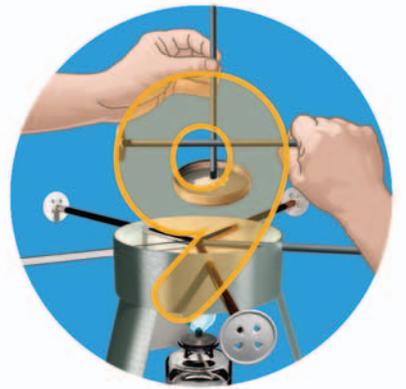
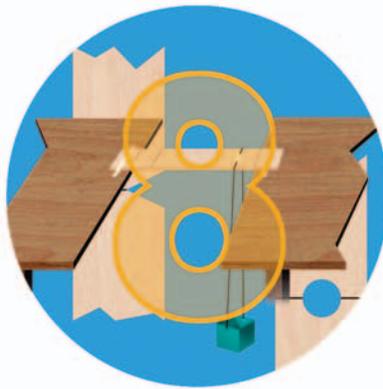


# ENGINEERING YOUR FUTURE

## TEACHER'S GUIDE



American Welding Society



National Center for Welding Education and Training

# IT TAKES A SPARK TO IGNITE A CAREER AND IMPACT A LIFE

Dear Educator:

Go back to your early days as a student in middle school and high school. How did you discover which career was right for you?

Like many of your fellow students you were probably confused and maybe a bit overwhelmed with this important decision. Ultimately, someone came along and inspired you to pursue a career educating youth in STEM. That inspiration — whether from a teacher, mentor, family member or career counselor — made a huge impact in your life and led to your current career.

Now as an educator, you have the opportunity and obligation to reciprocate and provide the same spark that impelled you to make your career decision.

The American Welding Society Foundation and The National Center for Welding Education and Training (Weld-Ed) are pleased to present this publication, **Engineering Your Future**, an educational program designed to introduce your students to the prospects of a career in engineering and welding engineering.

**Engineering Your Future** was developed to complement a variety of subjects, including math, science and industrial technology. Through this program, students will learn the critical role welding engineers play in the world today, and will discover a direct link between their course work and the tasks performed by an engineer in the field.

As YOU are the driving force which sparks the inspiration that will lead your students to this important and rewarding career path, it is our hope that **Engineering Your Future** can greatly assist you in your efforts.

For further assistance, and to view additional career resources, please visit [www.CareersInWelding.com](http://www.CareersInWelding.com) or [www.Weld-Ed.org](http://www.Weld-Ed.org).

## ACKNOWLEDGEMENTS:

### American Welding Society Foundation

Executive Director, Sam Gentry  
Corporate Director, Monica Pfarr

### American Welding Society

Executive Director, Ray Shook

### Weld-Ed

Center Director, Duncan Estep  
Research Analyst, Michael Fox

### Weld-Ed Regional Centers

Chattanooga State Technical College  
College of the Canyons  
Honolulu Community College  
Illinois Central College  
Lorain County Community College  
North Dakota State College of Science  
Texas State Technical College  
The Ohio State University  
Weber State University  
Yuba College

### Technical Reviewer:

The Hobart Institute of Welding Technology  
400 Trade Square East  
Troy, Ohio



**American Welding Society**



**Weld-Ed**

National Center for Welding Education and Training



**National Science Foundation**  
WHERE DISCOVERIES BEGIN

Copyright 2012 by American Welding Society Foundation and National Center for Welding Education & Training (Weld-Ed) in both printed and electronic format.

All rights reserved. Permission to reproduce work sheets is hereby granted by American Welding Society Foundation and Weld-Ed to teachers for classroom use.

This material is based upon work supported by the National Science Foundation under Grant No. 1104107. Any opinions, findings, conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

# CONTENTS

OVERVIEW AND GENERAL GUIDELINES	—————	2
CURRICULUM RELATIONSHIPS	—————	3
TEACHER'S GUIDE WORKSHOPS	<b>1</b> <b>2</b> <b>3</b> <b>4</b> ———	4
	STUDENT WORKSHOP <b>1</b>	5
	STUDENT WORKSHOP <b>2</b>	6
	STUDENT WORKSHOP <b>3</b>	7
	STUDENT WORKSHOP <b>4</b>	8
TEACHER'S GUIDE WORKSHOPS	<b>5</b> <b>6</b> ———	9
	STUDENT WORKSHOP <b>5</b>	10
	STUDENT WORKSHOP <b>6</b>	11
TEACHER'S GUIDE WORKSHOPS	<b>7</b> <b>8</b> <b>9</b> ———	13
	STUDENT WORKSHOP <b>7</b>	14
	STUDENT WORKSHOP <b>8</b>	15
	STUDENT WORKSHOP <b>9</b>	17
TEACHER'S GUIDE WORKSHOPS	<b>10</b> <b>11</b> ———	18
	STUDENT WORKSHOP <b>10</b>	19
	STUDENT WORKSHOP <b>11</b>	21
TEACHER'S GUIDE WORKSHOPS	<b>12</b> ———	22
	STUDENT WORKSHOP <b>12</b>	23

## OVERVIEW

*Engineering Your Future*, an educational program sponsored by the American Welding Society, provides a unique science experience that points out the ever-increasing relationships among science, technology and society. These relationships have generated an increased need for science-based occupations, including welding engineers. Through *Engineering Your Future*, the American Welding Society hopes to excite students about some of the natural laws of physics and their application in the technological world in which we live, while perhaps guiding them to consider science-based careers.

*Engineering Your Future* has been designed for use in science classrooms in junior high grades and above. The program consists of 12 student workshops (activities) and accompanying teaching information.

The workshops emphasize hands-on learning and the use of higher-order thinking skills. Each workshop provides students with information about science or technology and then provides an opportunity to apply that information. A summary of the workshops is shown on the chart on page 3.

## STRUCTURE

This booklet contains 12 workshops; all are one page except workshops 6, 8, 10 and 12, which are two pages each. Corresponding teaching information is also provided for each workshop. In general, all workshops, except for Workshop 12, can be completed in one class period. Students will benefit the most from Workshop 12 if they do their planning one day and carry out their investigation on the following day. Allow enough time for students to concentrate on the process and not be pressured to “get the correct answer”.

## CONTENT

*Engineering Your Future* centers around properties of materials, especially as they relate to resistance to various kinds of stress. The process of experimenting, including analyzing and communicating data, is a major part of the program. The chart on page 3 provides detailed information about contents.

Each workshop builds upon the previous one. This design is based on the pedagogically sound practices of teaching a few things well and presenting the same information in various contexts. For example, if some students do not fully grasp the idea of types of stress and load in Workshop 1, do not hesitate to go on to subsequent workshops. These concepts are presented in various contexts throughout the program.

Although the workshops do build upon one another, several workshops can stand alone. Workshop 6, for example, provides an excellent opportunity for following and checking specifications. This workshop can be completed by students who have not mastered the previous workshops.

