Name: **Date:** **Class:**

What is Biomedical Engineering

Biomedical engineers (also called bioengineers) use their knowledge of science and math to help solve health problems. Biomedical engineers develop materials, processes, and devices that help prevent or treat disease or rehabilitate patients. According to the Biomedical Engineering Society, the areas of specialization for biomedical engineers include biomaterials; bioinstrumentation; biomechanics; medical imaging; rehabilitation; and cellular, tissue, and genetic engineering.

Biomedical engineers who specialize in biomaterials develop materials that can be safely implanted in the body. Engineers who work in biomechanics apply principles from physics to biological systems. They develop artificial organs, such as the artificial heart. Engineers who focus on bioinstrumentation use computers or other electronic devices to diagnose or treat disease. A rehabilitation engineer helps improve the quality of life for people with disabilities. Tissue and cellular engineers grow cells outside of the body to be implanted in the body and serve some function. Genetic engineering is a related discipline in which an organism's DNA is altered so that different proteins will be produced. Genetic engineering has many applications in drug production. For more information regarding the specialties within bioengineering, please see the "Introduction to Biomedical Engineering" worksheet below.

What are Material Properties?

The proper selection of materials is critical in all areas of engineering design. All materials have different properties that may or may not make them suitable for a given application. Materials come from natural resources. They are made up of the elements found on the periodic table. They may be elements in their pure form or a combination of elements. Materials are often processed to give them different properties. Some different types of materials include metals, plastics, composites, ceramics, and textiles. The properties of these materials are usually divided into three different categories: physical properties, mechanical properties, and chemical properties.

Physical properties include color, density, melting point, and water absorption rate. Mechanical properties include strength, ductility, and rigidity. Chemical properties include the composition of the material or the corrosion resistance of the material. To select the proper materials for an application, an engineer must first determine the properties that are important for his/her design. Once this determination has been made she/he can then research specific materials which may have the necessary properties.

For more information on materials see the handout "Material Properties" attached below.

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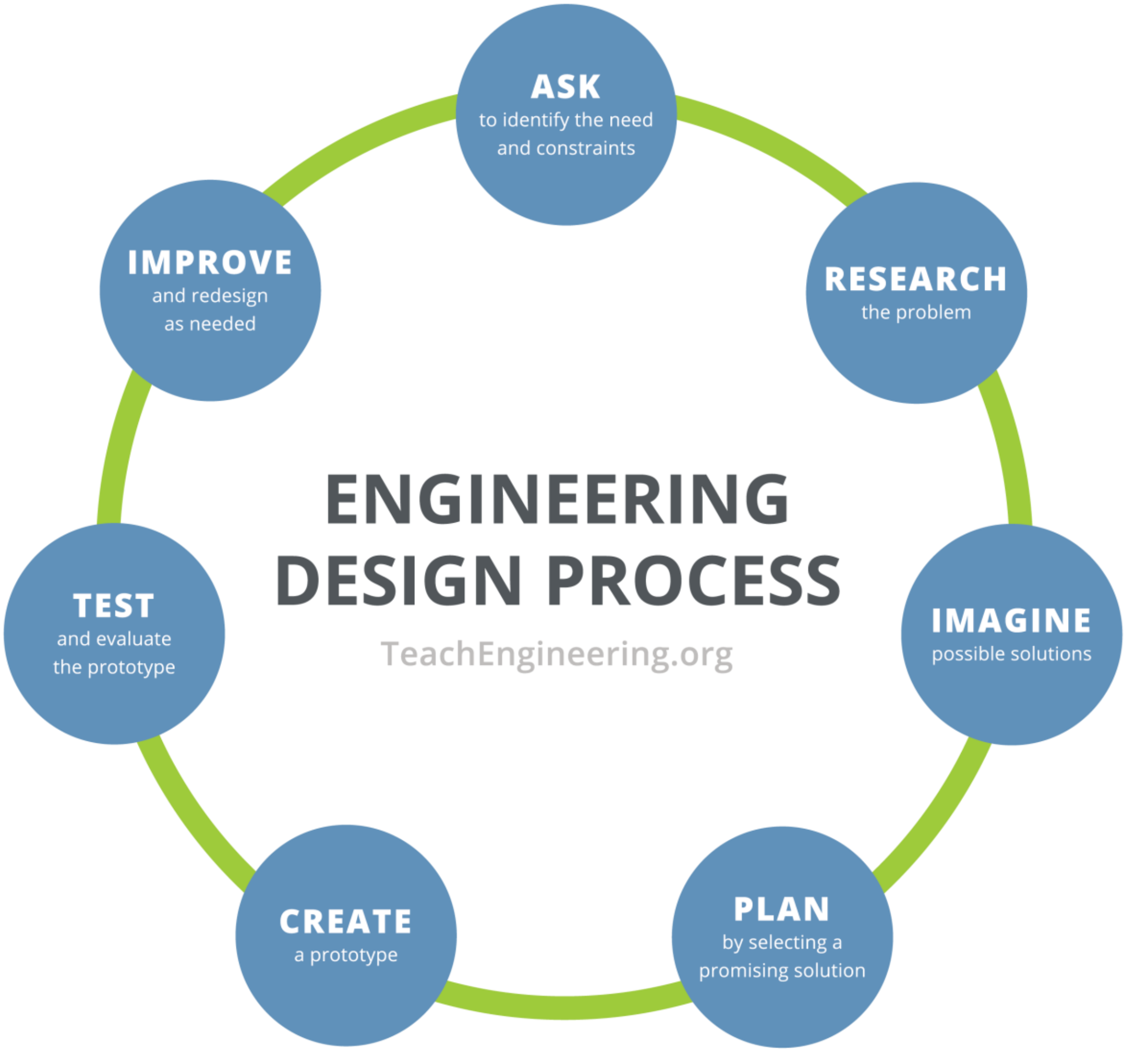

