buckets attached to lift the materials. This type of conveyor is called a bucket elevator.

Typically an electric motor drives a gear box that then drives a drum at the top of the conveyor. The top drum is called a head drum.

The gear box could be directly coupled to a shaft that supports and drives the head drum or could drive the shaft by being coupled through sprockets and chains just like on a bicycle. The top or head drum turns the belt or chain and also is adjustable to take up slack in the chain or belt. Material is scooped up at the bottom of the conveyor and discharged at the top.

Objectives

- Solve work/energy problems.
- Calculate scalar products of vectors.
- Write a clear, concise recommendation report.
- Locate and select products from vender information.
- Use conservation of energy to select a drive for a bucket elevator.

Performance Expectations

- ❑ Each student will be evaluated on the technical content of the team solution and the quality of the team presentation.
- ❑ Students will have opportunities for self evaluation, peer evaluation, and team evaluation.
- ❑ Preliminary reports in memo or e-mail format may be required. The final report should include recommendations, purchase requisitions, documentation, and calculations with a cover memo.
- ❑ Student teams also may be required to make oral presentations explaining their work.

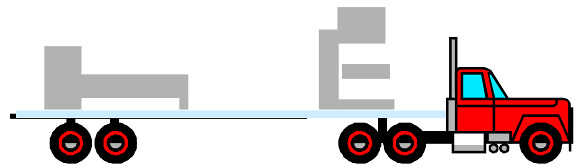
Engineering Technology Core
Mechanical Module #4

Equilibrium

Weight Distribution in a Flatbed Trailer

Problem Scenario for the Student

Your company has purchased machine tool equipment from a manufacturing company in a nearby town, and you are being sent to bring the equipment back to your plant. You have rented a flatbed, spread-tandem 18-wheeler to transport the equipment. The rental company has advised you that you will need to place the equipment on the flatbed so that there is an equal distribution of weight on the tires of the trailer. Your team will determine how the trailer should be loaded and report your findings to the plant supervisor.



Include the following in your report:

- Safety considerations in loading the equipment.
- A technical description of equipment to be loaded.
- A proposal of how to the load the equipment.
- A CAD drawing showing the placement of the equipment on the trailer.
- A cover memo to your plant supervisor.

Setting the Stage

In the second mechanical module, we investigated the vector nature of forces. We also developed the relationship between forces and motion by observing Newton's Laws of Motion, specifically considering a dynamic (i.e., moving) situation.

In this module, we will investigate the static (i.e., no movement) nature of forces. The study of statics is based on a special case of Newton's Second Law and Newton's Third Law, where the net force acting on an object is zero.

For complete equilibrium, a second condition must be satisfied. The object must not move in a linear or rotational manner. In physics, this condition exists when the net torque acting on an object is zero.

Many problems in industry require equipment to be in a state of equilibrium. When equipment is mounted in place, it is desirable to know how much loading is placed on its supports. One such application is the loading of transport trucks. Workers must know not only the amount of the load, but also the placement of the load on the truck.

Meet the Problem

Each team will identify the machine tool equipment to be loaded. Equipment catalogs should be consulted for specifications of equipment. A hands-on examination of a transport trailer would be desirable. A visit to a truck driving school or a web search could determine the dimensions of the truck bed.

Notes to the Instructor

1. Construct a "Know/Need-to-Know" chart.

Problem-Based Learning Know/Need-to-Know Chart		
What do we know?	**What do we need to know?**	**How do we find out?**

2. Students will discover the two equilibrium conditions through exercises both in the lab and with simulation software. Resource material such as *Technical Physics: Selected Units* by Robert Eshelman, Stanley Briggs, and Richard Bailey (modified for use at Forsyth Technical Community College, Winston-Salem, NC, by Bob Tyndall) provides a problem-based series of activities. Once students have an understanding of equilibrium conditions and how to solve equilibrium problems, they can then use a spreadsheet to determine possible solutions to the problem scenario. Students also can use simulation software to test their solutions. Using a scale model flatbed transport and model machine tool equipment, students can position the equipment on the trailer and measure the distribution of weight.

3. As time permits, it may be possible to discuss loading procedures using a crane.

4. It should be noted that to achieve proper placement of the equipment on the scale model, the students have to determine the center of mass of both pieces of equipment. For the scale models, this can be done experimentally. Also the students should note that the center of mass of some machines, such as a milling machine, is above the geometric center and thus the piece is top heavy. By adjusting the position of the top "motor," the center of mass can be lowered for a more stable condition.

5. This is an opportunity to expand on systems of equations with more than two unknown forces. For the problem at hand, there is no single solution but a series of solutions. This presents an excellent situation to set up spreadsheets for "what if" analysis.

6. If resumes and employee interview techniques have not been studied in previous modules, then they should be addressed in preparation for Mechanical Module #5.

Objectives

- Calculate vector products.
- Research and use technical data on equipment.
- Solve mechanical equilibrium problems.
- Apply the conditions for static equilibrium to the loading of equipment onto a flatbed trailer.

Content Strands

Physics

Torque
Center of mass
Equilibrium conditions

Mathematics

Vector products
Systems of equations
Volume of irregular shapes

Technology

Safety considerations
Equipment specifications
Computer-aided design (CAD)

Communications

Trip reports
Technical descriptions
Recommendation reports/proposals

Student Workshop Activities

- Static equilibrium — linear and rotational
- Volume formulas (calculating volumes, mass, and center of mass)
- Resumes and applications
- Employment interviews
- Trailers and loading
- Safety of loading equipment
- Systems of equations

Concept Map

Student Assessment

- Faculty will assess the technical content of the problem solution and the quality of reports/presentations given by the teams. Each student will evaluate his/her own work and the work of each student in his/her team.
- Individual assessments will be on written tests of physics and mathematics concepts presented in the unit.
- Faculty will evaluate team proposals based on safety considerations, technical descriptions of equipment, CAD drawings showing the placement of the equipment on the trailer, and cover memos.

Student Competencies

C.2.1.1 Demonstrate a conceptual understanding of forces and static equilibrium problems.
C.2.1.2 Apply Newton's laws of motion to describe translational equilibrium.
C.2.1.3 Calculate the mass/weight of an object from density and volume and determine the center of mass.
C.2.1.4 Construct free body diagrams and apply vector techniques for solutions to static problems.
C.5.1.1 Demonstrate a conceptual and analytical understanding of torque/moments.
C.5.1.2 Determine center of mass and apply to solutions of rotational static problems.
C.5.1.3 Apply rotational equilibrium conditions and free body diagrams to static problems.
C.5.1.4 Apply rotational and translational equilibrium conditions to analyze structural arrangements.
C.5.1.5 Use systems of equations to solve equilibrium problems.
C.7.1.1 Employ problem-solving skills to solve a team task.
C.7.1.2 Use appropriate human relations skills.
C.7.1.3 Demonstrate various listening skills.
C.7.1.4 Apply small group dynamics/teamwork skills.
C.7.1.5 Apply large group dynamics/teamwork skills.
C.7.1.7 Work in teams to collaborate on assignments.
C.7.2.1 Use various media to obtain information.
C.7.2.2 Demonstrate engineering technology-appropriate computer skills.
C.7.2.3 Demonstrate ability to conduct primary/secondary research.
C.7.2.4 Collaborate with others to obtain information.
C.7.2.5 Document research information.
C.7.3.1 Format appropriate documents (letters, memos, manuals, reports).
C.7.3.2 Demonstrate the four C's of writing: clear, concise, correct, complete.
C.7.3.3 Revise written material.
C.7.3.4 Use appropriate organizational patterns.
C.7.3.5 Use appropriate engineering technology terminology.
C.7.3.6 Collaborate on the creation of written material.
C.7.3.7 Document written material.
C.7.3.8 Use computer programs to create/revise written material.
C.7.5.2 Use computers to make written and oral presentations.
C.7.5.3 Analyze audiences (setting, demographics, size).
C.7.5.4 Define the purpose of presentations.
C.7.5.5 Support presentation with appropriate visuals.

Integrated Skills

Data collection
Computer skills
Calculator skills
Teaming skills
Problem solving
Research skills
Dimensional analysis

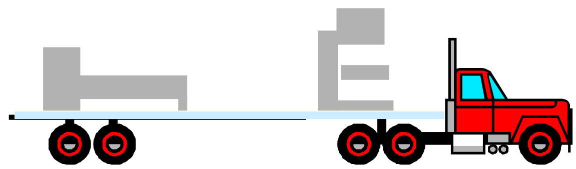
Engineering Technology Core
Mechanical Module #4 — Student Handout

Equilibrium

Weight Distribution in a Flatbed Trailer

Problem Scenario

Your company has purchased machine tool equipment from a manufacturing company in a nearby town, and you are being sent to bring the equipment back to your plant. You have rented a flatbed, spread-tandem 18-wheeler to transport the equipment. The rental company has advised you that you will need to place the equipment on the flatbed so that there is an equal distribution of weight on the tires of the trailer. Your team will determine how the trailer should be loaded and report your findings to the plant supervisor.



Include the following in your report:

- Safety considerations in loading the equipment.
- A technical description of equipment to be loaded.
- A proposal of how to the load the equipment.
- A CAD drawing showing the placement of the equipment on the trailer.
- A cover memo to your plant supervisor.

Setting the Stage

In the second project, you investigated the vector nature of forces. You also developed the relationship between forces and motion by observing Newton's Laws of Motion, specifically considering a dynamic (i.e., moving) situation.

In this project, you will investigate the static (i.e., no movement) nature of forces. Statics is based on a special case of Newton's Second Law and Newton's Third Law, where the net force acting on an object is zero.

For complete equilibrium, a second condition must be satisfied. The object must not move in a linear or rotational manner. In physics, this condition is that the net torque acting on an object is zero.

Many problems in industry require equipment to be in a state of equilibrium. When equipment is mounted in place, it is desirable to know how much loading is placed on its supports. One such application is the loading of transport trucks. Workers must know not only the amount of the load, but also the placement of the load on the truck.

Objectives

- Calculate vector products.
- Research and use technical data on equipment.
- Solve mechanical equilibrium problems.
- Apply the conditions for static equilibrium to the loading of equipment onto a flatbed trailer.

Performance Expectations

- ❑ Each student will be evaluated on the technical content of the team solution and the quality of the team report.
- ❑ Students will have opportunities for self evaluation, peer evaluation, and team evaluation.
- ❑ Instructors will test and evaluate individual student performance on the content of workshops and participation in class activities.
- ❑ Team proposals should include safety considerations, technical descriptions of equipment, CAD drawings showing the placement of equipment on the trailer, and cover memo.

Engineering Technology Core
Mechanical Module #5

Rotation

Chipper Brake

Problem Scenario for the Student

Your team is assigned the task of designing a brake that will stop a chipper's rotation in 15 seconds or less. There is sufficient room on the chipper shaft to attach a brake. The chipper disk is 8 feet in diameter, 24 inches thick, and has a 7-inch diameter shaft. The chipper disk and shaft are directly coupled to a 1,000 HP, 600 RPM motor. The disk, shaft, and coupling are constructed of carbon steel.

Your team is to prepare professional-quality documents to use in a presentation for a company that makes commercial chippers used at large construction sites. Requirements demand that the chipper be equipped with a braking system that will stop the disk in 15 seconds or less.

Setting the Stage

In past modules, we have focused on force and motion along a straight line. We have defined several measurable quantities that have allowed us to characterize that motion. In industry, equipment that converts electrical energy into mechanical energy usually involves circular motion or rotation.

In this module, we will investigate and define several new quantities and relationships to describe rotational motion. These quantities include angular displacement, angular velocity, angular acceleration, torque, and moment of inertia.

As with linear systems, basic laws still hold. There will be the equivalent of Newton's law for rotational system, and conservation of energy will be operative.

Paper mills use a chipper to cut wood chips approximately 3/8 inch thick before the wood is cooked to make pulp. Chippers are usually very thick heavy steel rotating disks (thus having a high moment of inertia and a large rotational kinetic energy) with slots and surfaces machined to hold knives. Chips are cut to size by knives bolted to the disk. Chips pass through the disk after being cut by the knives.

Some chipper systems are equipped with braking systems for fast and smooth stoppage. Because of the large kinetic energy, it can take an hour or more to slow the chipper to a stop unless a braking system is used.

Meet the Problem

Students can investigate chipper brake systems on the Internet. One web site is: www.fulghum.com. Students should investigate appropriate stopping times and safety considerations.

Objectives

- Write a professional resume and/or design business cards.
- Relate angular and linear quantities.
- Solve rotational dynamic problems.
- Investigate various braking systems.
- Design a brake to stop a chipper's rotation in a reasonable amount of time.

