Science/Technology
Content Area:

Student Competencies:

Science:
Physics
Understand physical and chemical properties of materials
Understand how to apply density calculations to determine weight and/or mass of products

Mathematics:
Calculate area and volume
Interpret cost data to review and make business decisions for manufacturing and production
Interpret and apply manufacturing and testing specifications and units

Engineering Technology:
Understand how physical and chemical properties of plastics and polymers influence their useful applications and the required manufacturing processes
Understand the use of national and international testing standards in assessing quality control processes and application performance

Communications:
Be able to prepare short reports on technical analyses and recommendations
Be able to prepare technical proposals and recommendations
Effectively apply research techniques and provide proper documentation
Demonstrate professionalism and effective techniques during oral presentations
Provide appropriate cites of reference sources

Problem Scenario
Polymers, Inc. manufactures plastic containers for the food industry. Annual profits average $20 million. Current products are made from Society of the Plastics Industry (SPI) types 1, 2, 4, and 5 plastic resins. Recently, the Vice President for Business Development attended a conference where he heard a presentation on a rapidly emerging product generically called plastic lumber. The VP was interested in exploring the possibilities of producing plastic lumber as a new and somewhat different product line.
He has tasked your Business Engineering and Applications Development (BEAD) Team to do the following:
1. Determine which coded plastics might be most suitable for the company to use to manufacture common food product containers from no more than two resin types, but that also have recycle potential for plastic lumber. The VP suggested that each team member look at 5 - 10 types of plastic containers at home.
2. Research background information on plastic lumber. Identify at least five ASTM standards that apply to production quality and performance of plastic lumber. He is also interested in comparing the weight of an equivalent grade of plastic lumber to a pine wood 2 x 4.
3. Advise management on one type of plastic most suitable for recycling and remanufacture as plastic lumber. Discuss some of the applications and products that currently use plastic lumber.
4. Based upon application selections, and current virgin and recycled resin price information that the team has researched and analyzed, prepare a general overview and recommendations on the benefits and challenges of using one or two types of plastic for the company's main products. Also comment on the feasibility of producing plastic lumber using that same type of plastic using production waste and recycled sources. The Vice President asks that you present a 10 minute briefing on your report of findings and recommendations. Submit the 2-3 page executive written report to him for further review and reference.
Science/technical background information
“Setting the Stage”

Many persons are not very familiar with the symbols embossed on plastic bottles and containers. Those symbols identify the type of plastic resin used for that container. The symbols also indicate the general potential for recycling that product.

This lesson combines an awareness overview of the plastics manufacturing and recycling industries, with a business problem. The problem will be to evaluate some technical applications, manufacturing standards, and financial considerations, for executive consideration of introducing a new product line and of reassessing the current products offered.

These are the seven common categories of plastics considered for their recycling potential. Not all have the same degree of recyclability.

Module Objectives

1. Explore, compare and contrast various physical, chemical and manufacturing properties and characteristics of several types of coded plastics.

2. Explore, compare and contrast various applications of several coded plastics.

3. Research background information and draw conclusions on the recycle potential of various types of coded plastics.

4. Prepare a short report of background findings and recommendations in response to an executive request for information on the feasibility of incorporating an additional product line that uses recycled materials.

Student Performance Expectations

1. Work will be evaluated individually and/or by teams to assess task performance and teaming skills.
2. Interpret codes stamped on common plastic products, and discuss common applications
3. Calculate comparative densities of several plastics and other materials
4. Determine which type of coded plastic is most suitable for a particular product type
5. Research background information on plastic lumber. Identify at least five ASTM standards that apply to production quality and performance of plastic lumber.
6. Advise management of the plastic most suitable for recycling and remanufacture as plastic lumber.
7. Review some financial background data on plastic resin prices over a few years
8. Based upon researched application and price information, prepare a general overview and recommendations on the feasibility of using no more than two types of plastics for the company’s main products. Also comment on the feasibility of producing plastic lumber using that same type of plastic from production waste and recycled sources.
9. Students present their analyses and recommendations through oral and/or written reports

