NOTE: This Summer Training Institute (STI) Notebook is not the entire Project Lead The Way® (PLTW) course curriculum. This notebook is a subset of the PLTW curriculum for training purposes only. Please refer to the course curriculum for the complete materials and resources needed to teach the course.
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Teacher Signature __________________________________________ Date __________

Print Name ____________________________________________________________

School Name __________________________________________ State __________

Participant Copy
Please sign and retain this copy for your records.
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Teacher Signature________________________________ Date________________

Print Name ____________________________________________________________

School Name ________________________________ State ____________

PLTW, Inc. Copy

Please sign and give to your Core Training Instructors. The Affiliate Director will send all signed copies to PLTW, Inc. at the completion of the STI.
Principles Of Engineering™ (POE)
Statement of Understanding
2009 Summer Training Institute™

Name (please print): __________________________________________

All participants at the Project Lead The Way® Summer Training Institute™ (STI) are required to maintain a portfolio of exercises, activities, and projects as assigned by the instructors during the STI. Your instructors will periodically review and sign-off on completed portions of the portfolio over the duration of the STI.

The course portfolio is collection of the selected coursework that was assigned during the STI and provides evidence that the participant successfully completed the material at the STI. An instructor will initial each activity when it has been determined by the instructor to demonstrate adequate competency with the subject matter.

The STI provides a comprehensive overview of the course content, and is not inclusive of the full scope and breadth of the course. Due to the time constraints inherent in a 2-week professional development session, the STI provides only an introduction to select lessons, activities and projects within the course. In preparation to teach the course, it is the responsibility of the participant to continue to familiarize him or herself with the entire course curriculum upon completing the STI.

I understand it is my responsibility to complete a course portfolio and to continue to become competent in the full scope of the specific Project Lead The Way® curriculum for this course.

Signature: ___________________________ Date: ______________

Note to STI Participants:
It is the intent that all of the activities on the Portfolio Checklist be completed either during the scheduled class time or as a homework exercise.
Principles Of Engineering™ (POE)
Statement of Understanding
2009 Summer Training Institute™

All participants at the Project Lead The Way® Summer Training Institute™ (STI) are required to maintain a portfolio of exercises, activities, and projects as assigned by the instructors during the STI. Your instructors will periodically review and sign-off on completed portions of the portfolio over the duration of the STI.

The course portfolio is collection of the selected coursework that was assigned during the STI and provides evidence that the participant successfully completed the material at the STI. An instructor will initial each activity when it has been determined by the instructor to demonstrate adequate competency with the subject matter.

The STI provides a comprehensive overview of the course content, and is not inclusive of the full scope and breadth of the course. Due to the time constraints inherent in a 2-week professional development session, the STI provides only an introduction to select lessons, activities and projects within the course. In preparation to teach the course, it is the responsibility of the participant to continue to familiarize him or herself with the entire course curriculum upon completing the STI.

I understand it is my responsibility to complete a course portfolio and to continue to become competent in the full scope of the specific Project Lead The Way® curriculum for this course.

Signature: ___________________________  Date: ________________

Note to STI Participants:
It is the intent that all of the activities on the Portfolio Checklist be completed either during the scheduled class time or as a homework exercise.
Participant’s Name: ________________________________

STI Location: ________________________________

STI Dates: ________________________________

School District: ________________________________

School Name: ________________________________

Email Address: ________________________________

Instructors’ Names: ________________________________

My instructor(s) has reviewed the Portfolio Checklist with me and I am aware of the final evaluation.

Signature: ________________________________ Date: __________

The student ( has / has not ) met the requirements of this course.

Instructor’s
Signature: ________________________________ Date: __________

Instructor’s
Signature: ________________________________ Date: __________

Note to STI Instructors:
When completed, please provide a copy of the Statement of Understanding, Participant Completion Report, and the Portfolio Checklist to the participant and to the STI Affiliate Director.
<table>
<thead>
<tr>
<th>Day</th>
<th>Assignments and Deliverables</th>
<th>Instructor Initials</th>
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<tr>
<td>DAY 9</td>
<td>1.3a - Engineering Career Research</td>
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<td>DAY 2</td>
<td>2.1a Perspective Sketching, 2.1b Orthographic Sketching, Sketching (PPT)</td>
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<td>Build and Program Three Advanced Fischertechnik Projects</td>
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<td>DAY 4</td>
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<td>DAY 4</td>
<td>Marble Sorter PowerPoint</td>
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<td>DAY 5</td>
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<td>DAY 5</td>
<td>8.2c - Mathematic Calculations with Excel</td>
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<td>DAY 7</td>
<td>5.1e - West Point Bridge Builder Introduction, 5.1f - West Point Bridge Design</td>
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<td>8.1a - The BD Project</td>
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<td>5.2a - Centroids Activity with MDSolids</td>
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<tr>
<td>DAY 8</td>
<td>5.2b - Moment of Inertia Activity with MDSolids</td>
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<td>6.1a - Materials Property Display</td>
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<td>6.2b - Engineering Problems</td>
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<td>DAY 10</td>
<td>6.2b - Engineering Problems</td>
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<td>DAY 10</td>
<td>6.5 - Instructions for the SPC Device, Material Testing Requirements, Materials Testing Formulas - Template</td>
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<td>DAY 10</td>
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<td>8:00 AM - 10:00 AM</td>
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<td>10:00 AM - 11:30 AM</td>
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<td>DAY 1</td>
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<td>1:00 PM - 5:00 PM</td>
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<td>8:00 AM - 12:00 PM</td>
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<td>DAY 2</td>
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<td>4.5</td>
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<td>1:00 PM - 5:00 PM</td>
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## Principles Of Engineering™ (POE)
### Scope and Sequence
#### 2009 Summer Training Institute™

<table>
<thead>
<tr>
<th>Day</th>
<th>Estimated Time</th>
<th>Lesson</th>
<th>Topics</th>
<th>Assignments and Deliverables</th>
<th>Due Date</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAY 3</td>
<td>8:00 AM - 12:00 PM</td>
<td>4.5</td>
<td>Introduce Marble Sorter Project Formally – Introduction of project and design process skills necessary for this project; Planning, sketching, and written description of the sorter</td>
<td>4.5K - Have You Lost Your Marbles</td>
<td>DAY 4</td>
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<td></td>
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<td>4.5</td>
<td>Design Marble Sorter (no parts) – Sketch, explain, etc.</td>
<td>4.5K - Have You Lost Your Marbles</td>
<td>DAY 4</td>
<td></td>
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<tr>
<td></td>
<td>1:00 PM - 5:00 PM</td>
<td>4.5</td>
<td>Begin to Build Marble Sorter – Construct sorter; Generate documentation of process (i.e. digital pictures for presentations)</td>
<td><code>Simple Machines Part 1</code> (VA)</td>
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<td>4.5</td>
<td>Build Marble Sorter – Construct sorter; Generate documentation of process (i.e. digital pictures for presentations)</td>
<td><code>Simple Machines Part 2</code> (VA)</td>
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<td></td>
<td>Overview of math skills needed for tomorrow</td>
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<td><strong>Homework</strong></td>
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<td>Evening Session (if needed) &amp; Continue building and programming your marble sorter.</td>
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<td>Review Curriculum &amp; Virtual Academy Lessons</td>
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<td>Review Curriculum &amp; Virtual Academy Lessons</td>
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<td></td>
<td>All About Simple Machines (with integrated math review)</td>
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<td>Marble Sorter PowerPoint</td>
<td>Marble Sorter PowerPoint</td>
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<td>DAY 4</td>
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<td>Demonstrate Marble Sorters &amp; Show Presentations</td>
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<td>1:30 PM - 2:00 PM</td>
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<td>Disassemble Marble Sorters</td>
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<td>Debrief (Discuss relevance to classroom/kids; Grading, etc.)</td>
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<tr>
<td>DAY 4</td>
<td>2:00 PM - 5:00 PM</td>
<td>4.1</td>
<td>All About Simple Machines (with integrated math review)</td>
<td>4.1a - All About Simple Machines</td>
<td>x</td>
<td>DAY 5</td>
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<td>Review SMET and Mousetrap Car Activities</td>
<td>4.1a - The SMET Project, 4.1b - Mousetrap Powered Vehicle</td>
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<td><strong>Homework</strong></td>
<td>Review Curriculum &amp; Virtual Academy Lessons</td>
<td><code>Autodesk Inv.11 Tutorial</code> (VA)</td>
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<tr>
<td>Day</td>
<td>Estimated Time</td>
<td>Lesson</td>
<td>Topics</td>
<td>Assignments and Deliverables</td>
<td>Due Date</td>
<td>Comments</td>
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<td>8.1 &amp; 8.2</td>
<td>Introduction to the Ballistic Device</td>
<td>8.1a - The BD Project</td>
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<td>8.1 &amp; 8.2</td>
<td>The Physics of Trajectory Motion</td>
<td>8.2a - Calculating Velocity, 8.2b - Calculating Range</td>
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<td>8.1 &amp; 8.2</td>
<td>Creating the BD Excel Workbook</td>
<td>8.2c - Mathematic Calculations with Excel</td>
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<td>Demonstration of Sample Ballistic Device</td>
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<td>Complete the Excel spreadsheet calculations for the device</td>
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<td>Predicting Ranges Using the Firing Angle vs. Range Plot</td>
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<td>1:00 PM - 5:00 PM</td>
<td>Ballistic Device Design for Portfolio – Create and discuss plans (Inventor) for a Ballistic Device (students in teams or individually)</td>
<td>8.1a - The BD Project</td>
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<td>Review Curriculum &amp; Virtual Academy Lessons</td>
<td>&quot;Kinematics&quot; (VA)</td>
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<td>&quot;Free Body Diagrams 1&quot; (VA)</td>
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<td>&quot;Free Body Diagrams 2&quot; (VA)</td>
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<td>&quot;Free Body Diagrams Project&quot; (VA)</td>
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<td>8.1</td>
<td>Ballistic Device Design - Finish Inventor Assembly Models</td>
<td>8.1a - The BD Project</td>
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<td>8.1 &amp; 8.2</td>
<td>History of Bridges and Related Career Paths</td>
<td>History of Bridges (PPT)</td>
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<td>8.1 &amp; 8.2</td>
<td>Strength of Shapes</td>
<td>PBS Building Big Website</td>
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<td>8.1 &amp; 8.2</td>
<td>Vector vs. Scalar Quantities</td>
<td>5.1a - X and Y Components of Vectors</td>
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<td>Free-Body Diagrams</td>
<td>5.1b - Free Body Diagram Worksheet</td>
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<td>10:30 AM - 12:00 PM</td>
<td>Pin and Roller Supports &amp; Reaction Forces</td>
<td>Reaction Forces (PPT)</td>
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<td>10:30 AM - 12:00 PM</td>
<td>Vector vs. Scalar Quantities</td>
<td>5.1a - X and Y Components of Vectors</td>
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<td>5.1b - Free Body Diagram Worksheet</td>
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<td>Simply Supported Beam Calculations by Hand</td>
<td>Math for Truss Calc. (PPT)</td>
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<td>Checking for Static Determinacy</td>
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<td>Free-Body Diagram of Entire Structure</td>
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<td>Calculating Reaction Forces</td>
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<td>Free-Body Diagram of Each Joint</td>
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<td>Calculating Internal Member Forces (Method of Joints)</td>
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<td>Using MD Solids to Check Answers</td>
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<td>Hand Calculations for PLTW Truss Problem #2</td>
<td>5.1d - Truss Calculations (Hand Calculations for PLTW Truss Problem #2)</td>
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<td>Verify and Print PLTW Truss Problems #1-4 in MD Solids</td>
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<td>DAY 7</td>
<td>8:00 AM - 10:30 AM</td>
<td>5.1</td>
<td>Statics Recap - Question &amp; Answer Session</td>
<td>5.1d - Truss Calculations</td>
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<td>West Point Bridge Design Activity</td>
<td>5.1e - West Point Bridge Builder Introduction, 5.1f - West Point Bridge Design</td>
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<td>Ballistic Device Presentation</td>
<td>8.1a - The BD Project</td>
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<td>DAY 7</td>
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<td>DAY 8</td>
<td>10:30 AM - 12:00 PM</td>
<td>5.2</td>
<td>Centroids Activity with MD Solids</td>
<td>5.2a - Centroids Activity with MDSolids</td>
<td></td>
<td>DAY 8</td>
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<tr>
<td></td>
<td></td>
<td>5.2</td>
<td>Moment of Inertia Activity with MD Solids</td>
<td>5.2b - Moment of Inertia Activity with MDSolids</td>
<td></td>
<td>DAY 8</td>
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<td></td>
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<td></td>
<td>2x4 Scale Activity</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Review Curriculum &amp; Virtual Academy Lessons</td>
<td>&quot;MD Solids Tutorial&quot; (VA)</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td>&quot;Centroids&quot; (VA)</td>
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<td></td>
<td>&quot;Deflection&quot; (VA)</td>
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<td></td>
<td></td>
<td>&quot;Moment of Inertia (VA)&quot;</td>
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<td></td>
<td></td>
<td>6.1</td>
<td>Material Properties Display</td>
<td>6.1a - Materials Property Display</td>
<td></td>
<td>DAY 8</td>
</tr>
<tr>
<td></td>
<td>8:00 AM - 12:00 PM</td>
<td>6.2</td>
<td>Strengths of Materials Computations – Do specific examples of strengths problems; Assign strengths problems to be done on paper and using MD Solids.</td>
<td>6.2b - Engineering Problems</td>
<td></td>
<td>DAY 8</td>
</tr>
<tr>
<td></td>
<td>1:00 PM - 5:00 PM</td>
<td>6.3; 6.4</td>
<td>Plant Tour</td>
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<td></td>
<td>Review Curriculum &amp; Virtual Academy Lessons</td>
<td>&quot;Finite Element Analysis&quot;, &quot;Fluid Power Introduction&quot;, &quot;Finite Element Analysis Tutorial&quot;, &quot;Magnetism PPT&quot; (VA)</td>
<td></td>
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<td></td>
<td>Self Reflection</td>
<td></td>
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<td></td>
<td></td>
<td>Complete everything covered to this point</td>
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<tr>
<td>Day</td>
<td>Estimated Time</td>
<td>Lesson</td>
<td>Topics</td>
<td>Assignments and Deliverables</td>
<td>Due Date</td>
<td>Comments</td>
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<tr>
<td>Scheduled</td>
<td></td>
<td>Schedule and participate in an exit interview with an instructor</td>
<td></td>
<td>Self Reflection Review Interview</td>
<td>x</td>
<td>DAY 10</td>
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<tr>
<td></td>
<td></td>
<td>Engineering Problems</td>
<td></td>
<td>6.2b - Engineering Problems</td>
<td>x</td>
<td></td>
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<tr>
<td>8:00 AM - 10:00 AM</td>
<td></td>
<td>Statistics – Review statistics for the tensile specimen; Measure tensile specimens and generate tapes from the SPC devices.</td>
<td>Introduction to Statistics (PPT)</td>
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<tr>
<td>DAY 9</td>
<td></td>
<td>Material Testing – Review what we’ll be doing with the tensile specimen (measurement, statistics, packet). Break samples using SSA. (Tensile Template is located on the Curriculum)</td>
<td>6.5 - Instructions for the SPC Device, Material Testing Requirements, Materials Testing Formulas - Template</td>
<td></td>
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<tr>
<td>10:00 AM - 12:00 PM</td>
<td></td>
<td>Statistics – Quality control (to help with the analysis of tapes from SPC)</td>
<td>Statistics &amp; Statistical Process Control (PPT)</td>
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<td></td>
<td>Statistics – M&amp;M Activity with Excel.</td>
<td>6.4c - Introduction to Statics</td>
<td></td>
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<tr>
<td>1:00 PM - 5:00 PM</td>
<td></td>
<td>Materials Testing – Time to work on material testing packets (review of tensile testing calculations, stress-strain graphs, etc. for aluminum and brass) and assigned problems.</td>
<td>6.5 - Instructions for the SPC Device, Material Testing Requirements, Materials Testing Formulas - Template</td>
<td>x</td>
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<td></td>
<td>Show Force-Displacement &amp; Stress-strain diagrams using MDSolids. (Optional)</td>
<td>STI Instructor and Site Evaluation – Online</td>
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<td></td>
<td></td>
<td>Finish Materials Testing Packet</td>
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<td></td>
<td>Take Final Exam Parts A, B, and C</td>
<td>End-of-Course Assessment</td>
<td>x</td>
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<td></td>
<td></td>
<td>Review Curriculum &amp; Virtual Academy Lessons</td>
<td></td>
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<tr>
<td>8:00 AM - 10:00 AM</td>
<td></td>
<td>Overview of New Curriculum</td>
<td></td>
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<tr>
<td>DAY 10</td>
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<tr>
<td>10:00 AM - 11:30 AM</td>
<td></td>
<td>Course Conclusion Checklist</td>
<td></td>
<td></td>
<td></td>
<td>Use provided Course Conclusion Checklist</td>
</tr>
<tr>
<td>Graduation</td>
<td></td>
<td>Attend graduation/closing ceremonies.</td>
<td></td>
<td></td>
<td></td>
<td>Coordinate with Affiliate Director</td>
</tr>
</tbody>
</table>
Principles Of Engineering™ Self Reflection

Name: _____________________________

The self reflection is to be used as an assessment tool that will identify skills you have acquired during training. It will also identify other areas of the curriculum that you will investigate on your own as preparation for teaching the course. Complete the log to evaluate your understanding of the curriculum objectives.

Once you have completed the self evaluation, make arrangements with an instructor for an exit interview that will be guided using this document. This document will only be viewed by you and the instructors.

Instructions to Complete Self Reflection Log:

☐ Upon completion of each unit, evaluate the objectives listed.
☐ Objective clarification can be sought through your instructor.
☐ The Personal Notes section is provided to record questions, items of attention, etc.
☐ Objective(s) receiving a rating of 1 should be reinforced using the resources available.

1 = I need to further investigate the curriculum to prepare for teaching this subject material.
2 = I think I could do an adequate job teaching this subject material right now.
3 = I’m very confident that I could teach this subject material.

1 2 3 Software Installation
☐ ☐ ☐ I know which software to install for this course.
☐ ☐ ☐ I know how to access the Tech Support from the PLTW Virtual Academy website.