STUDENT WORKSHEET

Worksheet 1: Introduction to Biomedical Engineering

Biomedical engineers (also called bioengineers) use their knowledge of math and science to solve health problems. Biomedical engineers develop materials, implants, and devices for the treatment of disease and rehabilitation. Biomedical engineers specialize in biomaterials; bioinstrumentation; biomechanics; medical imaging; rehabilitation; and cellular, tissue, and genetic engineering.

Biomaterials

Biomedical engineers who specialize in biomaterials develop materials that can be safely placed in the human body. Medical devices that are placed in the body are called implants. Examples of implants include contact lenses, catheters, artificial heart valves, and joint prostheses. The biomaterial specialist has to make sure that a material provides the necessary biological function and is non-toxic, not degraded over time, strong enough to absorb stress, resistant to infection, and does not allow protein buildup that causes blood clots. Although these biomaterials can be made from many different substances, polymer blends, metal alloys, and ceramics are most common.

The second type of biomaterial refers to materials that scientists and engineers develop to mimic diseased or damaged bodily components, such as artificial skin, blood, and cartilage. A team from the University of Illinois developed a plastic material that is being examined for its use as artificial skin in the creation of organs. Just like real skin, this substance can bleed and heal itself. Some forms of artificial skin are already available commercially and are used to provide skin replacement for burn victims. They are also used as temporary patches that prevent infection while allowing a patient's skin grafts to heal during the treatment of severe burns.

Bioinstrumentation

A biomedical engineer involved in bioinstrumentation uses computers or other electronic devices to either diagnose or treat disease. A person employed in this field might develop monitoring devices such as an electrocardiograph (a device that records heart activity) or a sleep apnea monitor (a device that records pauses in breathing), or they may develop software that helps to analyze the signals from such devices.

Biomechanics

The field of biomechanics applies physics to biological systems. Artificial organs, such as an artificial heart, are designed and improved by biomedical engineers who specialize in biomechanics. Biomedical engineers from ABIOMED have created an artificial heart. Although the artificial heart is only being used in clinical trials on very ill patients, researchers hope that patients can live an extra two years with the device.

Another example of a biomechanical project is conducting stress and strain tests on ligaments and cartilage tissue. Many people are familiar with anterior cruciate ligament (ACL) injuries and know someone who has needed knee surgery. By studying the differences between ACL deficient tissue and the healthy knee, researchers can help rehabilitate patients faster.