Notes to the Instructor

1. Construct a "Know/Need-to-Know" chart.

Problem-Based Learning Know/Need-to-Know Chart		
What do we know?	**What do we need to know?**	**How do we find out?**

2. Students can measure and calculate rotational energy.

3. Students can measure and calculate time to brake and stop the chipper.

4 Students can graph the braking time vs. torque.

5. A food processor would help students understand how a chipper works.

6. Students can produce a portfolio of business materials such as business cards.

7. Students can produce a safety brochure related to the use of chippers in industry.

8. Students can set up separate consulting firms with business cards and resumes to use when presenting their teams' recommendations.

Student Assessment

- Faculty will assess the technical content of the problem solution and the quality of the profession documents produced by the teams. Each student will evaluate his/her own work and the work of each student in his/her team.
- Individual assessments will be conducted through written tests of physics and mathematics concepts presented in the unit.
- Faculty will evaluate the feasibility of the brake system design and quality of the team presentation.

Content Strands

Physics

Torque
Moment of inertia
Rotational motion
Rotational kinetic energy

Mathematics

Direct variation
Angular/linear displacements, velocity, and acceleration
Polar/rectangular coordinates

Technology

Braking systems
Business card design
Detailed problem analysis

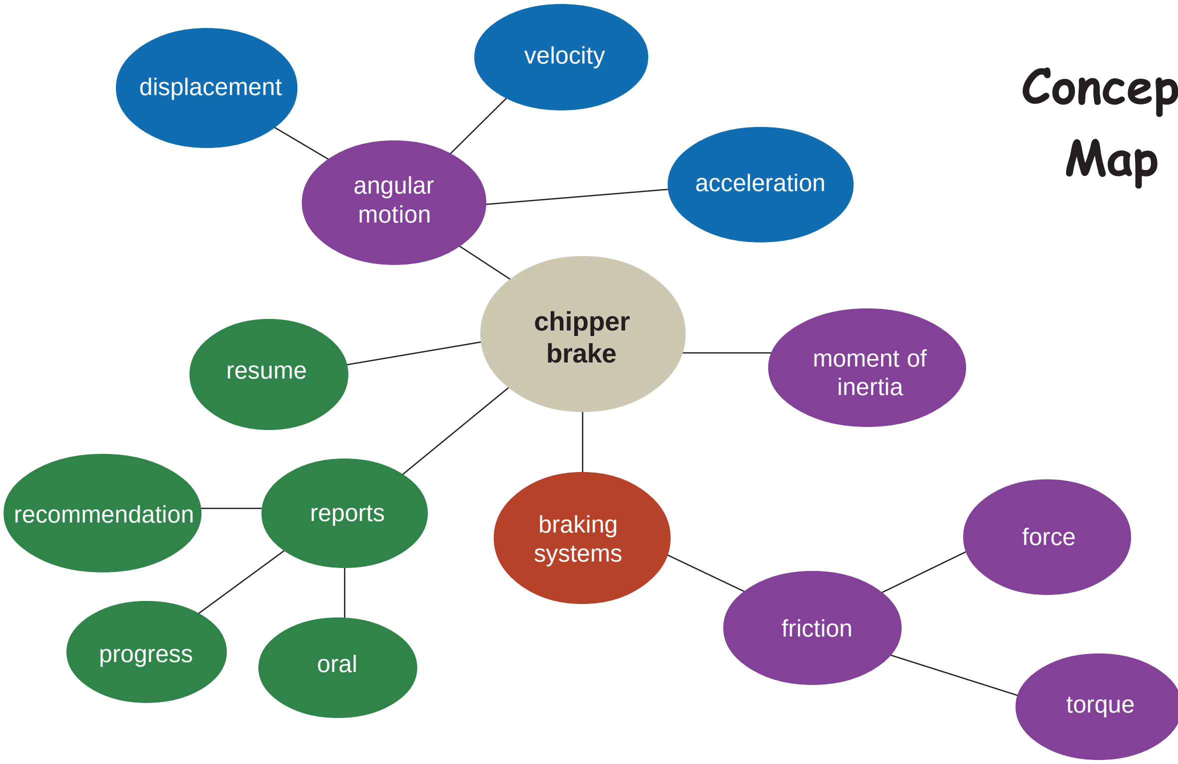
Communications

Progress reports
Oral presentation
Resumes and application letters
Recommendation reports/proposals

Student Workshop Activities

- Rotational energy
- Brake systems
- Safety related to rotating machinery
- Angular measurements
- Rotational conversions
- Linear to rotational relationships
- Layout and design using Word templates
- Angular kinetics
- Angular dynamics

Concept Map



Student Competencies

C.2.1.3 Calculate the mass/weight of an object from density and volume and determine the center of mass.
C.2.2.1 Demonstrate a conceptual understanding of force in kinetic friction problems.
C.4.1.1 Demonstrate a conceptual understanding of work and energy by calculating and measuring kinetic potential energy for gravitational and spring systems.
C.4.1.2 Use appropriate data acquisition devices to measure angular displacement.
C.4.1.3 Convert between angular and linear displacements.
C.4.2.1 Demonstrate a conceptual and analytical understanding of rotational displacement by expressing measurements in different units.
C.4.2.2 Use appropriate data acquisition devices to measure angular displacement.
C.4.2.3 Use appropriate data acquisition devices to measure rotational rates and store the data in electronic files.
C. 4.3.1 Demonstrate a conceptual and analytical understanding of angular acceleration.
C.5.2.1 Demonstrate a conceptual understanding of moment of inertia.
C.5.2.2 Apply the rotational version of Newton's Second Law to the solution of rotational problems.
C.6.1.1 Demonstrate a conceptual and analytical understanding of work and energy by calculating rotational kinetic energy.
C.7.5.1 Demonstrate professional delivery skills.
C.7.5.2 Use computers to make written and oral presentations.
C.7.5.3 Analyze audiences (setting, demographics, size).
C.7.5.4 Define the purpose of presentations.
C.7.5.5 Support presentation with appropriate visuals.

Integrated Skills

Data collection
Computer skills
Calculator skills
Teaming skills
Problem solving
Research skills
Dimensional analysis

Engineering Technology Core
Mechanical Module #5 — Student Handout

Rotation
Chipper Brake

Problem Scenario

Your team is assigned the task of designing a brake that will stop a chipper's rotation in 15 seconds or less.There is sufficient room on the chipper shaft to attach a brake. The chipper disk is 8 feet in diameter, 24 inches thick, and has a 7-inch diameter shaft. The chipper disk and shaft are directly coupled to a 1,000 HP, 600 RPM motor. The disk, shaft, and coupling are constructed of carbon steel.

Your team is to prepare professional-quality documents to use in a presentation for a company that makes commercial chippers used at large construction sites. Requirements demand that the chipper be equipped with a braking system that will stop the disk in 15 seconds or less.

Setting the Stage

In past modules, we have focused on force and motion along a straight line. We have defined several measurable quantities that have allowed us to characterize that motion. In industry, equipment that converts electrical energy into mechanical energy usually involves circular motion or rotation.

Objectives

- Write a professional resume and/or design business cards.
- Relate angular and linear quantities.
- Solve rotational dynamic problems.
- Investigate various braking systems.
- Design a brake to stop a chipper's rotation in a reasonable amount of time.

In this module, we will investigate and define several new quantities and relationships to describe rotational motion. These quantities include angular displacement, angular velocity, angular acceleration, torque, and moment of inertia.

As with linear systems, basic laws still hold. There will be the equivalent of Newton's law for rotational system, and conservation of energy will be operative.

Paper mills use a chipper to cut wood chips approximately 3/8 inch thick before the wood is cooked to make pulp. Chippers are usually very thick heavy steel rotating disks (thus having a high moment of inertia and a large rotational kinetic energy) with slots and surfaces machined to hold knives. Chips are cut to size by knives bolted to the disk. Chips pass through the disk after being cut by the knives.

Some chipper systems are equipped with braking systems for fast and smooth stoppage. Because of the large kinetic energy, it can take an hour or more to slow the chipper to a stop unless a braking system is used.

Performance Expectations

- ❑ Each student will be evaluated on the technical content of the team solution and the quality of the team proposal.
- ❑ Students will have opportunities for self evaluation, peer evaluation, and team evaluation.
- ❑ Instructors will test and evaluate individual student performance on the content of workshops and participation in class activities.
- ❑ The design of the braking system will be evaluated on its reasonableness and the feasibility of installation.

Fluids

Safety Shower

Problem Scenario for the Student

As a mechanical design team for your company, you have been requested to prepare recommendations on gravity-fed safety showers that conform to American National Standards Institute (ANSI) standards. The shower is to be placed in a mobile chemical-testing unit whose drawings are in the CAD files for the chemical units.

The shower is to be capable of five flushes, with each flush not to exceed one minute. There also should be recommendations for disposal of the shower water.

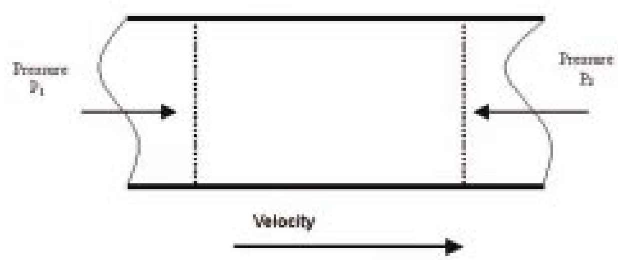
Prepare a proposal for the company's management that includes your recommendations with supporting data.

Setting the Stage

The term fluid can refer to a gas or liquid. Gases and liquids will conform to the shape of the container in which they are placed; a liquid presents a free surface and retains its volume, but a gas will always fill the volume of the container. For a gas, a change in volume occurs when either the pressure or temperature is changed; whereas, with a liquid, the volume undergoes little change when there is a change in pressure.

When a fluid is confined to a container, the molecules in the fluid strike the sides of the container. These collisions of the molecules with the sides of the container cause a force to be exerted on the sides. Pressure is defined as being equal to this applied force divided by the surface area that is perpendicular to the force.

In electrical systems, the laws of conservation lead to Kirchhoff's laws of current and voltage. In mechanics, conservation of energy requires that the sum of potential and kinetic energy remain constant over time. In a dynamic fluid system, conservation laws must include the work associated with fluid flow. Bernoulli's equation expresses the law of conservation of energy for a fluid system.



The motion of a fluid is governed by two conservation laws that are useful in analyzing the dynamics of a fluid.

1. Conservation of mass — which can be stated in the continuity equation.

   The mass of a fluid in the control volume is constant. This condition requires that the net mass flowing into the control volume must equal the net mass flowing out of the control volume at any instant in time.

2. Conservation of energy — which will be stated in the Bernoulli equation.

   For a system with fluid friction, the energy terms are potential energy, kinetic energy, and work.

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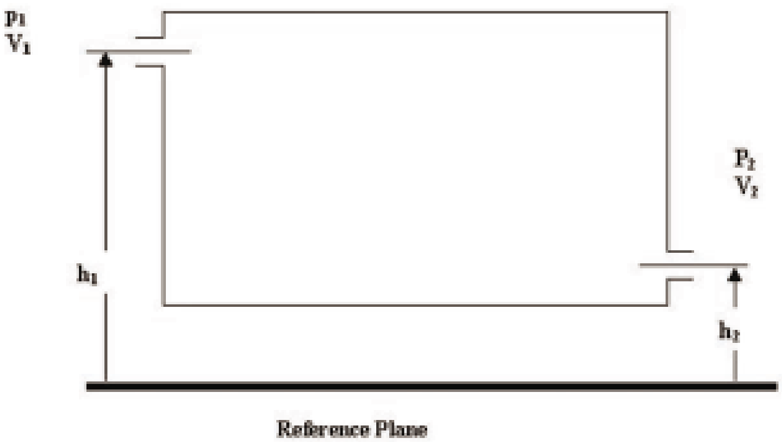
Setting the Stage, continued



Potential Energy:	$m \cdot g \cdot h$
Kinetic Energy:	$\frac{1}{2}\, m \cdot V^2$
Work (pressure):	$m \cdot g \cdot \frac{p}{\gamma}$ γ is the weight density
Friction Loss:	$m \cdot g \cdot h_L$

Which will lead to:

$$m \cdot g \cdot h_1 + \frac{1}{2} \cdot m \cdot \left(V_1\right)^2 + m \cdot g \cdot \frac{p_1}{\gamma} = m \cdot g \cdot h_2 + \frac{1}{2} \cdot m \cdot \left(V_2\right)^2 + m \cdot g \cdot \frac{p_2}{\gamma} + m \cdot g \cdot h_L$$

$$h_1 + \frac{\left(V_1\right)^2}{2 \cdot g} + \frac{p_1}{\gamma} = h_2 + \frac{\left(V_2\right)^2}{2 \cdot g} + \frac{p_2}{\gamma} + h_L$$

The friction loss h_L depends on the source of the friction (pipe walls, obstruction such as elbows, type of flow, etc.). In general the frictional terms are proportional to $V^2/2g$.