Personal Notes:
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1 2 3 Curriculum
☐ ☐ ☐ I know how to effectively use the curriculum as it is designed to be used.
☐ ☐ ☐ I know how to access the Virtual Academy to download curriculum and VA lessons onto my hard drive.
☐ ☐ ☐ I can access the Project Lead The Way® website and can utilize the exam section.
☐ ☐ ☐ I know how to use the Project Lead The Way® Forums.
☐ ☐ ☐ I know how to access and use the True Outcomes website.

Personal Notes:
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Unit 1 Definition and Types of Engineering

Lesson 1.1 - Engineers and Problem Solvers
☐ ☐ ☐ I have an understanding of engineering and can describe engineering achievements through history.
☐ ☐ ☐ I can identify five historical engineering role models, including minorities and women.
☐ ☐ ☐ I can explain how to identify problems for engineers to solve in the future.
☐ ☐ ☐ I can define attributes associated with being a successful engineer.

Personal Notes:
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Lesson 1.2 - Engineering Team
☐ ☐ ☐ I can explain why an engineering team must work together to solve problems, with each team member
having individual and collective responsibilities.
☐ ☐ ☐ I can explain the role of out-sourcing in the engineering process and why effective communication is
essential.
☐ ☐ ☐ I can explain how gender-bias, racial-bias, and other forms of stereotyping and discrimination can
adversely affect communications within an engineering team.
☐ ☐ ☐ I can explain how ethics influences the engineering process.
☐ ☐ ☐ I can explain how social, environmental, and financial constraints influence the engineering process.

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Lesson 1.3 - Careers in Engineering
☐ ☐ ☐ I can explain the difference between engineering disciplines and job functions.
☐ ☐ ☐ I can explain the professional and legal responsibilities associated with being an engineer.
☐ ☐ ☐ I can explain how to research and discover the educational requirements to become an engineer.
☐ ☐ ☐ I can explain how to become familiar with an area of engineering by preparing for and conducting an
interview with an engineer in that field of engineering.

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Unit 2 Communication and Documentation

Lesson 2.1- Sketching

☐ ☐ ☐ I can demonstrate how to compose sketches and use proper sketching techniques in the solution of design problems.

☐ ☐ ☐ I can explain how to select the appropriate sketching styles for presentation of a design problem to a group.

☐ ☐ ☐ I can demonstrate how to use proper proportioning while producing annotated sketches.

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Lesson 2.2- Technical Writing

☐ ☐ ☐ I can explain how to plan and compose a written technical research report about a career field in engineering.

☐ ☐ ☐ I can demonstrate how to formulate an organized outline for a technical paper.

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Lesson 2.3- Data Representation and Presentation

☐ ☐ ☐ I can demonstrate how to design and create tables, charts, and graphs to illustrate data that has been collected.

☐ ☐ ☐ I can explain how to evaluate and select an appropriate type of table, chart, or graph to accurately communicate collected data for written work or presentations.

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Lesson 2.4- Oral Presentations

☐ ☐ ☐ I can explain how to design and deliver a presentation utilizing appropriate research support materials.

☐ ☐ ☐ I can explain how to create and assemble support materials to demonstrate concepts used in presentations.

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Unit 3 Design Process

Lesson 3.1 - Design Process

☐ ☐ ☐ I can demonstrate, compose, and diagram the product development life cycle of an invention and report findings to the class.
☐ ☐ ☐ I can explain how to trace the history of an invention and evaluate its effects on society and the environment.
☐ ☐ ☐ I can explain how to examine the evolution of an invention and report on how the design process is applied to continuously redesign and improve the product.

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Unit 4 Engineering Systems

Lesson 4.1 - Mechanisms

☐ ☐ ☐ I can identify and explain the function of the essential components of a mechanical system.
☐ ☐ ☐ I can demonstrate how to create a display of a mechanical system from a disassembled household item.
☐ ☐ ☐ I can mathematically explain the mechanical advantage gained and the function of the six different types of simple machines.

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Lesson 4.2 - Thermodynamics

☐ ☐ ☐ I can explain how to conduct an energy analysis on a home and calculate the heat loss through walls and windows.
☐ ☐ ☐ I can explain how to research and evaluate systems undergoing thermodynamic cycles for efficiency and present findings to the group.
☐ ☐ ☐ I can explain how to give an oral presentation incorporating the first and second laws of thermodynamics and describe the concept and function of a heat engine.

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Lesson 4.3- Fluid Systems

☐ ☐ ☐ I can explain how to evaluate and select specific fluid power sources for different functions.
☐ ☐ ☐ I can demonstrate how to create a flow diagram schematic sketch and compare it to an actual fluid power circuit.
☐ ☐ ☐ I can mathematically calculate and explain the work being done by a specific fluid power device.
☐ ☐ ☐ I can safely demonstrate proper setup and adjustment of a fluid power system.

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Lesson 4.4- Electrical Systems

☐ ☐ ☐ I can create schematic drawings to facilitate experimental measurements of electrical circuits.
☐ ☐ ☐ I can explain how to apply Ohm’s and Watt’s laws in designing safe electrical circuits.
☐ ☐ ☐ I can appraise community needs and evaluate the impact electrical generation has on communities.
☐ ☐ ☐ I can explain how to estimate current consumption in a circuit and can compare estimates to accurate measurements.

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Lesson 4.5- Control Systems

☐ ☐ ☐ I can demonstrate how to design, diagram, and implement a program to control a device constructed to perform a sorting operation.
☐ ☐ ☐ I can explain how to select and apply concepts of mechanical, electrical, and control systems in solving design problems.
☐ ☐ ☐ I can explain how to formulate a plan for evaluating the functioning of a sorting device and how to make appropriate changes in design, circuitry, or programming.
☐ ☐ ☐ I can demonstrate how to defend a solution to a design problem in an oral presentation.

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Unit 5 Statics and Strength of Materials

Lesson 5.1- Statics

☐ ☐ ☐ I can mathematically analyze a simple truss to determine types and magnitude of forces supported in the truss.
☐ ☐ ☐ I can define, describe, and analyze the stresses and forces acting on an object.
☐ ☐ ☐ I can design, construct, and test a model bridge to support the greatest amount of weight per gram of bridge mass.
☐ ☐ ☐ I can explain how to prepare and present a mathematical analysis of a truss design.

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Lesson 5.2- Strength of Materials

☐ ☐ ☐ I can explain the use of factors of safety in the design process.
☐ ☐ ☐ I can explain the difference between the area of a cross section of an object and the second moment of the area (moment of inertia) and predict the relative strength of one shape vs. another.
☐ ☐ ☐ I can demonstrate how to use a computer aided engineering package to analyze a shape.
☐ ☐ ☐ I can explain the effect that stress has on a material and explain how the material will react.

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Unit 6 Materials and Materials Testing in Engineering

Lesson 6.1- Categories of Materials

☐ ☐ ☐ I can identify and differentiate the five basic categories of solid engineering materials.
☐ ☐ ☐ I can compare and contrast the physical properties of organic materials, metals, polymers, ceramics, and composites.
☐ ☐ ☐ I can explain how to trace the production of raw material to finished product.
☐ ☐ ☐ I can identify practical applications of each material category to engineered products and processes.
☐ ☐ ☐ I can demonstrate how to collect, analyze, and test samples of the four basic materials.
☐ ☐ ☐ I can explain how to document and present laboratory data related to studies of material classifications.

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Lesson 6.2- Properties of Materials

☐ ☐ ☐ I can explain how to identify and document the properties of materials.
☐ ☐ ☐ I can demonstrate how to design an experiment to identify an unknown material.
☐ ☐ ☐ I can explain how to formulate conclusions through analysis of recorded laboratory test data for presentations in the form of charts, graphs, written, verbal, and multi-media formats.
☐ ☐ ☐ I can explain how to analyze word problems about forces acting on materials.

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Lesson 6.3- Production Processes

☐ ☐ ☐ I can define and state examples of the major categories of production processes.
☐ ☐ ☐ I can explain how to analyze a component of a product and describe the processes used in its creation.
☐ ☐ ☐ I can explain how to interpret a drawing and produce a part.
☐ ☐ ☐ I can explain the production processes used to create products from different categories of materials.

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Lesson 6.4- Quality Assurance

☐ ☐ ☐ I can explain the difference between mass and weight.
☐ ☐ ☐ I can demonstrate how to utilize a variety of precision measurement tools to measure appropriate dimensions, mass, and weight.
☐ ☐ ☐ I can explain why companies have a need for quality control and can describe what customers and companies refer to when the term “quality” is used.
☐ ☐ ☐ I can explain how to calculate the mean, median, mode, and standard deviation for a set of data and apply that information to an understanding of quality assurance.
☐ ☐ ☐ I can explain the difference between process and product control.
☐ ☐ ☐ I can explain how to distinguish between the characteristics of quality in a final product and the control of quality in each step of a process.
☐ ☐ ☐ I can explain how control charts are used in industry and how to predict whether a process might go out of control by using a control chart.

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Lesson 6.5- Material Testing

☐ ☐ ☐ I can explain and safely demonstrate destructive and non-destructive material testing and can explain how to use the data collected through these tests to compute and document mechanical properties.

☐ ☐ ☐ I can analyze a product that breaks and explain how the material failed.

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Unit 7 Engineering and Reliability

Lesson 7.1- Reliability

☐ ☐ ☐ I can diagram a system and identify the critical components.

☐ ☐ ☐ I can explain how to mathematically estimate the possibility of a component failure in a system.

☐ ☐ ☐ I can demonstrate how to list the causes of a failure and propose solutions.

☐ ☐ ☐ I can prepare and defend a position on an ethical engineering dilemma.

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Lesson 7.2- Case Studies

☐ ☐ ☐ I can explain how to research the engineering, legal, social, and ethical issues related to a final design developed in a case study.

☐ ☐ ☐ I can explain how to analyze an engineering failure for the purpose of presenting an oral report that identifies cause, damage done, design failures, and other areas where the failure has impacted the environment or society.

☐ ☐ ☐ I can explain how to prepare a written report analyzing an engineering failure.

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Unit 8 Kinematics

Lesson 8.1- Linear Motion

☐ ☐ ☐ I can explain the difference between distance traveled and displacement.

☐ ☐ ☐ I can design and build a device for the purpose of conducting experiments of acceleration, displacement, and velocity.
Lesson 8.2- Trajectory Motion

☐ ☐ ☐ I can demonstrate how velocity and acceleration are calculated.
☐ ☐ ☐ I can explain how to calculate range and initial acceleration from data recorded from experiments
☐ ☐ ☐ I can demonstrate how to design and produce a three fold pamphlet to include an explanation of a ballistic device, drawings, and a summary of data recorded from experiments.
☐ ☐ ☐ I can explain how to analyze test data and utilize the results to make decisions.
End of Course Assessment

The following pages contain the end of course assessment documents. These are to be kept confidential, and not shared with anyone, especially your students.
End-of-Course Assessment Administrative Regulations

General Rules

To ensure the quality, consistency and integrity of the testing process, Project Lead The Way, Inc. has developed the following regulations regarding the PLTW® end-of-course assessments. All school personnel who are involved in the end-of-course assessment process are required to follow these guidelines.

- The end-of-course assessments are published twice during the school year; once in the fall for schools that are on an accelerated semester block and again in the spring for schools that operate on an annual calendar.
- Due to the proprietary nature of these exams, any school not administering the assessments at the time they are published shall not access the exams. Previous exam questions shall never be shared with students as practice exams. Only tests designated as “Practice Exams” on the PLTW® Virtual Academy may be used as such.
- PLTW® exams shall never be returned to or be reviewed by students.

Because all students, teachers, and schools benefit from the national reliability of these tests, any school/teacher who feels the integrity of the end-of-course assessments has somehow been compromised should immediately contact the PLTW Coordinator of Quality Initiatives, Melissa Daigle at mdaigle@pltw.org or (518) 877-6491, Ext. 342.

College Credit Rules

The following regulations regarding the Project Lead The Way® college credit portion of the end-of-course assessment have been mandated by our university partners. Any PLTW® School offering college credit to its students must strictly adhere to all rules as specified below.

- Only PLTW® certified schools may administer the college credit portion of the end-of-course assessments to qualified students.
- Within a PLTW® certified school; only teachers who have successfully completed PLTW® Core Training for a course may administer the college credit exam for that course to their students.
- The college credit portion of the end-of-course assessment must be administered to students as published by Project Lead The Way, Inc. The tests may not be altered in any way. Possible consequences for the improper use, administration, or handling of the exams include denial of college credit to students, loss of school certification, and/or inability of a school to offer the college credit to its students in the future.
- Students are only allowed to take the college credit portion of the exam for a course once. Students who do not pass the college credit exam at the conclusion of their course may not retake any subsequent college credit exams for that course to pass the test or to raise their grade.
- Students are only eligible to apply for college credit during the school year in which they have taken the PLTW® course and successfully completed the college credit exam. Students who have taken a PLTW® course prior to their school being certified are not eligible to apply for credit retroactively.
- All PLTW® National Engineering Affiliates who grant college credit reserve the right to call in and review the exams administered by schools that are seeking college credit for their students.

Please refer to your local PLTW® National Engineering Affiliate for the specific rules regarding eligibility requirements and application procedures for receiving college credit.

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End-of-Course Assessment Administrative Regulations - Page 1
End-of-Course Assessment
Rules and Grading Criteria

Important:
Before administering this Project Lead The Way® (PLTW) assessment, please read the document “End-of-Course Assessment Administrative Regulations,” which can be found on the Registered Teacher’s page of the PLTW website. This document contains important information regarding the rules for administering the end-of-course exams.

Teacher Directions:
This assessment tool has been designed to serve a dual purpose. The exam components are intended to be combined to serve as students’ year-end exam, or as their *college credit examination. The assessment should be administered as follows:

\[ \text{Part A combined with Part B} = \text{High School Credit} \]
\[ \text{Part A combined with Part C} = \text{College Credit} \]

Each part of the assessment (A, B or C) is worth 50% of the exam. Part A combined with either Part B or Part C is worth a total of 100 points.

* Only students who are from PLTW certified schools, have a class average of 85% or higher, and have achieved a score of 70% on Parts A & C combined are eligible to apply for transcripted college credit.

All students will take Part A of the assessment. Part A is a timed exam and must be completed in its entirety within a 45-minute continuous time period.

Depending on the type of credit desired, students will take either Part B (high school credit) or Part C (college credit). Parts B and C are also timed exams and must be completed in their entirety within a 45-minute continuous time period.

Based on your school’s calendar and your class schedule, students may take their two-part exam over two 45-minute periods or all at once during one 90-minute period. If the assessments are administered during one continuous block of time, students may not start the second part of the assessment (B or C) before the allotted time has expired for Part A.

POE - Part A : 40 Multiple Choice Questions - 50 Points

Supplies / Tools:

CLOSED NOTEBOOK – CLOSED TEXT BOOK. Students ARE allowed to use calculators, but are NOT allowed to use any simulation/course software during this exam. A formula reference sheet is provided at the end of the exam.

NOTE: Programmable calculators should be cleared of stored data before the start of the exam.

Grading Part A:

An answer key has been provided for Part A. Because Part A consists of 40 points, an Excel Spreadsheet (POE Conversion Chart – Spring 2007.xls) has been provided to convert a student’s raw score to its 50-point equivalent and to calculate the student’s exam grade for high school or college credit. Please use the spreadsheet to calculate students’ exam grades.
POE - Parts B & C: High School & College Performance Examinations – 50 Points

Supplies / Tools:

CLOSED NOTEBOOK – CLOSED TEXT BOOK. Students ARE allowed to use calculators, but are NOT allowed to use any simulation/course software during this exam.

Students may bring a single-sided, 8-1/2” x 11” sheet of HANDWRITTEN notes to the exam. Each student must create his or her own notes sheet and may not use a facsimile of another student’s notes. *The teacher must collect each student’s note sheet at the conclusion of the examination period along with the student exam documents.*

A formula reference sheet is provided at the end of the exam.

NOTE: Programmable calculators should be cleared of stored data before the start of the exam.

Guidelines:

Though it is specified in the directions, students should be reminded to show their math work when calculations are needed to determine an answer. This consists of identifying a formula, showing substitutions, and stating the answer with the correct units. A formula reference sheet is provided at the end of the exam.

Grading Parts B & C:

An answer key has been provided for Parts B & C. The process of obtaining the solution for all questions that require calculations is paramount. One point is awarded for identifying the formula used. One point is awarded for showing substitutions. One point is awarded for identifying the correct answer with the correct units. (If the number is correct, but the units are incorrect, then the student does not receive the final point for the answer.) Slight answer variations for questions may occur. The formulas provided in the answer key may not represent what the students used. Points should not be deducted if the identified formula could be used to determine the answer. The accuracy of students’ numerical answers is based on the precision noted on the exam questions.

Because Parts B & C total 36 points each, an Excel Spreadsheet (*POE Conversion Chart – Spring 2007.xls*) has been provided to convert the raw score to its 50-point equivalent and to calculate the student’s exam grade for high school or college credit. Please use the spreadsheet to calculate students’ exam grades.

Each student’s raw (unconverted) scores for Parts A & B or Parts A & C must be entered into the Excel score conversion chart (*POE Conversion Chart – Spring 2007.xls*). The program will then convert each score respectively, and add them together to determine a student’s total final exam grade.
Principles Of Engineering™
Final Examination

Part A

Spring 2007

Student Name: _____________________________________

Date: ________________________

Class Period: _____________

Total Points: ____________/40

Converted Score: ____________/50
Directions: Circle the letter of the response that best answers the question or completes the statement. Then fill in the Part A answer sheet.

Reference Tables are available at the end of the document.