Medical Imaging

Medical imaging involves the use of different types of waves (ultrasound, magnetic, and X-rays) to create an image of the body. Engineers are trying to create sharper and more accurate images while minimizing discomfort to the patient. Currently, the best way to detect for colon cancer is to use an invasive procedure known as a colonoscopy in which a patient under anesthesia has a long flexible tube with a light and a tiny camera "look" inside his or her large intestine. However, research is underway to create a virtual colonoscopy, in which a patient's colon could be imaged through the skin. Researchers at Wake Forest University are working on this painless and non-invasive method.

Rehabilitation Engineering

Dean Kamen and the iBOT

The job of a rehabilitation engineer is to improve the quality of life of people with disabilities. For example, rehabilitation engineers have designed the iBOT™ Mobility System, a sophisticated wheelchair that can tackle stairs, rough terrain, and even lift the patient to be eye-level with standing adults. The iBOT was created by Worcester Polytechnic Institute alum Dean Kamen, who also invented the Segway scooter.

Another product designed by rehabilitation engineers is the Smartphone for cognitively-impaired elderly persons. This phone is currently being developed by researchers at the University of Florida. The Smartphone sends reminders for taking medication, turns appliances on and off, checks remotely if doors are locked, provides directions outside the home, and signals for help when needed.

Cellular, Tissue, and Genetic Engineering

Tissue and cellular engineers grow cells outside of the body, often with the intention of later implanting them in the body. The goal of a tissue or cellular engineering project could be to create a biomaterial, such as skin. Skin can be grown in a laboratory setting by tissue engineers and later used to treat severe burns.

Professor George Pins and Ph.D. student Brett Downing from Worcester Polytechnic Institute are building skin substitutes that can heal and regenerate. Besides helping burn victims, this work can benefit diabetics by preventing amputations for foot ulcers that do not heal.

Professor George Pins and Ph.D. student Brett Downing

Genetic engineering is a related discipline, in which an organism's DNA is altered to produce different proteins. Genetic engineering has many applications in drug production. For example, some of the proteins that are used in pharmaceutical products are expensive or impossible to manufacture chemically. Living cells, including bacteria, yeasts, plants, and animal cells, can often be grown in a laboratory setting. These living cells can be used as factories to produce important therapeutic proteins. Sometimes the amount of protein that the cell naturally produces is so small that the process becomes expensive. Genetic engineering can be used to increase production of a desired protein or to make the process occur faster or cost less. Professor Susan Roberts from the University of Massachusetts Amherst is using genetically-engineered plant cells to maximize the production of the breast cancer drug paclitaxel. *Taxus* cells already produce taxol under certain growth conditions, but genetic engineering allows more of the protein to be produced.

In other cases, the genes that code for the production of a therapeutic protein can be inserted into a bacterium or other microorganism. Microorganisms are much easier and cheaper to work with in a laboratory than plant or animal cells. For example, microorganisms in baker's yeast are used to produce the protein in the Hepatitis B vaccine, which is now widely available in the United States.

For more information about biomedical engineering, visit the Biomedical Engineering Society website at **www.bmes.org/links.asp**.

STUDENT WORKSHEET

Worksheet 2: Material Properties

For engineers, choosing materials is an important step in the design process. All materials have different properties that may or may not make them suitable for a given application. This handout is designed to give you some background on different types of materials and material properties.

What are Materials?
Materials come from nature. They are made up of the elements found on the periodic table. They may be elements in their pure form or a combination of elements. Materials are often processed to make them have different properties. For example, trees are found in nature and processed to make paper, petroleum is made into plastic, and cotton is made into clothes.

What are Some Types of Materials?
Metals
Metals are elements with a valence number of 1, 2, or 3 on the periodic table. Metals are typically chosen for their strength and their ability to be formed into practical shapes. Metals are also good conductors of electricity. One of the drawbacks associated with metals is their density. They are much denser than other materials. Metals tend to be stronger and more rigid than other materials, such as polymers. They are often combined with other elements to form an alloy. When alloys are formed, they exhibit different properties than the original elements. Alloys may be lighter in weight, stronger, or more flexible than the original elements. An example of an alloy is brass, which is made up of zinc and copper. Another alloy that we often refer to as a metal is steel. Steel is a combination of iron and other elements, such as carbon.