Objectives

- Research disposal of hazardous materials.
- Evaluate fluids formulas.
- Solve statics and dynamics problems.
- Investigate industry codes and standards.
- Design the size and placement of a storage reservoir for a gravity-fed safety shower.

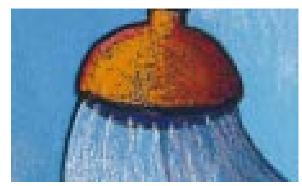
Content Strands

Physics
Density
Pressure
Bernoulli's equation
Equation of continuity

Mathematics
Formula evaluation
Cross-sectional area

Technology
Fluids vocabulary
Safety codes and standards
Disposal of hazardous materials

Communications
Persuasive team presentation

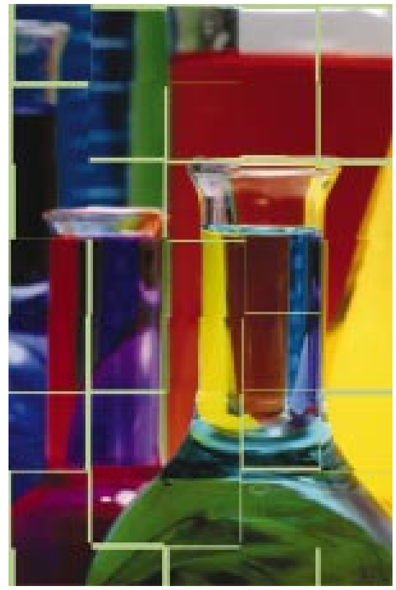


Student Workshop Activities

- Motivated sequence for persuasive writing and speaking
- Proposal writing
- Units and unit conversions, symbols
- Chemical safety
- Fluids concepts (ex., velocity vs. height)
- Review algebra manipulations
- Equation of continuity
- Bernoulli's equation
- Viscosity/friction
- Safety (chemicals and showers)

Notes to the Instructor

1. Information on the calculation of frictional losses from pipes, walls, and other obstructions can be found in a fluid-flow text.
2. Useful web site: www.safetyshowers.com
3. Examine different proposals and identify elements for proposal writing.
4. Walk-through of continuity equation (simulate water in a pipe).
5. Jigsaw of various concepts (e.g., different diameter pipes).
6. Demonstrate viscosity by comparisons of different fluids.
7. Glove on hand underwater to feel pressure differences at different depths.
8. Use a falling ball viscometer.
9. Pascal's principle — pressure points in all directions at same depth.
10. Use differently-shaped containers to show pressure depends on height only.
11. Use fluid trainers to demonstrate Bernoulli's equation.
12. Have students find other applications of gravity-fed fluid flows (e.g., water cooler in an office).
13. Plot velocity vs. height (head).
14. Plot velocity vs. pipe diameter.
15. Plot flow rate (volume/time) vs. height.
16. Research and write about fluids scientists.
17. Discuss elements of persuasion writing.
18. Introduce fluids symbols, units, conversions.
19. Review "complicated" algebraic solutions.
20. Examine proposals for content.
21. Prepare persuasive speeches.
22. Present impromptu speeches.
23. Have students analyze TV ads for motivated sequence.



Problem-Based Learning
Know/Need-to-Know Chart

What do we know?	What do we need to know?	How do we find out?

Student Competencies

D.1.1.1 Compare and contrast properties of solids, liquids, and gases.
D.1.2.1 Calculate density using measurements of mass and volume.
D.1.2.2 Express density in appropriate units.
D.2.1.1 Calculate pressure using force and area.
D.2.1.2 Define absolute pressure, gauge pressure, and atmospheric pressure.
D.2.1.3 Express pressure in units of Pascal, atm., and millimeters of mercury, etc.
D.2.2.1 Verify that pressure is independent of the area or shape of the container.
D.2.2.2 Calculate pressure in a fluid given height and density of the fluid.
D.2.2.3 Measure fluid pressure using a manometer.
D.2.3.1 State and apply Pascal's law to solve problems involving hydraulic pressure.
D.3.1.1 Describe the operation of a physical devise in terms of Archimedes' principle.
D.3.2.1 Draw a free-body diagram including buoyant forces.
D.3.3.1 Determine the density of a fluid using Archimedes' principle.
D.4.1.1 Explain the components of Bernoulli's equation.
D.4.1.2 Explain/describe the operation of a venturi tube.
D.4.2.1 Determine the flow and velocity of a fluid in a pipe using the continuity equation.
D.4.3.1 Calculate the velocity and pressure of a fluid in a pipe using Bernoulli's equation.
D.5.1.1 Define/describe viscosity.
D.6.1.1 Format appropriate documents (letters, memos, manuals, and reports).
D.6.1.2 Use appropriate organizational patterns.
D.6.2.1 Apply appropriate organizational patterns (informative, persuasive).
D.6.2.2 Create various means of visual support (slides, PowerPoint, graphs).
D.6.2.3 Cite information.
D.6.2.4 Use computers to organize presentations.
D.6.3.1 Demonstrate professional delivery skills.
D.6.3.2 Use computers to make written and oral presentations.
D.6.3.3 Support presentation with appropriate visuals.

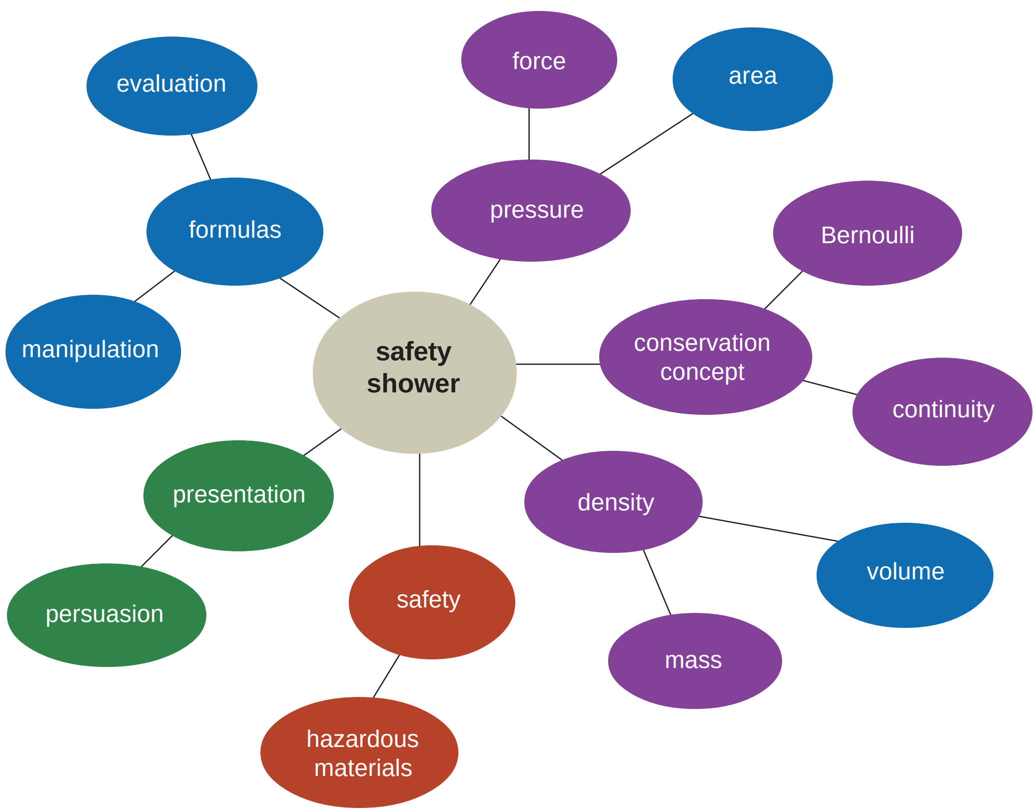
Integrated Skills

Data collection
Computer skills
Calculator skills
Teaming skills
Problem solving
Research skills
Dimensional analysis

Student Assessment

- Faculty will assess the technical content of the problem solution and the quality of the profession documents produced by the teams. Each student will evaluate his/her own work and the work of each student in his/her team.
- Individual assessments will be conducted through written tests of the physics and mathematics concepts presented in the unit.
- Faculty will evaluate the feasibility of the shower design and quality of the team presentation.

Concept Map


evaluation
force
area
formulas
pressure
Bernoulli
manipulation
safety shower
conservation concept
continuity
presentation
density
volume
persuasion
safety
mass
hazardous materials

Engineering Technology Core
Fluids Module — Student Handout

Fluids

Safety Shower

Problem Scenario

As a mechanical design team for your company, you have been requested to prepare recommendations on gravity-fed safety showers that conform to American National Standards Institute (ANSI) standards. The shower is to be placed in a mobile chemical-testing unit whose drawings are in the CAD files for the chemical units.

The shower is to be capable of five flushes, with each flush not to exceed one minute. There also should be recommendations for disposal of the shower water.

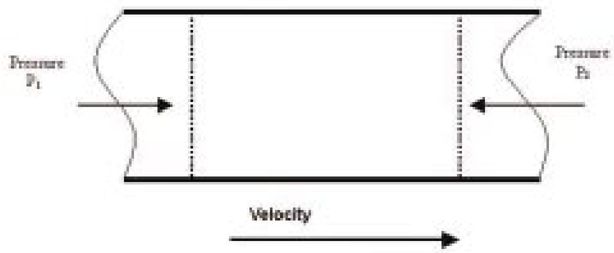
Prepare a proposal for the company's management that includes your recommendations with supporting data.

Setting the Stage

The term fluid can refer to a gas or liquid. Gases and liquids will conform to the shape of the container in which they are placed, a liquid presents a free surface and retains its volume, but a gas will always fill the volume of the container. For a gas a change in volume occurs when either the pressure or temperature is changed; whereas, with a liquid the volume undergoes little change when there is a change in pressure.

When a fluid is confined to a container, the molecules in the fluid strike the sides of the container. These collisions of the molecules with the sides of the container cause a force to be exerted on the sides. Pressure is defined as being equal to this applied force divided by the surface area that is perpendicular to the force.

In electrical systems, the laws of conservation lead to Kirchhoff's laws of current and voltage. In mechanics, conservation of energy requires that the sum of potential and kinetic energy remain constant over time. In a dynamic fluid system, conservation laws must include the work associated with fluid flow. Bernoulli's equation expresses the law of conservation of energy for a fluid system.



The motion of a fluid is governed by two conservation laws that are useful in analyzing the dynamics of a fluid.

1. Conservation of mass — which can be stated in the continuity equation.

   The mass of a fluid in the control volume is constant. This condition requires that the net mass flowing into the control volume must equal the net mass flowing out of the control volume at any instant in time.

2. Conservation of energy — which will be stated in the Bernoulli equation.

   For a system with fluid friction, the energy terms are potential energy, kinetic energy, and work.

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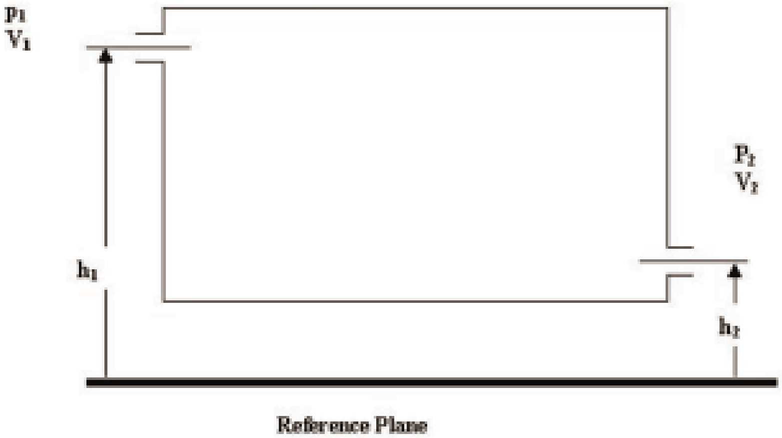
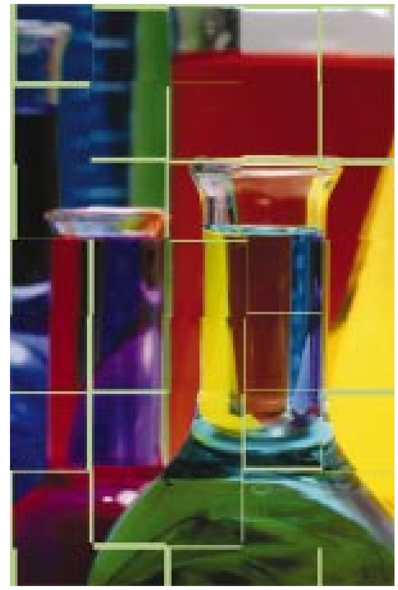
Setting the Stage, continued





Potential Energy:	$m \cdot g \cdot h$
Kinetic Energy:	$\frac{1}{2} m \cdot V^2$
Work (pressure):	$m \cdot g \cdot \frac{p}{\gamma}$ — γ is the weight density
Friction Loss:	$m \cdot g \cdot h_L$

Which will lead to:

$$m \cdot g \cdot h_1 + \frac{1}{2} \cdot m \cdot (V_1)^2 + m \cdot g \cdot \frac{p_1}{\gamma} = m \cdot g \cdot h_2 + \frac{1}{2} \cdot m \cdot (V_2)^2 + m \cdot g \cdot \frac{p_2}{\gamma} + m \cdot g \cdot h_L$$

$$h_1 + \frac{(V_1)^2}{2 \cdot g} + \frac{p_1}{\gamma} = h_2 + \frac{(V_2)^2}{2 \cdot g} + \frac{p_2}{\gamma} + h_L$$

The friction loss h_L depends on the source of the friction (pipe walls, obstruction such as elbows, type of flow, etc.) In general the frictional terms are proportional to $V^2/2g$.