1. An engineer begins the process of brainstorming potential solutions to a design problem. One of the requirements of the final product is that it be biodegradable. This restriction would be referred to as a ___________.
   A. matrix  
   B. holdover  
   C. constraint  
   D. design brief

2. An engineering technician would generally be more involved in ______ than would an engineer.
   A. researching a product idea  
   B. the initial design of a product  
   C. conducting complex analysis  
   D. servicing and maintaining equipment

3. The image shown in Figure 1 represents a(n) ______ drawing.
   A. perspective  
   B. oblique  
   C. orthographic  
   D. isometric

4. The _______ of a technical report might include drawings, schematics, exploded views, written programs, flow charts, and tables of information pertinent to the report that are grouped as supplements at the end of the report rather than throughout the report.
   A. appendices  
   B. citations  
   C. abstract  
   D. design brief

5. The image shown in Figure 2 represents a ______.
   A. line graph  
   B. spreadsheet  
   C. bar chart  
   D. pie chart

6. An effective presentation _____________.
   A. would not include visual aids.  
   B. contains a few graphics and large amounts of text.  
   C. has text that will be read word for word by the presenter.  
   D. has diagrams to simplify technical concepts.
7. In the design process, optimization would be defined as ______.
   A. making a system as effective as possible.
   B. a restriction or guideline.
   C. the introduction of a new idea.
   D. an old idea being reintroduced.

8. If a simple machine in a frictionless environment requires more effort force than resistance force, then the mechanical advantage value would be ______.
   A. one.
   B. less than one.
   C. greater than one.
   D. zero.

9. The wheels on a mousetrap-powered vehicle have a diameter of 8.15 inches. If the mousetrap-powered vehicle must travel exactly 12 feet, how many revolutions of the wheel are required? Assume that no sliding or slipping occurs between the wheel and the road.
   A. .563
   B. .469
   C. 5.63
   D. 4.69

10. When the device shown to the right is used to keep a door from swinging closed, it functions as a(n) ______.
    A. inclined plane.
    B. first class lever.
    C. wedge.
    D. screw.

11. The stapler in Figure 3 is an example of what class of lever?
    A. 1st class
    B. 2nd class
    C. 3rd class
    D. 4th class

12. If the pulley system, shown in Figure 4, is in static equilibrium and 10 lbs. of effort is applied, what is the resistance force?
    A. 2 lbs.
    B. 50 lbs.
    C. 5 lbs.
    D. 15 lbs.
13. Figure 5 represents a belt driven system. Pulley B, which has a diameter of 16 inches, is being driven by Pulley A, which has a diameter of 4 inches. If Pulley A is spinning at 60 RPMs, then Pulley B is spinning at ______ RPMs.
   A. 240  C. 4
   B. 15    D. 64

14. Circular motion that occurs in a heated fluid, as shown in Figure 6, is an example of _________.
   A. convection.  C. radiation.
   B. conduction.  D. R-value.

15. Oil is most commonly used in a hydraulic system because it ______.
   A. conducts heat.  C. has a low boiling point.
   B. burns well.    D. does not compress.

16. Which law states that force exerted on a fluid will be transferred equally against the walls of that fluid’s container?
   A. Pascal’s Law  C. Newton’s 1st Law
   B. Newton’s 3rd Law D. Ohm’s Law

17. If a string of lights is wired in ______, all the lights go out when one light fails.
   A. series  C. order
   B. line    D. parallel

18. If a motor requires 6 Volts and has 80 Ohms of resistance, what is the amperage value?
   A. 65  C. 480
   B. 0.75 D. 0.075
19. If the Fischertechnik™ switch shown in Figure 7 is wired using ports 1 and 2, it is said to be normally ______.
   A. common.  C. neutral.

20. Which of the following is a light sensitive input device?
   A. Reed Switch  C. Electromagnet
   B. Photoresistor D. Lamp

21. A computer program timing loop that is used to keep a conveyor belt running for a fixed amount of time is an example of ______ control.
   A. feedback  C. open loop
   B. closed loop  D. output

22. A(n) ______ device would be the most precise way to determine if a light is on or off.
   A. digital input  C. analog input
   B. digital output  D. analog output

23. Which of the following is a vector quantity?
   A. Distance  C. Density
   B. Mass  D. Velocity

24. For the truss shown in Figure 8, which of the following moment equations related to the pin connection would be used to mathematically prove that the truss is in a state of static equilibrium?
   A. \( F_1(R_{1y}) + F_1(A) = R_{2y}(B) \)  C. \( F_1(A) + F_2(A+B) = R_{2y}(A+B) \)
   B. \( F_1 + R_{1x} = R_{1y} + R_{2y} \)  D. \( F_1(A) = R_{2y}(A+B) \)
25. In Figure 9, what will be the combined magnitude of the reaction forces \( R_{1Y} \) and \( R_{2Y} \)?
   A. 4 lbs  
   B. 8 lbs  
   C. 12 lbs  
   D. 16 lbs

**Figure 9**

\[ F_1 = 4 \text{ lbs} \]
\[ F_2 = 4 \text{ lbs} \]
\[ A = B = C = D = 1 \text{ foot} \]

26. Based on the truss shown in the Figure 10, what is the value of the reaction force that occurs in the vertical direction at pin connection A?
   A. 10 lbs  
   B. 15 lbs  
   C. 20 lbs  
   D. 5 lbs

**Figure 10**

27. Young’s Modulus or the Modulus of Elasticity is defined as the ratio of ______ to strain.
   A. displacement  
   B. force  
   C. stress  
   D. elongation

28. Figure 11 shows cross sections of three shapes. What do points A, B and C represent in each?
   A. Medians  
   B. Centroids  
   C. Mid Points  
   D. Yield Points

**Figure 11**
29. Because brass is a combination of copper and zinc, it would be classified as a(n) ________.
   A. alloy  B. elastomer  C. thermoset  D. oxide

30. An engineer could determine the ______ in a cylindrical rod by knowing the applied force and cross sectional area.
   A. spatial configuration  B. strain  C. stress  D. fatigue

31. Soft drink bottles are commonly made from ______ material. If they are recycled, they can be softened through reheating and hardened again to form new bottles.
   A. thermoplastic  B. brittle  C. ferrous  D. thermoset

32. Which of the following is the process of separating a material by applying force from opposite directions?
   A. Knurling  B. Shearing  C. Conditioning  D. Rolling

33. The dial caliper in Figure 12 is set to a measurement of ______ inches.
   A. 0.708  B. 0.780  C. 0.680  D. 0.068
34. In Figure 13, Part A is designed to slide with little friction through Part B, which has a .5 inch square opening. The designer has decided that the allowable corresponding height and depth dimensions of Part A are between .480 and .465 inches. What is the resulting tolerance of both the height and depth dimensions of Part A?
   A. Anything over .48 inches  
   B. Anything under .48 inches  
   C. .015 inches  
   D. .945 inches

35. What is the strain value of a 10 inch long rod that has a cross-sectional area of 0.2 in², and that has elongated 0.05 inches?
   A. 0.005  
   B. 0.0025  
   C. 0.002  
   D. 10.05

36. A material that is capable of considerable plastic deformation would be referred to as a __________ material.
   A. brittle  
   B. polymer  
   C. tensile  
   D. ductile

37. Engineers can use a ______ to determine a material’s strength when it has experienced elastic or plastic deformation.
   A. break analysis  
   B. stretch curve  
   C. creep test  
   D. stress-strain curve

38. If an engineer created an evaluation report that describes why a skyscraper failed during an earthquake, it would likely be presented as a(n) ______.
   A. abstract  
   B. design brief  
   C. case study  
   D. essay

39. When a projectile is launched, the ______ component of its velocity will remain constant throughout its flight.
   A. Z  
   B. Y  
   C. vertical  
   D. horizontal

40. The horizontal distance that a projectile travels is referred to as ______.
   A. free fall  
   B. range  
   C. initial velocity  
   D. variance
### Circular Shapes

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</tr>
<tr>
<td>A = \pi r^2</td>
<td>\pi = pi</td>
</tr>
<tr>
<td>D = diameter</td>
<td>A = area</td>
</tr>
<tr>
<td>r = radius</td>
<td></td>
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### Electrical Systems

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<td>R = resistance</td>
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### Mechanisms

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<tr>
<td>Screw MA = C ÷ Pitch</td>
<td>L = slope length</td>
</tr>
<tr>
<td>Pitch = 1 ÷ TPI</td>
<td>H = slope height or width thickness</td>
</tr>
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</table>

### Statics

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<td>M = F×D</td>
<td>M = moment about a point</td>
</tr>
<tr>
<td>F = force</td>
<td>D = perpendicular distance</td>
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### Static Equilibrium

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<td>( \Sigma F_x = 0 ) = X(right) – X(left)</td>
<td>( \Sigma ) = sum</td>
</tr>
<tr>
<td>( \Sigma F_y = 0 ) = Y(up) – Y(down)</td>
<td>F = force</td>
</tr>
<tr>
<td>( \Sigma M = 0 ) = CCW - CW</td>
<td>M = moment about a point</td>
</tr>
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<td>CCW = counter-clockwise</td>
<td>CW = Clockwise</td>
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### Properties of Materials

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<tr>
<td>( \delta = \frac{P}{A} )</td>
<td>( \delta = ) total deformation</td>
</tr>
<tr>
<td>( \epsilon = \frac{\delta}{L} )</td>
<td>( \sigma = ) stress</td>
</tr>
<tr>
<td>( \delta = \frac{PL}{AE} )</td>
<td>( \epsilon = ) strain</td>
</tr>
<tr>
<td>( E = \frac{\sigma}{\epsilon} )</td>
<td>E = modulus of elasticity, Young’s Modulus</td>
</tr>
<tr>
<td>E = ( \frac{(P_1-P_2)L_0}{(\delta_1-\delta_2)A} )</td>
<td>P = axial force</td>
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<td>A = area</td>
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</tbody>
</table>
### Right Triangle Ratios

<table>
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<tbody>
<tr>
<td>( \sin \theta = \text{opposite} / \text{hypotenuse} )</td>
<td>( \theta = \text{angle} )</td>
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<tr>
<td>( \cos \theta = \text{adjacent} / \text{hypotenuse} )</td>
<td></td>
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<tr>
<td>( \tan \theta = \text{opposite} / \text{adjacent} )</td>
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### Gear Ratios

<table>
<thead>
<tr>
<th>Formulas</th>
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<tbody>
<tr>
<td>( GR = \text{gear ratio} )</td>
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<tr>
<td>( GR = \frac{\text{Input Rate}}{\text{Output Rate}} )</td>
<td>( N_{in} = \text{number of teeth on driver gear} )</td>
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<td>( SR = \frac{W_{in}}{W_{out}} )</td>
<td>( N_{out} = \text{number of teeth on driven gear} )</td>
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<td>( W_{in} / W_{out} = \frac{D_{out}}{D_{in}} )</td>
<td>( D_{in} = \text{driver gear diameter, in} )</td>
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<td>( T_{in} / T_{out} = \frac{D_{in}}{D_{out}} )</td>
<td>( D_{out} = \text{driven gear diameter, in} )</td>
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<tr>
<td>( W_{in} = \text{driver gear speed, rpm} )</td>
<td>( W_{out} = \text{driven gear speed, rpm} )</td>
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<td>( T_{in} = \text{torque of driver gear, ft lbs.} )</td>
<td>( T_{out} = \text{torque of driven gear, ft lbs.} )</td>
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<td>( SR = \text{speed ratio} )</td>
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### Kinematics

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<tr>
<td>( x = \frac{v_i^2 \sin(2\theta)}{g} )</td>
<td>( v_i = \text{initial velocity} )</td>
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<td>( \theta = \text{angle} )</td>
<td>( g = \text{gravity} )</td>
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**Total Score _______/40**

**Converted Score _______/50**
Principles Of Engineering™
Final Examination

Part B
High School Credit Performance

Spring 2007

Student Name: _______________________________________

Date: __________________

Class Period: __________

Total Points: ___________/36

Converted Score: ___________/50
Directions: Complete all of the items in problems 1 through 8. To receive full credit on any problem that requires calculations, you must: 1) identify the formula, 2) show substitutions, and 3) state the answer with the correct units.

Reference Tables are available at the end of the document.

1. Study the truss in Figure 1 and complete the following problems.

   a) Calculate the length of truss member BC. (answer precision = 0.0) [3 points]

   b) The free body diagram of joint B in Figure 2 shows $F_{BC}$ in compression, $F_{AB}$ in tension and $R_{BY}$ with a magnitude of 33.33 lbs. Using the free body diagram in Figure 2, calculate the magnitude of $F_{BC}$. (answer precision = 0.00) [3 points]
2. A soccer ball is kicked from the ground with an initial velocity of 80 ft/s at an angle of 45º degrees, and eventually lands at the same height, as shown in Figure 3. Use 32.15 ft/sec² for acceleration due to gravity.

![Figure 3](image)

How far away does the ball land from the place it was kicked? (answer precision = 0.00) [3 Points]

3. The cylindrical bar, shown in Figure 4, has a cross-sectional area of 8 in² and is subjected to an axial load as it is being pulled away from a wall with a force of 150 lbs. Determine the stress in the bar. (answer precision = 0.00) [3 Points]

![Figure 4](image)
4. A tensile test specimen was tested under a tensile load. The force–displacement diagram that resulted is shown in Figure 5.

![Figure 5](image)

a) Point A represents the ________________________________. [1 Point]

b) Point B represents the ________________________________. [1 Point]

c) Determine the Modulus of Elasticity of the test specimen, if the cross section area is 0.53 in$^2$ and the length is 10 in. (answer precision = 0.0) [3 Points]
5. The closed-loop program shown below is designed to send a shuttle back and forth between two points. In one direction the lamp will be on. In the other direction the lamp will be off. Study the program description and decide which of the program elements from the answer bank (A through J) must be used to complete the flowchart program. Write the letter of the correct icon in the corresponding empty box. No icon will be used more than once, and some may not be used at all. [4 points]

**Program Description:**
When the program starts, shuttle M1 is turned on in the clockwise direction, and the computer checks to see if limit switch I2 (wired normally open) is being pressed. The program will loop back until switch I2 is pressed. From there, shuttle M1 will stop and then start again in the counter-clockwise direction. The computer will then loop back until switch I1 (wired normally open) is pressed. Once I1 has been pressed shuttle M1 stops. The program then loops back to the beginning.
6. The incomplete image below identifies a 9-step design process. Using the answer bank, write the correct step in each empty box. [4 points]

**Answer Bank**

- Define the Criteria
- Identify the Need, Want or Problem
- Model and Prototype
- Investigate and Research

1. 

2. 

3. 

4. Generate Alternative Solutions

5. Choose a Solution

6. Develop the Solution

7. 

8. Test and Evaluate

9. Redesign and Improve
7. Study the technical drawing below, and sketch the missing object lines and hidden lines. There are two missing lines in each of the orthographic views. [6 points]
8a. What class of lever is shown in Figure 6? Justify your answer. [2 points]

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

8b. How much effort force is needed to balance 20.8 pounds of resistance? (answer precision = 0.0) [3 points]
## Circular Shapes

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<td></td>
<td>C = circumference</td>
</tr>
<tr>
<td></td>
<td>Pitch = screw pitch</td>
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<tr>
<td></td>
<td>TPI = threads per inch</td>
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<table>
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<tr>
<th>Formulas</th>
<th>Variables</th>
</tr>
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<tbody>
<tr>
<td>( \sin \theta = \text{opposite} / \text{hypotenuse} )</td>
<td>( \theta = \text{angle} )</td>
</tr>
<tr>
<td>( \cos \theta = \text{adjacent} / \text{hypotenuse} )</td>
<td></td>
</tr>
<tr>
<td>( \tan \theta = \text{opposite} / \text{adjacent} )</td>
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### Gear Ratios

<table>
<thead>
<tr>
<th>Formulas</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>GR = Input Rate / Output Rate</td>
<td>( N_{\text{in}} = \text{number of teeth on driver gear} )</td>
</tr>
<tr>
<td>SR = W_{\text{in}} / W_{\text{out}}</td>
<td>( N_{\text{out}} = \text{number of teeth on driven gear} )</td>
</tr>
<tr>
<td>W_{\text{in}} / W_{\text{out}} = D_{\text{out}} / D_{\text{in}}</td>
<td>( D_{\text{in}} = \text{driver gear diameter, in} )</td>
</tr>
<tr>
<td>T_{\text{in}} / T_{\text{out}} = D_{\text{in}} / D_{\text{out}}</td>
<td>( D_{\text{out}} = \text{driven gear diameter, in} )</td>
</tr>
<tr>
<td>( W_{\text{in}} = \text{driver gear speed, rpm} )</td>
<td>( W_{\text{out}} = \text{driven gear speed, rpm} )</td>
</tr>
<tr>
<td>( T_{\text{in}} = \text{torque of driver gear, ft lbs.} )</td>
<td>( T_{\text{out}} = \text{torque of driven gear, ft lbs.} )</td>
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<tr>
<td>SR = speed ratio</td>
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### Kinematics

<table>
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<th>Variables</th>
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<tr>
<td>( x = \frac{V_i^2 \sin(2\theta)}{g} )</td>
<td>( v_i = \text{initial velocity} )</td>
</tr>
<tr>
<td>( \theta = \text{angle} )</td>
<td></td>
</tr>
<tr>
<td>( g = \text{gravity} )</td>
<td></td>
</tr>
<tr>
<td>( x = \text{range} )</td>
<td></td>
</tr>
</tbody>
</table>
Directions: Complete all of the items in problems 1 through 6. To receive full credit on any problem that requires calculations, you must: 1) identify the formula, 2) show substitutions, and 3) state the answer with the correct units.

Reference Formula Tables are available at the end of the document.

1. Study the truss in Figure 1 and complete the following problems.
   a) Calculate the height of the truss. (answer precision = 0.00) [3 points]
   b) The free body diagram of joint A in Figure 2 shows $F_{AC}$ in compression, $F_{AD}$ in tension, $R_{AX}$ and $R_{AY}$ replaced with a magnitude of 100 lbs. Using the free body diagram in Figure 2, calculate the magnitude of force $F_{AC}$. (answer precision = 0.00) [3 points]
2. A golf ball is launched at a 60° angle to the horizontal with an initial velocity of 40 ft/s.

Figure 3

a) Determine the vertical component of the initial velocity. (answer precision = 0.00). [3 points]

b) Calculate the distance to where the golf ball will hit the ground. Use 32.15 ft/sec² for acceleration due to gravity. Neglect any air resistance and assume the ground is level. (answer precision = 0.00). [3 points]
3. A tension test was conducted on a cylindrical specimen of titanium alloy. The gage length of the specimen was 2.25 inches and the cross sectional area in the test region before loading was 1.57 in². Figure 4 shows the resulting Force - Displacement diagram.