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## Content Strands

<table>
<thead>
<tr>
<th>Science</th>
<th>Mathematics</th>
<th>English/Speech</th>
<th>Engineering Technology</th>
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<tr>
<td>Physical Properties - Density</td>
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<tr>
<td>Financial Data Analysis</td>
<td>Oral Presentations</td>
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## Concept Map

![Concept Map Diagram]

### Science
- **Physical and Chemical Properties**
- **Density Calculations**

### Mathematics
- **Area and Volume**
- **Financial and cost data analysis**

### Communications
- **Oral Presentation techniques**
- **Preparing Proposals and Recommendations**
- **Research Techniques - Documentation**

### Engineering Technology
- **Plastics and recycling codes and symbols**
- **Quality Control - ASTM Standards**
- **Materials selection and applications**

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### Student Assessment Strategies

Faculty teams will evaluate the technical accuracy and sufficiency of student reports and/or presentations and verify that the required task requirements have been achieved.

Faculty will assess individual student performance in discipline-specific workshops, labs, and activities.

Teaming skills and problem-solving skills will be evaluated by faculty, peers, and students' self-assessments.

### Equipment specific to this module

- Internet and/or library access to literature and information on properties and applications of coded plastics.
- References that discuss plastic/polymer engineering materials and applications.
- Collect common household plastic samples to evaluate.

### Notes to the Instructor (to be completed after the module has been pilot tested)

1. Emphasis in this lesson is on the concept of evaluating the characteristics of various plastics and making appropriate selections.

2. The lesson is intended to be more toward applications and business perspectives rather than the more focused engineering and math calculations.

3. Student research should show that Type 2 resins (HDPE) are generally most suitable for widespread applications as food containers, as well as being recyclable and suitable for production of plastic lumber.

4. Enrichment classes and/or students could be challenged by pursuing the engineering and mechanical properties and design performance of plastic lumber as compared to wood.
**Pilot Test Faculty Response Form**

**Team Members:** ______________________________________________________________

**Reporting Instructor's Name:** Prof. Nancy Adams ______________________________________________________________

**Course Titles/Numbers:** ____________________________________________________________

**Module Tested:** Applications of Recycled Materials The Plastic Lumber Report Term/Date Spring 2005

**Length of Module (number of class hours):** __________________________________________

I. Please comment on the effectiveness of the following and add any ideas, examples, lesson/assessment strategies that you used.

a. Problem Scenario: (student interest, clarity, feasibility, difficulty level, team success in solving the problem)

b. Level of student competencies (too high, too low?):

c. Workshop topic list: (did you conduct all suggested workshops? others?)

d. Content strands: (is list accurate? discipline topics additions?)

e. Assessment strategies: (please attach your successful assessment instruments, rubrics, team evaluations)

II. How did this module work in your class?

*Please rate (circle) on a scale of 1 (low) to 5 (high).*

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<tr>
<td>a. Ease of use of material</td>
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<td>c. Appropriate content</td>
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<td>d. Student teaming/participation</td>
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<td>e. Student/team success</td>
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**Comments:**

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Applications of Recycled Materials
The Plastic Lumber Report

Task Objectives: Students will

- Demonstrate how to interpret the codes stamped on common plastic products
- Research and summarize background and application data on several of the coded plastics
- Calculate comparative densities of the several plastics and other materials
- Given a description and application of a primary product, determine which type of coded plastic might be most suitable for your company to use to produce that product
- Research some background information on plastic lumber. Identify at least five ASTM standards that apply to production quality and performance of plastic lumber.
- Advise management on the type of plastic most suitable for recycling and remanufacture as plastic lumber
- Review some financial background data on plastic resin prices over a few years
- Based upon researched application and price information, prepare a general overview and recommendations on the profitability of using one type of plastic for the company’s main products. Also comment on the feasibility of producing plastic lumber using that same type of plastic from production waste and recycled sources.

