WORKSHOP 1

Science Concept Links molecular structure, force, stress properties

SCIENCE DIGEST

A material's properties are determined by the arrangement of the atoms of which the material is comprised. Mechanical properties describe how a material withstands stress (force per unit area). Main types of stress include tensile (pulling), compression (pushing), shearing (separating into layers due to a sliding force), flexure (bending) and torsion (twisting). The force that stresses a part is the *load*. Loads can be static, impact or repetitive.

STUDENT OBJECTIVES

- Identify three types of stress: tensile, compression and shearing.
- Identify three kinds of load: static, impact and repetitive.

TEACHING HINTS

You may want to include examples of bending and twisting. A hinge is a good example of repetitive bending. A screwdriver is a good example of torque.

ANSWERS:

Fig. 1- a compression/static
b compression/static
c tensile/static
d shearing/repetitive

Fig. 2- a compression/impact
b tensile/impact

Fig. 3- a tensile/static
b shearing/repetitive

Conclusions and Inferences Static load. Tensile stress, because the weight of the books will pull the shelf down and away from the sides.

WORKSHOP 2

Science Concept Links properties of materials, force, mass, predicting, testing, measuring

SCIENCE DIGEST

The characteristics of one property of a material do not necessarily indicate the characteristics of another property. Cast iron has a greater ability to withstand compression than tension; glass can withstand static loads more than impact loads.

STUDENT OBJECTIVES

- Test materials and conclude that the characteristic of one property in a material does not necessarily indicate the characteristic of another.

TEACHING HINTS

Caution! Students must wear safety glasses. Have students build setups on several layers of newspaper to protect floor.

ANSWERS:

1. Ability to withstand static loads increases with mass.
2. Ability to withstand static loads does not always indicate ability to withstand impact loads of the same mass.

Conclusions and Inferences Tom is assuming that the glass brick's ability to withstand static loads and impact loads is the same. Experience shows this is not true.

WORKSHOP 3

Science Concept Links properties of metals, force, mass, predicting, testing, measuring

SCIENCE DIGEST

Metals have certain properties that distinguish them from other elements. In general, metals are hard, shiny, ductile (can be drawn into thin wire), malleable (can be hammered into thin sheets) and good conductors of heat and electricity. The specific properties of a metal determine its range of usefulness.

STUDENT OBJECTIVES

- Test materials and conclude that aluminum compounds generally are less able than brass to resist impact loads but able to resist repetitive loads.

TEACHING HINTS

Caution! Students must wear safety glasses. (see Workshop 2)

ANSWERS:

1. No. Brass has more resistance to impact loads.
2. No. Brass compared with aluminum has a greater resistance to impact but a lesser resistance to repetitive loads.

Conclusions and Inferences Nicholas should use the aluminum wire because it will probably have a greater resistance to repetitive stress. The spring will be stretched over and over.

ADDITIONAL ACTIVITY

Have students design and carry out an experiment to test a small spring's ability to resist repetitive loads.

WORKSHOP 4

Science Concept Links engineering, testing, comparing

SCIENCE DIGEST

Being able to explain and predict things such as strength of materials is an important part of engineering design. Special publications are available to engineers listing the results of various tests on various materials.

STUDENT OBJECTIVES

- Identify similarities in tests from Workshops 2 and 3 with tests engineers make.

ANSWERS:

1. Tensile test. Additional Activity, Workshop 3, both apply pulling force.
2. Guided bend test. Similar to testing for repetitive loads in Workshop 3. All involve bending materials to observe resistance.
3. Impact test. Both tests in Workshop 2 and the first test in Workshop 3 are similar. All involve a force suddenly applied.

Conclusions and Inferences

a. impact **b.** guided bend
c. tensile **d.** impact
e. tensile

WORKSHOP 5

Science Concept Links construction of objects and structures, joints, stress, load

SCIENCE DIGEST

Many objects and structures are cast, molded or carved and are, therefore, of single-piece construction. Most objects and structures, however, are made of multiple pieces. Pieces are joined by a variety of methods, including welding, riveting, gluing, bolting and nailing. The method used to join pieces is primarily determined by the type of materials, the type of loads and stress that the joint must withstand and how permanent the joint should be.