Objectives

- Research disposal of hazardous materials.
- Evaluate fluids formulas.
- Solve statics and dynamics problems.
- Investigate industry codes and standards.
- Design the size and placement of a storage reservoir for a gravity-fed safety shower.

Performance Expectations

- Faculty will assess the technical content of the problem solution and the quality of the professional documents produced by the teams. Each student will evaluate his/her own work and the work of each student in his/her team.
- Individual student assessments will be conducted through written tests of the physics and mathematics concepts presented in the unit.
- Faculty will evaluate the feasibility of the shower design and quality of the team presentation.

Engineering Technology Core
Optics Module #1

Geometrical Optics

Projection System

Problem Scenario for the Student

The company for which you work as a technician assembles component parts on an assembly line. At some point in the assembly process, the parts enter a covered compartment for environmental reasons. While in the covered area of the assembly line, several parts are fitted together and then they emerge from the covered area. Your team is responsible for monitoring what goes on in the covered area for efficiency and quality control.

Your job is to investigate the use of lenses and mirrors to determine an arrangement suitable for projecting images onto a flat screen that can be viewed by a technician. Your supervisor wants you to present your recommendations, including cost estimates, using presentation software such as PowerPoint . Before approval, your supervisor wants to see a prototype of your proposed projection system.

Setting the Stage

Optics is the study of light and the phenomena associated with its generation, transmission, and detection. In a broader sense, optics includes all phenomena associated with not only visible light but with infrared and ultraviolet radiation. Geometrical optics assumes that light travels in a straight line and is concerned with the laws that govern the reflection and refraction of rays of light. Other optical phenomena such as diffraction, interference, and polarization depend on the wave nature of light.

Meet the Problem

The team will need to determine the layout of the assembly line and dimensions of the covered area. They will apply geometric principles to arrange lenses and mirrors in such a way that the process that takes place out-of-sight can be seen and monitored via projection of images. A camera may be employed to capture the process, which can then be viewed on a video monitor. The nature of the light source inside the covered compartment will have to be considered.

When a ray of light strikes a surface, part of the light may be reflected back into the incident medium. This reflection of light is what allows us to see ourselves in a plane mirror. The ray that strikes the surface is called the incident ray and the ray that is "bounced' from the surface is called the reflected ray. For all rays there are two basic laws:

- *The angle of incidence is equal to the angle of reflection.*
- *The incident ray, the reflected ray, and the perpendicular to the surface all lie in the same plane.*

Light that is reflected from a smooth surface is called regular or specular reflection. Light that is reflected from a rough or irregular surface is called diffuse reflection. Specular reflection allows viewing of the image of an object, and diffuse reflection will scatter the rays and not allow viewing of an image.

Also, when light strikes a surface, part of the light may be transmitted through the medium. The light traveling through the medium travels in a straight line at a constant speed in the medium, but that speed may not be the same as that of the incident medium. When the speed of light changes, the ray of light will travel in a straight line, but along a new path. This bending of light is called refraction.

Continued on next page

Setting the Stage, continued

For refraction there are two basic laws:

When a ray of light enters a medium at an angle where the light slows down, it bends toward the normal; when a ray of light enters a medium at an angle where the light speed up, it bends away from the normal. The incident ray, the refracted ray, and the perpendicular to the surface all lie in the same plane.

In some manufacturing situations a process may be "hidden" from view because it is conducted in a controlled environment or involves objects too small to observe without magnification. In order to monitor and control such activities, mirrors and/or lenses can be used to project images of the objects and the manufacturing process to viewing screens or video monitors.

Notes to the Instructor

1. Teams should develop a Know/Need-to-Know chart for the problem. Conditions and dimensions of the assembly line and covered compartment need to be identified. Instructors may vary given dimensions from team to team.

Problem-Based Learning Know/Need-to-Know Chart		
What do we know?	**What do we need to know?**	**How do we find out?**

2. A plant tour (or video) could provide students with real experiences of assembly processes.
3. Provide students with drawings of the assembly process including dimensions and specifications of the problem.
4. Conduct mirror labs to illustrate reflection and lens labs to illustrate refraction.
5. Use ray diagrams to analyze geometrical optical systems.
6. Have students import images from several sources into a presentation software package.
7. Teams should build a prototype of the projection system they recommend as a solution to the problem.
8. Cameras may be used to capture the projected image in order to digitize the images. Computers can be used to view and monitor the process.
9. Use blackboard optics to measure angles created by optical rays of light.
10. Review normals, reciprocals, and rational equations. These topics may not have been studied recently.
11. Measure focal, object, and image distances in a lab setting to verify the lens equation.
12. Investigate similar triangles in a lab setting.
13. Equipment needed includes lenses, mirrors, holders, and benches.

Content Strands

Physics

Reflection
Refraction

Mathematics

Lines and angles
Similar triangles

Technology

CAD
Optics in industry
Prototype of projection system
Presentation software (PowerPoint)

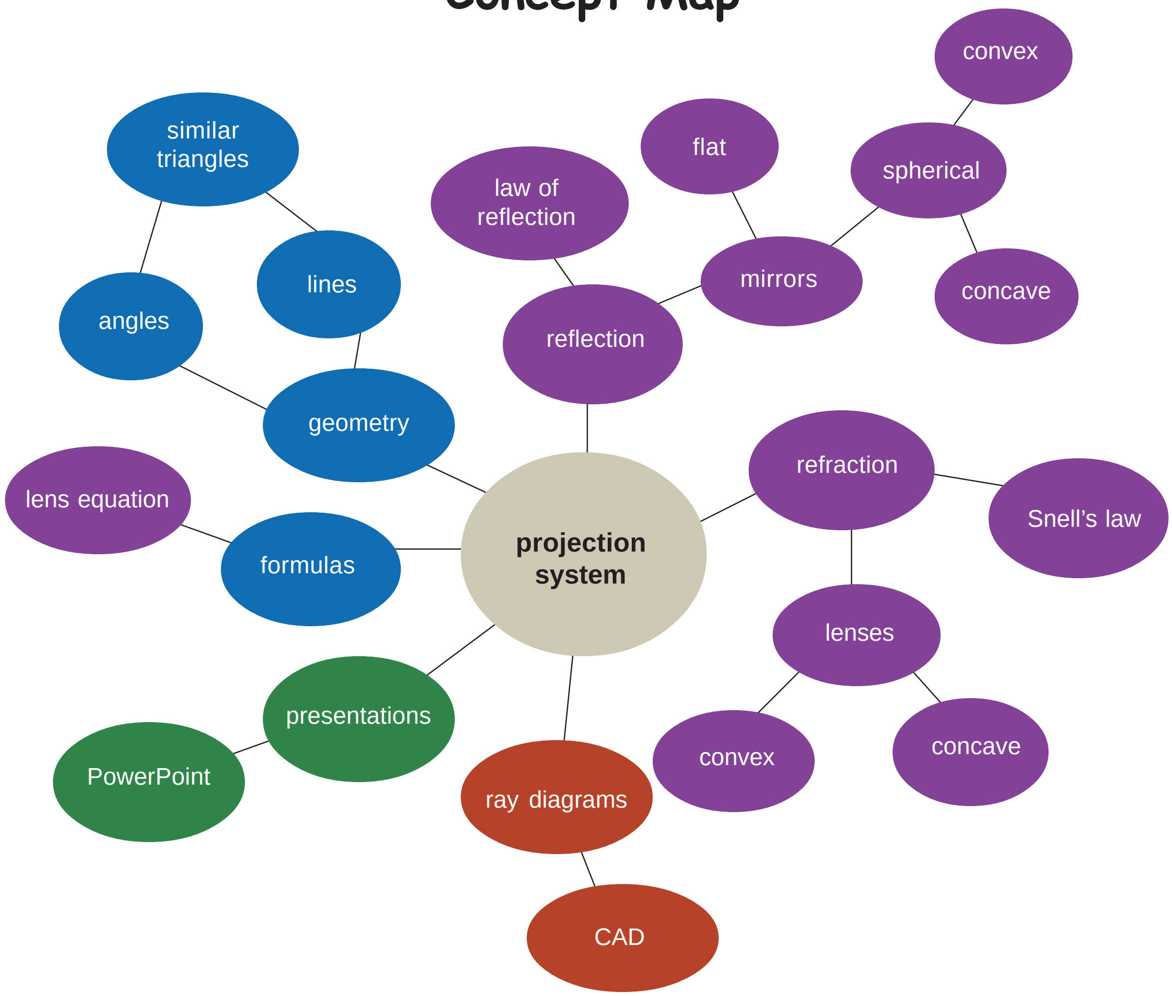
Objectives

- Use ray diagrams to analyze geometric optical systems.
- Build a prototype of an optical projection system.
- Apply geometric optics concepts to monitor a manufacturing process requiring projected images.

Student Workshop Activities

- Reflection
- Refraction
- Lines and angles
- Similar triangles
- Optics in industry
- Ray diagrams

Concept Map



Integrated Skills

Data collection
Data analysis
Computer skills
Calculator skills
Teaming skills
Problem solving
Ray diagrams

Student Assessment

- Faculty will assess the technical content, including cost estimates, of the team presentation and the quality of the prototype of the proposed projection system. Each student will evaluate his/her own teamwork and the work of each student in his/her team.
- Individual student assessments will be conducted through written tests of discipline-specific subject content and lab activities.

Student Competencies

F.1.1.1 Draw a tangent and normal to plane and spherical surfaces.
F.1.1.2 Draw an incident and reflected ray.
F.1.1.3 Determine the focal point of a spherical mirror by calculation and construction.
F.1.2.1 Determine image and object distance for a converging mirror by calculation and construction.
F.1.2.2 Determine and describe the optical characteristics of an image formed by a converging mirror.
F.1.2.3 Apply the properties of parallel and transverse lines.
F.1.2.4 Apply the properties of similar triangles.
F.2.1.1 Determine the angle of refraction.
F.2.1.2 Draw an incident and refractive ray.
F.2.1.3 Determine the focal point of a thin convex lens by calculation and construction.
F.2.1.4 Determine the critical angle for total internal reflection.
F.2.2.1 Determine image and object distance for a converging lens by calculation and construction.
F.2.2.2 Determine and describe the optical characteristics of an image formed by a converging lens.

Engineering Technology Core
Optics Module #1 — Student Handout

Geometrical Optics

Projection System

Problem Scenario

The company for which you work as a technician assembles component parts on an assembly line. At some point in the assembly process, the parts enter a covered compartment for environmental reasons. While in the covered area of the assembly line, several parts are fitted together and then they emerge from the covered area. Your team is responsible for monitoring what goes on in the covered area for efficiency and quality control.

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Setting the Stage

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Objectives

- Use ray diagrams to analyze geometric optical systems.
- Build a prototype of an optical projection system.
- Apply geometric optics concepts to monitor a manufacturing process requiring projected images.

When a ray of light strikes a surface, part of the light may be reflected back into the incident medium. This reflection of light is what allows us to see ourselves in a plane mirror. The ray that strikes the surface is called the incident ray and the ray that is “bounced’ from the surface is called the reflected ray. For all rays there are two basic laws:

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Setting the Stage, continued

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- *The incident ray, the refracted ray, and the perpendicular to the surface all lie in the same plane.*

In some manufacturing situations, a process may be "hidden" from view because it is conducted in a controlled environment or involves objects too small to observe without magnification. In order to monitor and control such activities, mirrors and/or lenses can be used to project images of the objects and the manufacturing process to viewing screens or video monitors.