Students present their analyses and recommendations through oral and/or written reports

Concept Strands:

- Physics
  Materials
    Physical and Chemical Properties
    Physical Properties
    Density
    Mechanical Properties
    Mass and Product Design

- Mathematics
  Materials
    Area
    Volume
    Cost analysis

- Technology
  Physical and Chemical Properties
  Mass
  Product Design
  Manufacturing Processes
  Quality Control
Mechanical Properties
  Mass
  Product Design

- Communications
  Written Communications - Short Reports
  Written Communications - Proposals/Recommendations
  Written Communications - Research Techniques – Documentation
  Written and Oral Presentations – Compare and Contrast
  Oral Presentations – Presentation Techniques
  Oral Presentations – Citing Sources
  Oral Presentations – Professionalism

Student Competencies Objectives

Materials

G.1.1 Describe materials properties.
G.1.1.1 Identify and classify materials based on physical properties
G.1.1.2 Identify chemical and physical properties of given materials.

Mechanical

C.7 Effective team and communications skills.
C.7.1 Demonstrate the ability to work in teams.
C.7.1.1 Employ problem solving skills to solve a team task.
C.7.1.2 Use appropriate human relations skills.
C.7.1.3 Demonstrate various listening skills.
C.7.1.4 Apply small group dynamics/teamwork skills.
C.7.1.6 Work in teams to make oral presentations.
C.7.1.7 Work in teams to collaborate on assignments.
C.7.2 Gather appropriate information.
C.7.2.1 Use various media to obtain information.
C.7.2.2 Demonstrate engineering-technology-appropriate computer skills.
C.7.2.3 Demonstrate ability to conduct primary/secondary research.
C.7.2.4 Collaborate with others to obtain information.
C.7.2.5 Correctly document research information.
C.7.2.6 Demonstrate ability to conduct interviews/surveys.
C.7.3 Organize written information.
C.7.3.1 Format appropriate documents (letters, memos, manuals, reports).
C.7.3.2 Demonstrate the four C’s of writing: clear, concise, correct, complete.
C.7.3.3 Revise written material.
C.7.3.4 Use appropriate organizational patterns.
C.7.3.5 Use appropriate engineering technology terminology.
C.7.3.6 Collaborate on the creation of written material.
C.7.3.7 Correctly document written material.
C.7.3.8 Use computer programs to create/revise written material.
C.7.4 Organize oral information.
C.7.4.1 Apply appropriate organizational patterns (informative, persuasive).
C.7.4.2 Practice key workplace interpersonal skills.
C.7.4.3 Create various means of visual support (slides, PowerPoint, graphs).
C.7.4.4 Correctly cite information.
C.7.4.5 Use computers to organize presentations.
C.7.5 Present written and oral information.
C.7.5.1 Demonstrate professional delivery skills.
C.7.5.2 Use computers to make written and oral presentations.
C.7.5.3 Analyze audiences (setting, demographics, size).
C.7.5.4 Define the purpose of presentations.
C.7.5.5 Support presentation with appropriate visuals.

Fluids

D.1 Density.
D.1.1 Demonstrate conceptual understanding of the basic properties of solids, liquids, and gases.
D.1.1.1 Compare and contrast properties of solids, liquids, and gases.
D.1.2 Apply density calculations.
D.1.2.1 Calculate density using measurements of mass and volume.
D.1.2.2 Express density in appropriate units.

Lesson Concept:

The lesson will have four primary areas of exploration, analysis, and reporting:

1. Explore, compare and contrast various physical, chemical and manufacturing properties and characteristics of several types of coded plastics.
2. Explore, compare and contrast various applications of several coded plastics.
3. Research background information and draw conclusions on the recycle potential of various types of coded plastics.
4. Prepare a short report of background findings and recommendations in response to an executive request for information on the feasibility of incorporating an additional product line that uses recycled materials.

Industry Application Problem:

Polymers, Inc. manufactures plastic containers for the food industry. It is a fairly successful company with profits on average of $20 million per year. Polymers, Inc.’s current primary products are made from Society of the Plastics Industry (SPI) code types 1, 2, 4, and 5 plastic resins.