Calculate the following quantities:

a) Stress at proportional limit. (answer precision = 0.00). [3 points]

b) Ultimate stress. (answer precision = 0.00). [3 points]

c) Starting at the origin and ending at the proportional limit, calculate the modulus of elasticity for this material. (answer precision = 0.00). [3 points]
4. The closed-loop program shown below uses a thermistor to detect resistance from temperature. Based on the resistance, the program is designed to turn on a fan to cool down the sensor or turn on the lamp to warm the sensor. Study the program description and decide which of the icons from the answer bank (A through N) must be used to complete the flowchart program. Write the letter of the correct icon in the proper empty box. No icon will be used more than once, and some may not be used at all. [5 points]

Program Description:

The analog input AX is connected to the thermistor and uses “temp” as the variable.

When the program begins, lamp (M4) is turned on. A compare statement is then used to see if the resistance from the thermistor is less than 525. If it is not less than 525, then the light stays on. When the reading becomes less than 525, lamp (M4) turns off, and motor (M1) attached to the fan turns on in the CCW direction. A compare statement is then used to see if the resistance from the thermistor has risen above 535. If it has not risen above 535, then the fan continues to run. When the resistance from the thermistor rises above 535, the fan (M1) turns off, and the program loops back to the beginning.

Answer Bank

A H
B I
C J
D K
E L
F M
G N

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5. Each of the following four statements represents a step in a design process. There are nine design process steps listed in the answer bank. Identify which of the steps from the answer bank is being represented by each statement by writing the step number on the line provided. [4 points]

a. A team of students conduct trial runs to determine the ability of the marble sorter to separate marbles by color.
   Identify the step in the design process: __________

b. Students in small groups list ideas based on the constraints identified in the design brief.
   Identify the step in the design process: __________

c. Students build their marble sorter design.
   Identify the step in the design process: __________

d. A team of students modifies the sensing system of their design after the device fails to accurately separate all marbles.
   Identify the step in the design process: __________

---

**Answer Bank**

<table>
<thead>
<tr>
<th>Step #</th>
<th>Design Process Step Description</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Identify the Problem</td>
</tr>
<tr>
<td>2</td>
<td>Define the Criteria</td>
</tr>
<tr>
<td>3</td>
<td>Research and Investigate</td>
</tr>
<tr>
<td>4</td>
<td>Generate Alternative Solutions</td>
</tr>
<tr>
<td>5</td>
<td>Choose a Solution</td>
</tr>
<tr>
<td>6</td>
<td>Refine and Develop the Solution</td>
</tr>
<tr>
<td>7</td>
<td>Model and Prototype the Solution</td>
</tr>
<tr>
<td>8</td>
<td>Test and Evaluate the Solution</td>
</tr>
<tr>
<td>9</td>
<td>Redesign and Improve the Solution</td>
</tr>
</tbody>
</table>
6. Study the technical drawing below, and sketch the missing object lines and hidden lines. There are two missing lines in each of the orthographic views. [6 points]
### POE Exam Reference Tables

#### Circular Shapes

<table>
<thead>
<tr>
<th>Formulas</th>
<th>Variables</th>
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<tbody>
<tr>
<td>C = \pi D</td>
<td>C = circumference</td>
</tr>
<tr>
<td>A = \pi r^2</td>
<td>\pi = pi</td>
</tr>
<tr>
<td></td>
<td>D = diameter</td>
</tr>
<tr>
<td></td>
<td>A = area</td>
</tr>
<tr>
<td></td>
<td>r = radius</td>
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#### Electrical Systems

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<td>E = IR</td>
<td>E = voltage</td>
</tr>
<tr>
<td></td>
<td>I = current</td>
</tr>
<tr>
<td></td>
<td>R = resistance</td>
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#### Mechanisms

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<tr>
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<th>Variables</th>
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</thead>
<tbody>
<tr>
<td>MA = R ÷ E</td>
<td>MA = Mechanical Advantage</td>
</tr>
<tr>
<td>Lever MA = LE ÷ LR</td>
<td>R = resistance force</td>
</tr>
<tr>
<td>Wheel and Axle MA = LE ÷ LR</td>
<td>E = effort force</td>
</tr>
<tr>
<td>Pulley MA = Total number of strands supporting the load</td>
<td>LE = distance to effort</td>
</tr>
<tr>
<td>Inclined Plane or Wedge MA = L ÷ H</td>
<td>LR = distance to resistance</td>
</tr>
<tr>
<td>Screw MA = C ÷ Pitch</td>
<td>L = slope length</td>
</tr>
<tr>
<td>Pitch = 1 ÷ TPI</td>
<td>H = slope height or width thickness</td>
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#### Statics

<table>
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<tr>
<td>M = F×D</td>
<td>M = moment about a point</td>
</tr>
<tr>
<td></td>
<td>F = force</td>
</tr>
<tr>
<td></td>
<td>D = perpendicular distance</td>
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#### Static Equilibrium

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<tbody>
<tr>
<td>\sum F_x = 0 = X(right) – X(left)</td>
<td>\sum = sum</td>
</tr>
<tr>
<td>\sum F_y = 0 = Y(up) – Y(down)</td>
<td>F = force</td>
</tr>
<tr>
<td>\sum M = 0 = CCW - CW</td>
<td>M = moment about a point</td>
</tr>
<tr>
<td></td>
<td>CCW = counter-clockwise</td>
</tr>
<tr>
<td></td>
<td>CW = Clockwise</td>
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#### Properties of Materials

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<tr>
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<th>Variables</th>
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<tbody>
<tr>
<td>\sigma = P ÷ A</td>
<td>\delta = total deformation</td>
</tr>
<tr>
<td>\epsilon = \delta ÷ L</td>
<td>\sigma = stress</td>
</tr>
<tr>
<td>\delta = PL ÷ AE</td>
<td>\epsilon = strain</td>
</tr>
<tr>
<td>E = \sigma ÷ \epsilon</td>
<td>E = modulus of elasticity, Young’s Modulus</td>
</tr>
<tr>
<td>E = (P_1-P_2)L_0 / (\delta_1-\delta_2)A</td>
<td>P = axial force</td>
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<td></td>
<td>A = area</td>
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### Right Triangle Ratios

<table>
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<th>Variables</th>
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<tr>
<td>(\sin \theta = \frac{\text{opposite}}{\text{hypotenuse}})</td>
<td>(\theta = \text{angle})</td>
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<tr>
<td>(\cos \theta = \frac{\text{adjacent}}{\text{hypotenuse}})</td>
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</tr>
<tr>
<td>(\tan \theta = \frac{\text{opposite}}{\text{adjacent}})</td>
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### Gear Ratios

<table>
<thead>
<tr>
<th>Formulas</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>GR = gear ratio</td>
<td></td>
</tr>
<tr>
<td>GR = (\frac{\text{Input Rate}}{\text{Output Rate}})</td>
<td></td>
</tr>
<tr>
<td>SR = (\frac{\text{W}<em>{\text{in}}}{\text{W}</em>{\text{out}}})</td>
<td></td>
</tr>
<tr>
<td>(\text{W}<em>{\text{in}} / \text{W}</em>{\text{out}} = \frac{\text{D}<em>{\text{out}}}{\text{D}</em>{\text{in}}})</td>
<td></td>
</tr>
<tr>
<td>(\text{T}<em>{\text{in}} / \text{T}</em>{\text{out}} = \frac{\text{D}<em>{\text{in}}}{\text{D}</em>{\text{out}}})</td>
<td></td>
</tr>
<tr>
<td>(\text{N}_{\text{in}} = \text{number of teeth on driver gear})</td>
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</tr>
<tr>
<td>(\text{N}_{\text{out}} = \text{number of teeth on driven gear})</td>
<td></td>
</tr>
<tr>
<td>(\text{D}_{\text{in}} = \text{driver gear diameter, in})</td>
<td></td>
</tr>
<tr>
<td>(\text{D}_{\text{out}} = \text{driven gear diameter, in})</td>
<td></td>
</tr>
<tr>
<td>(\text{W}_{\text{in}} = \text{driver gear speed, rpm})</td>
<td></td>
</tr>
<tr>
<td>(\text{W}_{\text{out}} = \text{driven gear speed, rpm})</td>
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<tr>
<td>(\text{T}_{\text{in}} = \text{torque of driver gear, ft lbs.})</td>
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<tr>
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</tr>
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<td>SR = speed ratio</td>
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### Kinematics

<table>
<thead>
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<tbody>
<tr>
<td>(\text{x} = \frac{\text{vi}^2 \sin(2\theta)}{g})</td>
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<tr>
<td>(\text{vi} = \text{initial velocity})</td>
<td></td>
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<td>(\theta = \text{angle})</td>
<td></td>
</tr>
<tr>
<td>(g = \text{gravity})</td>
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</tr>
<tr>
<td>(x = \text{range})</td>
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</table>
** IMPORTANT **

Please read the document “POE Exam Directions – Spring 2007” before you administer and grade your students’ exams.

All three parts of the POE End-Of-Course exam (A, B & C) require a conversion to obtain a student’s score out of 50 points.

Each student’s raw (unconverted) scores for Parts A & B or Parts A & C must be entered into the Excel score conversion chart (POE Conversion Chart – Spring 2007.xls) in order to obtain the student’s calculated score.

The spreadsheet is designed to convert the student’s raw score for each part of the exam, and to calculate the student’s final test score for either the high school or college credit portion of the exam.

A sample conversion chart for each part of the exam has been included below. These are for information purposes only. Please download and use the spreadsheet to obtain your students’ final exam scores and do not convert and add your students’ scores by hand.

### Part A Scoring Conversion Chart

<table>
<thead>
<tr>
<th>Score</th>
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<th>Score</th>
<th>Conversion</th>
<th>Score</th>
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### Part B and C Scoring Conversion Chart

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### Part A – Multiple Choice Questions

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<th>Answer</th>
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<td>1.1 – Engineers as Problem Solvers</td>
</tr>
<tr>
<td>2</td>
<td>D</td>
<td>1.3 – Careers in Engineering</td>
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<tr>
<td>3</td>
<td>B</td>
<td>2.1 – Sketching</td>
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<tr>
<td>4</td>
<td>A</td>
<td>2.2 – Technical Writing</td>
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<td>5</td>
<td>A</td>
<td>2.3 – Data Representation &amp; Presentation</td>
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<td>2.4 – Oral Presentations</td>
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<td>28</td>
<td>B</td>
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**Answer Breakdown: A-10; B-10; C-10; D-10**
Part B – High School Performance Exam

1. Study the truss in Figure 1 and complete the following problems.

a) Calculate the length of truss member BC. (answer precision = 0.0) [3 points]

\[
\cos \theta = \frac{AB}{BC} \quad \cos 37^\circ = \frac{4 \text{ ft}}{BC} \quad \overline{BC} = 5.0 \text{ ft}
\]

1 point for stating the formula

1 point for showing substitutions

1 point for the correct answer with correct units

b) The free body diagram of joint B in Figure 2 shows \( F_{BC} \) in compression, \( F_{AB} \) in tension and \( R_{BY} \) with a magnitude of 33.33 lbs. Using the free body diagram in Figure 2, calculate the magnitude of \( F_{BC} \). (answer precision = 0.00) [3 points]

\[
33.33 \text{ lbs} - F_{BC}\sin37 = 0 \\
F_{BC}\sin37 = 33.33 \text{ lbs} \\
\frac{33.33 \text{ lbs}}{0.602} = F_{BC} \quad F_{BC} = 55.37 \text{ lbs.}
\]

1 point for stating the formula

1 point for showing substitutions

1 point for the correct answer with correct units
2. A soccer ball is kicked from the ground with an initial velocity of 80 ft/s at an angle of 45º degrees, and eventually lands at the same height, as shown in Figure 3. Use 32.15 ft/sec² for acceleration due to gravity.

How far away does the ball land from the place it was kicked? (answer precision = 0.00) [3 Points]

\[ X = \frac{v_i^2 \sin 2\theta}{g} \]

\[ X = \frac{(80 \text{ ft} / \text{sec})^2 \sin(2 \times 45^{\circ})}{32.15 \text{ ft} / \text{sec}^2} \]

\[ X = 199.07 \text{ ft} \]

1 point for stating the formula

1 point for showing substitutions

1 point for the correct answer with correct units

3. The cylindrical bar, shown in Figure 4, has a cross-sectional area of 8 in² and is subjected to an axial load; as it is being pulled away from a wall with a force of 150 lbs. Determine the stress in the bar. (answer precision = 0.00) [3 Points]

\[ \sigma = \frac{P}{A} \]

\[ \sigma = \frac{150 \text{ lbs}}{8 \text{ in}^2} \]

\[ \sigma = 18.75 \text{ psi} \]

1 point for stating the formula

1 point for showing substitutions

1 point for the correct answer with correct units
4. A tensile test specimen was tested under a tensile load. The force – displacement diagram that resulted is shown in Figure 5.

![Force Displacement Diagram]

Figure 5

a) Point A represents the _______________________________. [1 Point]
   **Proportional Limit**

b) Point B represents the _______________________________. [1 Point]
   **Ultimate Force or Ultimate Strength or Ultimate Stress**

c) Determine the Modulus of Elasticity of the test specimen, if the cross section area is 0.53 in$^2$ and the length is 10 in. (answer precision = 0.0) [3 Points]

\[
E = \frac{\Delta F \cdot L_o}{\Delta \delta \cdot A} \quad \Rightarrow \quad E = \frac{600 \text{ lbs} \cdot 10 \text{ in}}{0.01 \text{ in} \cdot 0.53 \text{ in}^2} = 1,132,075.5 \text{ psi}
\]

1 point for stating the formula  
1 point for showing substitutions  
1 point for the correct answer with correct units
5. The closed-loop program shown below is designed to send a shuttle back and forth between two points. In one direction the lamp will be on. In the other direction the lamp will be off. Study the program description and decide which of the program elements from the answer bank (A through J) must be used to complete the flowchart program. Write the letter of the correct icon in the corresponding empty box. No icon will be used more than once, and some may not be used at all. [4 points]

**Program Description:**
When the program starts, shuttle M1 is turned on in the clockwise direction, and the computer checks to see if limit switch I2 (wired normally open) is being pressed. The program will loop back until switch I2 is pressed. From there, shuttle M1 will stop and then start again in the counter-clockwise direction. The computer will then loop back until switch I1 (wired normally open) is pressed. Once I1 has been pressed shuttle M1 stops. The program then loops back to the beginning.
6. The incomplete image below identifies a 9-step design process. Using the answer bank, write the correct step in each empty box. [4 points]

1. **Identify the Need, Want or Problem**
2. **Define the Criteria**
3. **Investigate and Research**
4. Generate Alternative Solutions
5. Choose a Solution
6. Develop the Solution
7. **Model and Prototype**
8. Test and Evaluate
9. Redesign and Improve

**Answer Bank**
- Define the Criteria
- Identify the Need, Want or Problem
- Model and Prototype
- Investigate and Research

1 point for each correct answer
7. Study the technical drawing below, and sketch the missing object lines and hidden lines. There are two missing lines in each of the orthographic views. [6 points]

*Each view is worth a maximum of 2 points. 1 point for each correct line*
8a. What class lever is shown in Figure 6? Justify your answer. [2 points]

**Figure 6 shows a second class lever. Second class levers always have the load (resistance) located between the fulcrum and the effort.**

1 point for stating the correct class of lever 1 point for stating a valid justification

8b. How much effort force is needed to balance 20.8 pounds of resistance? (answer precision = 0.0) [3 points]

**Method 1**

\[ L_E \times E = L_R \times R \]

\[ 16 \text{ ft} \times E = 2 \text{ ft} \times 20.8 \text{ lbs} \]

\[ E = \frac{20.8 \text{ lbs}}{16 \text{ ft}} \]

\[ E = 2.6 \text{ lbs.} \]

**Method 2**

\[ MA = \frac{L_E}{L_R} \]

\[ MA = \frac{16 \text{ ft}}{2 \text{ ft}} \]

\[ E = \frac{R}{MA} \]

\[ E = \frac{20.8 \text{ lbs}}{8} \]

\[ E = 2.6 \text{ lbs.} \]

**Method 3**

\[ \Sigma M = 0 = CCW - CW \]

\[ 0 = 16 \text{ ft} \times E - 2 \text{ ft} \times 20.8 \text{ lbs} \]

\[ 41.6 \text{ ft/lbs} = 16 \text{ ft} \times E \]

\[ E = \frac{41.6 \text{ ft/lbs}}{16 \text{ ft}} \]

\[ E = 2.6 \text{ lbs.} \]

1 point for stating the formula 1 point for showing substitutions 1 point for the correct answer with correct units
1. Study the truss in Figure 1 and complete the following problems.

   a) Calculate the height of the truss. (answer precision = 0.00) [3 points]

   \[ a^2 + b^2 = c^2 \]
   \[ 2 \text{ ft}^2 + b^2 = 3 \text{ ft}^2 \]
   \[ b = \sqrt{5} \text{ ft} \]

   b = height = 2.24 ft.

   1 point for stating the formula
   1 point for showing substitutions
   1 point for the correct answer with correct units

   b) The free body diagram of joint A in Figure 2 shows $F_{AC}$ in compression, $F_{AD}$ in tension, $R_{AX}$, and $R_{AY}$ replaced with a magnitude of 100 lbs. Using the free body diagram in Figure 2, calculate the magnitude of force $F_{AC}$. (answer precision = 0.00) [3 points]

   \[ 0 = 100\text{lbs} - F_{AC} \sin 48.19 \]
   \[ F_{AC} \sin 48.19 = 100\text{lbs} \]
   \[ F_{AC} = \frac{100\text{lbs}}{\sin 48.19} \]

   $F_{AC} = 134.16$ lbs.