Performance Expectations

- Student are expected to develop and present a team proposal for an optical projection system to meet the requirements of an assembly production line. Presentation software, such as PowerPoint, is expected, along with cost estimates.
- A prototype of the proposed optical projection system is required.
- Each student will evaluate his/her own teamwork and the work of each student in his/her team.
- Individual student assessments will be conducted through written tests of discipline-specific subject content and lab activities.

Engineering Technology Core
Optics Module #2

Physical Optics

Micro-Measurement — A Case Study

Case Study

It is 9:15 on Tuesday morning, and Jan is just entering the testing lab at Micro Machining, Inc. As she opens the door, she feels the rush of cool air blowing out of the testing room. Jan goes to the preparation table near the door, opens the middle drawer and takes a container of baby power and powders her hands. She then opens a package of latex gloves and inserts her hands into them. She goes from the table to the storage bin, selects a new plastic lab jacket from the storage bin, and puts it on.

The first set of tests that Jan will perform today is to check a sampling of blocks machined last week. She will be testing the height of each block against a standard and evaluating the flatness of each block. Since Jan will be measuring height difference in the micro-inch range, she will be using an optical flat for both tests.

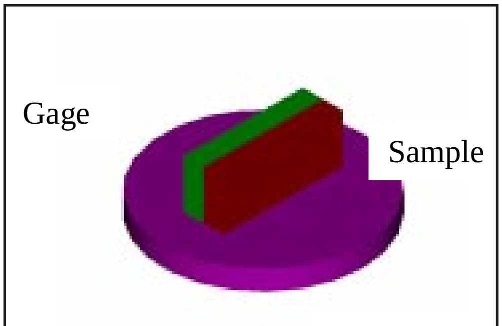


Figure 1

Jan goes to the testing booth where the samples, gage block, and optical flats were placed yesterday afternoon after all were cleaned. Jan takes one of the optical flats and brushes it with a camel's hair brush and brings the gage block to the flat. Next, she selects one of the samples and brings it to the optical flat so that it is against the gage block with the long dimension of the two blocks adjacent. (See Figure 1) She then places these under the beam splitting mirror and turns on the helium light source. (See Figure 2)

Jan brushes the second optical flat and places it on top of the two blocks. She first presses the flat on the gage block side and then on the sample side and observes which causes a change in the pattern and records the results. Since the gage block and the sample are the same width, Jan will count the number of fringes only on the gage block to calculate the height differences.

Jan then analyzes her data and records her conclusions.

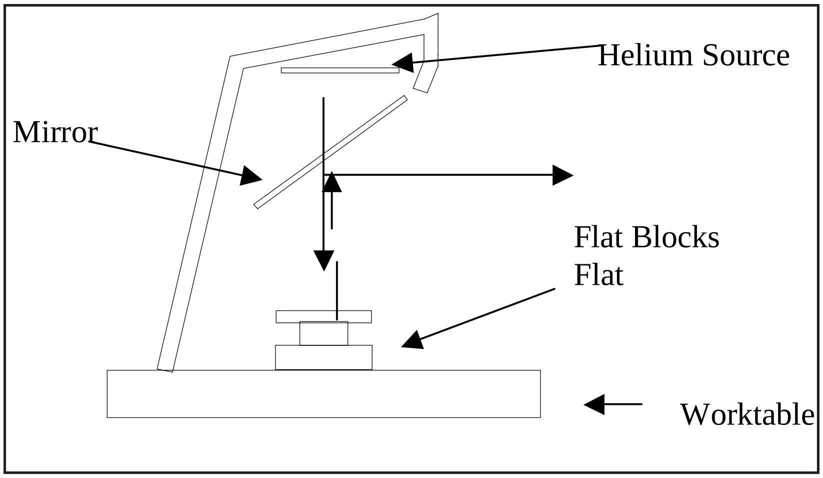
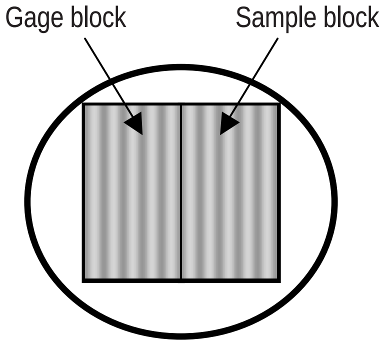
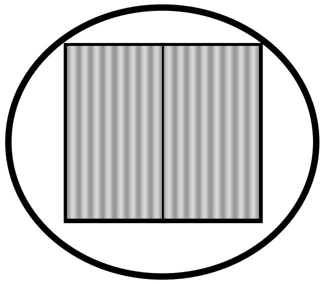


Figure 2

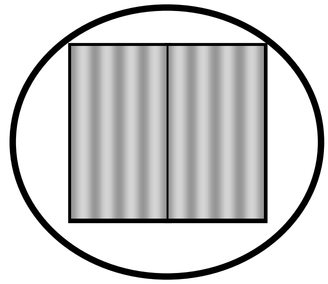
Below is a diagram of what Jan observed. The gage block is on the left and the sample on the right.



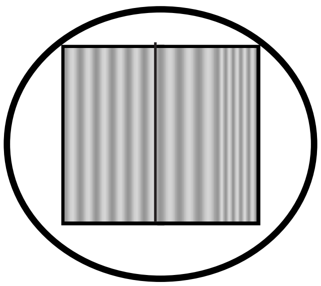
I



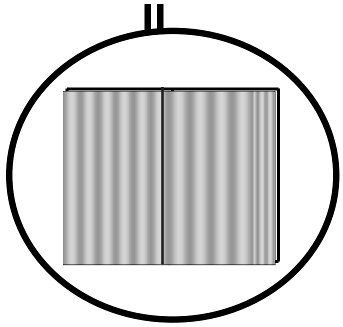
II



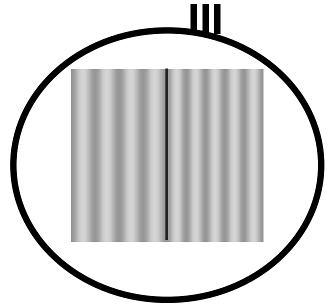
III



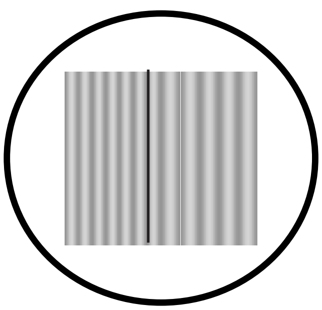
IV



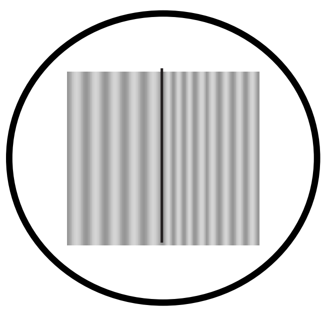
V



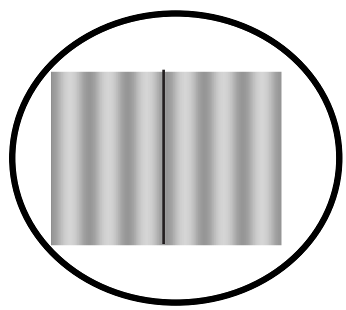
VI



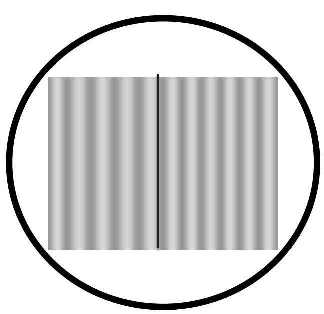
VII



VIII



IX



X

Below is the report that Jan sent to her supervisor.

Light Source:	Helium		Wave length: 587nm	
Gage Block width	45.00 mm		Sample block width: 45.00 mm	
Sample number	**Pattern change**	**Number of fringes**	**Height difference**	**Comments**
I	Sample	5	.00147 mm	Sample higher
II	Sample	8	.00235 mm	Sample higher
III	Gage	4	.00117 mm	Sample lower
IV	Sample	6	.00176 mm	Sample higher
V	Sample	6	.00176 mm	Sample higher, not flat
VI	Gage	4	.00117 mm	Sample higher, not flat
VII	Gage	7	.00205 mm	Sample lower
VIII	Sample	5	.00147 mm	Sample higher
IX	Gage	3	.00088 mm	Sample lower
X	Sample(?)	5	.00147 mm	Sample higher (?), only small pattern change when pressure applied.

After Jan's supervisor reviews the results he instructs her to measure sample VI, VII, VIII, and X again. He suggests that the samples should be measured twice by reversing the adjacent sides.

Setting the Stage

Geometrical optics assumes that light travels in straight lines and follows the laws of reflection and refraction of light rays. There are many phenomena such as diffraction, interference, and polarization of light that can only be explained by the wave nature of light.

When we place an object in the path of light, some of the light will be blocked and the light will cast a shadow. We view the shadow as having well-defined edges defined by the shape of the object. However, close inspection will reveal that the edges of the shadow are blurred because there is a slight bending of the light around the edges of the object. This bending of light is called diffraction. Diffraction can only be explained by studying light as a wave.

When waves are superimposed on one another they result in an addition that is different from either wave alone. For example, if we consider light as a sine wave and two similar waves in phase are added, then the resultant is a reinforced wave or a wave of greater amplitude. If these same two are added out of phase, then there is cancellation and reduced amplitude. This phenomenon of adding waves is called interference and will produce constructive and destructive interference.

Several measuring instruments use the interference of light to make measurements of small distances. The wave length of light is small; thus, is well suited to making distance measurements in the micrometer range.

Notes to the Instructor

Problem-Based Learning Know/Need-to-Know Chart		
What do we know?	**What do we need to know?**	**How do we find out?**

Questions:

1. When Jan enters the testing lab, it is obvious that there is a positive pressure in the room. Is there a reason for this positive pressure?
2. The blocks and optical flats were cleaned one afternoon and not measured until the next day. Do you think this is because they may have been cleaned late in the day and there was not time to do the measurements, or was this part of the procedure?
3. Why brush the optical flats with a camel's hair brush?
4. Why does Jan conclude that samples IV and V are not flat? Is this a correct description?
5. Why does Jan's supervisor direct her to check some samples again?
6. Should Jan change her procedure; if so, how?

Strategies:

1. Prepare a short lecture on metrology, and focus on linear measurements. Give the students a collection of measuring devices and a collection of objects to be measured (room dimensions, tables, boxes, hair, etc). Have the students select the appropriate device for each and give a reason for the selection.
2. Present the case study as a written document, and show a video of optical flats or an interferometer.
3. Demonstrate sine wave addition by using two tuning forks of close frequency to have the students hear the beats.
4. Demonstrate the addition of sine waves of the same frequency by using two function generators and an oscilloscope. Also, this same concept can be simulated with electronic simulation software.
5. Use a spreadsheet and/or graphing calculator to graph the sine waves and the summed wave.
6. Demonstrate interference pattern from two slits using laser. Have students measure separation of slits, distance to screen, and distance between fringes to determine the wavelength of the source.
7. Use optical flats and wedges to determine the thickness of various thin objects or the flatness of an object.
8. Place a fast evaporating solvent on a metal plate with an optical flat on it. Observe how the patterns change, and continue to observe that the pattern does not return to its original pattern in a short time. This demonstrates the importance of having the two at an equilibrium temperature and how long it takes to reach equilibrium because of the different thermal properties.
9. Students can replicate the process presented in the case study and verify the results. They will write their findings, which include analysis of process and reasonableness of the data and results.
10. Students will research topics on optics such as use of lasers for micro measurements, history of optics for measurements and alignment, time line of major milestones in optics, etc.

Continued on next page

Content Strands

Physics

Interference
Introduction to spectrum
Properties of light waves

Mathematics

Sine wave addition
Graphing sine waves
Point, lines, and planes
Right triangle geometry

Technology

Metrology
Optical flats
Standards (units)
Linear measurements

Objectives

- Analyze, interpret, and replicate processes and procedures described in a case study, and verify results stated in the case study.
- Use interference of light to make measurements of small distances.
- Demonstrate the addition of sine waves using physical devices, instrumentation, and graphs.