STUDENTS OBJECTIVES

- Identify characteristics of objects with and without joints.
- Identify appropriate means of joining pieces depending on materials and intended use.

TEACHING HINTS

You may want to return to the example of a bicycle from Workshop 1. Discuss with students which parts of a bicycle are probably welded and which parts are joined mechanically, using nuts and bolts and why each method is used. (Parts that need to be adjusted or removed for repairs should be joined mechanically. Parts that need to be permanent and unchanging should be welded.)

ANSWERS:

1. Fig. 1 (saucepan) joined; static; shearing at base [arrow where handle joins pan], shearing or torsion (twisting)

Fig. 2 (hammer) not joined; impact; compression, shearing

Fig. 3 (shovel) joined; repetitive; shearing, flexure (bending), torsion [arrows where handle joins scoop and grip joins handle], shearing, flexure (bending), torsion

2. Answers may vary. Sample answers: Pyrex measuring cup, cast-iron frying pan, forks and spoons, screws, eye hooks, the metal part of a garden rake.

3. Answers may vary. Sample answers: doorknob, leaf rake, pliers

Conclusions and Inferences One-piece objects: tools, plumbing, cabinetry. Joined objects: housewares. Objects to be joined to other objects: plumbing, cabinetry.

WORKSHOP 6

Science Concept Links models, building to specification, measurement, five basic joints.

SCIENCE DIGEST

Modeling provides a means of describing a system in order to increase one's understanding of it. A model is a simplified imitation of a system usually on a smaller scale. A model can be a device, a plan, a diagram, an equation, a computer program or just a mental picture. Models are helpful because they help us see how things work or might work. A small scale physical model, however, cannot be expected to represent the full-scale phenomenon with total accuracy. For example, the way the water in a laboratory tank flows around tiny model boat will be much different than the flow of the ocean around a huge boat.

STUDENT OBJECTIVES

- Identify the five basic types of joints.
- Follow working drawings to create models built to specification.
- Check measurements on models for adherence to specifications.

TEACHING HINTS

- Discuss regulating specifications and inspecting. Point out how these procedures help ensure product safety (correct size for job); reliability (people can count on the product to provide the service they expect); and predictability (people know what to expect from a product).
- Have students work in pairs. Note: Join pairs into teams of four for Workshop 12. This arrangement provides two sets of models for Workshop 12 testing while keeping the number of team members manageable.
- *Caution students about safe use of the craft knife. Demonstrate correct ways to hold and cut wood.*
- If students are working in pairs, have them act as checkers for each other's work. Work out a system for inspection that does not allow any two students to inspect each other's work. List inspectors and whose work each will inspect. Make clear that materials and measuring tools are not precise. Come to an agreement as to what is acceptable and what is not. Checkers and inspectors should not sign items if work is not acceptable.
- Tell students to use sandpaper to smooth and level edges for a tight joint.
- *Save all of the models students make in this Workshop. They will be used in Workshop 12.* It is important that final sets of models come as close to specifications as possible to increase the credibility of the tests that will be carried out in Workshop 12.

ANSWERS:

Fig. 2 butt joint; Example: Answers will vary. Sample answers: pipes, wood floors.

Fig. 3 T joint; Example: Answers will vary. Sample answers: book ends, shelf dividers.

Fig. 4 lap joint; Example: Answers will vary. Sample answers: shovel, fence, scissors.

Fig. 5 edge joint; Example: Answers will vary. Sample answers: shelves, drawer handles.

Fig. 6 corner joint; Example: Answers will vary. Sample answers: radios, decorative boxes.

Conclusions and Inferences Lap where the cylinder is welded to itself; corner where the cylinder is welded to the bottom; corner joints; edge joint.

ADDITIONAL ACTIVITY

Computer modeling is another way to model a system. An engineer draws an object, assembly, or system on a computer and it is then converted into a mathematical representation. This model is a very detailed and highly accurate representation including mechanical and physical properties. Tests may be performed and prints for manufacture of the object can be produced directly from the computer model. Have students describe the advantages of computer models instead of building models.