   1 point for stating the formula
   1 point for showing substitutions
   1 point for the correct answer with correct units
2. A golf ball is launched at a 60° angle to the horizontal with an initial velocity of 40 ft/s.

a) Determine the vertical component of the initial velocity. (answer precision = 0.00). [3 points]

\[ V_{iy} = V_i \sin \theta \]
\[ V_{iy} = 40 \text{ ft/s} \sin 60° \]
\[ V_{iy} = 40 \text{ ft/s} \times 0.866 \]
\[ V_{iy} = 34.64 \text{ ft/s} \]

1 point for stating the formula
1 point for showing substitutions
1 point for the correct answer with correct units

b) Calculate the distance to where the golf ball will hit the ground. Use 32.15 ft/sec^2 for acceleration due to gravity. Neglect any air resistance and assume the ground is level. (answer precision = 0.00). [3 points]

\[ X = \frac{v_i^2 \sin 2\theta}{g} \]
\[ X = \frac{(40 \text{ ft/sec})^2 \sin(2(60°))}{32.15 \text{ ft/sec}^2} \]
\[ X = 43.10 \text{ ft} \]

1 point for stating the formula
1 point for showing substitutions
1 point for the correct answer with correct units
3. A tension test was conducted on a cylindrical specimen of titanium alloy. The gage length of the specimen was 2.25 inches and the cross sectional area in the test region before loading was 1.57 in². Figure 4 shows the resulting Force - Displacement diagram.

Calculate the following quantities:

a) Stress at proportional limit. (answer precision = 0.00). [3 points]

\[
\sigma_{PL} = \frac{P_{PL}}{A} = \frac{110,000 \text{ lbs}}{1.57 \text{ in}^2} = 70,063.69 \text{ psi}
\]

1 point for stating the formula, 1 point for showing substitution, 1 point for the correct answer with correct units

b) Ultimate stress. (answer precision = 0.00). [3 points]

\[
\sigma_U = \frac{P_U}{A} = \frac{165,000 \text{ lbs}}{1.57 \text{ in}^2} = 105,095.54 \text{ psi}
\]

1 point for stating the formula, 1 point for showing substitution, 1 point for the correct answer with correct units

c) Starting at the origin and ending at the proportional limit, calculate the modulus of elasticity for this material. (answer precision = 0.00). [3 points]

\[
E = \frac{\Delta F \cdot L_o}{\Delta \delta \cdot A} = \frac{110,000 \text{ lbs} \cdot 2.25 \text{ in}}{.078 \text{ in} \cdot 1.57 \text{ in}^2} = 2,021,068.10 \text{ psi}
\]

1 point for stating the formula, 1 point for showing substitution, 1 point for the correct answer with correct units
4. The closed-loop program shown below uses a thermistor to detect resistance from temperature. Based on the resistance, the program is designed to turn on a fan to cool down the sensor or turn on the lamp to warm the sensor. Study the program description and decide which of the icons from the answer bank (A through N) must be used to complete the flowchart program. Write the letter of the correct icon in the proper empty box. No icon will be used more than once, and some may not be used at all. [5 points]

**Program Description:**

The analog input AX is connected to the thermistor and uses “temp” as the variable.

When the program begins, lamp (M4) is turned on. A compare statement is then used to see if the resistance from the thermistor is less than 525. If it is not less than 525, then the light stays on. When the reading becomes less than 525, lamp (M4) turns off, and motor (M1) attached to the fan turns on in the CCW direction. A compare statement is then used to see if the resistance from the thermistor has risen above 535. If it has not risen above 535, then the fan continues to run. When the resistance from the thermistor rises above 535, the fan (M1) turns off, and the program loops back to the beginning.
5. Each of the following four statements represents a step in a design process. There are nine design process steps listed in the answer bank. Identify which of the steps from the answer bank is being represented by each statement by writing the step number on the line provided. [4 points]

a) A team of students conduct trial runs to determine the ability of the marble sorter to separate marbles by color.
   Identify the step in the design process: _____8_____

b) Students in small groups list ideas based the constraints identified in the design brief.
   Identify the step in the design process: _____4_____

c) Students build their marble sorter design.
   Identify the step in the design process: _____7_____

d) A team of students modify the sensing system of their design after the device fails to accurately separate all marbles.
   Identify the step in the design process: _____9_____

Answer Bank

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<tr>
<th>Step #</th>
<th>Design Process Step Description</th>
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<td>Identify the Problem</td>
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<td>6</td>
<td>Refine and Develop the Solution</td>
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<tr>
<td>7</td>
<td>Model and Prototype the Solution</td>
</tr>
<tr>
<td>8</td>
<td>Test and Evaluate the Solution</td>
</tr>
<tr>
<td>9</td>
<td>Redesign and Improve the Solution</td>
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</tbody>
</table>
6. Study the technical drawing below, and sketch the missing object lines and hidden lines. There are two missing lines in each of the orthographic views. [6 points]

Each view is worth a maximum of 2 points. 1 point for each correct line.
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Unit 1: Definition and Types of Engineering

Concepts

1. According to ABET, Inc., engineering is the profession in which a knowledge of the mathematical and natural sciences, gained by study, experience, and practice, is applied with judgment, to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind.

2. Engineering is continuously adding to the core of human knowledge; every new invention and innovation is grounded in the work of people from previous generations.

3. To be a good engineer requires more than just a study of mathematics, science, and technology. A firm grasp of history, economics, philosophy, ethics, foreign language, music, and writing make a well rounded professional who will be lifelong learners and leaders.

Preface

Throughout history the human race has solved the problems facing it. When we first appeared on the planet, survival was our only concern. Finding things we could eat, places to stay warm and protection from predators occupied all of our time. In the early days, trial and error were the only methods available to solve problems. Over many thousands of years we learned that a sharp stick or a heavy rock would discourage predators. Our use of the natural materials around us to enhance our physical strength making our families safe was an early example of engineering.

From the pyramids of 5000 years ago to the space shuttle of today, engineers have played an essential role in creating the civilizations of history. In today’s world, while professions such as law, medicine and law enforcement dominate the media, engineers quietly create the planes that take us safely and quickly to all parts of the world, the automobiles that need virtually no maintenance, the computer networks that give us instant access to the world’s data bases, cellular phones to keep us in touch anywhere, as well as a vehicle to explore Mars. The engineer strives to give the user a product that is affordable, safe, durable, reliable, and evermore useful.

The 21st century will demand better and faster computers and communication systems, faster and more efficient airplanes, and less costly but more effective medical diagnostic tools. These demands mean many more trained and capable engineers will be needed. This need has started to draw more women and minority engineers into the profession. Still, the engineering profession has been much less successful at bringing minorities and women into its ranks than law or medicine, for
example. There still are many opportunities and incentives for these underrepresented groups to join the engineering profession.

The engineering field, as most other fields, offers opportunities for all types of personalities and interests. Those who enjoy working on computers to examine complex problems can be designers; those who like to work with their hands can be involved with manufacturing; those with strong people skills can move into management, sales, or customer support; those who want to be involved in helping people directly can work side by side with doctors to develop major new technologies.

**Essential Questions**

1. In what ways do the discoveries of prehistoric engineers affect your life today?
2. Since most problems facing us today are too difficult to solve by yourself how can you work with others to come up with innovative solutions?
3. What process should you follow to become an engineer?

**Lessons**

- Lesson 1.1 Engineers as Problem Solvers
- Lesson 1.2 The Engineering Team
- Lesson 1.3 Careers in Education

**Unit Assessments**

1. Students will be assessed on the accuracy and completeness of term definitions and notes on engineering history recorded in their lab notebooks.
2. Students will be evaluated on their responses to essential and key questions.
Activity 1.3a - Careers in Engineering

Purpose

Engineering is a small word encompassing an entire career cluster. There are as many job descriptions as there are people who hold them. Engineers are involved in pure research, managing jobs and people, design, manufacturing, and planning. Some have careers in places you would never expect. Disney World has an extensive collection of different kinds of engineers. Movie animation, agriculture, medicine, clothing, household products, and just about any product you can think of are all places where engineers are employed.

Equipment

Word®
PowerPoint®
Access to internet

Procedure

1. Students will select one area of engineering.
2. Students will conduct research about the area they have chosen. This research is to include:
   - Description of the field (Field Report)
   - Areas of specialization
   - Job prospects
   - Where this type of engineer might work
   - Expected salary ranges
   - Duties and responsibilities of this type of engineer
   - College preparation needed
     - Sample listing of courses from an established university or college which offers this as a major
   - Courses needed in high school to attend university
3. Students will call and conduct a personal interview with a professional who is working in the engineering field being researched.
4. Students will create a written report following the basic outline given in the Written Report Format. This report is to include:
   - Title Page
   - Table of Contents
   - Abstract of the Report – Field Report
• Written copy of the interview which includes person being interviewed, the questions asked and responses given
• College courses needed and the course descriptions
• Summary of the report
• Citations

5. Students will create a PowerPoint® presentation that summarizes the information researched.

6. Students will give a 5 minute oral to the class.
Unit 2 - Communication and Documentation

Concepts

1. Ideas can be communicated in many different ways and the match between the selection of the form of communication and the audience determines the effectiveness of the presentation.

2. Sketches are frequently used to quickly communicate technical ideas.

3. Engineers keep a daily log or notebook in order to keep a record of their work, including experiment results, sketches of new ideas, records of conversations and ideas.

Preface

For centuries doctors performed surgery without the benefit of any pain deadening agent. In fact in the early 1800’s all hope had been abandoned of ever finding something that would work. Ether was discovered in the year 1275. Scientists used ether for a variety of purposes for centuries before discovering it could be used as an anesthetic.

In the early 1800’s people attended many types of entertainment. A doctor named Long from Georgia had attended what was known as an ether frolic while in medical school. At an ether frolic people were given nitrous oxide and ether and the audience watched them stagger around a stage. Dr. Long remembered that the people involved would fall down and feel no pain.

Taking a chance Dr. Long administered ether to a patient in 1842 while removing a tumor from his neck. The patient remembered feeling no pain during the surgery. This was perhaps the greatest advance in the field of medicine at the time but no one found out about it for several years.

It took a former con man named Morton to make the discovery public. Although he claimed to have a degree in dentistry he had only worked with a dentist named Wells for a year. During that year he observed Wells use nitrous oxide in the dentistry practice for minor procedures. Morton left Wells and began medical school. While there he began to experiment with ether. He found it would prevent pain during surgery. He built a very complex apparatus to administer the ether so people would not be able to identify his secret. When the first surgery was completed in 1846 Morton applied for a patent and published his work in the attempt to gain from his discovery.
The results were duplicated in Europe by the end of the next month and ether was in wide use shortly thereafter. Why did it take four years for the world to discover what Dr. Long had found in 1842?

**Essential Questions**

1. When working on new concepts and ideas why do you need to keep records?

2. In what ways is technical writing different from the writing style we learned in school and why is it important?

3. Frequently large amounts of data are difficult to understand. How can you collect and arrange data to be quickly understandable by others?

4. If you have a CAD system why learn how to sketch?

**Lessons**

- Lesson 2.1 Sketching
- Lesson 2.2 Technical Writing
- Lesson 2.3 Tools for Data Collection, Representation, and Presentation
- Lesson 2.4 Oral Presentations

**Unit Assessments**

1. Students will be assessed on the accuracy and completeness of term definitions and notes on communication and documentation recorded in their lab notebooks.

2. Students will be assessed on the sketches produced to solve engineering problems.

3. Students will be evaluated on their oral presentation of their engineering research project according to the Presentation Rubric.

4. Students will be evaluated on the graphs and charts produced for their oral presentations.

5. Students will be evaluated on their written report on the engineering research project according to Written Report Rubric.

6. Students will be evaluated on their responses to essential and key questions.
Activity 2.1a – Perspective Sketching

Purpose

Drawing and sketching are forms of language whose symbols are pictures rather than letters. Languages are based on rules and standards. Following the standards is important for accurate communications. To create new products many people have to work together and communications is essential to getting the job accomplished.

Sketches are classified by use and drawing types.

Equipment

Pencil

Procedure

**Thumbnail sketch:** This is a very quick way of getting an idea onto a sheet of paper. A sketch is usually small but made in proportion. The pencil lines initially should be very light in nature and should be darkened when the drawing is in its final stage. Thumbnails can be any type of sketch but they are done very quickly in order to get many ideas on a piece of paper.

**Perspective Drawing:** Perspective drawings are pictorial representations of objects. They look like a photograph or as your ‘eye’ might see it. Geometrically, an ordinary photograph is a perspective. Perspective sketches are of major importance to architects, industrial designers, illustrators, and engineers.
**One point perspective:** In a one-point perspective an object is situated with one face parallel to the plane of projection, and only one vanishing point is required.

![One-point perspective diagram](image)

1. Using the outline below draw a one-point perspective view of the object your teacher selects.

**Two-point perspective:** In this type of perspective drawing, the object is situated at an angle with the picture plane but with vertical edges parallel to the picture plane. Two vanishing points are required due to the turning of the object from the picture plane and the result is a two-point perspective. This is the most common type of perspective drawing. On the picture below notice how the lines extend out to the vanishing points.

![Two-point perspective diagram](image)
2. In the setup below create a two point perspective of an object selected by the teacher.
Activity 2.1b - Orthographic Sketches

Purpose

A photograph or a perspective drawing shows an object as it appears to the observer, but not as it truly is. Such a picture cannot describe the object fully, no matter from which direction it is viewed. It is said that it doesn’t show true size and shape. What is needed is a complete and accurate description of the shape and size of an object that is to be made. In order to provide information clearly and accurately, a number of views are needed and systematically arranged so anyone in the world can understand. [Universal Language] Drawing many views to describe an object accurately and clearly is called Orthographic or Multiview.

Drawing [Orthographic projection]

You will learn to look at objects differently. When you look at an object, you see three different dimensions [width, height, depth] all at once. In a multiview or orthographic drawing you will be looking at the object in two dimensions at a time. You will look at the front view and get height and width; the top view shows width and depth, and finally the right side view shows height and depth. You must also keep in mind that this is a Universal Language therefore where views are placed is standardized and should not be arbitrary. The front view is placed in the lower left, top directly above the front view and the right side view to the right of the front view.
Procedure

The same block is shown in each exercise. The block has been turned to a different position for each drawing. Draw the top, front and right side views of the block in each position it is shown. The dimensions of the block are given in figure 1, and are to be used for all the drawings of the block. Let each small square represent one inch. However, some have been placed in more favorable positions than others. Pay attention to which drawings seem to fit best in the drawing space and have the least amount of hidden lines.
Conclusion

1. Is it important which side is labeled front?

2. What is the purpose of hidden lines?

3. Why is the center line the most important part of sketching a circle?
4. Select an item from home and create an orthographic drawing of the object in the space below.
Unit 3 – Design Process

Concepts

1. The purpose of commercial design is to create a product which will function efficiently and will be a financial success.

2. The steps from idea to production are based on logical and well-known design principles. The steps can be used for the creation of any product from a breakfast cereal to a space shuttle.

3. Frequently problems are too complex for a single person to solve. Teams are formed and duties shared. It is important to have a diversified team to help discover solutions that someone might miss.

Anticipatory Set

In the late 1960’s a scientist at 3M was working on a new adhesive. He developed an adhesive that formed itself into tiny spheres with a diameter of a paper fiber. The spheres would not dissolve, could not be melted and were very sticky individually. Because the particles were round the adhesive didn’t stick well. Many people felt the adhesive had great possibilities but there wasn’t a use for it.

It took ten years for a use to be found, a scientist tired of his book mark slipping all the time and put a small coating on a piece of scrap paper to hold it in place. He found he could remove the bookmark and use it over again. He put together a team to study the possible uses for the new product. 3M almost killed the post-it note because who would buy scrap paper when they could get it for free? Undeterred the team did research and finally sold the company on the concept. The next year (1981) the Post-It note was named 3M’s outstanding new product.

How can you tell if a new product will sell or not?

Essential Questions

1. Why should people use the design process when they already know how they want to solve a problem?

2. Why is it important to include a wide variety of people on a team charged with making decisions?
Lessons

- Lesson 3.1 Design Process

Unit Evaluation

1. Students will be assessed on the accuracy and completeness of term definitions and notes on design process recorded in their lab notebooks.

2. Students will be evaluated on the completion and thoroughness of Invention Card.

3. Students will be evaluated on their PowerPoint® presentation on the application of the product development lifecycle.

4. Students will be evaluated on their responses to essential and key questions.
Unit 4 – Engineering Systems

Concepts

1. Mechanical engineers design and manufacture machines that move and lift loads, transport people and goods, and produce energy and convert it to other forms. The design and production of such machines requires training in a variety of subjects, including mechanical design, thermodynamics, fluid mechanics, and heat and mass transfer.

2. Electrical engineering, the largest of all engineering professions, deals with the transfer of energy and information, whether the medium is sound, data, or images, and whether the transfer is by satellite, television, computer, telephone network, radio, or sound system.

3. As the world has become more technologically and computer-driven, a substantial demand has been created for engineers who are particularly capable of examining a complex system and optimizing its performance.

4. A system is a group of related elements that work together for a specific outcome.

Anticipatory Set

Many people wonder about the rapid rise of the US on the world stage. Why did this country prosper when others with the same resources flounder? One of the reasons might be the country decided that inventions should belong to the inventor. Until that time inventions belonged to the King or rulers of a country.

In 1922 Philo T. Farnsworth was a young student attending a rural school. Electricity had just been installed and Phil conducted endless experiments with it. He experimented with generators and electric motors and duplicated experiments he had read about. There were many books at the time encouraging young people to duplicate famous experiments and discussing the problems facing the future.

One article he read was about combining radio with the movies. Phil read about ways that were being tried at the time and decided that he could accomplish the task another way. He sketched the idea out and shared it with other students and his teacher. He had come up with the idea of a light sensitive tube that he could scan and then reproduce using a beam of electrons traveling over the surface of another tube, controlled by magnetic fields.

Although he didn’t get the patent for many years, those early conversations with his peers and teacher were part of the reason he was awarded the patent for television.
Ideas, no matter how far fetched, should be discussed while attempting to solve a problem.

**Essential Questions**

1. What process do engineers use to design a new machine to solve a problem?
2. How is energy transformed into a form that can be used to accomplish tasks?