## VOCABULARY

*Engineering Your Future* uses science terms that usually appear in science text discussions of these concepts. All terms are defined, and many opportunities are provided to apply terms in the context of a concrete activity. Significant terms are repeated in subsequent workshops.

## MATERIALS

All workshops, except for workshops 1, 4 and 5 require gathering materials beforehand. (See materials list on page 25.) Although Workshop 12 has no specific materials, you can probably predict what kinds of materials students will request.

Most of the materials used in the workshops are easy to find or make. Materials that you may not have available, such as metal samples and wood, can be found in most hobby or craft stores. Other materials, such as paraffin, can be found in most variety stores.

## GENERAL GUIDELINES

### WHEN TO USE

These workshops can be used in a variety of ways. They may be used as classroom activities to supplement regular science curriculum, they may be integrated into existing curriculum, they may be used as a mini-class series for special groups, or they may be assigned as extra-credit homework assignments.

### HOW TO ASSIGN

These workshops are designed for two or more students to work together as a team. The open-ended quality of many of the workshops makes them especially suitable for cooperative learning. Students will enjoy this low-pressure opportunity to work together to solve problems.

### SAFETY

These workshops provide challenging and interesting activities. Although none are inherently dangerous for students, caution must be taken. All cautions that appear in the teaching information and on the student pages should be followed. Several of the workshops require safety glasses. It is best to err on the side of caution. Teachers should always set a good example when it comes to safety. If you routinely take time to put on your safety glasses, students will be less likely to skip this precaution. Review appropriate classroom safety rules before each workshop.

### EVALUATION

When possible, answers are given to questions asked in the workshops, but several questions are open ended. This program is designed to emphasize independent thinking and provides opportunities for students to practice higher-order thinking skills. This program will help endorse the idea that an important goal in learning is understanding and creative thinking—not merely getting a single correct answer written down. To this end, the answers to the various experiments may vary from group to group.

# CURRICULUM RELATIONSHIPS

WS	SCIENCE CONCEPTS	STUDENT OBJECTIVES	PROCESS SKILLS	WORKSHOP SUMMARY
1	Molecular Structure, Force, Stress, Properties	<ul style="list-style-type: none"> <li>Identify three types of stress: tensile, compression and shearing.</li> <li>Identify three kinds of load: static, impact and repetitive</li> </ul>	Observing, Inferring	After reading descriptions of three types of stress and three kinds of load, students label stress and load points on diagrams of a bike, a basketball backboard and a canoe.
2	Properties of Materials, Force, Mass, Predicting, Testing, Measuring	<ul style="list-style-type: none"> <li>Test materials and conclude that the characteristic of one property in a material does not necessarily indicate the characteristic of another</li> </ul>	Observing, Inferring	Students predict and experiment with wood boards to determine if the quality of one property predicts the quality of another property in a given material.
3	Properties of Metals, Force Mass, Predicting, Testing, Measuring	<ul style="list-style-type: none"> <li>Test materials and conclude that aluminum compounds generally are less able than brass to resist impact loads but better able to resist repetitive loads.</li> </ul>	Observing, Inferring	Students predict and experiment to determine if brass and aluminum have the same resistance to impact loads and if a metal that has a high resistance to impact loads also has a high resistance to repetitive loads.
4	Engineering, Testing, Comparing	<ul style="list-style-type: none"> <li>Identify similarities in tests from workshops 2 and 3 with tests engineers make.</li> </ul>	Observing, Relating, Comparing	After reading descriptions of tests used by professionals to determine the properties of materials, students label diagrams of testing equipment and compare the tests they have done to the professional tests.
5	Construction of Objects and Structures, Joints, Stress, Load	<ul style="list-style-type: none"> <li>Identify characteristics of objects with and without joints.</li> <li>Identify appropriate means of joining pieces depending on materials and intended use.</li> </ul>	Categorizing, Applying	Students label diagrams of a hammer, cooking pan and shovel as being of one-piece or joined-pieces construction. They apply information from previous workshops to label points of stress.
6	Models, Building to Specification, Measurements, Five Basic Joints	<ul style="list-style-type: none"> <li>Identify the five basic types of joints.</li> <li>Follow working drawings to create models built to specification.</li> <li>Check measurements on models for adherence to specifications.</li> </ul>	Observing, Measuring	Students follow specifications for building balsa wood models of the five basic joints and check adherence to specifications on the models built by others.
7	Vibrations, Wave Motion, the Structure of Matter	<ul style="list-style-type: none"> <li>Demonstrate that force acting on one part of a structure can cause stress in other parts.</li> </ul>	Observing, Inferring	Students demonstrate that stress applied directly to one part of a structure can affect other parts.
8	Force, the Structure of Matter, Mass, Engineering	<ul style="list-style-type: none"> <li>Demonstrate that altering the shape and structure of an object can alter its resistance to stress.</li> <li>Gather and analyze experimental data.</li> </ul>	Relating, Inferring	Students predict and experiment to determine if plain, notched and drilled slats vary in their ability to withstand tensile stress.
9	Heat Conduction, Properties of Metal, Atoms, Gathering and Presenting Data	<ul style="list-style-type: none"> <li>Demonstrate that not all metals have the same capacity to conduct heat.</li> </ul>	Ordering, Inferring	Students predict and experiment to rank aluminum, copper, steel, brass and glass according to efficiency in conducting heat.
10	Coalescence, Molecular Cohesion, Heat, Pressure, Welding, Modeling	<ul style="list-style-type: none"> <li>Identify the characteristics of fusion welding and deformation bonding.</li> <li>Model fusion welding and deformation bonding.</li> </ul>	Applying, Inferring	Students use candles and paraffin blocks to model fusion welding and solid-state bonding.
11	Melting Point, Specific Heat	<ul style="list-style-type: none"> <li>Define specific heat.</li> <li>Demonstrate differences in specific heats of aluminum, copper and steel.</li> </ul>	Ordering, Applying, Inferring, Communicating	Students predict and experiment to rank aluminum, copper, and steel according to their specific heats.
12	Scientific Methods And Processes, Designing Investigations, Predicting, Testing, Measuring, Presenting Data, Cooperative Learning, Teamwork	<ul style="list-style-type: none"> <li>Work effectively as a team to plan, organize, carry out and report the results of a scientific inquiry.</li> </ul>	Applying, Ordering, Inferring, Communicating	Student teams plan, organize, carry out and report the results of an investigation to determine the ranking of the joint models made in Workshop 6 for ability to resist compression stress and tensile stress.

## 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

## UNDERSTANDING STRESS & LOAD

When engineers design an object or a structure, they must understand and consider the types of stress the object or structure will be under. They also consider the kind of load, or force that is going to cause the stress.

Three types of stress are **tensile** (pulling apart), **compression** (pushing together) and **shearing** (applying a sliding force). Three kinds of loads cause stress. A **static load** exerts a constant force. A **repetitive load** is applied again and again. An **impact load** is a suddenly applied load.

A material's ability to withstand various stresses and loads is a mechanical property of the material. A material's properties depend on the arrangement of the atoms of which the material is made.