WORKSHOP 7

Science Concept Links vibrations, wave motion, the structure of matter

SCIENCE DIGEST

Stress resulting from a load applied to an object is measurable to some degree throughout the object, not just at the point where the load is directly applied. Impact stresses the molecular attraction among particles that unites them into a whole. Repeated stress in metals can cause metal fatigue, an altering of the molecular structure of the metal that results in cracking.

STUDENTS OBJECTIVE

- Demonstrate that force acting on one part of a structure can cause stress in other parts.

TEACHING HINTS

Relate hitting a ball with a bat or a racket and feeling the impact in your hand to the lesson.

ANSWERS:

1. Yes. Stress at the bottom travels to the rim.

2. Glass, metal and wood each carry stress from its source throughout the piece.

4. Answers will vary.

6. Compression. The material was pushed (hit) to cause stress.

Conclusions and Inferences Yes. The force of the waves will stress the supports; the stress will travel up through the bridge structure to the parts supporting the roadway.

ADDITIONAL ACTIVITY

The famous instance of the collapse of the Tacoma Narrows Bridge, which is available on video, can be shown to illustrate how powerfully stress can resonate throughout a structure.

WORKSHOP 8

Science Concept Links force, the structure of matter, mass, engineering

SCIENCE DIGEST

Force acting on an object causes stress, or resistance to the force, throughout the object. Sometimes force spreads evenly throughout an object, such as in an arch. In other cases, often as the result of a defect in structure, force can be concentrated on one part of an object and result in excessive stress at that point.

STUDENTS OBJECTIVES

- Demonstrate that altering the shape and structure of an object can alter its resistance to stress.
- Gather and analyze experimental data.

TEACHING HINTS

Have students work in pairs or teams of four to carry out experiments. With students' help, compile information from all Data Tables and calculate class averages. Graph class data. Help students design a line graph to plot break points.

ANSWERS:

1. Notched slat is less able to withstand stress than is the unnotched slat.

2. Drilled slat is less able to withstand stress than is the undrilled slat.

3. Notched slat is less able to withstand stress than is the drilled slat.

Conclusions and Inferences She could call for beams with circular holes, but not for beams with notches. The beams with notches are very likely to break because notches cause stress to be concentrated at the point of the V. Stress is distributed evenly around circular holes.

WORKSHOP 9

Science Concepts Links heat conduction, properties of metals, atoms, gathering and presenting data

STUDENTS OBJECTIVES

Demonstrate that not all metals have the same capacity to conduct heat.

SCIENCE DIGEST

Thermal conductivity is the movement of heat through a material. The fast moving atoms at the source of the heat vibrate nearby cooler atoms, which in turn, vibrate other atoms and so on through the material. Metal objects often feel colder than the environmental temperature because they quickly conduct body heat away from the hands. The speed with which metals conduct heat varies from metal to metal.

TEACHING HINTS

Use the type of burner that meets the safety code of your school; or, make alcohol lamps like the one shown in Fig. 3 of Workshop 9 from a baby food jar, a wick and rubbing or isopropyl alcohol. Use an awl to punch a hole in the lid. Push the wick through the lid until about 3/8 inch extends above the top. Fill the bottom of the jar with alcohol. Screw the top onto the jar. When ready, light the wick.

Make a steel-can tripod like the one shown in Fig 3 by using an awl to punch five evenly spaced 1/4 in. holes near the top of an empty can. Remove the bottom with a can opener and use metal shears to cut away three rectangular sections slightly larger than the height and diameter of the baby food jar (for the alcohol lamp).

ANSWERS:

1. In order, from most conductive to least conductive, the materials are copper, aluminum, brass, steel.

2. All metals are more conductive than glass.

Conclusions and Inferences The bottom of the cooking pan but not the handle, poker or tongs. Copper is a very efficient conductor of heat. This property will help the heat spread quickly and evenly at the bottom of a pan to speed cooking. This same property will cause heat to travel quickly to the hand holding the pan handle, poker and tongs and could results in burns.

ADDITIONAL ACTIVITY

Have students measure each rod's response to cold by taping the bulb of a thermometer to the rod, putting the rod in a glass full of ice and recording the temperature at 10-second intervals.