**Lessons**

- 4.1 Mechanisms
- 4.2 Thermodynamics
- 4.3 Fluid systems
- 4.4 Electrical systems
- 4.5 Control systems

**Unit Evaluation**

1. Students will be assessed on the accuracy and completeness of term definitions and notes on engineering systems recorded in their lab notebooks.
2. Students will be assessed on the design of their marble sorter.
3. Students will be evaluated on the application of mathematical formulas to engineering problems associated with thermodynamics.
4. Students will be evaluated on their sketches and explanation of their use of simple machines.
5. Students will be evaluated on their oral presentation of their reverse engineering project according to the [presentation rubric](#).
6. Students will be evaluated on the accuracy of plans and engineers report about the Mouse Trap car.
7. Students will be evaluated on the presentation of their poster of the heat engine according to the [presentation rubric](#).
8. Students will be evaluated on the accuracy of the calculations using Ohm’s and Watt’s laws.
9. Students will be evaluated on their oral presentation of their Marble sorter according to the [presentation rubric](#).
10. Students will be evaluated on their solution to the programming problem in the Marble Sorter problem.
11. Students will be evaluated on their responses to essential and key questions.
Activity 4.1a - All About Simple Machines

Purpose
Any mechanical device that humans use is made from six basic building blocks called simple machines. A simple machine will increase force output by decreasing direction output or can decrease force output by increasing direction output. It’s important to note that when a simple machine is used the same amount of work is required - it just seems easier. A simple machine reduces the amount of effort needed to move an object, but it results in moving it a greater distance to accomplish the same amount of work. All complex mechanisms are made from simple machines.

Equipment
- Paper and pencil
- Calculator

Procedure
For each section read the examples. Look up any terms you are unfamiliar with. Solve the problems by applying the examples. Show all work.

The Lever
The lever is the first of the simple machines and consists of a lever arm and a fulcrum.

Effort (E) is the input force which must be supplied by the user or an engine of some kind.

Load (R) is the output force which is also the force resisting motion.

Concepts:
Force applied to a body
Distance from fulcrum to weight
Distance from fulcrum to forces
Support on which the lever rests
The object to be moved

**Equations:**

1) The first equation shows the formula for calculating the Mechanical Advantage for a Lever:

\[
\text{Mechanical Advantage (M.A.)} = \frac{\text{Distance from Fulcrum to Effort}}{\text{Distance from Fulcrum to Load (R)}} = \frac{\text{LE}}{\text{LR}}
\]

2) The second equation calculates the Load (R) that can be moved if one knows the Effort (E) and the Mechanical Advantage (M.A.):

\[
\text{Load} = \text{Mechanical Advantage} \times \text{Effort}
\]

Or

\[
R = \text{M.A.} \times E
\]

3) The second equation can be manipulated algebraically to find the Effort needed if one knows the Load (R) and the Mechanical Advantage (M.A.):

\[
\text{Effort (E)} = \frac{\text{Load (R)}}{\text{Mechanical Advantage}} = \frac{R}{\text{M.A.}}
\]

**Lever Practice Problems**

1. Using the diagram below and the equations discussed earlier, fill in the missing spaces on the table below. Be sure to show all work in the space provided under the chart.

![Lever Diagram]

<table>
<thead>
<tr>
<th>Load (R)</th>
<th>Resistance Arm (LR)</th>
<th>Effort Arm (LE)</th>
<th>Effort (E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 lbs.</td>
<td>2 feet</td>
<td>4 feet</td>
<td>4 lbs.</td>
</tr>
<tr>
<td>13 lbs</td>
<td>2 feet</td>
<td></td>
<td>4 lbs.</td>
</tr>
<tr>
<td></td>
<td>6 feet</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Show all work below:

<table>
<thead>
<tr>
<th>Weight</th>
<th>Distance 1</th>
<th>Distance 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 lbs.</td>
<td>3 feet</td>
<td>5 feet</td>
</tr>
<tr>
<td>113 lbs.</td>
<td>2 feet</td>
<td>40 lbs.</td>
</tr>
<tr>
<td></td>
<td>1 foot</td>
<td>10 feet</td>
</tr>
</tbody>
</table>

2. Select an example of a lever that you have in your home and how it is used to help make it easier to do the work.

3. Name five devices that use the principles of a lever.
4. If you were unable to move an object using an effort arm that was 5 feet long, would increasing the length of the effort arm help? Explain.

Types of levers

First class lever:
The fulcrum is located in the center of the lever arm and the effort and load are at opposite ends. Example Seesaw

Second class lever:
With a second-class lever the weight is located in the middle and the fulcrum and the effort or at opposite ends. Example Wheelbarrow

Third class lever:
The effort is applied at the middle of the arm and the weight is held at one end while the fulcrum is at the other end.

| First Class | Second Class | Third Class |
5. List 5 examples of each lever.

The Wheel & Axle

A wheel & axle is similar to a rotating lever. The wheel and axle can also be used to change from rotary to linear motion. By increasing the diameter of the wheel, the linear distance traveled for one revolution of the axle can be increased.

A wheel & axle can be made from a 2nd or 3rd class lever.
Equations and Definitions:

1) The first equation shows the formula for calculating the Mechanical Advantage for a Wheel and Axle:

\[
\text{M.A.} = \frac{\text{Radius to Effort}}{\text{Radius to Load}} = \frac{LE}{LR}
\]

2) The second equation finds Resistance if the Effort and Mechanical Advantage are known:

\[
\text{Resistance} = \text{M.A.} \times \text{Effort}
\]

3) The third equation is obtained by algebraically manipulating equation #2 above:

\[
\text{Effort} = \frac{\text{Resistance}}{\text{M.A.}}
\]

4) **Torque** is a twisting force. The units for torque are typically ft-lbs or inch-lbs. Torque can be calculated using the formula:

\[
\text{Torque} = \text{force} \times \text{radius}
\]

5) **Rotary Motion** is the circular motion which occurs when the wheel and axle are rotated about the centerline axis. Usually rotary motion is defined in terms of degrees of revolution.

6) **Linear Motion** is the straight-line motion which occurs when a wheel rolls along a flat surface. The linear distance traveled when the wheel completes one revolution is equal to the circumference of the wheel.
Wheel and Axle Practice Problems

1) A wheel is used to turn a valve stem on a water valve. If the wheel radius is 1 foot and the axle radius is .5 inches, what is the mechanical advantage of the wheel and axle?

2) How much resistance force can be overcome when an effort of 80 lbs is applied to the wheel of the water valve in problem 1?

3) What is the linear distance traveled when a 2.5' diameter wheel makes one revolution?
4) On an automobile how could you increase the distance traveled for each revolution of the axle while keeping bearing friction constant?

The Pulley

A pulley is an adaptation of a wheel and axle. A single pulley simply reverses the direction of a force. When two or more pulleys are connected together, they permit a heavy load to be lifted with less force. The trade-off is that the end of the rope must move a greater distance than the load.

Concepts:
- Effort

![Diagram of a pulley system](image)
**Equations and Definitions:**

1) The first equation shows the formula for calculating the Mechanical Advantage for a Pulley:

   \[ \text{Mechanical Advantage} = \text{Total number of strands supporting the load} \]

   *(Note: Count the end strand only when the effort is pointed upwards. For Example – for the diagram shown above the Mechanical Advantage is 6.)*

2) The second equation finds the Load if the Effort and Mechanical Advantage are known:

   \[ \text{Load} = \text{M.A.} \times \text{Effort} \]

3) The third equation is obtained by algebraically manipulating equation #2 above:

   \[ \text{Effort} = \frac{\text{Load}}{\text{M.A.}} \]

---

**The Three Types of Pulleys**

<table>
<thead>
<tr>
<th>Fixed Pulley</th>
<th>Movable Pulley</th>
<th>Block and Tackle</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Fixed Pulley Diagram" /></td>
<td><img src="image2.png" alt="Movable Pulley Diagram" /></td>
<td><img src="image3.png" alt="Block and Tackle Diagram" /></td>
</tr>
</tbody>
</table>

4) A **Fixed Pulley** is defined when a pulley is attached or *fixed* to a strong member, which will not move. When a fixed pulley is used the force needed to lift a weight does not change.

5) A **Movable Pulley** splits the work in half. The effort needed to lift 180 pounds weight is 90 pounds. The mechanical advantage of a movable pulley is 2.
6) The **Block and Tackle** is a system of three pulleys. It reverses the direction of the effort so that a downward pull can be used to lift an object. The mechanical advantage is 3 so that 40 pounds of effort is needed to lift an object weighing 120 pounds. (The distance of the rope pulled is tripled.)

**Pulley Practice Problems**

1) Using a block and tackle pulley system, determine the number of strands that will be needed to lift a weight of 1092 lbs. by applying 80 pounds of force.

2) Using a block and tackle pulley system, with 7 strands and an input force of 45 pounds, what is the maximum weight that can be lifted?
The Incline Plane

An inclined plane is a flat sloping surface along which an object can be pushed or pulled. An incline plane is used to move an object upward to a higher position.

Concepts:

The secret of the incline plane is that it splits the resistance into a horizontal force and a vertical force (gravity). The effort only needs to overcome the horizontal force since the plane supports the vertical force.

Equations and Definitions:

1) The first equation shows the formula for calculating the Mechanical Advantage for the Incline Plane:

\[ \text{M.A.} = \frac{\text{Length}}{\text{Height}} = \frac{L}{H} \]

2) The second equation finds the Load if the Effort and Mechanical Advantage are known:

\[ \text{Force} = \text{M.A.} \times \text{Effort} \]

3) The third equation is obtained by algebraically manipulating equation #2 above:

\[ \text{Effort} = \frac{\text{Force}}{\text{M.A.}} \]

Incline Plane Practice Problems

1) Using the diagram below find the force and mechanical advantage. Be sure to show your work.
2) Using the diagram below find the mechanical advantage and effort needed to move the object up the inclined plane. Be sure to show your work.
Mechanical Advantage =

Effort =

Bonus Question:
With the given information, calculate the angle (in degrees) of the incline plane. (Show all work) Hint: use trigonometry
The Wedge

The wedge is a modification of the inclined plane. Wedges are used to separate or hold devices.

There are two major differences between inclined planes and wedges. During its use, an inclined plane remains stationary, while the wedge moves. With an inclined plane the effort force is applied parallel to the slope of the incline. With a wedge the effort force is applied to the vertical edge (height) incline.

Wedge - Comparison to the Inclined Plane

Equation: (Notice the similarity to those of the inclined plane):

1) The equation for Mechanical Advantage for the Wedge is similar to that of the inclined plane:

\[ M.A. = \frac{\text{Length}}{\text{Height}} = \frac{L}{H} \]

The Screw
A screw is a combination of two other simple machines: 1) an inclined plane (wrapped around a cylinder); and 2) a wheel and axle

1) An inclined plane (wrapped around a cylinder):

AND

2) A wheel and axle:

Equations and Definitions:

1) The **screw** can be used to change from rotary to straight line (linear) motion.

2) **Screw Pitch** is the distance between two adjacent threads on a screw. The formula to calculate pitch is:
Pitch = \frac{1}{\text{Number of threads per inch of length}}

3) The **Circumference** of the screw is calculated using the Geometry formula:

\[
\text{Circumference} = \pi \times \text{Diameter}
\]

4) The formula for the Mechanical Advantage of a screw is:

\[
\text{Mechanical Advantage} = \frac{\text{Circumference}}{\text{Pitch}}
\]

---

**Screw Practice Problems**

- Obtain a sheet of construction paper.
- Draw a diagonal line from one corner to another.
- Cut along the diagonal line, creating right two triangles, one of which looks like the picture below.
- Obtain a different colored sheet of construction paper.
- Roll this sheet of construction paper into a cylinder of length B and tape in place.

- Hold the cylinder upright and one of the right triangles (shown above) with Side B parallel to the cylinder. Starting with the Side B of the triangle, wrap the triangle around the cylinder and tape in place.

1) Find the definition of pitch. Measure the pitch of the screw you created with construction paper, above.

2) Why do screw heads have a larger diameter than the screw shaft?
3) What is the mechanical advantage of a 3/8" diameter screw with a pitch of 20 threads per inch if a 1.5" diameter screwdriver is used to install the screw?
Activity 4.5k - Have You Lost Your Marbles?

Purpose

Teams of students will simulate an industrial sorting process using Fischertechnik-building components.

Problem Statement

Today’s consumer pays a steep price (both long and short term) for products made from virgin materials. Most often, these products find their final resting-place in the local landfill. As a post-industrial society, we have a need, as well as a responsibility to view our used products as a resource, to reuse, remanufacture, or recycle these products back into the manufacturing cycle. As recycling centers become a more common sight in our community, we must try to make them as efficient and cost effective as possible. Sorting the various components of trash is a time consuming process. Any effort made at trying to automate this task would increase the cost effectiveness of this operation.

Design Statement

You and your partner(s) are to design an automated separation system that simulates the separation process that is used in an industrial recycling plant. You are required to separate two different colored marbles, clear and opaque, into separate collection bins.

The system your team designs must include the following sub-systems:

- **Hopper System:** A place to dump, not place, the raw material (trash), to begin the process. You can use non-Fischertechnik parts for the hopper.
- **Transport System:** A system to move the marbles from point to point: from the inspection station to the proper bin for those color marbles.
- **Sensing System:** A system for recognition of part or position of the bin
- **Bin System:** A system to collect and hold the marbles after the system has determined its classification.
- **Program:** A computer program used to automate the sorting system. You must use subroutines in your program.

Documentation
Project Journal
Your team will be required to maintain a daily journal of the marble sorter design and construction. At the end of the project this will be submitted as part of the project grade. The journal will be made up of the following sections:

- **Cover**
- **Initial sketches** – You will conceptualize your design and prepare a quality sketch of your system. This will be the concept you develop to completion. Any changes to your sorter will have to be sketched and documented.
- **Program Narrative** – A written step-by-step description of how you want your team’s marble sorter to operate.
- **Daily Entries** – Every day keep track of your progress. Your entries must be made in the following form.
  - Date:
  - Tasks Accomplished
  - Tasks yet to be addressed
- **Print out of Program and Sub-routines** – A copy of the program, and each subroutine in that program, will be copied to *Word*. A written description of each part of the program will need to be included.
- **Application paper** – A 1 – 2 page paper explaining how the major concepts studied through the Fischertechnik activities relate to the theory of operation and construction of your marble sorter.
- **Additional Comments**

**Project Constraints:**
- The raw material (*trash*) will consist of clear (transparent) and black (opaque) marbles.
- Only Fischertechnik components may be used in the construction of your sorter, except for the hopper, which will be constructed from cardboard. (Type and amount of material per team will be announced.)
- Each team will consist of two people, three only by permission of instructor.
- Periodically throughout the life of the project you will receive progress reports. These are designed to make sure you are addressing all aspects of the problem in a timely manner.

**Timeline:**
- Due dates to be established by your instructor
Unit 5– Statics and Strength of Materials

Concepts

1. Structural analysis is a systematic study of the relationship of the material, members, and the construction of the structure when loaded to determine the resulting deflections and forces.

2. Static equilibrium is concerned with the special condition that exists when a body is in equilibrium and at rest when subjected to force.

3. All objects can be deformed with the application of an external force. The external force is called stress. Strain is the degree of deformation.

4. A scalar quantity is one that represents force with the amount only; a vector quantity represents a force and direction.

5. Moments of Inertia are sometimes called second moments of areas. They are a mathematical expression of the strength or stiffness of the shape expressed in a unit of in$^4$.

Anticipatory Set

Everyone wants the car they drive in to be safe. Years of research and design changes has made the Auto a strong and reliable shape. What of the other products in our lives? From the floors we walk on to the bridges we drive over we rarely think about the thought that went into those products. They have become so safe that we take them for granted.

It has not always been that way. Over the past century things have become lighter in weight but stronger and more resistive to the forces that apply. A modern tennis racket is far stronger than the best model made even twenty years ago. The concept of long bridges over water has only come about over the last century and a half. Before that we didn’t understand the forces involved enough to predict what would survive and what would fail. Riding on a ferry is a special treat for children instead of a regular occurrence.

Essential Questions

1. What things do I need to find out in order to predict if what I design will stand up to the use I intend to put it to?

2. What forces act on an object and what effect will they have on what I build?

Lessons
Unit Evaluation

1. Students will be assessed on the accuracy and completeness of term definitions and notes on kinematics recorded in their lab notebooks.
2. Students will be assessed on the design and completeness of the bridge design.
3. Students will be evaluated on the application of mathematical formulas to engineering problems associated with structure problems.
4. Students will be evaluated on the graphing of vector problems.
5. Students will be evaluated on the graphs produced to show relationship between deflection and area or second moment of area.
6. Students will be evaluated on the accuracy and clarity of the calculations produced from their statistical data.
7. Students will be evaluated on their oral presentation of their bridge design and analysis according to the presentation rubric.
8. Students will be evaluated on their responses to essential and key questions.
**Activity 5.1a - Working with X and Y Components of Vectors**

**Purpose**

In order to be effective in design work it is necessary to be able to mathematically discover answers to questions. This exercise is designed to help you discover forces and what effect the angle that force is exerted from has on your design.

**Equipment**

- Ruler
- Calculator
- Pencil and paper

**Procedure**

1. Find the x and y components of vector V.

   ![Diagram](image)

   Solution hint: Think of the vector as pointing southeast. You will need to split it up into its y component (pointing south) and its x component (pointing east).

2. Find the x and y components of vector W. Can you predict the solution based on Problem 1?
Solution hint: Think of the vector as pointing southwest. You need to split it up into its y component (pointing south, and its x component (pointing west).

3. This picture is hung from a nail with wire. The nail supports two forces $V = 5\text{N}$ and $W = 5\text{N}$. If the resultant of these forces acts vertically downwards, find its X and Y components (Using your solutions from Problems 1 and 2).

4. Find the x and y components of vector A.
5. Find the x and y components of vector B.

Solution: Think of the vector as pointing northeast. You need to split it up into the y component (pointing north, and the x component pointing east).

6. Two ropes are attached to the screw eye hook in this picture. Rope B is being pulled with a force of 100N at an angle of 15 degrees to the y-axis. Rope A is being pulled with a force of 50 N at an angle of 20 degrees to the x-axis. Use your solutions from Problems 4 and 5 to find x and y components of the resultant force, F:
Conclusion

1. When you are opening a classroom door what are the forces acting on it and how are they balanced out so the door does not slam shut when released?

