

Module Title: The Odd Behavior of Rubber Bands		
Lab compiled by: Tom Stoebe, MatEd Partner	Address:	Email: tgstoebe@earthlink.net
Time to complete module: Simple exploration (10 minutes, including discussion), effects of heat and hystersis may require an additional 20 minutes.		
Description of module, lab or demonstration:  Students will have the opportunity to explore the structure of a simple rubber band in this easy and quick in-class activity. Students will also observe the behavior of rubber bands when stretched and when contracted.		
Pre-requisite knowledge and skills:  A basic knowledge of polymers and their structures.		
Materials Category:	Structure of Materials	<input type="checkbox"/>
	Metals	<input type="checkbox"/>
	Ceramics	<input type="checkbox"/>
	Polymers	<input checked="" type="checkbox"/>
	Composites	<input type="checkbox"/>
	Other	<input type="checkbox"/>
Target Grade Level(s)	Middle School 6-8	<input type="checkbox"/>
	High School 9-12	<input checked="" type="checkbox"/>
	Two-year College 13-14	<input checked="" type="checkbox"/>
	Four-year College 15-16	<input type="checkbox"/>
MatEd core competencies that the training meets:		
<ul style="list-style-type: none"> <li>• 2.001 Demonstrate mastery of basic arithmetic including proportions, percentages, etc.</li> <li>• 7.048 Describe how polymers differ from metals, glasses, and ceramics; how this affects properties</li> </ul>		
List of equipment and supplies needed:		
<ul style="list-style-type: none"> <li>• A supply of mid to large rubber bands; at least one per participant- for part I Example: 30 students - at least 30 rubber bands will be needed</li> <li>• Additional rubber bands for remainder of procedure-should students perform in a group setting approximately 3-4 rubber bands per group may be needed.</li> <li>• 1 Hair dryer for the observation of hysteresis (1 per group if done in a team setting)</li> <li>• Marker (i.e., Sharpie) for measuring the extension of contraction of rubber bands (at least one per group will be necessary)</li> <li>• Weights for the stretching of the rubber bands (note: 1-2 lbs is all that may be necessary, <b>note:</b> for the review process-set volumes of water were used under the</li> </ul>		

assumption that the density of water is 1g/mL)

- 1 Bucket to be suspended with a rubber band (1 per group if utilized)
- 30- safety glasses (PPE)
- Optional: 1- can of Cold Spray (used for computers and electronics to clean and test)

Curriculum overview and notes to instructor:

The molecules in rubber can be envisioned as disordered, entangled, and coiled upon one another (much more extensively than spaghetti being boiled in a pot). In natural rubber, there is generally no linkage between molecules, which are held together do to the entanglement. If rubber bands were made from natural rubber, they would gradually pull apart and fail as the molecules uncoil and slide past one another. In synthetic rubbers, activities are used to form "cross-links" between molecules. Therefore, rubber has an elastic limit, which occurs when the molecules move past one another, eventually being stopped by the "cross-links."

The disorder in the rubber band is described in scientific terms by its "entropy." By definition, the entropy of the band is high when disorder is present. Upon stretching, the molecules straighten out and align themselves along the axis by which the rubber band is extended. When the entropy of a system decreases, the system gives off heat. Thus, when the rubber band is stretched, it should release heat and in contrast when the rubber band is contracted it should absorb heat. This can be felt by holding a rubber band on a sensitive place on the body (i.e. the lips or forehead) and then stretching and contracting the rubber band. Using the same effect, a stretched rubber band will contract on its own when heated. By heating the rubber band, we increase the entropy. The molecules become more disordered and tangled, and thus they shrink. This is just the opposite of what happens when we stretch the band.

When the stretching force is removed from a stretched rubber band, the molecules also have trouble returning to their original length. This is because the structure of the band has been altered. Stretching uncoils the kinks and tangles in the molecules, which do not return to their original positions when outstretched. This is called "hysteresis." Further, if the band is stretched past its elastic limit, the cross-links can also be stretched, causing a permanent lengthening of the rubber band.

	<p>The important point here is that these properties of the rubber band are related directly to the molecular structure of the rubber band. Without the unique distribution of the molecules in the rubber band, these properties would not exist.</p>
<p>Mode of presentation: Laboratory or Demonstration</p>	
<p>Module</p>	<p><b>Abstract:</b>  Rubber bands behave in a manner opposite to that of most solids: They contract when heated, expand when cooled. Further, the length of the stretched rubber band does not return immediately to its original non-stretched length. These behaviors are due to the structure of rubber, being long, loose, twisted chains of molecules. Experiments that can demonstrate these effects are included in this module.</p> <p><b>Experimental Process: Part 1 (Simple Exploration)</b></p> <ol style="list-style-type: none"> <li>1. Distribute a set of relatively heavy (strong) rubber bands to students. Have them experiment with the maximum stretch for the band. Discuss the structure of the rubber, the presence of cross-links, and ask them to demonstrate when the cross-links come into play.</li> <li>2. Ask the students to stretch the rubber band then touch it to a heat-sensitive place on their face (usually a lip or the forehead provide the best results).</li> <li>3. Then ask the student to contract the rubber band and hold it to the same spot on their face. Ask what the difference in temperature is.</li> <li>4. Have them repeat the experiment several times to make sure that they feel the difference in temperature. Discuss in terms of the structure of the rubber band.</li> </ol> <p><b>Experimental Process: Part 2 (Applying Heat and Observing Hysteresis)</b></p> <ol style="list-style-type: none"> <li>5. Students should work in groups for this portion of the experiment, or choose a small team of students to demonstrate this to the rest of the class. Have the students hang a rubber band from a hook or a doorknob and suspend a small bucket from it. Add weights to the bucket, heavy enough to stretch the rubber band (use whatever is available). Mark the maximum stretch length of the rubber band.</li> <li>6. Warm up a hair dryer, and then aim it at the rubber band. Have the students observe the change in length. Mark the new length and calculate the percentage change in length. Have them explain, in light of the</li> </ol>

	<p>earlier experiment, why they observe this change in length.</p> <p>7. To observe hysteresis, use another rubber band, hang it from a hook or door knob, add the bucket and use a scale so that the length of the band may be determined exactly. Add weights to the bucket, noting the length after each weight is added. Now remove each weight in the reverse order to which it was added. Note the length! How much change is seen between stretching and contraction? Have students discuss in terms of the structure of the rubber band.</p> <p><b>Further Study</b></p> <ul style="list-style-type: none"> <li>• Repeat steps 6 and 7 by cooling instead of heating the rubber band. Use ice water, Cold Spray (used in computer and electronics cleaning and service), or carbon dioxide vapor for cooling.</li> <li>• Investigate further properties of using text or the internet</li> <li>• Predict the outcome of these experiments if natural rubber were used, opposed to synthetic rubber found in common rubber bands.</li> </ul>
References:	Wikipedia.org. (2007). <i>Hysteresis</i> . Retrieved August 19, 2007, from <a href="http://en.wikipedia.org/wiki/Hysteresis">http://en.wikipedia.org/wiki/Hysteresis</a> .
Briefly describe how the effectiveness of the module was evaluated:	The effectiveness of the module was evaluated in "10 Simple and Effective In-class Experiments and Demonstrations for Materials Education." The review provides several notes and observations for the module.
Author Bio:	Dr. Tom Stoebe works with the National Resource Center for Materials Technology Education (MatEd) housed at Edmonds Community College. Dr. Stoebe is a Professor Emeritus in Materials Science and Engineering at the University of Washington and has been at the forefront of materials education in the United States.