WORKSHOP 10

Science Concept Links coalescence, molecular cohesion, heat, pressure, welding, modeling

SCIENCE DIGEST

Welding draws upon the cohesive properties of the metal pieces being joined—in other words, upon the molecular attraction among metal particles that unites them into a whole. Coalescence, or the joining together of two pieces to form one mass, can be brought about by melting, by pressure or by a combination of heat and pressure. When materials coalesce, the new unit formed, including the joint, has the strength of the material itself.

There are more than 60 welding processes. The official definitions of welding processes and process categories established by the American Welding Society are much more technical and extensive than those supplied to students here and include arc welding, brazing, solid-state welding, resistance welding, oxyfuel gas welding and soldering. The American Welding Society does not recognize "fusion welding" as a grouping because they feel that fusion is involved with too many of the processes to be recognized as a separate category.

STUDENT OBJECTIVES

- Identify the characteristics of fusion welding and deformation bonding.
- Model fusion welding and deformation bonding.

TEACHING HINTS

Have students work in pairs on this activity. Before starting, discuss safety rules and fire emergency procedures and lay down firm rules for behavior.

If paraffin blocks are not available, short votive candles can be joined at the base. If votive candles are used, remove the metal tag that holds the wick at the base before starting.

ANSWERS:

1. Fusion welding. *Key terms & phrases: Melts the edges* of the parts to be joined. *A filler metal is added. . . during the melting process.*
2. Deformation bonding. *Key terms & phrases:* Involves heating the pieces to be joined just below the melting point and *applying . . . pressure.*
3. Answers will vary.

Conclusions and Inferences Answers to first three questions will vary. Most students should conclude that inferences about welded metal joints based on the wax models will not be dependable because the properties of wax and metal are very different. Some students may make an argument that conclusions will be dependable because the process of joining matched the definition. You may wish to point out that this investigation modeled the process, rather than actually carried it out.

ADDITIONAL ACTIVITY

Contact your community volunteer service and ask for a volunteer to provide a welding demonstration for your students.

WORKSHOP 11

Science Concept Links melting, point, specific heat

SCIENCE DIGEST

To melt a metal, it is necessary to increase its temperature to its melting point. How much heat must be applied to reach the melting point of a given type of metal is a function of the *specific heat* for that particular metal. The specific heat of water is 1 calorie per gram per °C, meaning that 1 calorie of energy is needed to raise the temperature of 1 gram of water 1°. Metals, as a group, have relatively low specific heats. The specific heat of stainless steel is well above average for metals but only one-third that of water. In other words, the amount of energy that raises the temperature of water 1° C would raise the temperature of the stainless steel 3° C.

It is possible for a metal with a high melting point but a low specific heat to require less heat to melt than a metal with a lower melting point but a higher specific heat.

STUDENT OBJECTIVES

- Define specific heat.
- Demonstrate differences in specific heats of aluminum, copper and steel.

TEACHING HINTS

The metal samples to be tested can be bought as a kit, but you can easily make your own samples from metal rods or strips available from most science supply companies and in most hobby or craft stores. If copper, aluminum and steel samples are not readily available, you can substitute the metals that you have.

The samples must be the same mass. Start by cutting a sample of your lightest metal that will fit in the bottom of the test beakers without touching the sides. Then cut samples of equal mass from the heavier metals. If you need to cut more than one piece for any sample, tie the pieces tightly together with thread.

You may wish to boil water beforehand and store in vacuum bottles until needed.

If necessary, instruct students on proper use of alcohol burners.

ANSWERS:

1. Aluminum, copper and steel have different specific heats.
2. The metals ranked from highest specific heat to lowest are as follows: aluminum (0.22); steel (0.118); copper (0.09).

Conclusions and Inferences Aluminum (Note: A substance with a low specific heat will increase in temperature more than an equal mass of a substance with a high specific heat if both substances receive the same amount of heat. The substance with the low specific heat will also release its heat quicker than the substance with a high specific heat. In this experiment, the substance that increases the temperature of the water the most should be the one with the lowest specific heat.)