Welding engineers are especially concerned about stresses and loads along joints. Welding engineers apply their knowledge of materials, types of stress, and kinds of load to determine the sizes of the pieces to be welded and the size of the weld needed to join them.

### APPLYING WHAT YOU KNOW

Study the diagrams of the bicycle, canoe and basketball backboard. Label the type of stress (tensile, compression, shearing) and the kind of load (static, repetitive, impact) causing the stress at each point.

Fig. 1

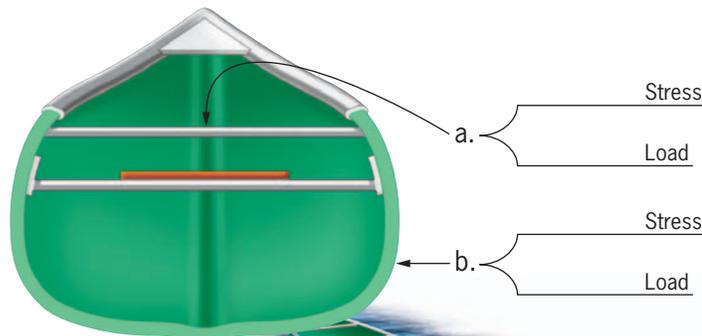
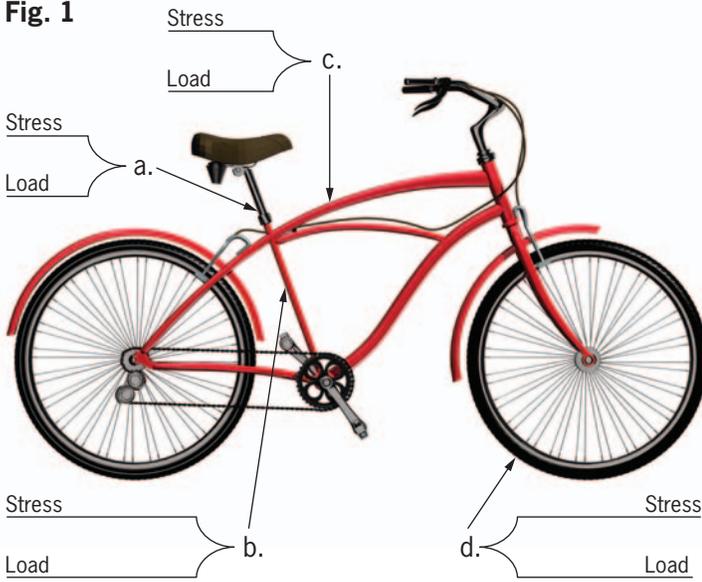


Fig. 3

### CONCLUSIONS & INFERENCE

Mary is building a bookcase using only wood and glue. What kind(s) of load(s) will be applied to the bookcase when it is in use? Will she be better off relying on the bookcase's ability to

Fig. 2



withstand shearing stress, tensile stress or compression stress at the joints between the shelves and sides? Why?

## RESISTING FORCE

Mass, color, melting point and ability to conduct heat are examples of physical properties. Elasticity, hardness and stiffness are examples of mechanical properties. Both physical and mechanical properties combine differently in various materials. Do you think that the quality of one property predicts the quality of another property? For example, does great mass indicate great elasticity?

### EVIDENCE & PROOF

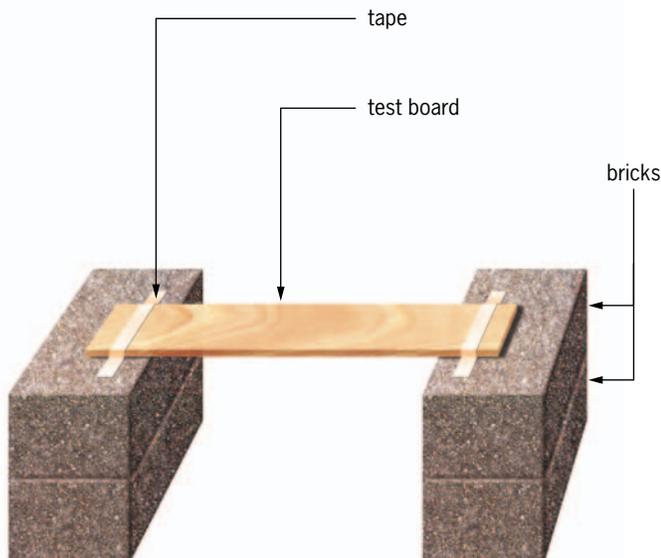
#### Materials:

3 to 4 pairs of wood boards of various thicknesses (1/8 to 3/8 in.) about 1 ft. long;  
 4 bricks or wood blocks about brick size;  
 heavy books or bricks or other compact heavy objects;  
 masking tape;  
 string;  
 balance scale;  
 2 yardsticks;  
 safety glasses.

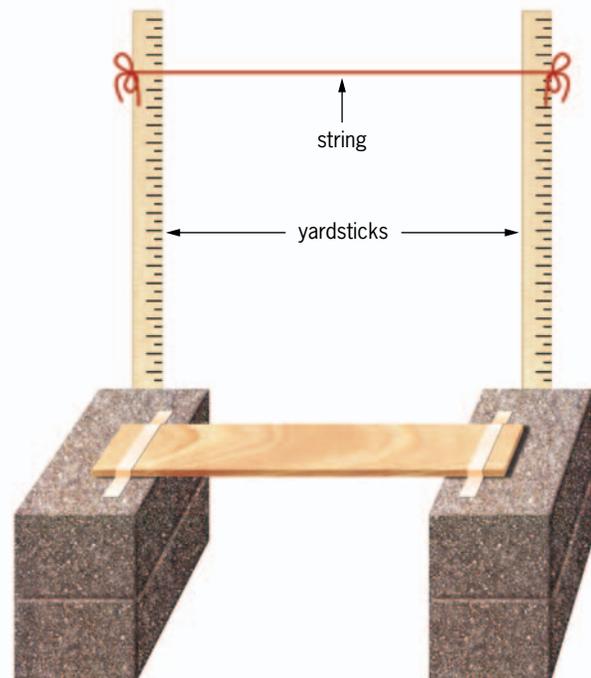
**Process:** Follow these steps. Compare your results with your predicted answers to the question.



**Caution:** Wear safety glasses.



**Fig. 1** Lay test board across brick and tape. On each side, allow only 1/4 inch of end of board to rest on bricks.



**Fig. 2** Tape test board as in Fig.1. Align bottom of objects to be dropped with string.

**Questions & Predictions** Predict and record answers to these questions. Observe and measure for Evidence & Proof below.

**Fig. 1** Can a wood board of greater mass resist a greater static load than a board of lesser mass can resist?

**Fig. 2** Can a wood board that is able to resist a static load of a certain mass resist an impact of the same mass?

**Fig. 1** Label the boards 1A, 1B, 2A, 2B, etc. Measure and record the mass of each board.

**Fig. 2** Use the setup shown in Fig. 1 or devise your own method to test one board from each pair for resistance to static loads. Pile the board being tested with books, bricks, etc., until the board breaks or a maximum mass (19 lbs.) is supported. Measure the mass of the objects the test board supported without breaking. Record your data.