Recently, the Vice President for Business Development attended a conference where he heard a presentation on a rapidly emerging product generically called plastic lumber. The VP was interested in exploring the possibilities of producing plastic lumber as a new and somewhat different product line.

He has tasked his Business Engineering and Applications Development (BEAD) Team (which includes you and your group) to do the following:

1. Determine which coded plastics might be most suitable for your company to use to manufacture common food product containers from no more than two types of materials, but that also have recycle potential for plastic lumber. In order to strengthen the BEAD Team’s appreciation for the subtleties among various types of plastics produced, the VP has suggested that each team member look at 5 - 10 types of plastic containers at home. Which coded types were most commonly found?

2. Research some background information on plastic lumber. Since quality control requirements and specifications will be important in the business decision, identify by name and property tested at least five ASTM standards that apply to production quality and performance of plastic lumber. He is also interested in knowing how much an equivalent grade of plastic lumber to a wood 2 x 4 would weigh.
3. Advise management on one type of plastic most suitable for recycling and remanufacture as plastic lumber. Discuss some of the applications and products that currently use plastic lumber. Indicate new major production equipment that may be required in order to manufacture the plastic lumber.

4. Review financial background data on virgin and recycled resin prices over the last few years. Highlight the current or recent market conditions and outlook for the selected recycled material and the plastic lumber industry.

5. Based upon application and price information the team has researched and analyzed, prepare a general overview and some recommendations on the benefits and challenges of using one or two types of plastic for the company’s main products. Also comment on the feasibility of producing plastic lumber using that same type of plastic from production waste and recycled sources. The Vice President asks that you present a 10 minute briefing on your report of findings and recommendations. Submit the 2-3 page executive written report to him for further review and reference.

**Background and Reference Material**

Many persons are not very familiar with the symbols embossed on plastic bottles and containers. Those symbols identify the type of plastic resin used for that container. The symbols also indicate the general potential for recycling that product.

This lesson combines an awareness overview of the plastics manufacturing and recycling industries, with a business problem. The problem will be to evaluate some technical applications, manufacturing standards, and financial considerations, for executive consideration of introducing a new product line and of reassessing the current products offered.

**Plastics Categories (General Properties and Applications)**

The plastic types were defined by the Society of the Plastics Industry (SPI):

* Type 1 - PETE  Polyethylene Terephthalate (PET)  
  Soda & water containers, some waterproof packaging.
* Type 2 - HDPE  High-Density Polyethylene  
  Milk, detergent & oil bottles.  Toys and plastic bags.
* Type 3 - V  Vinyl/Polyvinyl Chloride (PVC)  
  Food wrap, vegetable oil bottles, blister packages.
* Type 4 - LDPE  Low-Density Polyethylene  
  Many plastic bags.  Shrink wrap, garment bags.
* Type 5 - PP  Polypropylene  
  Refrigerated containers, some bags, most bottle tops,  
  some carpets, some food wrap.
* Type 6 - PS  Polystyrene  
  Throwaway utensils, meat packing, protective packing.
* Type 7 - OTHER  Usually layered or mixed plastic.  
  No recycling potential - must be landfilled.

This list is not inclusive of all applications and recycling potential of the various types.
Vocabulary and Plastics Terminology

**Blow Mold** – Blow molding is a two-step process in which plastic is inserted into a heated mold. Next, hot air is blown into the plastic causing it to take on the shape of the mold.

**Extrusion** – Extrusion is a process in which plastic is heated, then the molten plastic is pushed through a mold in the shape of an object or material. Fibers, pipe coating, and molded pipes are examples of materials formed through extrusion.

**Flexural** – **Flexural Strength and Modulus (ASTM D790)**

Flexural strength is the measure of how well a material resists bending, or what is the stiffness of the material. Unlike tensile loading, in flexural testing all force is applied in one direction. A simple, freely supported beam is loaded at mid-span thereby producing three-point loading (see figure below). On a standard testing machine, the loading nose is pushed onto the specimen at a constant rate of 2 mm/min.

