Polymer Properties (MECH 580)
Winter, 2007

Laura L. Sullivan, Ph. D.
Assoc. Prof., Mechanical Engrg.
(810)762-9838
lsulliva@kettering.edu

Office Hrs: Wednesday 10:15am - 12:15pm
2:00pm - 3:00pm
Or email me at lsulliva@kettering.edu and I'll meet you at your convenience

Week	Day	Date	Topic
1	M	1/8	**1. Polymer Synthesis and Architecture**
			1.1. Molecules and Monomers
			1.2. Addition Polymerization
			1.3. Condensation Polymerization
1	R	1/11	1.4. Copolymers and Terpolymers
			1.5. Stereoisomerism
			1.6. High Polymer Degree of Polymerization
2	M	1/15	HOLIDAY – NO CLASSES
2	R	1/18	1.7. Molecular Forces – Primary and Secondary bonding
			1.8. Thermoplastics and Thermosets
			1.9. Polymer categories
			1.9.1. Polymers with C only in backbone
			1.9.2. Polymers with N in backbone
			1.9.3. Polymers with O in backbone
			1.9.4. Polymers with S in backbone
			1.9.5. Copolymers
3	M	1/22	**2. Polymer Characterization**
			2.1. Molecular Weight
			2.2. Polydispersity
3	R	1/25	2.3. Methods for Determining Molecular Weight
			2.3.1. Colligative measurements
			2.3.2. Light dispersive measurements
4	M	1/29	**3. Molecular Order**
			3.1.1. Polymer Crystallinity
			3.1.2. Entropy and Enthalpy
			3.1.3. Configurations and Conformations
			3.1.4. Crystal Growth
			3.1.5. Spherulites
			3.1.6. Effect of Temperature and Cooling Rate
			3.1.7. Melting Temperature

Week	Day	Date	Topic
4	R	2/1	3.2. Methods for Measuring Crystallinity
			3.2.1. DSC
			3.2.2. Cross Polarized Microscopy
			3.2.3. Birefringence
5	M	2/5	3.3. Amorphous Polymers
			3.3.1. Structure
			3.3.2. Glass Transition Temperature
			3.4. Polymer transitions
5	R	2/8	**Exam One** – Topic 1: Polymer Synthesis and Architecture, and Topic 2: Polymer Characterization
6	M	2/12	**4. Mechanical Behavior**
			4.1. Deformation and viscoelastic behavior
			4.1.1. Hookean, Linear elastic behavior
			4.1.2. Newtonian, purely viscous behavior
			4.1.3. Polymer behavior in the fluid state
			4.1.4. Polymer behavior in the solid state
			4.1.5. Linear viscoelastic models
			4.1.5.1. Maxwell model
			4.1.5.2. Voigt-Kelvin model
			4.1.5.3. Four parameter model
			4.1.5.4. Model/Molecule analogy
6	R	2/15	4.1.6. Boltzmann superposition
			4.2. Time/Temperature superposition
			4.3. Yield and Ductility
7	M	2/19	4.4. Fracture
			4.5. Impact Toughness
			4.6. Creep and Stress Relaxation
7	R	2/22	**5. Flow Behavior**
			5.1. Newtonian and Non-Newtonian Flow
			5.2. Elongational Flow
			5.3. Shear Flow
8	M	2/26	**Exam Two** – Topic 3: Molecular Order, and Topic 4: Mechanical Behavior
8	R	2/29	**6. Testing for Design**
			6.1. Fluid Properties
			6.1.1. Melt index [ASTM D1238]
			6.1.2. Rheometry

Week	Day	Date	Topic
9	M	3/5	6.2. Solid Properties
			6.2.1. Tensile test behavior [ASTM D638]
			6.2.2. Flexural behavior [ASTM D790]
			6.2.3. Compressive behavior (rigid plastics) [ASTM D695]
			6.2.4. Poisson's Ratio behavior
9	R	3/8	6.2.5. Hardness [DIN 53.456] and it's relationship with yield
			6.2.6. Dynamic behavior [ASTM D4065]
			6.2.7. Effect of temperature on short term modulus
			6.2.8. Heat deflection temperature [ASTM D648]
10	M	3/12	6.2.9. Impact behavior
			6.2.9.1. Izod and Charpy Impact Tests [ASTM D256]
			6.2.9.2. Drop Weight Impact Test
			6.2.9.3. Fracture Toughness
			6.2.9.4. Effect of Temperature
10	R	3/15	6.2.10. Time dependent behavior
			6.2.10.1. Creep testing [ASTM D2990]
			6.2.10.2. Time-temperature superposition
			6.2.11. Fatigue behavior [ASTM D671]
			6.2.12. Environmental Stress Cracking [ASTM 1693]
11			PROJECT PRESENTATIONS
Final exam period			**Exam Three** – Topic 5: Flow Behavior, and Topic 6: Testing for Design

Grades will be calculated as follows:

Three Exams, 20% each	60%
Group Project, 25%	25%
Homework, 10%	10%
Participation*, 5%	5%

There will be NO make-up exams!
A COMPREHENSIVE make-up exam will be offered outside of class during 11th week.