**Fig. 3** Use the setup shown in Fig. 2 or devise your own method to test the remaining boards for resistance to impact loads. Drop the object with the least mass on the board. If the board does not break, tape a second object to the first and repeat. Continue until the board breaks or a maximum mass has been dropped. Record your data.

### CONCLUSIONS & INFERENCE

Tom wants to drive a large nail into a thick, hard board, but he doesn't have a hammer. Nearby, glass blocks are supporting shelves holding heavy books. Tom decides to use a block as a

hammer. What assumptions about properties is Tom making? Do you agree with his assumptions? What evidence from your Evidence & Proof activity support your answer? Why?

## DIFFERING STRESS RESISTANCE OF METALS

All metals are somewhat elastic; they can be bent. The shape of a metal object can be changed by impact loads, such as hammering. Some metals bend more easily than others because various metals have different properties. For example, one metal may have more or less resistance to impact or to repetitive loads than another metal.

**Questions & Predictions** Predict and record answers to these questions. Observe and measure for Evidence & Proof below.

**Fig. 1** Do brass and aluminum have the same resistance to impact loads?

**Fig. 2** If a metal has a high resistance to impact loads, does it therefore also have a high resistance to repetitive loads?

### EVIDENCE & PROOF

#### Materials:

2 rods or strips each of aluminum and brass, the same width and about .040 in. thick and 14 in. long; bricks or blocks and yardsticks used in Workshop 2; a heavy dispensable book, taped closed; string; ruler; masking tape; hammer; safety glasses, thick gloves.

**Process:** Follow these steps. Compare your results with your predicted answers to the question.



**Caution:** Wear safety glasses. Wear thick gloves when picking up the pieces of metal by their sharp edges.

**Fig. 1** Measure and mark the center of each metal strip with tape. Construct the apparatus shown in Workshop 2, Fig. 2, but without the wooden board (1B). Place the bricks or blocks exactly 4 in. less than the length of the metal strips apart.

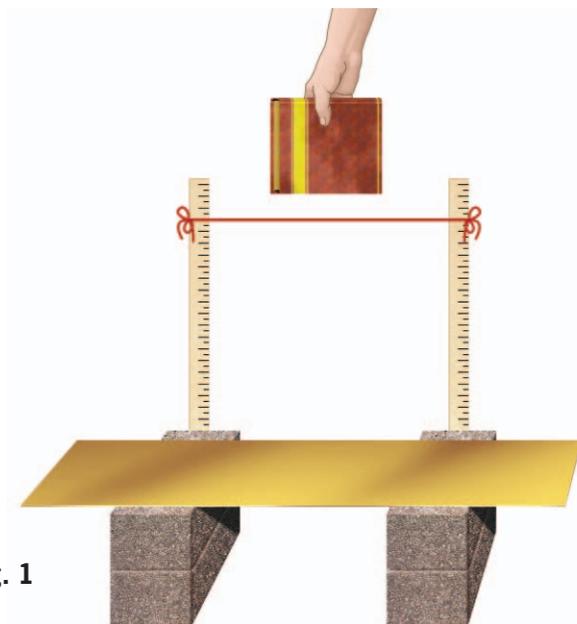
**Fig. 2** Lay one of the metal strips over the blocks, shown in Fig. 1. Be sure to center the strip. Hold the book, spine down, over the metal sheet level with the tops of the yardsticks. Drop the book onto the center of the metal strip. Measure the resulting bend, as shown in Fig. 2. To measure bend, turn metal bend-side up on a firm surface. Measure distance from highest point of bend to surface. Repeat for the second metal.

**Fig. 3** Test the second pieces of metal for resistance to repetitive loads. Pile the blocks or bricks on top of one another. Bend one metal strip over the blocks as shown in Fig. 3. Try to bend the metal to form a right angle. Then straighten the metal as much as possible. Use a hammer if needed. Examine the bend area for changes. Record what you see. Repeat the process 15 times or until you note clear deformation (change in size or shape) or breakage. Repeat for the second metal.

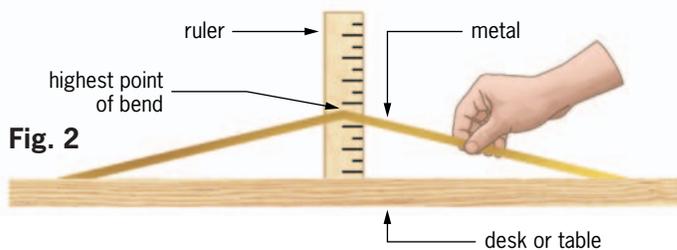
### CONCLUSIONS & INFERENCE

Nicholas is building a model that involves the stretching of a spring to its maximum length over and over. Because Nicholas needs a special size spring, he is going to make one by

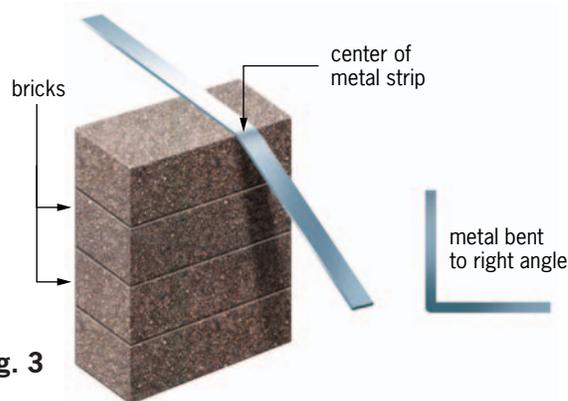
wrapping wire around a rod. He has aluminum wire and brass wire of the same thickness. Which should he use? Why?



**Fig. 1**



**Fig. 2**



**Fig. 3**

## TESTING PROPERTIES

Professionals who work with metals are concerned about the reliability of those metals. Welders and welding engineers, for example, need to know how welding materials will perform under various stresses and loads. These characteristics are determined by the properties of the materials used and by the welding techniques used to join the pieces. Welding technicians perform various tests on materials and on welding structures to discover this information.

Three kinds of tests used by welding technicians are the **impact test**, the **tensile test** and the **guided bend test**. In general these tests are described by their names. The impact test involves dropping something onto a sample, the tensile test involves stretching the sample and the guided bend test involves bending the sample. The test results are reported in professional publications. Welding engineers and others involved in materials science consult these publications to check the characteristics of various metals.

### APPLYING WHAT YOU KNOW

Based on the information above, label the test each drawing depicts. Then describe a test you performed in Workshop 2 or 3 that was similar to the illustrated test. Tell why you think the tests are similar.