2. You have been asked to hang a mirror ball in the center of the gym, ten feet from the ceiling. There are beams that run across the gym but they are not centered. One beam is 10 feet off center in one direction and the other is 7 feet from the center. The mirror ball weighs 67 pounds. How long should each cable be and how much force should each one be able to hold?
Activity 5.1b – Free Body Diagrams Worksheet

Purpose
Free-body diagrams are diagrams used to show the relative magnitude and direction of all forces acting upon an object in a given situation. A free-body diagram is a special example of a vector diagram.

Equipment
Pencil
Straight edge

Procedure
Draw free body diagrams (force diagrams) for each of the following:

1. Draw free body diagram for items A, B, C, D.

![Diagram of items A, B, C, D]

2. Draw free body diagram for member AB and cylinder D.
3. Draw a free body diagram for member AB which is pin connected at A and supported by member BC.

Conclusion
1. What is the point behind creating a free body diagram of an object?

2. Sketch a free body diagram of a person sitting in a car seat. Which force arrows do you think would be the largest? Why?
Activity 5.1d - Truss Calculation

Purpose

A truss is formed by connecting members with one another with pin connections. We calculate the forces on a truss to accurately predict the type and amount of force each member must carry. The sizing of members determines the weight of the truss and is a factor in the final cost.

Equipment

Paper & Pencil
MDSolids program

Procedure

1. Sketch a diagram for each truss replacing the supports with the appropriate reaction forces.

2. Predict which beams would be in tension, which would be in compression, and which would be supporting the most force.

3. Draw the truss in MD Solids.

4. Record the forces at the supports and in each beam.
Conclusion

1. Were your predictions for the forces accurate? If not why were your predictions inaccurate?
2. How would your analysis help in the selection of size and kind of material you would select for the truss?
Activity 5.2a - Centroid Activity with MDSolids

Purpose

The moment of inertia is defined as the second moment of an area about an axis. For beams and columns, the moments of inertia about the centroidal axes are needed. After finding the centroidal locations, the moments of inertia may be calculated. For very simple shapes if is fairly easy to find the Centroid. As the shapes become more complex they must be broken down into simpler forms to be dealt with.

Equipment

MDSolids or Inventor program
Paper and pencil

Procedure

Find the centroid location for the following shapes using MDSolids or Inventor.

Problem 1: C Shape (American Standard Channels)
Problem 2: L Shape – Equal Legs

Problem 3: Sketch and dimension your own unsymmetrical shape and calculate the centroid location.

Conclusion

1. Is there a coordinate relationship between the location of the centroid of the individual shapes that make up a complex shape and the centroid of the complex shape?

2. How is finding the centroid useful in determining the strength of the shape?
3. Does the location of the centroid have anything to do with the balance of an object?
Activity 5.2b - Moment of Inertia Activity with MDSolids

Purpose
This activity will introduce the concept of using computer software to calculate moment of inertia. Moment of inertia, as it is used here, will allow us to compare different cross sectional areas of a structural member and analyze how the shape of a beam affects its stiffness.

Equipment
MDSolids program
Pencil
Paper

Procedure
Using MDSolids, complete the following table for a beam loaded as shown in the figure below. Start with a beam with a rectangular cross section (2" x 4") made from Douglas Fir. Investigate the effects of changing the shape of the cross section and not exceeding the overall cross section size of the 2x4.

200 lb

5'

10'

[Diagram of a beam with a load of 200 lb at 5 feet from one end, supported over a distance of 10 feet]
### Conclusion

1. Which mass property has a more profound effect on the deflection of the beam, area, or moment of inertia?

2. Create two charts using Excel (a) Area vs. Beam Deflection, and (b) Moment of Inertia vs. Beam Deflection to show the relationships graphically.
Unit 6 - Materials and Materials Testing in Engineering

Concepts

1. Every material has its origin in the elements, and has the same component parts as every other material (protons, neutrons, and electrons) but has its own unique structure, mechanical and physical properties, and characteristics.

2. The core of material selection is the comparison of the properties to maximize the advantages while minimizing the disadvantages.

3. The choice of a fabrication method is based on, material properties, finished design, machine capabilities, safety, environmental concerns, and cost.

4. Quality control reduces unacceptable parts by the use of statistical techniques thus leading to cost and material savings and reduced damage to the environment.

5. Testing of materials before, during, and after fabrication is essential to guaranteeing the reliability of a product.

Anticipatory Set

Since the beginning of civilization, the evolution of human society has been correlated with how well humans adapted materials for application to our environment. How a civilization functions within an environment is directly related to how well materials can be fabricated into useful products and processes while minimizing the damage done to that environment. The need for properly “engineered” products was as true in the Stone Age as it is in the Information Age. Whether the societal need is in the area of agriculture, architecture, civil engineering, medicine, environmental science, transportation, or any other area of technology, materials must be available to be appropriately incorporated into our products. Societies which have possessed an abundance of materials, and have applied technology and engineering towards the improvement of materials for better products and processes, have prospered.

Through the study of materials, and improvement of materials testing in engineering, technology will produce better products for applications in areas such as communications, production, and transportation. Study of material classification, material properties, testing processes and procedures, and material selection and application will provide a foundation for the creation of engineered products which will continue to allow humans to adapt to the changing global environment.
Companies keep buying the more expensive equipment because new machines can produce a higher quality product in less time thus increasing productivity. There has been, and continues to be, an explosion in new industrial processes. Metal saw blades are being replaced by waterjet, laser, and Electro Discharge Machining (EDM) cutters. Thousands of expensive machined metal parts have been replaced by inexpensive injection molded plastic parts or pressurized water molded metal parts. The student should observe that the goal is almost always to turn raw material into a finished product with the least number of steps, minimal waste, and minimal defects.

**Essential Question**

1. How can I assure that the parts I am making will stand up the abuse they will take, fit when assembled, and still be as inexpensive as possible?

**Lessons**

- Lesson 6.1 Categories of Materials
- Lesson 6.2 Properties of Materials
- Lesson 6.3 Manufacturing Processes
- Lesson 6.4 Quality Assurance
- Lesson 6.5 Material Testing

**Unit Evaluation**

1. Students will be evaluated on their ability to present and publish technical information verifying test results from a material test.
2. Students will be assessed on the accuracy and completeness of term definitions and notes on materials, machines, and processes recorded in their lab notebooks.
3. Students will be assessed on their ability to identify and group material categories and their properties.
4. Students will be evaluated on the application of mathematical formulas to engineering problems associated with material selection.
5. Students will be evaluated on their team’s research of a material, and the classroom presentation.
6. Students will be evaluated on their teams’ research of a material, and the visual classroom presentation of a display.
7. Students will be evaluated on the accuracy and clarity of the calculations produced from their statistical data.
8. Students will be evaluated using performance and objective tests as well as written, oral, and multimedia presentations.
9. Students will be evaluated on their responses to essential and key questions.
Activity 6.2b – Engineering Problem Solving

Purpose

Engineers are technical problem solvers. The way in which they solve problems varies. In general, engineers implement a logical approach, or method, in solving the problems they encounter. Mathematically based science and engineering courses attempt to prepare future engineers for such problem-solving by stepping them through a methodological approach in solving both word problems and more authentic design problems. The method shown here has been used for years with students in physics and engineering classes and will help in solving more complex problems later on.

Materials

Paper and Pencil
Calculator
MDSolids Program

Procedure

1. Study the five steps below.

Five Steps to Textbook Problem-Solving:

I. Identify **Knowns** (what you’re given) and **Unknowns** (what you want to find out). Assign variable names to the knowns and unknowns and specify each using the correct number and unit name. For example: diameter = \( d = 3\text{m} \).

II. Draw a picture. Be sure to label all parts shown.

III. Find an **Equation** (or series of equations) that will get to the answer. Write it down. Manipulate it using algebraic principles, if necessary.

IV. Substitute **numbers and units into the equation, and solve.** Write your answer in terms of the variable name you previously chosen. Be sure to specify not only the numeric answer but the units as well. For example: \( F = 4\text{N} \).

V. **Convert, if necessary. Use the conversion method.**

2. Memorize the phrase below. Remember what the letters stand for.
THINK:             Knowns and unknowns
DON’T            Drawing
EVER            Equation(s)
SAY            Substitute and solve
“CAN’T”        Convert

3. Study this example problem.
Example 1: A force of 150 lbs. pushes on a round plate with an area of 30 in². How much pressure does the plate apply to the ground?

4. Step one: Identify the Knowns and the Unknowns.

   \[
   \begin{array}{ll}
   \text{KN} & \text{UNK} \\
   F &= 150 \text{ lb} \\
   A &= 30 \text{ in}^2 \\
   P &= ? \\
   \end{array}
   \]


6. Step three: Write an equation.

   \[
   \text{EQN: } P = \frac{F}{A}
   \]

7. Step 4: Substitute Knowns into the equation.

   \[
   \begin{array}{c}
   P = \frac{150 \text{ lb}}{30 \text{ in}^2} = 5 \text{ lb/in}^2 = P
   \end{array}
   \]

8. Step 5: Convert if necessary. In this problem, the \( \frac{5 \text{ lbs}}{\text{in}^2} \) is in the form we desire, so no conversion is necessary.
Now apply the method on the following problems. Be sure to show your work. Make a list of the Knowns and Unknowns. Create a diagram. Write the formulas down even if you are using a calculator or the MDSolids program to help you solve the problems. Months later, it is important to be able to follow your thought process. Substitute the numbers into the equation and convert, if necessary. Complete each of the problems below.

**Common Variable Names:**

- $\Delta$ = the change in
- $\delta$ = total deformation
- $\sigma$ = stress (force per unit area)
- $\epsilon$ = strain
- $E$ = modulus of elasticity, Young's Modulus
- $P$ = axial force
- $A$ = cross section area
- $L$ = length
- $r$ = radius of a circle
- $d$ = diameter of a circle
- $\text{Press} = \text{Pressure}$

**Formulae you might use are:**

- $\sigma = \frac{P}{A}$
- $\epsilon = \frac{\delta}{L}$
- $\delta = \frac{PL}{AE}$
- $E = \frac{\sigma}{\epsilon}$

$A = \pi r^2$ (area of circle when using the radius)

$A = .7854 d^2$ (area of circle when using the diameter)

$\text{Press} = \frac{P}{A}$

1. A force of 200 lbs pushes against a rectangular plate that is 1 ft. by 2 ft. Determine the pressure in $\frac{\text{lb}}{\text{ft}^2}$ and $\frac{\text{lb}}{\text{in}^2}$ that the plate exerts on the ground due to this force.

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POE – Unit 6 – Activity 6.2b – Engineering Problem Solving – Page 3
2. A piece of steel wire 100 feet long, with a cross-sectional area of 0.004 sq. in., must be stretched with a pull of 16 pounds when in use. If the modulus of elasticity of steel is 30,000,000 psi:
   
   a) What is the total elongation $\delta$ in the entire length of the wire?

   b) What tensile stress is produced by the pull?

3. A 2” by 4” rectangular piece of steel, that is 20 feet long between centers of the pins at its ends, is used as the diagonal member in a bridge. If the total tensile load in the steel is 80,000 pounds and the modulus of elasticity is 30,000,000 psi, calculate:

   a) The tensile stress-
b) The total elongation caused by the load-

c) The unit elongation-

4. A sample of material is \( \frac{1}{4} \) “diameter and must be turned to a smaller diameter to be able to be used in a tensile machine. The target breaking point for the material is 925 pounds. The tensile strength of the material is 63,750 psi. What diameter would the sample have to be turned to in order to meet the specified requirements?
5. Two pieces of steel are held together with six bolts. One end of the first piece of steel is welded to a beam and the second piece of steel is bolted to the first. There is a load of 54,000 pounds applied to the end of the second piece of steel. The tensile strength of steel is 74,000 psi, the shear strength is 48,000 psi.

a) Calculate the diameter of the bolts needed to support the load.

b) Find the width of the steel if the thickness of the steel is ¼”. The bolt holes are 1/16” larger than the bolt.
6. Determine the required nominal diameter of a threaded steel rod to carry an axial load of 16,000 pounds in tension if the tensile stress of 20,000 psi is permitted.

7. A piece of wire 1200 feet long, with a cross-sectional area of 2.25 sq. in., must be stretched with a pull of 1600 pounds when in use. If the modulus of elasticity of this steel is 30,000,000 psi:
   a) What is the total elongation \( \delta \) in the entire length of the wire?

   b) What tensile stress is produced by the pull?

8. A 2” circular piece of steel, that is 20 feet long between centers of the pins at its ends, is used as the diagonal member in a bridge. If the total tensile load in the steel is 180,000 pounds and the modulus of elasticity is 30,000,000 psi, calculate:
a) The tensile stress-

b) The total elongation caused by the load-

c) The unit elongation-

9. A round, steel 1-1/8" diameter rod, is 85 feet 6 inches in length, and supports an axial load \( P \) in tension. Calculate:
   a) The maximum unit tensile stress in the rod, if the axial load \( P \) is 12,000 lb.

   b) The maximum allowed load \( P \) on this rod, if the unit tensile stress must not exceed 25,000 psi.
c) The total elongation of the rod, if $E = 30,000,000$ psi using the maximum allowed load from part B.

10. A sleigh is supported and held off the ground with four vertical $\frac{1}{2}$" diameter rods. If the modulus of Elasticity is 10,000,000 psi and the length of each rod is 1 ft., how much weight in toys can be put into this sleigh without compressing the rods more than .01" and ultimately destroying the sleigh?
11. A piece of wire is subjected to a load of 8000 lb. and is 60 ft. in length. The wire deforms a total of 1” in length due to this weight. If the Modulus of Elasticity is 30,000,000 psi, what is the diameter of the wire?

12. A piece of circular aluminum with a diameter of ¼ ft. and 13 ft. in length is used as a structural component of a robot. If the tensile load applied to the component is equivalent to 84 tons and the Modulus of Elasticity is 10,000,000 psi, what is the total elongation in the entire length of the rod?

13. Calculate the stress created in a 3” diameter piece of steel that is 21 feet long between the centers of pins at its ends, and is used as a diagonal member in a
bridge. The load applied to this member is 181,000 pounds and the modulus of Elasticity is 30,000,000 psi.

14. A strand of wire 1,000 ft. long with a cross-sectional area of 3.5 sq. inches must be stretched with a load of 2000 lb. The modulus of Elasticity of this metal is 29,000,000 psi. What is the unit deformation of this material?

Conclusion

1. You have been asked to design a machine to punch circular holes into a sheet of metal. Create a sketch of the problem and set up the equations to calculate shear stress in the metal sheet. Make sure to include applied force, hole diameter, modulus of elasticity and sheet thickness.
2. A community in a mountainous area has developed a playground in a park by a stream. The time it takes for children who live on the other side of the stream to walk to the playground is an hour. The stream is 60 feet across. You have been asked to come up with a design for a cable bridge for foot traffic only. What size cables will need to be obtained so 10 average-sized children can walk on the bridge at once?
Activity 6.3a - Machining the Tensile Testing Samples

Purpose

Engineers that design parts for any product must be sure that the parts made are reliable, safe and function in a predictable way. To achieve this objective a great deal of care must be taken in choosing the material from which the part is to be fabricated. In choosing this material the engineer must know all the properties and characteristics that the material exhibits. For this information to be known a great deal of testing of the material used must be performed. Material testing is a process by which properties of a material can be investigated and determined. This process is very important when designing products and parts that will perform in the desired way.

Materials

One 1/4" round diameter aluminum bar 3 inches long
One 1/4" round diameter brass bar 3 inches long.
Metal lathe and lathe tooling
Micrometer 1 inch
Die holder or wrench and die with 1/4" – 20 NC thread.
Hacksaw
Bench grinder

Procedure

1. Study the following drawing:
2. Using a bandsaw cut the length of the rod to 3-1/16”.

3. Remove burrs on ends of material with a file.

4. Place material in lathe collet and face one end, then chamfer.

5. Remove the stock from the lathe, measure and mark material at 3.000”.

6. Place material in lathe collet, turn to the mark you made, then chamfer (refer to drawing).

7. Center drill end to include tapered portion of center drill.

8. Put the lathe in the backgears setting and thread (1/4-20) both ends of the material (refer to drawing).

9. Mark material for appropriate gage section location (refer to drawing).

10. Place material in lathe between centers.

11. Turn material to correct tensile diameter in cuts no greater than .030” and ending cuts of no more than .005”. Be sure that the ends of the cuts are filleted.

12. Submit to instructor for grading.

**Conclusion**

1. What is the purpose of the fillets on the test sample?

2. How is the diameter of the center section determined?
3. How much thread must be held at each end of the test sample when testing?
Activity 6.4C – Introduction to Statistics

Purpose
To be able to describe a set of numbers and then make accurate inferences (a.k.a. educated guesses) about that group of data based on incomplete information

Materials
Bag of M&Ms
Excel®
Volume measuring device (Graduated cylinder or equivalent)

Procedure
1. Make a prediction on how many M&Ms are in your bag ______________
2. Open the bag and count the M&Ms
   Record the actual number ______________
3. What was the difference in the number you guessed vs. the actual number?
4. Place the M&Ms in the measuring device. What volume does the entire pack fill?
   ___________ml
5. Divide the M&Ms into sets by color.
6. Open Excel and create the spreadsheet shown here.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Candy Lab</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Yellow</td>
<td>Red</td>
<td>Blue</td>
<td>Brown</td>
<td>Green</td>
<td>Orange</td>
<td>Total</td>
<td>Volume</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>7</td>
<td>8</td>
<td>25</td>
<td>7</td>
<td>5</td>
<td>57</td>
<td>67</td>
</tr>
</tbody>
</table>

7. Enter your data in the appropriate spaces.
8. Obtain data from other groups and record them on additional lines.
9. Write a formula to sum each column.
10. For each color create a statistical profile to include the mean, median, mode, and standard deviation for each color.