To calculate the flexural modulus, a load deflection curve is plotted using the recorded data. This is taken from the initial linear portion of the curve by using at least five values of load and deflection.

The flexural modulus (ratio of stress to strain) is most often quoted when citing flexural properties. Flexural modulus is equivalent to the slope of the line tangential to the stress/strain curve, for the portion of the curve where the plastic has not yet deformed. Values for flexural stress and flexural modulus are reported in MPa (psi).

![Flexural Strength and Modulus Diagram](image)

**Impervious** – not admitting of passage or capable of being affected; "a material impervious to water";

**Injection Mold** – Injection molding is a process in which melted plastic is introduced into a heated mold. As the plastic cools, it hardens and retains the shape of the mold.

**Life Cycle Cost** – Life Cycle Cost is the total discounted dollar cost of owning, operating, maintaining, and disposing of a building or a building system over a period of time.

**Mobius (Mobius Strip)** – a continuous closed surface with only one side; formed from a rectangular strip by rotating one end 180 degrees and joining it with the other end. Concept used to create the type code symbols used to identify plastics. Named after a concept discovered by **August Ferdinand Mobius**, German mathematician and theoretical astronomer (1790 - 1868).
**Polyethylene** – Polyethylene (PE) is a resin or plastic polymer of ethylene (a gaseous hydrocarbon). Polyethylene is used in many different types of packaging and is also known for its excellent electrical properties.

**Polyethylene Terephthalate (PET)** – Polyethylene Terephthalate (PET) is a strong, lightweight plastic resin and form of polyester. PET is commonly used in food packaging due to its strong barrier properties against water vapour, dilute acids, gases, oils and alcohols. PET is also shatter-resistant and can be recycled in the form of Recycled Polyethylene Terephthalate (RPET).

**Polymer** – A large molecule in the form of a long chain of repeating units or mers

**Polypropylene** – Polypropylene (PP) is a strong, light-weight, low-density plastic used in food packaging. PP has a high melting point, making it suitable for hot food processing and packaging.

**Polystyrene** – Polystyrene is a colorless, transparent thermoplastic that softens slightly above 100°C (212°F) and becomes a viscous liquid at around 185°C (365°F). It is resistant to acids, alkylies, oils, and alcohols. It is produced either as a solid or as a foamed plastic marketed under the trade name Styrofoam. Its many uses include electrical and thermal insulation, translucent window panels, storage-battery cases, and toilet articles.

**Polyvinyl Chloride** – thermoplastic that is a polymer of vinyl chloride. Resins of polyvinyl chloride are hard, but with the addition of plasticizers a flexible, elastic plastic can be made. This plastic has found extensive use as an electrical insulator for wires and cables. Cloth and paper can be coated with it to produce fabrics that may be used for upholstery materials and raincoats.

**Resin** – any of a class of solid or semisolid viscous substances obtained either as exudations from certain plants or prepared by polymerization of simple molecules. Used as the base material in plastics manufacturing or processing to create the final product.

**Thermoplastic** – A material which is capable of softening or melting at elevated temperatures without degradation so that cooling of the material restores it to its original condition.

**Thermoset** – A plastic resin that is cured or transformed by elevated temperatures into a solid condition from which it does not change, upon reheating, until it reaches the decomposition point.

**Weatherability** – Weathering is defined as: To discolor, disintegrate, wear, or otherwise affect adversely by exposure. **Weatherability** is a measured characteristic that shows how well a product performs during exposure to outdoor weather conditions (ultraviolet light, rain, snow, high and low temperatures, humidity, environmental pollution and acidity in the air).
Engineering Reference Data and Formulas

\[ \text{Density} = \frac{\text{mass}}{\text{volume}} \]

Research reference tables for density of wood (pine board is ok for this comparison) and the selected recycled plastic resin of the equivalent 2 x 4 dimensions.

Reference Sources


- Resin Pricing June 2004 - Online Article
- Recycle Pricing March 2005 - Online Article