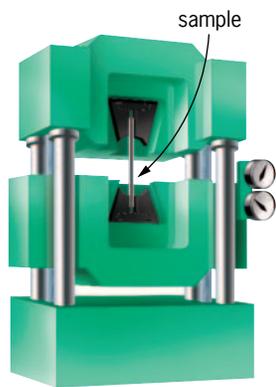


Fig. 1 \_\_\_\_\_ test.

\_\_\_\_\_ test.

This test is similar to \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Fig. 2 \_\_\_\_\_ test.

\_\_\_\_\_ test.

This test is similar to \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

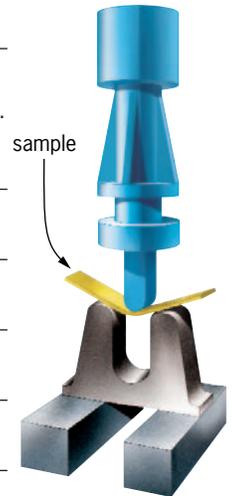


Fig. 3 \_\_\_\_\_ test.

This test is similar to \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

### CONCLUSIONS & INFERENCE

For each of the following items, identify which of the tests described and illustrated above was probably necessary in determining the material and the construction techniques

used for the item. Explain your thinking. a) stapler, b) metal coat hanger, c) industrial chain, d) automobile bumper, e) file drawer handle.

## 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:

- 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
- 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.
- 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.

## JOINING MATERIALS

Most functional objects are made of two or more pieces that are joined. Some functional objects do, however, consist of one piece. Cooking pans and molded wrenches are two examples. Also, some nonfunctional sculpture is made of joined pieces. Methods of joining pieces to make an object include gluing, screwing, nailing, bolting, riveting and welding.

Engineers consider many factors when they are making design decisions about how an object will be constructed and they particularly consider how pieces will be joined. They choose materials and methods of joining that will provide the greatest safety, economy and durability.

### APPLYING WHAT YOU KNOW

1. Look at the diagrams. For each, write "joined" or "not joined" to indicate whether the object is one piece or is made of joined parts. Then write one kind of load and the major kinds of stress each object has to withstand. Draw an arrow to show where each stress takes place. Label your arrows.



Fig. 1

Fig. 1 Joined? \_\_\_\_\_

Load \_\_\_\_\_

Stress \_\_\_\_\_



Fig. 2

Fig. 2 Joined? \_\_\_\_\_

Load \_\_\_\_\_

Stress \_\_\_\_\_

Fig. 3 Joined? \_\_\_\_\_

Load \_\_\_\_\_

Stress \_\_\_\_\_

2. Name other one-piece functional objects that you commonly see.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

3. Name other objects you see around you that consist of two or more metal parts joined together. Describe the method of joining the parts and list one advantage of the method.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_



Fig. 3

### CONCLUSIONS & INFERENCES

John is in a hardware store. Is he likely to find one-piece objects or objects made of joined parts in the tools,

housewares, plumbing and cabinetry sections? Where will he find objects intended to be joined to other objects?

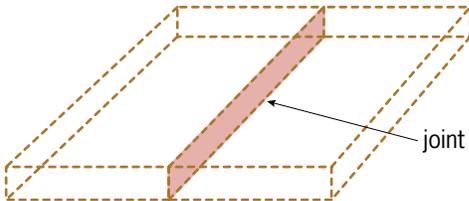
## MODELING AND BUILDING TO SPECIFICATION (page 1 of 2)

Skilled trades—welding, carpentry, masonry and plumbing—are very different fields that require specific skills and expertise unique to each trade. Yet these trades do have things in common. All use the five basic types of joints shown in Fig. 1. The type of joint used by a tradesperson is determined by the shapes of the pieces to be joined and the purpose of the joint. For example, if two pipes are to be joined to make a longer pipe, the choices are a butt joint or a lap joint. If a support for a shelf is being attached to a side, an edge joint would be a good choice.

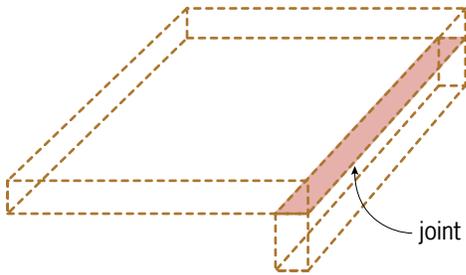
Another thing skilled trades have in common is strict quality specification requirements. All tradespeople must follow exact plans and their work is subjected to testing and inspection.

The use of models and modeling is also common among the trades. Modeling helps people understand problems and visualize possible solutions. It means creating a simpler version of a system. Today a great deal of scientific modeling is done by computer. However, sometimes building concrete models—that is, small, three-dimensional objects to represent larger objects made of different materials—can make it easier to see how parts within a system relate to one another. Models also make testing a structure possible in a much shorter time and at a much less cost than testing the actual structure. Engineers and others in the trades sometimes create models to aid them in making design decisions.

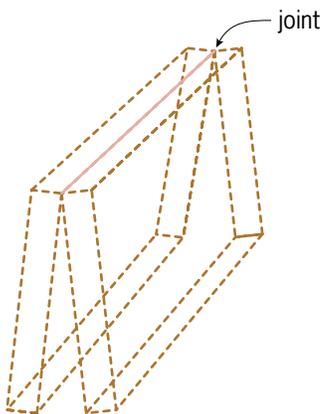
**Fig. 1 Five Basic Types of Joints**



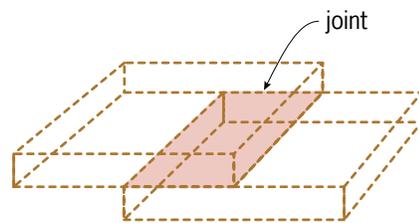
**A. Butt joint:** A joint between two pieces that are positioned in a more or less straight line on the same flat surface.



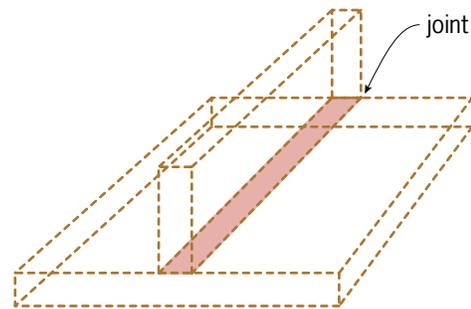
**B. Corner joint:** A joint between two pieces located at approximately right angles ( $90^\circ$ ) to each other.



**C. Edge joint:** A joint between the edges of two or more pieces that are parallel or nearly parallel.



**D. Lap joint:** A joint between two overlapping pieces.



**E. T joint:** A joint between two pieces located at approximately right angles ( $90^\circ$ ) to each other in the form of a T.

# MODELING AND BUILDING TO SPECIFICATION (page 2 of 2)

## APPLYING WHAT YOU KNOW

### Materials

2 balsa wood boards:  
 1 – 10 in. x 1 in. x 1/4 in. and 1 – 7 in. x 1 in. x 1/8 in.;  
 ruler; protractor; craft knife; wood glue;  
 wood filler; craft stick; fine sandpaper;  
 heavy magazine to protect work surface.