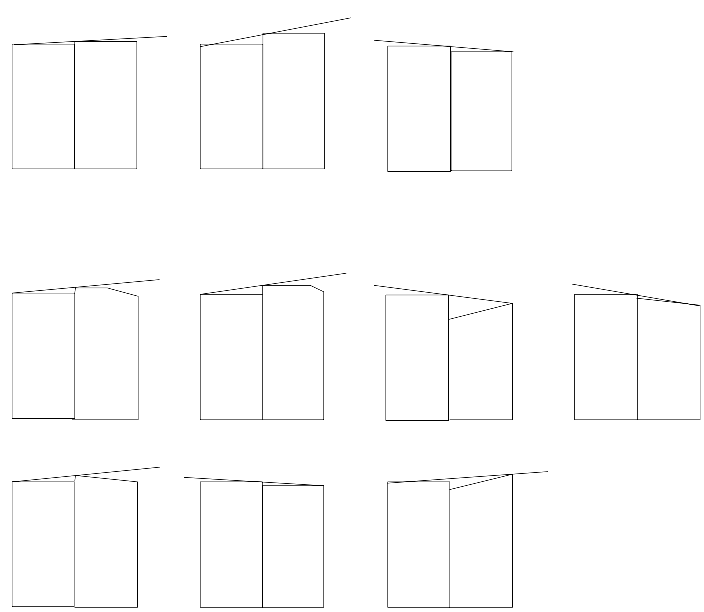
Integrated Skills

Data collection
Data analysis
Computer skills
Calculator skills
Teaming skills
Problem solving

Notes to the Instructor, continued

11. Throughout the module, it would be helpful to the student to review the concepts of precision, accuracy, significant figures, and error analysis. These concepts will also be needed in the materials projects.
12. Students can be guided through questions.
    - How does the accuracy of a micrometer compare to a tape measure? How many primary applications are there of optics to metrology?
    - What are the best reasons for the use of light waves in measurements?
    - What characteristics of light make it a standard?
    - Explain the reason for the increased use of light waves in measurements?
    - How did Albert A. Michelson contribute to metrology?
    - What characteristic of light is important for its role as the master standard of length?
    - What is an interferometer, and how is it used?
    - For practical work with optical flats, what is the most important requirement of light?
    - Why is temperature such an important consideration in optical flat measurements?
    - Why is cleanliness so important for measurements with optical flats?
    - Where do you place optical alignment in history?

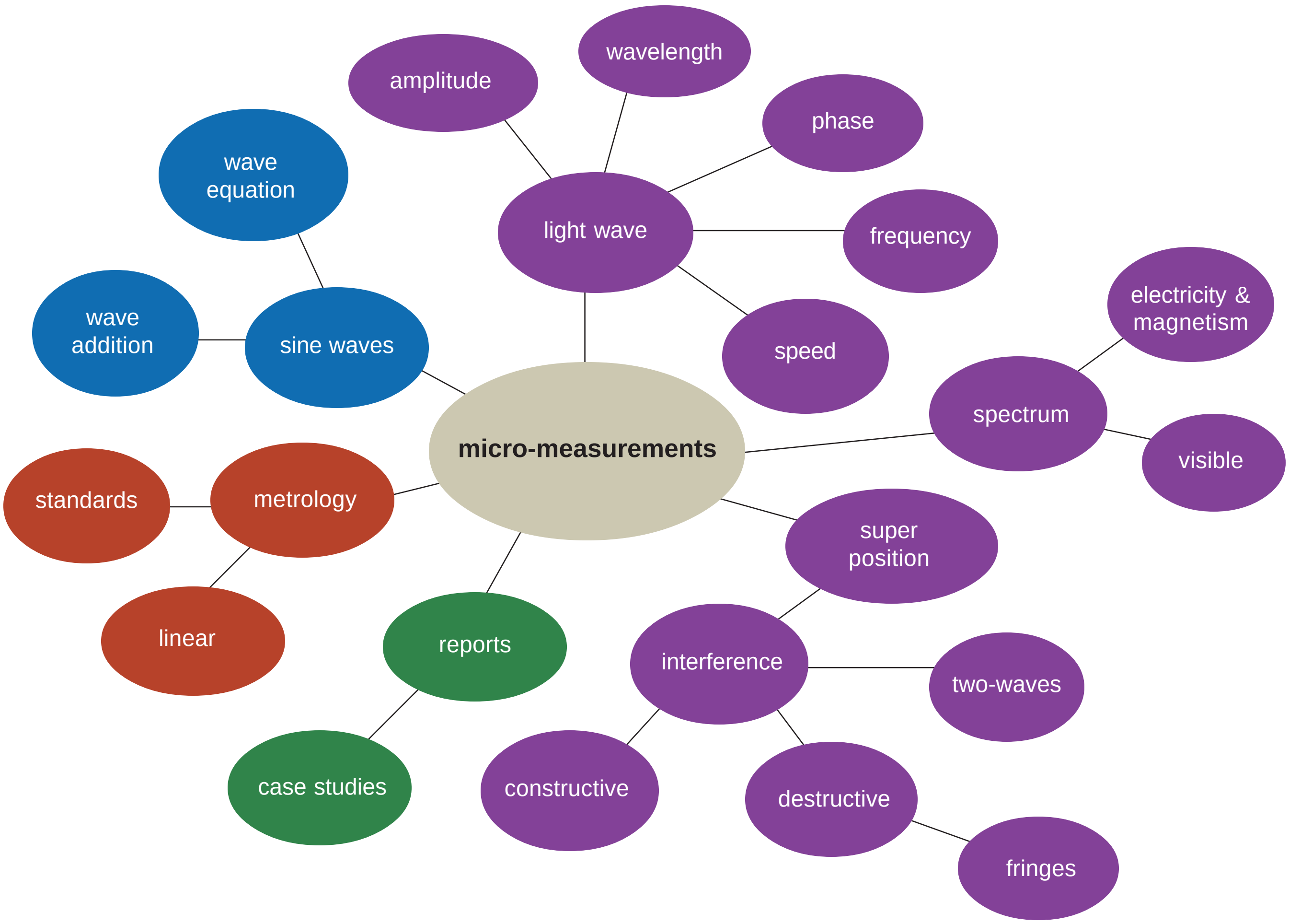
Below are possible alignments of the gage block and manufactured block.



Student Assessment

- This is a case study. Student will be assessed in teams on how well they analyze, interpret, and replicate procedures and processes.
- Individual assessments will be made on written tests of subject content and lab activities.

Concept Map



Student Competencies

F.3.1.1 Describe the relationship between wave length, frequency, and speed.
F.3.1.2 Calculate the energy content of a light wave.
F.3.1.3. Determine physical characteristics of a wave from a wave equation.
F.3.1.4 Write the wave equation given the physical characteristics.
F.3.2.1 Determine the phase difference between two waves at a given point.
F.3.2.2 Use the phase differences to describe constructive and destructive interference.
F.3.2.3 Describe the dispersion of a laser beam.

Engineering Technology Core
Optics Module #2 — Student Handout

Physical Optics
Micro-Measurement — A Case Study

Case Study

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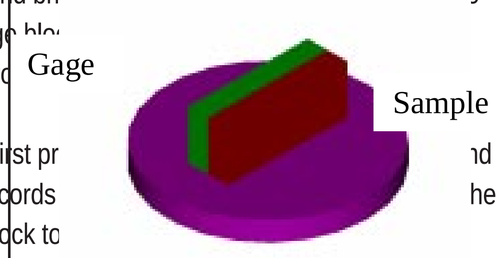


Figure 1

Jan brushes the second optical flat and places it on top of the two blocks. She first pr… nd then on the sample side and observes which causes a change in the pattern and records … he sample are the same width, Jan will count the number of fringes only on the gage block to…

Jan then analyzes her data and records her conclusions.

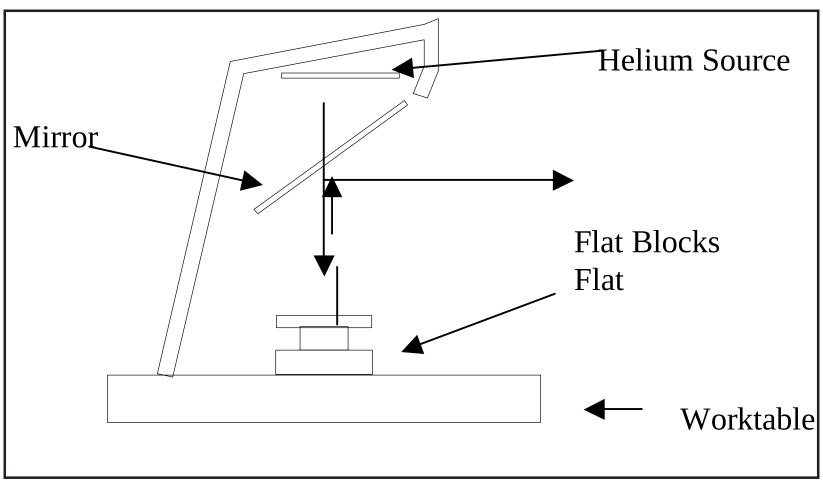
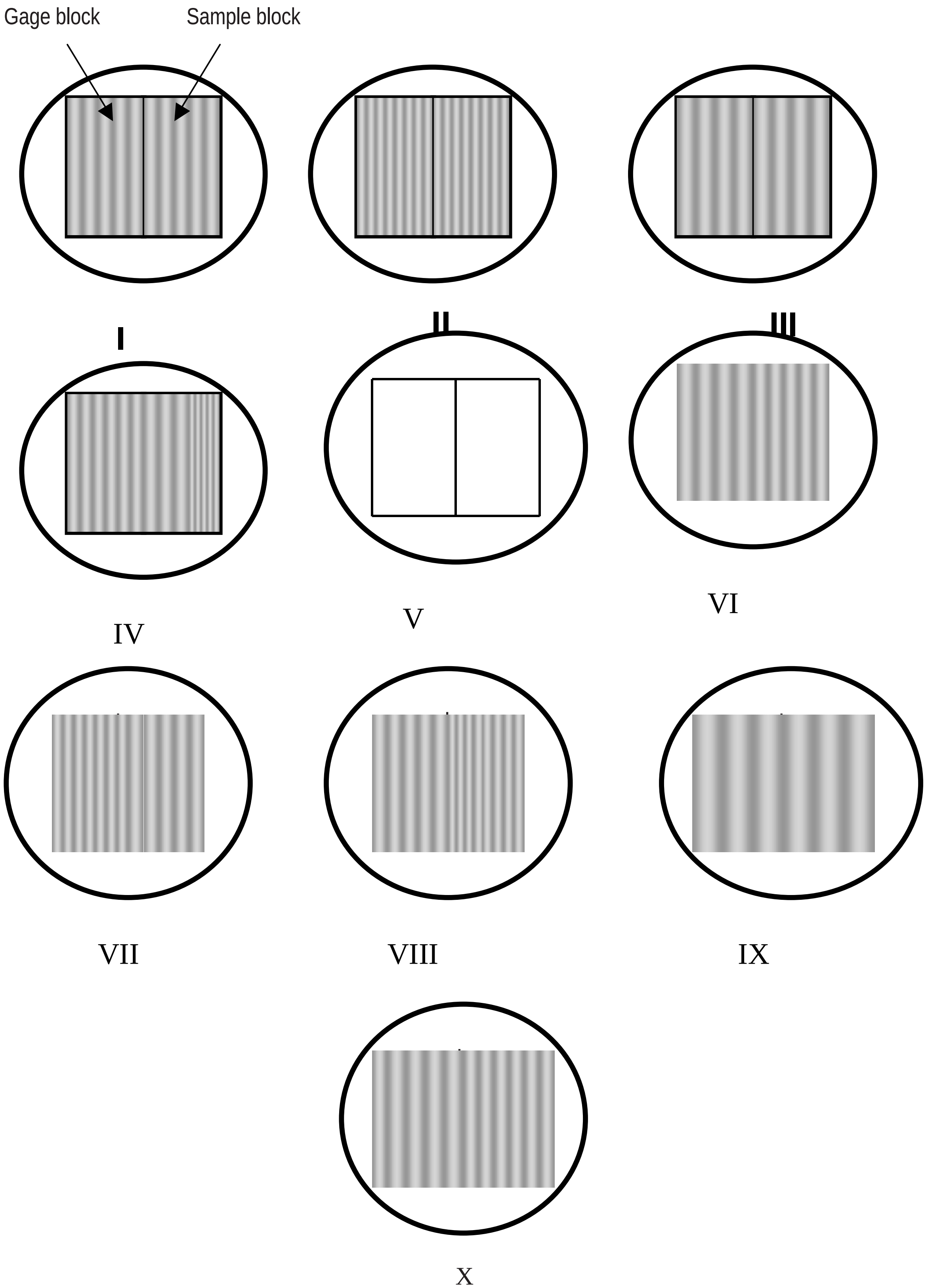


Figure 2

Below is a diagram of what Jan observed. The gage block is on the left and the sample on the right.



Below is the report that Jan sent to her supervisor.