WORKSHOP 12

Science Concept Links scientific methods and processes, designing investigations, predicting, testing, measuring, presenting data, cooperative learning, teamwork

SCIENCE DIGEST

Science, technology and society are in constant interaction and influence one another greatly. Science is the body of ideas we have about the natural world, arrived at through particular ways of observing, thinking, experimenting and validating. Scientific understanding contributes to technology, which is the application of science. Technology draws on science and provides the tools to further the pursuit of science. Even a casual look around the world today reveals the strong influences of technology on society. Communication is instantaneous and computers enable us to tract and categorize amounts of data what would have been unthinkable in precomputer days. Technology shapes people's lifestyles and people, in turn, decide what technology developments will be undertaken, financed, paid attention to and used.

Cooperation, interaction and team effort are at the core of successful science, technology and business enterprises.

STUDENT OBJECTIVES

- Work effectively as a team to plan, organize, carry out and report the results of a scientific inquiry.

TEACHING HINTS

Note: Students teams must each have two sets of models made in Workshop 6 to complete this workshop.

Have students work in teams of four. Form teams by joining two sets of partners from Workshop 6. This will provide each team with two sets of models to test. Students will need to test one model of each joint for tensile stress and one model for compression stress. Try to form teams of partner sets who have models that are of equal quality.

This activity is open ended; students may devise tests that are entirely new. Everyone should be encouraged to solve the problem in his or her own way. The emphasis should be on the process rather than the actual results of the investigation.

Before students start, have an open discussion about working as a team. Stress cooperation and equal participation. Address any concerns that students might have. If students have had problems in working as a team, have then brainstorm ways to avoid conflict in the team as a warm-up exercise

The fact that the models to be tested may vary from pair to pair should be discussed afterward. The variance factor is an excellent example to be used in a discussion of experiment validity.

Spend some time discussing predictions. Make the point that science is as much about recognizing when one is wrong as about proving oneself right.

ANSWERS:

In general, answers will vary. Some sample answers are provided.

Step One

1. Workshops 1 and 2 (compression). Board or metal rods are suspended between blocks and piled or bombarded with mass. Workshop 8 (tensile). Plain, drilled and notched slats are tested for ability to support suspended mass.

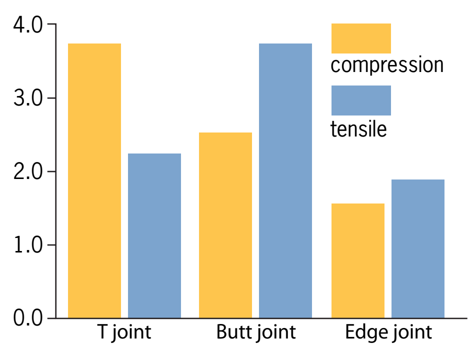
2. Answers will vary.

3. Answers will vary.

4. Two sets of models from Workshop 6.

5. Answers will vary. In most cases safety glasses should be recommended.

6. Answers will vary. One choice is to create a bar graph with elements as shown below:



Step Two

1. Answers will vary.

2. Answers will vary.

3. Answers will vary.

Step Three

1. Answers will vary but should include those mentioned in the example.

2. Answers will vary.

3. Answers will vary.

4. Answers will vary.

5. Answers will vary.

Step Four

1. Answers will vary but should model the structure of the example.

Step Five

1. Answers will vary.

2. Answers will vary.

3. Answers will vary.

4. Answers will vary.

Conclusions and Inferences Although the results of this experiment can be generalized as long as we are careful to look at the characteristics of the joints themselves and not of the materials, the reliability of the generalizations is very dependent upon the quality of the model joints. Students may decide that their model pairs were not identical enough for science accuracy. The team experience is real. Many of the feelings, problems, benefits, etc., encountered in this experience are very similar to those encountered by actual science/technology teams.

ADDITIONAL ACTIVITY

Have students look for evidence that their conclusions about joints can or cannot be generalized. For example, if T and corner joints formed by gluing balsa wood have low tension and high compression strengths, can the same be said about the same joints formed by welding pieces of metal together? Can students gather evidence from the world that this is or isn't true? Students might look at the welds on tubular furniture and note the loads each weld is intended to bear.