**Process:** Follow these steps.

 **Caution:** Craft knives are very sharp. Always cut away from the hand holding the wood.

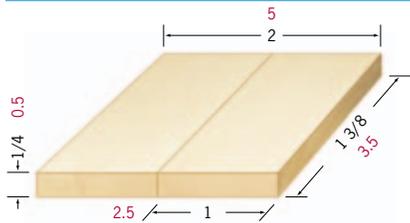


Fig. 2 \_\_\_\_\_

Example: \_\_\_\_\_

Specifications	Ck by	Ins by
1. Joined pieces correct measurements?		
2. Joint level and smooth? • top?		
• bottom?		
• ends?		
3. No visible gaps at joint?		
4. No excess glue visible?		

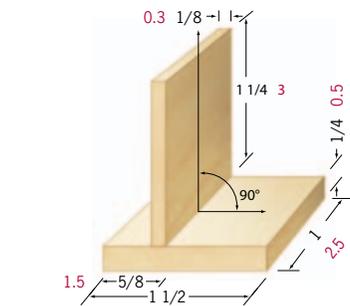


Fig. 3 \_\_\_\_\_

Example: \_\_\_\_\_

Specifications	Ck by	Ins by
1. Joined pieces correct measurements?		
2. Angle = 90°?		
3. Joint level and smooth? • sides?		
• ends?		
4. No excess glue visible?		

## CONCLUSIONS & INFERENCE

The earliest instance of welding seems to be in gold circular boxes made in Ireland more than 2000 years ago. What two types of joints are possible in a circular box? What type of joints

Study the diagrams of joints in Fig. 1 and the working drawings for joint models on this page. Label each joint on this page and list an example of this type of joint. Then build the models according to the specifications given. Note: All measurements are given in inches and centimeters. When a model is complete, have someone on your team check the items listed under the Specifications Check Chart for that model. If the model meets the specification, the checker (Ck) initials the item. When your team has completed its work, an inspector (Ins) from another team will inspect your models for the same specification items. **Save these models. You will need them in Workshop 12.**

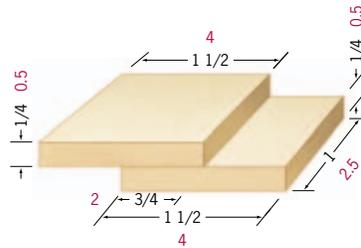


Fig. 4 \_\_\_\_\_

Example: \_\_\_\_\_

Specifications	Ck by	Ins by
1. Joined pieces correct measurements?		
2. Joint level and smooth on sides?		
3. No visible gaps at joint?		
4. No excess glue visible?		

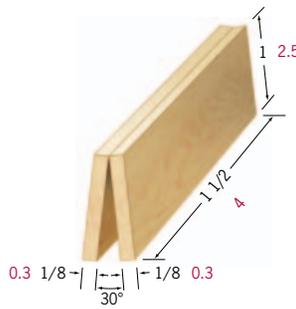


Fig. 5 \_\_\_\_\_

Example: \_\_\_\_\_

Specifications	Ck by	Ins by
1. Joined pieces correct measurements?		
2. Joint level and smooth? • top?		
• ends?		
3. No visible gaps at joint?		
4. No excess glue visible?		

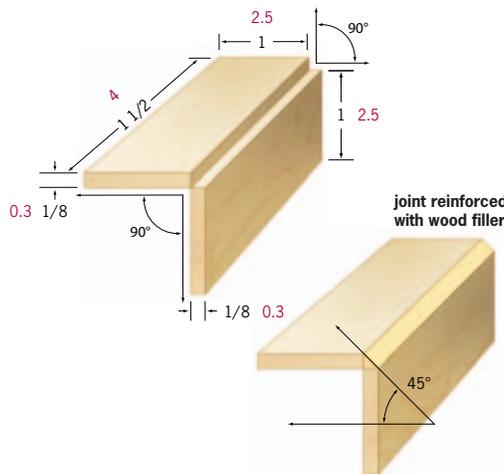


Fig. 6 \_\_\_\_\_

Example: \_\_\_\_\_

Specifications	Ck by	Ins by
1. Joined pieces correct measurements?		
2. Pieces joined along edge with no overlap?		
3. Unfilled angle = 90°?		
4. Filled angle = 45°?		
5. Inside joint smooth and even?		
6. Fill smooth and even?		
7. No excess glue, filler visible?		

must be present in a rectangular gold box? What types of joints are possible if two boxes were welded together to make a box with two compartments? Include sketches with your answer.

## 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 result 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.

## STRESS THROUGHOUT A STRUCTURE

Engineers design structures that can withstand the forces that will act on their parts. The towing bar on a tow truck must be able to withstand the tensile stress that results from pulling a car. The blade mechanism on a bulldozer must be able to withstand the compression stress that results from pushing against earth and heavy objects. Do you think loads applied directly to one part can affect other parts? For example, does stress on a bulldozer blade affect the joints holding it to the cab?

**Questions & Predictions** Predict and record answers to these questions. Observe and measure for Evidence & Proof below.

1. Can stress applied to the bottom of a glass affect the rim of the glass?
2. Do wood and metal react to stress about the same as glass reacts?

### EVIDENCE & PROOF

#### Materials:

drinking glass (made of glass);  
shirt button;  
thread;  
wood pencil or craft stick;  
solid metal strip or utensil;  
safety glasses;  
thick gloves

**Process:** Follow these steps. Compare your results with your predicted answers to the questions.



**Caution:** Wear safety glasses. Wear thick gloves when picking up the pieces of metal by their sharp edges.

1. Put the thread through two holes of the button. Hold the ends of the thread so that the button is suspended in air.
2. While your partner holds the glass firmly on the table, dangle the button until it is balanced on the rim of the glass. You do not need to let go of the thread. You do need to let the thread go limp. (See fig. 1)
3. While still holding the glass firmly so that it won't move, your partner should flick the glass near the bottom with his or her fingernail.
4. In the Fig. 2 box sketch the appearance of the button and glass after you have completed Step 3 of the process.
5. Use the button and thread to test how stress reacts in wood and metal. (i.e., Balance the button on the top of a pencil or craft stick. Holding the pencil firmly, flick it near the bottom with your fingernail. Repeat with the metal.)
6. Was the type of stress you tested compression stress or tensile stress? Why?