*Other than exams, I expect that much of the work that you do in this course will be done with a group. I will use the Participation portion of your grade to handle situations where a group member is not carrying his/her load in the group.

MECH 580
Winter, 2009
PRODUCT TESTING SPECIFICATIONS

Provide a WRITTEN Standard Testing Procedure for of each of your products, to include:

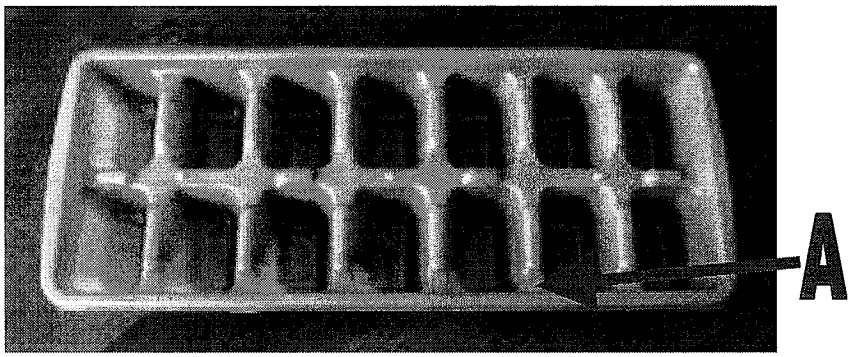
1. Description of product
   - Include product photo, all dimensions, and any material identification
2. Description of service environment for product
   - What mechanical, thermal, and chemical stresses would be experienced by polymer product during lifetime under "normal" use.
   - What mechanical, thermal, and chemical stresses would be experienced by polymer product during lifetime under "extreme" conditions.
3. Description of test set-up
   a. Environmental conditions (these are typically held constant throughout the test, and include temperature, pressure, humidity, any presence of chemicals that could potentially affect the test results
   b. Discuss the relationship between the environmental conditions recommended for the test and the environmental conditions seen in service.
   c. List all equipment that is used in the test, including devices used to measure dimensions and mass (as necessary).
   d. Include list of all constants (temperature, load signature, chemical environment). There may be information in this section that is the same as information in section 3a.
   e. Provide an illustration of test set up.
   f. Provide a list of independent variables. These are the "stresses" that will be applied to the product, such as concentration of a solvent, magnitude and orientation of a force or moment, and/or temperature. These are the variables that you CONTROL during the test.
   g. Provide a list of dependent variables. These are things such as extent of deformation or strain under stress, extent of deformation or strain after stress is removed (sometimes as a function of time), deformation on the surface (as a result of scratch test or hardness test, length of cracks formed, discoloration or change in surface texture*.
   h. Provide an illustrated, step-by-step description of the test procedure.
   i. Describe manner in which test data should be provided – provide a data sheet for the test teams to fill out.
   j. Identify ASTM test standards that align with the properties you are testing, and discuss the similarities and differences between your test procedure and the ASTM test standards you have noted.

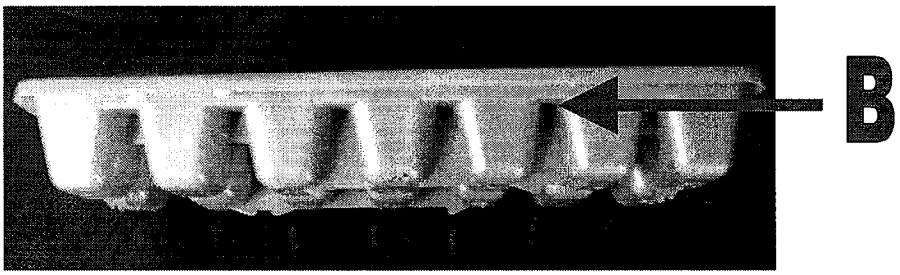
*extent of discoloration or changes in surface texture are difficult to quantify. For this type of evaluation, you should provide the test teams with a visual scale that they can used to "quantify" changes.

Product Test Development

You have been provided with a sample product. In this document, you'll also be provided with information regarding the mechanical, chemical, and thermal environments experienced by this product in service. You will also be provided information about the mode(s) of failure for this product. Your task is (1) to develop a standard test procedure for this product,(2) to correlate your procedure to standard ASTM tests, as described below, and (3) to relate the behavior of your product to mechanical and thermal behaviors of polymers (see FOLLOWUP QUESTIONS).

Product: Ice cube tray





Service Environment:

Mechanical Stresses: This product will experience mechanical torsion and bending stresses necessary to loosen ice from the tray.
Thermal stresses: This product can see temperatures ranging from 15-200 F.
Chemical Stresses: Citric and acetic acid present in fruit juices, detergents

Failure modes of concern: An increasing number of ice cube trays are being returned from retail stores, due to numerous cracks occurring (see locations A and B above). Failure is being noted during shipment and storage, as well as during customer use.