Some examples of metals: gold, iron, silver, titanium, aluminum, tungsten, platinum, and copper

Plastics
Plastics are technically polymers. They are made of many small molecules that are connected together in long chains. Polymers contain repeating elements, and each element will contain many carbon atoms and other nonmetallic elements, such as hydrogen. Polymers can be made by people, but some are naturally occurring and produced by plants or other kinds of living creatures. Polymers have some special characteristics which make them very useful in certain applications. They can be resistant to chemicals, insulate against both heat and electricity, are usually lightweight, and can be formed into many different shapes. Elastomers, such as rubber, are a group of plastics that return to their original shape after stress. We come into contact with polymeric materials hundreds of times each day. From the glue on the back of Post-it® Notes, to clothing, to Tupperware™, polymers are all around us.

Some examples of plastics: polystyrene, polyvinyl chloride, polyester, and nylon

Composites
A composite is a combination of two or more materials. When combined, the materials have improved properties. Plywood is an example of a composite made up of cellulose fibers from trees and glue. Composite materials are found in skis, boats, bike helmets, and tennis rackets.

Ceramics
Ceramics are a combination of one or more metals with a non-metallic element. Ceramics are made with a high temperature heat treatment. (Think of clay being fired in a kiln to make pottery.) Ceramics are strong but lighter in weight than metals. They do not rust. Ceramics can be used as electrical insulators, lubricants, and in many other areas.

Textiles
Textiles are fabrics consisting of fibers of other materials. These fibers can be either natural fibers such as cotton, wool, cashmere, and silk or synthetic fibers such as nylon, acetate, and polyester. Textiles may also be a combination of man-made and natural fibers.

What are Material Properties?
Physical Properties
Physical properties describe how a material interacts with different forms of energy. Some examples of physical properties are color, density, melting point, or water absorption.

Mechanical Properties
A mechanical property is the reaction of a material when a force is applied to it. Some examples of mechanical properties include strength, flexibility, and rigidity.

Chemical Properties
Chemical properties describe the make-up of the material, such as what elements it contains. For example, the chemical nature of water is that each molecule contains two hydrogen atoms and one oxygen atom. Some examples of chemical properties include composition (what the material is made of) and corrosion resistance (the material's ability to resist deterioration).

Engineers use many different resources to find the different properties of materials. These include textbooks, handbooks, websites, and performing experiments on the materials. One website with many different material properties is **www.matweb.com**.

Which Material is Best for the Job?
In order to choose materials for a particular design, you must decide which properties are important to solve your particular problem. Ask yourself some of the following questions.

- Is the weight of my design important? Consider the density of the materials you are using.

- Is the strength of my design important? Consider the strength of the materials you are using.
- Should my design be stiff or should it have some flexibility? Consider the rigidity of the material.
- Does my design need to withstand heat? Consider the melting point of the materials you are using.
- Does my design need to be water resistant? Consider the water absorption rate of the material.

One other factor that engineers must consider during the material selection process is the cost of the material. Although a material may have exactly the right properties, if it is too expensive a cheaper alternative will be used instead.

Materials at Work

Kevlar®
A composite material developed by Stephanie Kwolek, an engineer at Dupont, Kevlar is five times stronger than the same weight of steel and is corrosion-resistant. It can be found in bulletproof vests, skis, space vehicles and boats.

Gore-Tex®
A lightweight, breathable fabric with an ultra-thin, waterproof layer, Gore-Tex is used to make comfortable, waterproof jackets.

PhotoLink®
A coating for medical devices developed by Surmodics, PhotoLink reduces water absorption and has anti-bacterial properties.

The Engineering Design Process

All engineers follow a series of problem-solving steps called the engineering design process. This process consists of the following seven steps:
1. Ask to identify the need or problem
2. Research the problem
3. Imagine possible solutions
4. Plan by selecting a promising solution
5. Create a prototype
6. Test and evaluate the prototype
7. Improve and redesign as needed

Pass out the “Engineering Design Process” handout. Explain to students that they will be redesigning a cast. Review the design process with students. Encourage them to relate this process to their project.