---



---



---



---

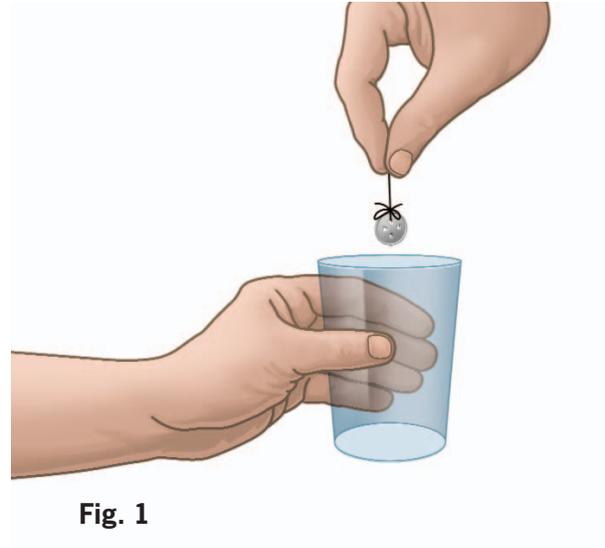


Fig. 1

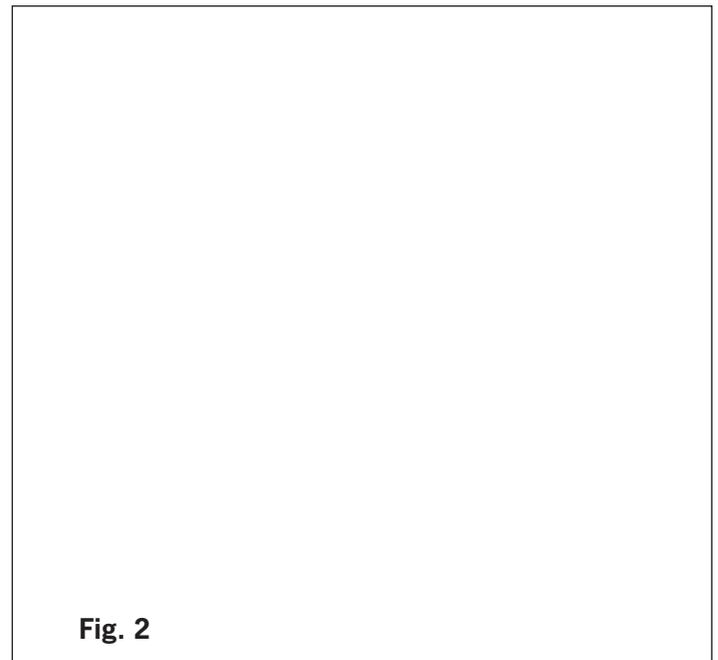


Fig. 2

### CONCLUSIONS & INFERENCE

Bridges are subject to constant vibrations. The vibrations exert stress on the bridge. Do engineers need to worry about

waves and currents in the river when they design the top of the bridge? Why?

## RELATING DESIGN TO STRESS (page 1 of 2)

Stress applied to only one point on an object causes stress throughout the object. The way a force travels through an object depends in part on the shape of the object. Before engineers can design a structure that will provide safe, reliable performance of its intended purpose, they must know how various materials formed or cut into different shapes will react in various conditions. Do you think small holes or notches made in a material make a difference in the overall way the material handles stress?

### EVIDENCE & PROOF

#### Materials:

6 balsa wood slats, each about 1/8 in. thick and about 1 in. wide and 12 in. long;  
 manual drill with a 3/8 in. bit; craft knife;  
 1 empty half-gallon drink carton, washed out, with the top cut off;  
 48 in. of heavy nylon cord;  
 masking tape;  
 balance scale;  
 about 1 cup of sand or salt;  
 safety glasses

**Process:** Follow these steps. Compare your results with your predicted answers to the questions.



**Caution:** Craft knives are very sharp. Always cut away from the hand holding the wood. Use drill with caution. Wear safety glasses

1. Draw lines 1 1/2 in. from both ends of all slats. Label A and B.
2. Draw two more lines on each slat, 1 1/2 in. inward from the first lines. Label these lines C and D.
3. On one slat, cut a V-shaped notch 3/8 in. wide and about 3/8 in. deep at line C. (See Fig. 1)

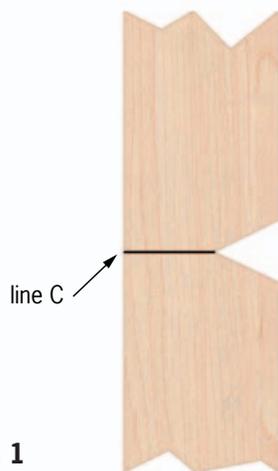


Fig. 1

**Questions & Predictions** Predict and record answers to these questions. Observe and measure for Evidence & Proof below.

1. Is a slat notched near one end able to resist the same amount of stress to its opposite end as an unnotched slat?
2. Is a slat with a hole drilled near one end able to resist the same amount of stress to its opposite end as an undrilled slat?
3. Is a drilled slat more able, less able, or equally able to resist stress as a notched slat?
4. On one slat, drill a hold at the center of line C. (See Fig.2)
5. Make a hanging bucket from the milk carton and cord: Poke holes in two opposite sides of the carton near the top. Thread the string through the holes and tie one end of the string securely to the other. Reinforce holes with masking tape.

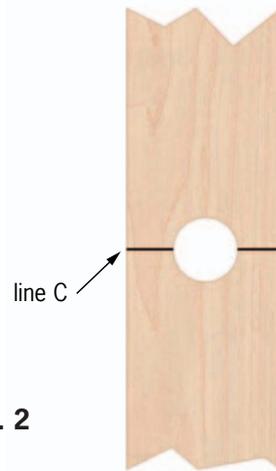


Fig. 2

6. Set up an unnotched, undrilled slat as shown in Fig. 3. Align slats so lines A and B are right at the edges of the desks. Tape in place. Hang the carton bucket from the slat. Place the string on line D. Tape lightly in place to avoid slipping. Be sure the bucket hangs free about 4 in. above the floor.

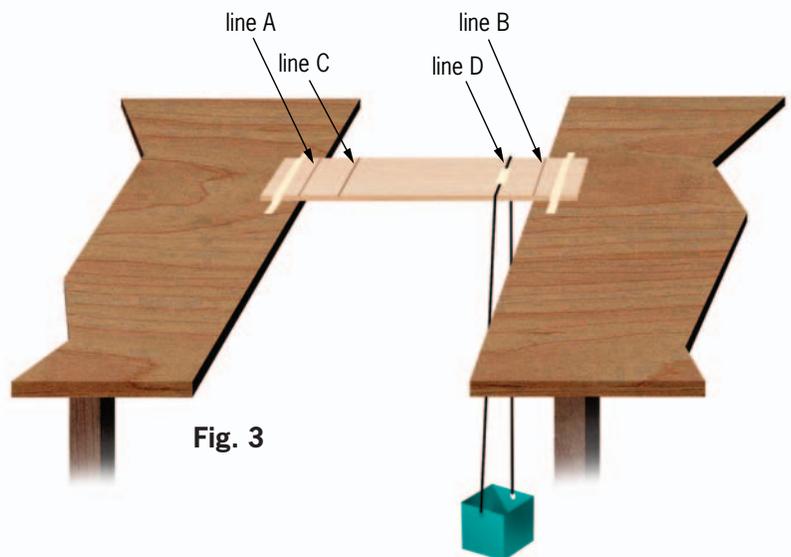


Fig. 3

**RELATING DESIGN TO STRESS** *(page 1 of 2)*

7. Without touching the milk carton, slowly pour sand or salt into the bucket until the slat breaks. Measure the mass of the bucket and sand. Record the mass in the Trial 1 row for an unchanged slat in the Data Table. Return the sand or salt from the milk carton to its container. Examine the broken stick. Measure and note in the Data Table where the break occurred.
8. Repeat Steps 6 and 7 with other undrilled, unnotched slat. Record the mass in the Data Table. Then find the average breaking mass by adding Trials 1 and 2 and dividing the sum by 2. Record your answer in the Average Mass column.
9. Repeat Steps 6-8 for the remaining slats.
10. Determine the best scale to graph your results. Use your scale and the information on your Data Table to complete the bar graph.