<table>
<thead>
<tr>
<th>Color</th>
<th>Total</th>
<th>Mean (Ave)</th>
<th>Median</th>
<th>Mode</th>
<th>St. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow</td>
<td>116</td>
<td>6.1052632</td>
<td>6</td>
<td>6</td>
<td>1.100239</td>
</tr>
<tr>
<td>Red</td>
<td>145</td>
<td>7.6315789</td>
<td>6</td>
<td>8</td>
<td>1.362852</td>
</tr>
<tr>
<td>Blue</td>
<td>103</td>
<td>5.4210526</td>
<td>5</td>
<td>4</td>
<td>1.539968</td>
</tr>
<tr>
<td>Brown</td>
<td>492</td>
<td>25.894737</td>
<td>26</td>
<td>27</td>
<td>2.492093</td>
</tr>
<tr>
<td>Green</td>
<td>106</td>
<td>5.5789474</td>
<td>6</td>
<td>4</td>
<td>1.261207</td>
</tr>
<tr>
<td>Orange</td>
<td>103</td>
<td>5.4210526</td>
<td>6</td>
<td>6</td>
<td>1.121298</td>
</tr>
<tr>
<td>All</td>
<td>1065</td>
<td>56.052632</td>
<td>57</td>
<td>57</td>
<td>4.377641</td>
</tr>
</tbody>
</table>

11. Enter formulas in the cells to extract the necessary information.

12. Using the data from the class totals create a histogram for a color of your choice. The first step is to create a bin range set using the median number in the middle and go two standard deviations in either direction. The example here is for the red color.

<table>
<thead>
<tr>
<th>Bin Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.24</td>
</tr>
<tr>
<td>6.62</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>9.36</td>
</tr>
<tr>
<td>10.76</td>
</tr>
</tbody>
</table>

13. Is your histogram skewed? If so explain which way and why.

Conclusion
1. Which color is most likely to have the same number in each bag? Explain your answer.

2. Does your histogram fit a classic bell curve? Why or why not?

3. Using the information you developed in the lab above combined with any other you think you might need, calculate the number of M&Ms it would take to fill your lab. Explain your answer mathematically.

4. How much would the M&Ms from question 3 weigh?
Unit 7 – Engineering for Reliability

Concepts

1. Reliability is the ability of a product to perform adequately for a given length of time under specific operating conditions.

2. Reliability is a property determined by many factors such as: design, materials, production, operator use and misuse, maintenance, and environmental exposure.

3. There are several design strategies to improve reliability: More robust components, interlocks, redundancy, quality control/quality assurance, or complete redesign.

Anticipatory Set

Things that are designed and built are expected to meet certain performance criteria. The degree to which an object meets its designed performance criteria every time it is used is called reliability. Designing for reliability is easy to do, but it adds expense to the production cost of the object. Engineering decisions must take into account the costs involved. Other factors that must be taken into account when addressing reliability are: the consequences of failure, the frequency of use, the conditions under which the object is used, and the worst-case reasonably expected scenario under which the object will be expected to perform.

Everyone has heard the expression Murphy’s Law. It has its origin in the year 1949. Murphy was an engineer working on a rocket sled experiment. Sixteen accelerometer transducers were wired to a test subject. There were two ways each sensor could be glued to its mount, and somebody methodically installed all 16 the wrong way. At the end of the expensive test there was no data. All 16 had failed to work during the test. Murphy was quoted as saying "If there are two or more ways to do something, and one of those ways can result in a catastrophe, then someone will do it." It has become a principle of defensive design. For example, you don't make a two-pin plug symmetrical and then label it "THIS WAY UP"; if it matters which way it is plugged in, then you make the design asymmetrical so it cannot be plugged in wrong.

How do reliability and Murphy’s Law relate?

Essential Question
1. In what ways has redundancy been built into your car? List a few examples and project into the future to possible future redundant systems that will be added.

Lessons

- Lesson 7.1 Reliability
- Lesson 7.2 Case Studies

Unit Evaluation

1. Students will be evaluated using performance and objective tests as well as written, oral and multimedia presentations.

2. Students will be assessed on the accuracy and completeness of term definitions and notes on reliability and redundancy recorded in their lab notebooks.

3. Students will be evaluated on the oral presentation of their case study according to the oral presentation rubric.

4. Students will be assessed for data calculations and applications

5. Students will be evaluated on their responses to essential and key questions.
Unit 8 – Kinematics

Concepts

1. Kinematics is the study of motion allowing us to predict the path of an object when traveling at some angle with respect to the Earth's surface. It is easy to calculate if the force of Gravity remains constant and we ignore the effects of air resistance.

2. Projectile motion follows a parabolic curve with the elevation being the Y axis and the distance displaced being the X axis. The velocity remains constant in the X direction but the Velocity in the Y direction changes with time in both magnitude and direction.

Anticipatory Set

In the early 1600's a man named Galileo threw away two thousand years of thinking and changed the way we all look at the world. Observing the world around him, he started applying mathematical equations to the way things moved. His famous experiment dropping differently weighted balls from the tower of Pisa was only one small example. He was excommunicated for his beliefs and teachings but persisted anyway. His work inspired many who followed including an Englishman named Newton who added greatly to the earlier works and brought about the publication of the Laws of Motion in his book Principia.

If we apply the Laws of Motion combined with the Vector and Scalar information we learned in Unit 5 we can predict with some accuracy the behavior of the flight of objects.

Essential Question

1. You have been assigned to design a 120 meter ski jump. A hill has been found with a 50 degree slope that can be used. The end of the jump should launch the jumper at an angle of 15 degrees above the horizontal. The average speed, of the skiers at the end of other ramp, is usually about 10 meters/second. How far up the hill should the take off be situated and what conditions should be considered?

Lessons

- Lesson 8.1 Linear Motion
Lesson 8.2 Trajectory Motion

Unit Evaluation

1. Students will be evaluated on their ability to present and publish technical information verifying test results from a ballistic test.

2. Students will be assessed on the accuracy and completeness of term definitions and notes on kinematics recorded in their lab notebooks.

3. Students will be assessed on the design and completeness of the three fold flyer describing the operation of their ballistic device.

4. Students will be evaluated on the application of mathematical formulas to engineering problems associated with ballistic problems.

5. Students will be evaluated on the graphs produced to show trajectory information data gathered in testing.

6. Students will be evaluated on the accuracy and clarity of the calculations produced from their statistical data.

7. Students will be evaluated using performance and objective tests as well as written, oral and multimedia presentations.

8. Students will be evaluated on their responses to essential and key questions.
Activity 8.1a - The BD Project

Purpose

Things move in predictable patterns. A ball thrown in the air moves in a curved path until it strikes the earth. We can analyze where it will strike the ground if we make some basic assumptions about free-fall acceleration and we discount the effects of wind resistance.

Materials

Scrap and recycled materials
Ping pong balls
Tape Measure
Excel®

Procedure

Objective: To create a device that will toss a ball accurately within a given range.

BD Constraints:
- Must be able to fire a projectile (to be specified by the instructor) anywhere within 5’ to 15’ operating range (design adjustability into your device!)
- Must fit within a 1’x1’ footprint (in “collapsed form”)
- Cannot utilize high-pressure gases or combustible materials
- Must be constructed primarily out of materials that are found, not bought.
- Must be sketched in engineering journals and approved by your instructor prior to building.

Testing:
- Performance Testing (after completion of final assembly and adjustment)
  - Choose at least ten firing angles between 10 and 80 degrees.
  - For each firing angle, fire the projectile and record range
  - Perform at least three trials for each firing angle
  - Record all procedures, tables, data etc. within engineering journals.
- Final Testing
  - Must be able to land in a 5-gallon bucket (the target) at a location specified by your instructor on the day of the test (and within the operating range)
  - Each team will have three tries to hit the target
Creating a Performance Sheet: Each team must create a three-fold flier that includes the following:
- Name of the device
- Team members’ names
- Sketch or drawing of the device
- Picture (digital image)
- Description of how it operates
- Summary of testing data and procedures
- Graph of firing angle versus range
- Other important information

Presenting your device: Each team must create and deliver a five-minute presentation for the class. Presentation requirements:
- The presentation must include:
  - All information contained in the performance sheet
  - A demonstration of the operation of the device
- All team members must contribute to the presentation.
- After all presentations are given, the class will vote on the “best” device; teams may not vote for their own device. The team with voted “best” will receive bonus points.

Conclusion

1. If you were in a canoe and wanted to paddle to the far side of a fast moving river explain the motion the canoe will travel in the river in respect to a fixed point on the shore.

2. A firefighter arriving at a fire finds the closest she can get to the fire is about 50 feet away. What angle should she set the fire hose to if the water pressure can hold an initial velocity of 115 ft./sec and she needs to have the water enter a second story window that is about 15 feet from the ground?
Activity 8.2a – Calculating Velocity from Angle and Range

Kinematics: the study of how objects move

Purpose
- To use knowledge of kinematics, projectile motion, algebra, and trigonometry to create an equation that allows us to find the initial velocity of the Ballistic Device (BD) given angle of projection and maximum range.
- To approximate the velocity of the BD through Experimentation

Equipment
Calculator

Procedure
Study the table below.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Variable Name</th>
<th>Description</th>
<th>English Units</th>
<th>Metric Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>s</td>
<td>Displacement</td>
<td>How far an object is from where it started (generalized term)</td>
<td>Feet (ft)</td>
<td>Meters (m)</td>
</tr>
<tr>
<td>x</td>
<td>Horizontal displacement</td>
<td>How far, horizontally, an object is from where it started</td>
<td>Feet (ft)</td>
<td>Meters (m)</td>
</tr>
<tr>
<td>y</td>
<td>Vertical displacement</td>
<td>How far, vertically, an object is from where it started</td>
<td>Feet (ft)</td>
<td>Meters (m)</td>
</tr>
<tr>
<td>t</td>
<td>Time</td>
<td>Time an object is in motion</td>
<td>Seconds (s)</td>
<td>Seconds (s)</td>
</tr>
<tr>
<td>vᵢ</td>
<td>Initial velocity</td>
<td>How fast an object moves in its initial position</td>
<td>Feet per second (ft/s)</td>
<td>Meters per second (m/s)</td>
</tr>
<tr>
<td>θ</td>
<td>Theta</td>
<td>The angle the initial velocity makes with the horizontal axis (between 0° and 90°)</td>
<td>Degrees (°)</td>
<td>Degrees (°)</td>
</tr>
<tr>
<td>Symbol</td>
<td>Description</td>
<td>Units</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td>-------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$v_{ix}$</td>
<td>Initial horizontal velocity</td>
<td>Feet per second (ft/s), Meters per second (m/s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$v_{iy}$</td>
<td>Initial vertical velocity</td>
<td>Feet per second (ft/s), Meters per second (m/s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>Acceleration</td>
<td>Feet per second squared (ft/s²), Meters per second squared (m/s²)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$a_x$</td>
<td>Horizontal acceleration</td>
<td>Feet per second squared (ft/s²), Meters per second squared (m/s²)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$a_y$</td>
<td>Vertical acceleration</td>
<td>Feet per second squared (ft/s²), Meters per second squared (m/s²)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>Acceleration due to gravity</td>
<td>Feet per second squared (ft/s²), Meters per second squared (m/s²)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Step 1:** Generating equations of motion for horizontal and vertical parts of projectile motion.

A general equation that is useful in the study of projectile motion reveals that the generalized displacement, $s$, is equal to the sum of the sum of two parts:

$$s = (1) + (2)$$

Where part (1) is the initial velocity of the object in the same direction as the displacement multiplied by the time (the constant velocity portion of the equation), and part (2) represents one half multiplied by the acceleration in the same direction as the displacement multiplied by time squared (the accelerated motion part of the equation). Written as a useful equation:

$$s = v_{ix} t + \frac{1}{2} a t^2$$

Projectile motion is most easily understood by separating the horizontal and vertical parts of the motion. When the equation, above, is rewritten for the horizontal and vertical parts of motion, two equations emerge:

**Horizontal Motion:**

$$x = v_{ix} t + \frac{1}{2} a_x t^2$$

**Vertical Motion:**

$$y = v_{iy} t + \frac{1}{2} a_y t^2$$
Vertical Motion: \[ y = v_y t + \frac{1}{2} a_y t^2 \]

**Step 2:** Solving for \( v_{ix} \) and \( v_{iy} \).

We can find \( v_{ix} \) and \( v_{iy} \) in terms of \( v_i \) and \( \theta \) by using trigonometry. Examining the initial velocity of a projectile at some angle, \( \theta \), we see that:

\[
\begin{align*}
\text{Trigonometry can provide a relationship between } v_{ix}, v_i \text{ and } \theta \text{ using cosine, since:} \\
\cos \theta &= \frac{\text{adjacent}}{\text{hypotenuse}} \quad \text{hence, } \cos \theta = \frac{v_{ix}}{v_i} \\
\text{Rearranging and solving for } v_{ix}, \text{ we see the following relationship:} \\
v_{ix} &= v_i \cos \theta \\
\text{Trigonometry also can provide a relationship between } v_{iy}, v_i \text{ and } \theta \text{ using sine, since:} \\
\sin \theta &= \frac{\text{opposite}}{\text{hypotenuse}} \quad \text{hence, } \sin \theta = \frac{v_{iy}}{v_i} \\
\text{Rearranging and solving for } v_{iy}, \text{ we see the following relationship:} \\
v_{iy} &= v_i \sin \theta
\end{align*}
\]

**Step 3:** Simplify horizontal and vertical equations of motion and substitute equations for \( v_{ix} \) and \( v_{iy} \).

<table>
<thead>
<tr>
<th>Horizontal Part of Projectile Motion</th>
<th>Vertical Part of Projectile Motion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original equation: [ x = v_{ix} t + \frac{1}{2} a_x t^2 ]</td>
<td>Original equation: [ y = v_{iy} t + \frac{1}{2} a_y t^2 ]</td>
</tr>
</tbody>
</table>
Applying concepts & simplifying the equation:

**Concept:** Horizontal motion is constant velocity motion where acceleration = 0

Resulting Simplification:
\[ x = v_{ix} t \]

<table>
<thead>
<tr>
<th>Substituting ( v_{ix} ):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Since ( v_{ix} = v_i \cos \theta )</td>
</tr>
<tr>
<td>( x = v_i \cos \theta \ t )</td>
</tr>
</tbody>
</table>

**Substituting \( v_{iy} \):**

Since \( v_{iy} = v_i \sin \theta \)
\[ v_i \sin \theta \ t = -\frac{1}{2} gt^2 \]

**Step 4:** We want to be able to determine the velocity of the projectile given the gravitational acceleration (a constant), angle \( \theta \), and range of motion (maximum horizontal displacement).

To do this, we will solve the vertical equation for \( v_i \) by dividing both sides by \( \sin \theta \ t \) and simplifying.

\[ v_i = -\frac{gt}{2 \sin \theta} \]

**Step 5:** Since time is difficult to measure accurately for projectile motion experiments, we will use the horizontal motion equation to solve for time, and then substitute this equation for time into the equation, above.

\[ t = \frac{x}{v_i \cos \theta} \]

Substituting this equation into the equation for \( v_i \): \vspace{1em}

\[ v_i = -\frac{gx}{2v_i \cos \theta \sin \theta} \]

Simplifying this equation yields the following:
\[ v_i^2 = \frac{-gx}{2 \cos \theta \sin \theta} \]

Solving for \( v_i \) yields:

\[ v_i = \sqrt{\frac{-gx}{2 \cos \theta \sin \theta}} \]

Finally, using the trigonometric identity \( 2\sin \theta \cos \theta = \sin 2\theta \), we can simplify this equation:

\[ v_i = \sqrt{\frac{-gx}{\sin 2\theta}} \]
Activity 8.2c – Range with Excel®

Purpose

After construction of the BD its time to make some trial shots, measure the range of the projectile, and make predictions for the range at different firing angles. This will help you mathematically predict what your device will do using MS Excel® to calculate and graph the theoretical and actual range of the Ballistic Device (BD).

Equipment

Excel®
Device
Tape Measure

Procedure

Step 1:

Make 10 trial shots holding the firing angle constant.

Calculate the average and standard deviation of the data set using MS Excel®. Use Excel® built in functions:
From the tool bar select \( f_x \). Under statistical select “Average” and “Stdev” in cells B14 and B15, respectively. Select the cells containing the data.

Note one sheet for each step.
Step 2:

Use the kinematics equations to calculate the initial velocity of the projectile knowing the average range and the firing angle from step 1.

Use the equation  
$$v_i = \sqrt{\frac{-gx}{\sin 2\theta}}$$

Use the following Excel® formula in cell D10:

`=SQRT(D5*D7/SIN(RADIANS(2*D6)))`

Square root function  
Radian to degrees conversion function

Link this cell to the range calculation on sheet “Average Range”

Step 3:

The initial velocity can then be used to predict the range for different values for the firing angle. Rearrange the same equation to solve for the range knowing the initial velocity and firing angle.

$$x = \frac{-v_i^2 \sin 2\theta}{g}$$
Use the following Excel® formula in cell B3:

=’initial velocity’!$D$10^2*SIN(RADIANS(2*A3))/’initial velocity’!$D$7

Notes:
'initial velocity'! appears when you select a cell from another sheet.
The $ in $D$10 and $D$7 fixes the address of the cell so it does not increment when the formula is copied to other cells.

Copy the formula to cells B3 to B13 using copy and paste commands.

Step 4:

Launch projectiles 3 times at different firing angles, record the range of each launch.

Calculate Average Range and standard deviation similar to step 1.

Use the following Excel® formula in cell E4: =AVERAGE(B4:D4)
Use the following Excel® formula in cell F4: =STDEV(B4:D4)

Copy the formula to cells E5 to F12 using copy and paste commands.
Step 5:
Create an xy scatter chart of both the ideal and actual ranges from steps 3 and 4.

First use the Chart wizard to create a chart of the ideal range versus angle, and then add a chart of actual range onto the same chart. The final chart is shown below.
To create a chart from the chart wizard select cells A3 to B13 and click on the chart wizard icon.

![Chart wizard icon]

Select XY (scatter) chart with data points connected by smoothed lines.

![Select chart type]

Label the axes and add the chart on a new sheet.

Go to the sheet containing the new chart. From the top menu...chart.. add dat.

Select cells from A4 to A12 and E4 to E12 from the “actual range data” sheet from step 4. Note to select groups of cells that are not adjacent, you must hold down the ctrl-key while dragging the left mouse key.

Add cells as a new series and select x values in 1st column.
Label the curves with text using the drawing toolbar…
view…toolbar…drawings…select the text box.

Conclusion

1. Compare what you did in this activity to a car’s speedometer. How are they alike and how are they different?

2. What differences would you have to account for if you were plotting a flight to Mars?