Light Source: Helium — Wave length: 587nm

Gage Block width 45.00 mm — Sample block width: 45.00 mm

Sample number	Pattern change	Number of fringes	Height difference	Comments
I	Sample	5	.00147 mm	Sample higher
II	Sample	8	.00235 mm	Sample higher
III	Gage	4	.00117 mm	Sample lower
IV	Sample	6	.00176 mm	Sample higher
V	Sample	6	.00176 mm	Sample higher, not flat
VI	Gage	4	.00117 mm	Sample higher, not flat
VII	Gage	7	.00205 mm	Sample lower
VIII	Sample	5	.00147 mm	Sample higher
IX	Gage	3	.00088 mm	Sample lower
X	Sample(?)	5	.00147 mm	Sample higher (?), only small pattern change when pressure applied.

After Jan's supervisor reviews the results he instructs her to measure sample VI, VII, VIII, and X again. He suggests that the samples should be measured twice by reversing the adjacent sides.

Setting the Stage

Geometrical optics assumes that light travels in straight lines and follows the laws of reflection and refraction of light rays. There are many phenomena such as diffraction, interference, and polarization of light that can only be explained by the wave nature of light.

When we place an object in the path of light, some of the light will be blocked and the light will cast a shadow. We view the shadow as having well-defined edges defined by the shape of the object. However, close inspection will reveal that the edges of the shadow are blurred because there is a slight bending of the light around the edges of the object. This bending of light is called diffraction. Diffraction can only be explained by studying light as a wave.

When waves are superimposed on one another they result in an addition that is different from either wave alone. For example, if we consider light as a sine wave and two similar waves in phase are added, then the resultant is a reinforced wave or a wave of greater amplitude. If these same two are added out of phase, then there is cancellation and reduced amplitude. This phenomenon of adding waves is called interference and will produce constructive and destructive interference.

Several measuring instruments use the interference of light to make measurements of small distances. The wave length of light is small; thus, is well suited to making distance measurements in the micrometer range.

Objectives

- Analyze, interpret, and replicate processes and procedures described in a case study, and verify results stated in the case study.
- Use interference of light to make measurements of small distances.
- Demonstrate the addition of sine waves using physical devices, instrumentation, and graphs.

Performance Expectations

- Students are expected to work in teams to analyze and interpret the results of processes and procedures presented in a case study.
- Micro-measurements will be made in lab settings using the physical properties of light waves.
- Individual student performance will be evaluated on the discipline-specific content of workshops and participation in labs and class activities.

Engineering Technology Core
Materials Module #1

Physical & Chemical Properties of Materials

Testing Paper Quality

Problem Scenario for the Student

Your team of technicians works for an independent testing laboratory. A publisher has asked you to evaluate samples of paper to be used to print brochures. Your team will perform tests and make recommendations as to which paper sample best meets the publisher's requirements.

Your written report of test results and recommendation of paper choice should include:

- Appropriate tables
- Graphs
- Sample calculations

Your team should be prepared to respond verbally to questions from the publisher.

Setting the Stage

Quality must be considered when a product is manufactured. There is *product quality control* and there is *process quality control*. Product quality control is performed through inspection of the product during the stages of production and at final inspection of the finished product. Product attributes such as dimensions, thickness, and hardness are just three of the possible quality inspections that may be performed.

Process quality control is the means through which all the factors, which we call inputs to production, are controlled. This includes the raw materials that will be converted into a product or components of the product, the equipment, the methods, and procedures used by the operators, the environment in which the product is produced, etc.

Quality in both cases is monitored through the use of statistical tools which fall into two categories: (1) *statistical quality control (SQC)* or (2) *statistical process control (SPC)*. Variation is what we are trying to control with these tools. Variation is the enemy of product quality and process quality. For example, if we were making 12-inch rulers, we would want every ruler to be as close as possible to 12 inches in length. If we had them coming off the assembly line measuring anywhere between 11 inches long and 14 inches long, we would have to scrap the shorter ones and we would be wasting material with the longer ones. Our goa,l using our statistical tools, would be to identify the causes of the wide variation (in this case, one inch below the standard of 12 inches and two inches above the standard of 12 inches).

With these math-based statistical tools, we would search for causes of variation in two areas: (1) product-to-product and (2) within the process itself. Product-to-product is important because it gives us information relating to the consistency of product quality as each piece is made. As we collect product-to-product data, that information becomes a larger data base from which statistical process control can be calculated using the statistical tools. By analyzing the SPC information, we can receive statistical "signals" from the process, which lets us know three things:

(1) Is the process in control? (Is it producing product to the standards specified by the customer?)

(2) Is the process out of control? (Has it started producing product which is outside of the standards specified by the customer?)

(3) Just how large is the variation from piece to piece?

Why is this important? Once we know how much variation is in a process, we can determine if it's too much and what is causing it so that we can design a quality plan to reduce the variation. The goal is no variation so that every product is perfectly the same from piece to piece. However, this is impossible to achieve because some variation will always exist in every process. The feasible, economical alternative is to work to continuously improve the process by eliminating the *causes* of the variation, thereby reducing the variation in the process.

Only through SQC and SPC can we "see" in charts and graphs what the process is doing in terms of variation, identify the causes of the variation, work to eliminate the causes, and thereby, continuously improve the product by improving the process that makes it.

Notes to the Instructor

1. Provide a variety of substances for the students to classify by properties using Venn diagrams.
2. A plant tour of a paper mill, foundry, steel mill, glass factory, or lumber mill will demonstrate the use of materials in manufacturing.
3. A good class activity is to have students make paper from different recyclable materials.
4. Testing stations can be set up in the lab for testing properties of paper and other materials.
5. Provide specifications for book paper and have students report test results in spreadsheet format.
6. Illustrate oxidation by bleaching paper and performing ash test on paper.
7. Tour the periodic chart to study properties (i.e., reactivity) of elements.
8. Have students 'scavenger hunt' recyclable materials and check suitability for recycled use based on industry standards found on Internet sites.
9. Invite an industry technician to speak on recyclable materials.
10. Introduce calculus concepts that will be needed for the next project on deforming materials.

Problem-Based Learning Know/Need-to-Know Chart		
What do we know?	What do we need to know?	How do we find out?

Recommended Classroom Materials

- Force probes for paper strength test
- Micrometers and calipers to measure paper thickness
- Mass balance (paper weight)
- Litmus paper (pH test)
- Magnifying glass(search for dirt, etc)
- Spreadsheet software
- Technical publications/specifications
- Light source (opacity, brightness)
- Photometers
- Food coloring, ink
- Blender (for making paper)
- Screen wire
- Dishpans
- Gloves
- Appropriate MSDS (Material Safety Data Sheets)
- Flat iron
- Chlorine bleach
- Paper, pulp
- Copies of periodic table
- Noncombustible container for ash test
- Matches
- Material samples (paper, metals, wood, plastics)

Content Strands

Physics

Types of materials
Chemical properties
  Periodic table
  pH
  Chemical equations
Physical properties
  Density
  Strength

Mathematics

Statistics
  Mean
  Standard deviation
  Tolerance
Percentages
Venn diagrams
Spreadsheets

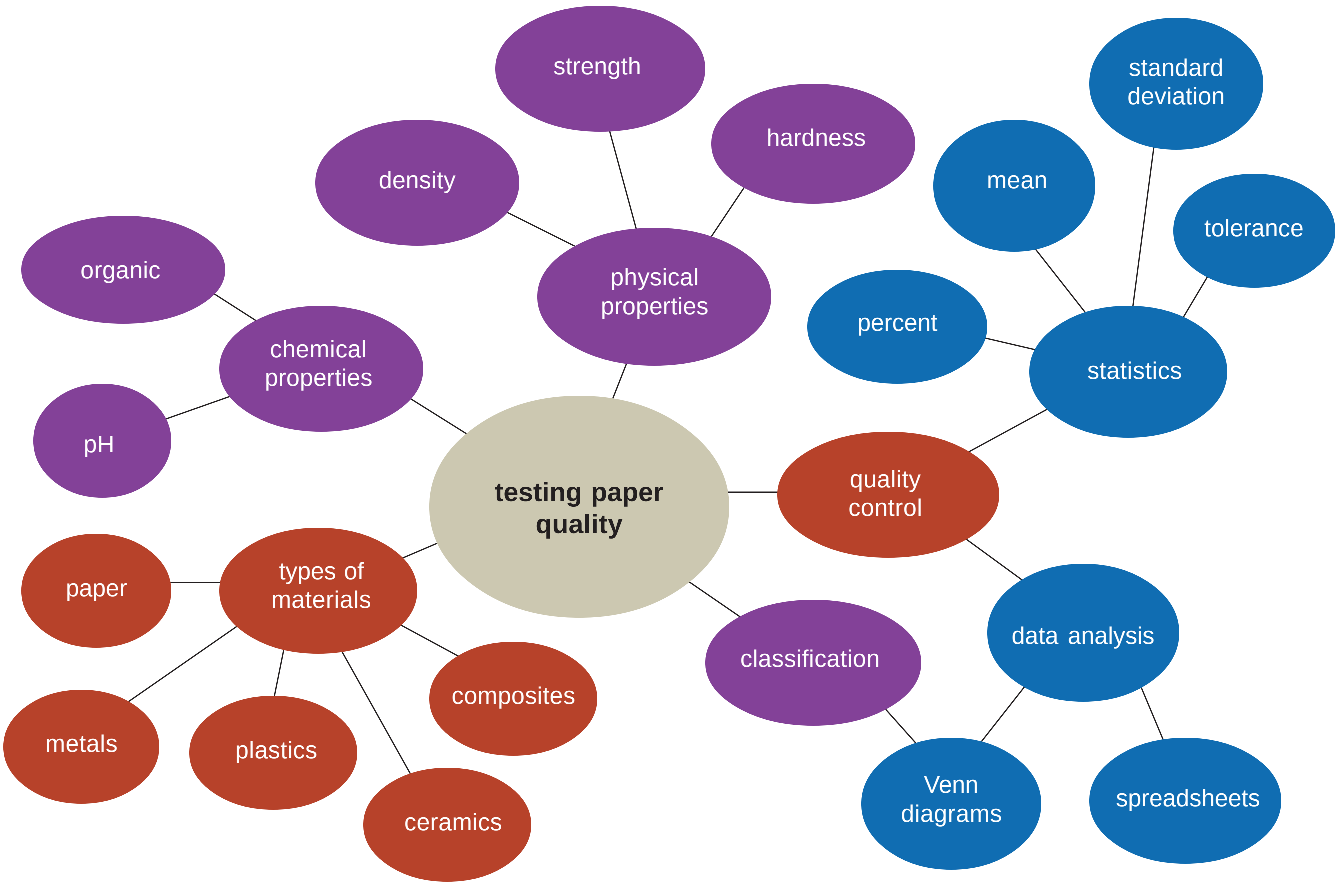
Technology

Paper-making process
Measurements
  Calipers
  Micrometers
  Force probes
Material specifications
Cost analysis

Integrated Skills

Data collection
Data analysis
Computer skills
Calculator skills
Basic statistics
Teaming skills
Problem solving
Dimensional analysis

Concept Map



Objectives

- Perform materials tests on paper samples.
- Report statistical analysis of test data.
- Use physical and chemical properties to determine the quality of paper samples and make recommendations based on specific requirements.

Student Competencies

G.1.1.1 Identify and classify materials based on physical properties.
G.1.1.2 Identify chemical and physical properties of given materials.

Student Assessment

- Team recommendations to the publisher should be evaluated on the choice of paper, appropriate tables, graphs, and sample calculation.
- Individual assessments will be made on written tests of subject content.
- Verbal responses to possible questions from the publisher should demonstrate knowledge of the problem, testing methods, and the solution.

Student Workshop Activities

- Types of materials
- Testing paper properties
- Properties of other materials
- Chemistry
  - Periodic chart
  - pH
  - Chemical equations
- Organic chemistry and polymers
- Measurements
  - Micrometers/calipers
  - Force probes
- Making paper (from other paper samples)
- Statistics
  - Mean
  - Standard deviation
  - Tolerance

Engineering Technology Core
Materials Module #1 — Student Handout

Physical & Chemical Properties of Materials
Testing Paper Quality

Problem Scenario

Your team of technicians works for an independent testing laboratory. A publisher has asked you to evaluate samples of paper to be used to print brochures. Your team will perform tests and make recommendations as to which paper sample best meets the publisher's requirements.

Your written report of test results and recommendation of paper choice should include:

- Appropriate tables
- Graphs
- Sample calculations

Your team should be prepared to respond verbally to questions from the publisher.

Setting the Stage

Quality must be considered when a product is manufactured. There is *product quality control* and there is *process quality control*. Product quality control is performed through inspection of the product during the stages of production and at final inspection of the finished product. Product attributes such as dimensions, thickness, and hardness are just three of the possible quality inspections that may be performed.