Assignment:

I. Develop a test procedure that would capture the mechanical behavior of your product in service and that would allow for the detection of inferior quality.
   1. Include a description of the test equipment and setup.
   2. Include a step-by-step description of the test procedure.

II. Identify one ASTM standard test procedure that correlates with the procedure you have developed. Discuss how data from this ASTM test on a polymer could be correlated to your product test data.

III. FOLLOWUP QUESTIONS:

1. Assuming that your product is manufactured from a semicrystalline polymer, how would the level of crystallinity affect the mechanical behavior of your product?

2. If your product were manufactured from an amorphous polymer, how would this affect the mechanical behavior of the product?

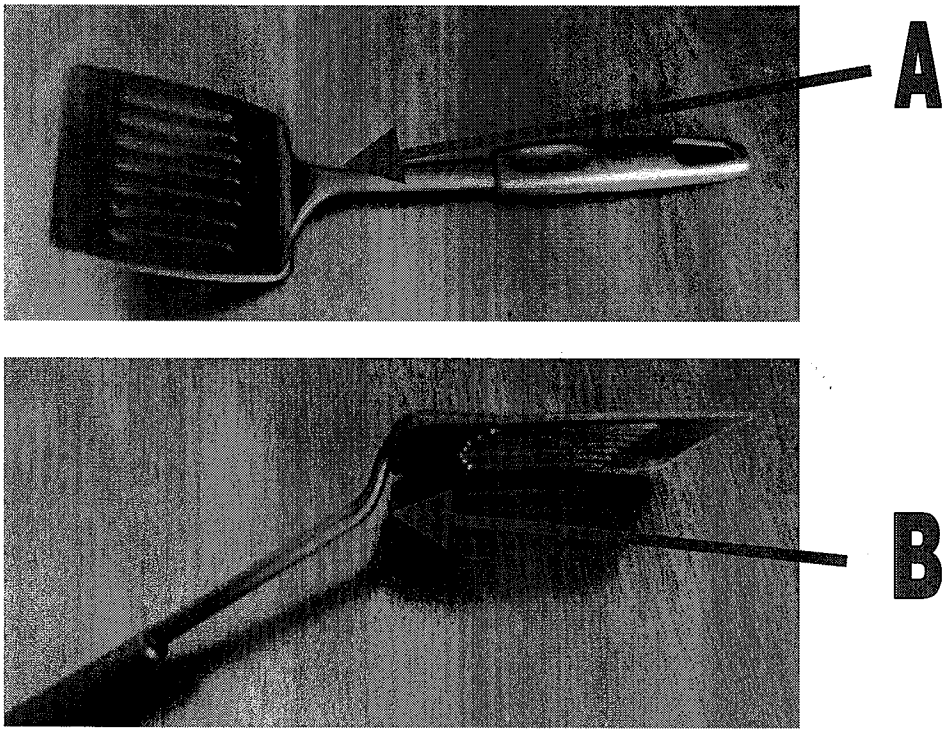
3. Is the polymer from which your product is manufactured above or below its glass transition temperature?

4. Describe a circumstance in which your product could exhibit viscoelastic behavior. Describe the Hookean nature of the product's behavior, and describe the viscous nature of the product's behavior.

Product Test Development

You have been provided with a sample product. In this document, you'll also be provided with information regarding the mechanical, chemical, and thermal environments experienced by this product in service. You will also be provided information about the mode(s) of failure for this product. Your task is (1) to develop a standard test procedure for this product,(2) to correlate your procedure to standard ASTM tests, as described below, and (3) to relate the behavior of your product to mechanical and thermal behaviors of polymers (see FOLLOWUP QUESTIONS).

Product:



Service Environment:

Mechanical Stresses: This product may experience mechanical torsion and bending stresses during packaging and shipment, as well as by end user following purchase.
Thermal stresses: This product can see temperatures ranging from 15-350 °F.
Chemical Stresses: This product can be exposed to a wide range of materials, including (but not limited to) detergents and acids.

Failure modes of concern: An increasing number of these spatulas are being returned from retail stores, due to deformation and failure at locations A and B (see above).

Assignment:

I. Develop a test procedure that would capture the mechanical behavior of your product in service and that would allow for the detection of inferior quality.
   1. Include a description of the test equipment and setup.
   2. Include a step-by-step description of the test procedure.

II. Identify one ASTM standard test procedure that correlates with the procedure you have developed. Discuss how data from this ASTM test on a polymer could be correlated to your product test data.

III. FOLLOWUP QUESTIONS:

1. Assuming that your product is manufactured from a semicrystalline polymer, how would the level of crystallinity affect the mechanical behavior of your product?

2. If your product were manufactured from an amorphous polymer, how would this affect the mechanical behavior of the product?

3. Is the polymer from which your product is manufactured above or below its glass transition temperature?

4. Describe a circumstance in which your product could exhibit viscoelastic behavior. Describe the Hookean nature of the product's behavior, and describe the viscous nature of the product's behavior.