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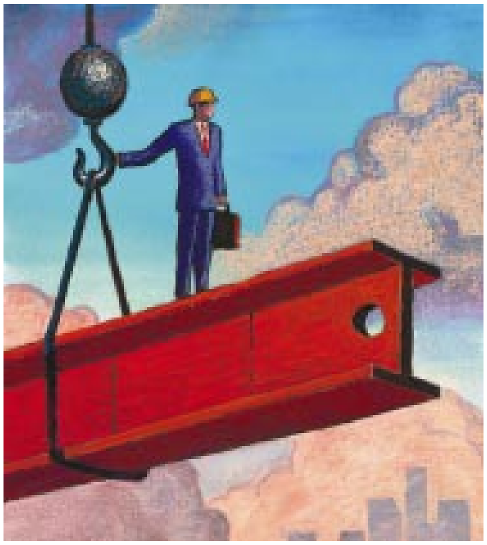
Quality in both cases is monitored through the use of statistical tools which fall into two categories: (1) *statistical quality control (SQC)* or (2) *statistical process control (SPC)*. Variation is what we are trying to control with these tools. Variation is the enemy of product quality and process quality. For example, if we were making 12-inch rulers, we would want every ruler to be as close as possible to 12 inches in length. If we had them coming off the assembly line measuring anywhere between 11 inches long and 14 inches long, we would have to scrap the shorter ones and we would be wasting material with the longer ones. Our goal, using our statistical tools, would be to identify the causes of the wide variation, work to eliminate the causes, and thereby, continuously improve the product by improving the process that makes it.

Performance Expectations

- Each student will be evaluated on the quality of the team's written report and recommendations.
- Instructors will test and evaluate individual student performance on the discipline-specific content of workshops and participation in class activities.
- Students will have opportunities for self-evaluation, peer evaluation, and team evaluation.

Objectives

- Perform materials tests on paper samples.
- Report statistical analysis of test data.
- Use physical and chemical properties to determine the quality of paper samples and make recommendations based on specific requirements.



Mechanical Properties of Materials

Hydraulic Press

Problem Scenario for the Student

Your company, Medallions, Inc., has been in the business of making small, “coin- size” medallions for the past 10 years. Over time, the business has grown from a small garage-sized operation to a company employing more than 150 people.

The vice president (VP) for manufacturing met with you and the other technicians to brief you on a new medallion that has been ordered and will go into prototype production within the next 60 days. This metal medallion will be three inches in diameter, which is two to three times larger than any medallion that the company now manufactures.

The VP told you and your team that there is a disassembled press in storage that could be adapted to produce the new medallion. He also told you that there is a hand sketch of the assembly for the press in the files. He asked you and your team to locate the disassembled press and make a written report with recommendations for adapting the old press for production of the prototype medallion. He also requested that you make an updated CAD drawing of the assembly.

Upon going to the storage area, you are able to locate, with the aid of the hand sketch, the hydraulic ram and all components of the frame. You are not able to locate the bolts that hold the cross member to the support frame. You notice that the cross member attached to the hydraulic ram is cracked. The rating on the hydraulic ram is 220 T.

Setting the Stage

In the section on mechanics, we studied the cause and effect of force and motion. The application of a force produced linear or rotational motion. In this study, the effect of the application of a force on the size or shape of the object itself was not considered. When a force is applied to an object, the force is distributed over the whole of the object and that force may cause the object to deform.

Objectives

- Create a stress/strain curve, and identify appropriate points on the curve (yield point, ultimate strength).
- Use stress/strain and shear/bending concepts to design a hydraulic press to form a metal part.

Objects subject to a force are said to be under stress. The amount of stress is the ratio of the applied force to the cross sectional. The ratio of the change in length to the original length is called strain. For materials, the stress-strain diagram is used to characterize the material. A stress-strain diagram is an experimentally determined graph for a given material. From the stress-strain diagram, it is possible to divide material into two broad categories or characteristics — ductile and brittle materials.

Ductile materials are characterized by their ability to yield and thus change shape and length permanently. Thus, they can be formed into shape. Brittle materials are characterized by the fact that a rupture occurs without a noticeable change in length. Brittle materials cannot be formed into shapes.

Notes to the Instructor

Problem-Based Learning Know/Need-to-Know Chart		
What do we know?	**What do we need to know?**	**How do we find out?**

1. Prepare the students for this project by providing an orientation to operation of presses used to form metal parts and the purpose of forming dies through activities such as a plant tour, videotapes, etc.
2. Use MBL (microcomputer-based laboratory) or CBL (calculator-based laboratory) with force probes to demonstrate and measure stress and strain relationships. Materials might include rubber bands, surgical tubing, or similar elastic materials.
3. Use bathroom scales to measure compression force of materials. Place a board on each end of a scale. Place an object at various positions on the board to illustrate changes in force.
4. Calculate the slope of several lines using a fixed point and another point that moves closer and closer to a fixed point. Use the PBS video series *Mechanical Universe* to help students conceptualize the relationship of the slope of line, limits, and derivatives.
5. Create a spreadsheet of extracted data from a stress/strain curve. The students will use the spreadsheet to create a stress/strain curve and identify appropriate points on the curve (as in yield point, ultimate strength, etc.)
6. Using a die, students will stress some material beyond the yield point, simulating the imprinting of a medallion. They may use a soft metal, modeling clay, cookie dough, or paper and seal (such as a notary seal). Ideally, the students should measure the force.
7. Students should see tension and compression in a loaded beam. This could be accomplished by loading a foam rubber beam, stack of paper, or a stack of tongue depressors. The foam beam could be cut to emphasize the tension and compression in the upper and lower sides of the beam.
8. Provide small cross-sectional area wooden beams (a piece of a 2-by-4 or a tomato stake). Students will support the beam at the ends and load with a known load. They will compare the experimental and calculated deflections. Any material may be used for which material properties are available in the literature.
9. Demonstrate how the moment of inertia of an object varies with mass and geometry. Paul Hewitt's *Conceptual Physics* video series contains a helpful segment entitled "Center of Mass."
10. Experimentally determine the moment of inertia of various objects. Possible techniques are an Atwood machine or pipe, cylinder, and sphere rolling down a plane. Time can be measured using photogates.
11. Refer students to communication resources to assist them in developing a formal written recommendation and an oral presentation.

Content Strands

Physics

Stress
Strain
Shear
Bending
Deflection
Moment of inertia

Mathematics

Slope of a line
Limits
Derivatives
Maximum/minimum
Definite integrals
Area under a curve

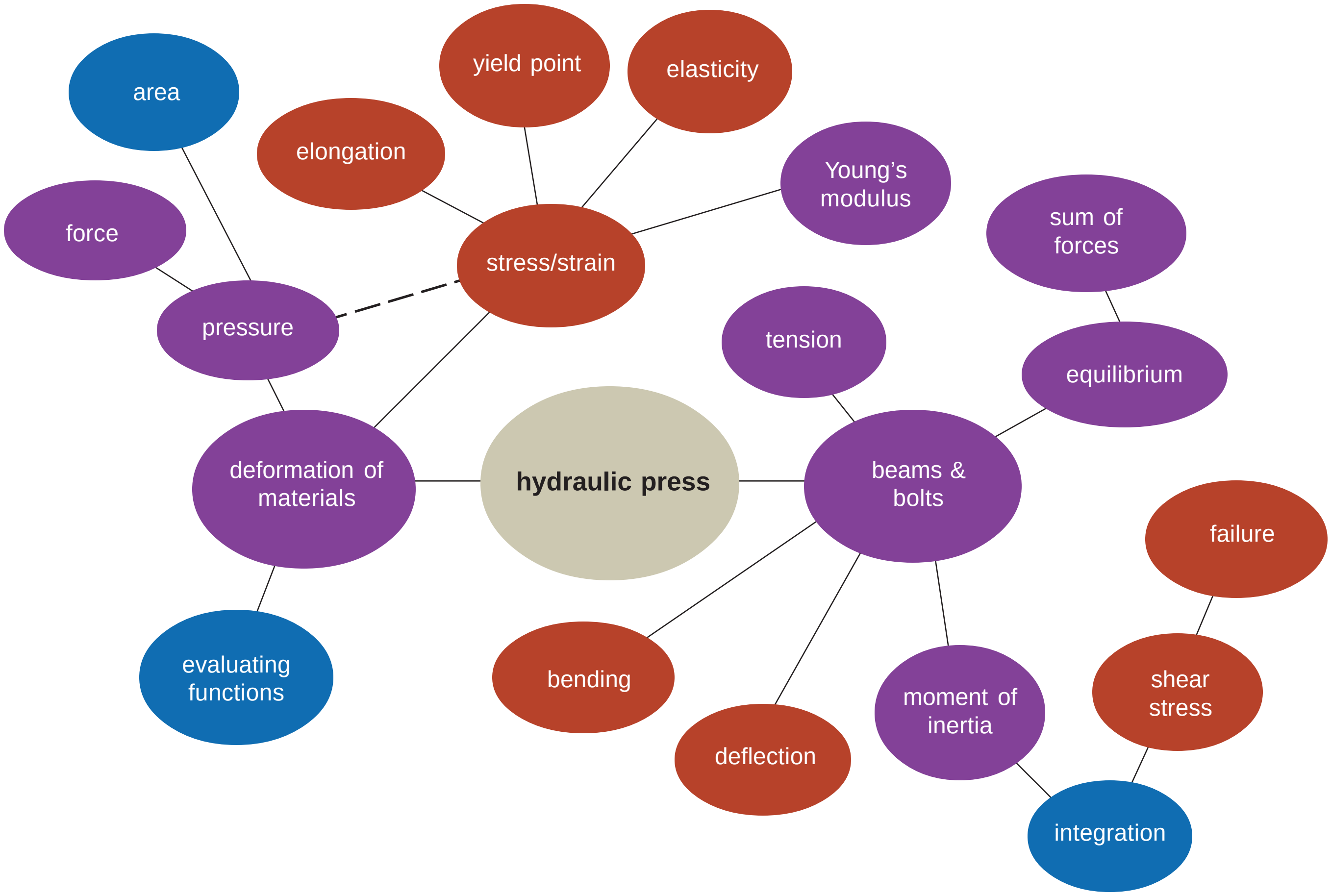
Technology

Hydraulic press
CAD drawings

Student Assessment

- Faculty will assess the technical contents, including an updated CAD drawing of the assembly, of the recommendations for adapting the old press for production of the prototype medallion. Each student will evaluate his/her own work and the work of each student in his/her team.
- Individual student assessments will be made on written tests of discipline-specific subject content.

Concept Map

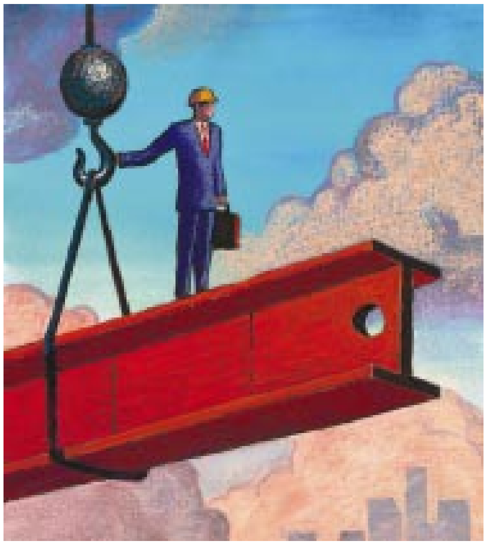


Student Competencies

G.1.2.1 Determine stress in an object subjected to applied forces.
G.1.2.2 Determine strain in an object subjected to applied forces.
G.1.2.3 Apply Hook's Law to determine the Young modulus of elasticity.
G.1.2.4 Use elastic limit and yield point to determine load limitations.
G.1.3.1 Construct a shear stress diagram for a loaded beam.
G.1.3.2 Construct a bending moment diagram for a loaded beam.
G.1.3.3 Determine maximum shear stress for a loaded beam.
G.1.3.4 Determine maximum bending moment for a beam.
G.1.3.5 Integrate a polynomial function.
G.1.3.6 Use definite integrals to calculate the area under a curve.

Integrated Skills

Data collection
Data analysis
Computer skills
Calculator skills
Basic statistics
Teaming skills
Problem solving
Dimensional analysis



Engineering Technology Core
Materials Module #2 — Student Handout

Mechanical Properties of Materials

Hydraulic Press

Problem Scenario

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Performance Expectations

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- Instructors will test and evaluate individual student performance on the discipline-specific content of workshops and participation in class activities.
- Students will have opportunities for self-evaluation, peer evaluation, and team evaluation.

Setting the Stage

In the section on mechanics, you studied the cause and effect of force and motion. The application of a force produced linear or rotational motion. In this study, you did not consider the effect of the application of a force on the size or shape of the object itself. When a force is applied to an object, the force is distributed over the whole of the object and that force may cause the object to deform.

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Objectives

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