**Bar Graph: Average Breaking Mass of Slat**



**Data Table: Testing Shape for Resistance to Stress**

TRIAL	SHAPE	MASS	LOCATION OF BREAK POINT	AVERAGE MASS
1	unchanged			}
2	unchanged			
1	notched			}
2	notched			
1	drilled			}
2	drilled			

**CONCLUSIONS & INFERENCES**

Assume that notching and drilling have the same effects on steel as on wood. Rosa is an engineer. She is designing steel beams for an aviation museum. Life-size replicas of aircraft

will hang from these beams. Should she consider notching the beams to hold the support wires? What about drilling holes? Why or why not?

## THE MOVEMENT OF HEAT THROUGH MATERIALS

When you put food in a metal pan and place it on a stove burner to cook, you are acting on your knowledge of the conductive property of metal. Conductivity is the movement of heat through a material by means of the action of atoms that make up the material. Atoms in the heated end vibrate other nearby atoms, which in turn, vibrate other cooler atoms. The heat travels in this way from atom to atom. Metals conduct heat better than most nonmetals, but do all metals conduct with the same efficiency?

**Questions & Predictions** Predict and record answers to these questions. Observe and measure for Evidence & Proof below.

1. In what order would aluminum, copper, steel and brass be placed if they were ranked with the highest rate of conductivity as #1 and the lowest as #4?
2. Glass is also used for cooking. Does glass conduct heat more quickly than some materials? Which ones?

### EVIDENCE & PROOF

#### Materials:

small candle; matches; steel, copper, brass, aluminum and glass rods, each about 3/8 in. in diameter and about 6 in. long; 5 small, different-colored buttons; a metal bottle cap or jar lid; laboratory tongs; a steel-can tripod provided by your teacher; burner (or alcohol lamp); stopwatch, watch with second hand or watch or timer that displays seconds; graph paper or computer program with graphing capabilities; safety glasses; container of water

**Process:** Follow these steps. Compare your results with your predicted answers to the questions.



**Caution:** Tie back long hair; wear safety glasses. Keep a container of water nearby. Know the location of the fire extinguisher.

1. Hold the candle with the tongs. Have your partner light it. Allow the wax to drip into the cap or lid. Quickly dip one end of one of the rods into the melted wax and carefully, while the wax is still hot, place a button on the melted wax. (See Fig. 1) When the wax has hardened, make sure the button stays attached to the rod when you hold the rod horizontally. (See Fig. 2) Do this for each of the five rods. Blow out the candle.

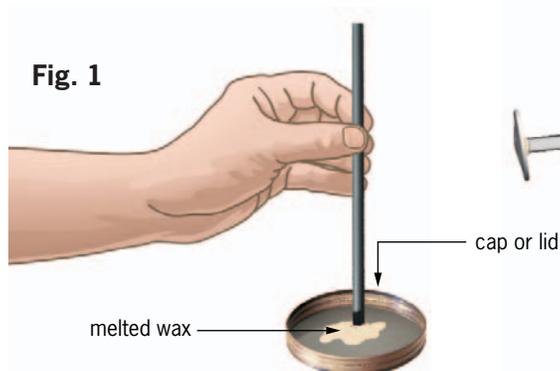


Fig. 1



Fig. 2

2. Place the five rods into the steel-can tripod as shown in Fig. 3. Make sure the rods inside the tripod are touching so that all are an equal distance from the flame. Make a chart showing the color of the button and the material of the rod to which that button is attached.
3. While your partner holds the stopwatch or timer, ready to start it, light the alcohol lamp and gently slide it under the tripod. Carefully, but quickly, move the lamp so that the tip of the flame is in the center of the pentagon made by the five rods. (See Fig. 3) When the lamp is centered under the rods, say, "Go!" Your partner should start the watch or timer.
4. Each time a button falls, call out its color. This is your partner's signal to note the time and call out the number of seconds that have passed. On your chart record the elapsed time next to the color of the button that fell.
5. Present your data in the form of a vertical bar graph. Label each bar with the name of the material. Label the y-axis "Time (Seconds)."

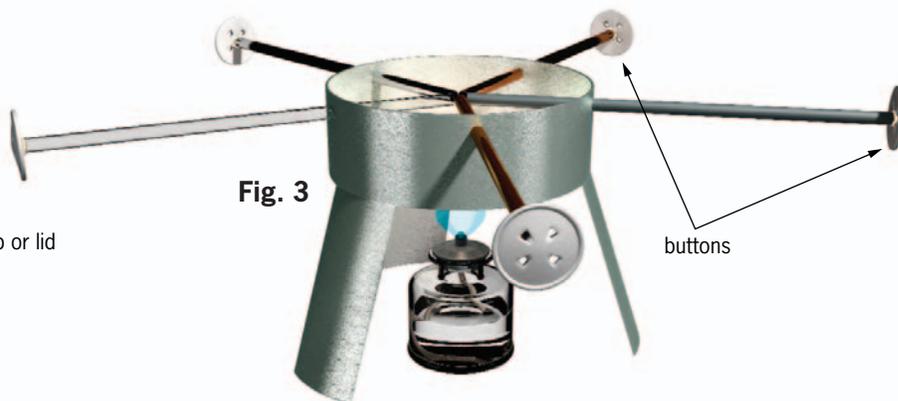


Fig. 3

### CONCLUSIONS & INFERENCE

Suppose that you are designing a variety of household items. For which of the following would you recommend using copper? The outside bottom of the cooking pan; the handle

for the cooking pan; a fireplace poker; kitchen tongs. Explain each of your answers.

## 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.)

## WELDING TO JOIN (page 1 of 2)

Welding is a widely used process for permanently joining metals and some kinds of plastic. Most of the more than 60 welding processes use heat. Some welding processes use heat and pressure.

Many welding processes involve fusion, or joining. Fusion welding melts the edges of the parts to be joined. When the melted metal cools and hardens, the two pieces are joined into one piece by the welded joint. This joint is usually as strong as any other part. Sometimes a filler metal is added to the weld

during the melting process. The filler fills in and adds strength to the joint.

Solid-state bonding is a category of welding that uses pressure and heat to join materials. Deformation bonding is a type of solid-state bonding that usually involves heating the pieces to be joined just below the melting point and applying enough pressure to create an atomic attraction between the pieces. The pressure also slightly deforms the joining edges.

### APPLYING WHAT YOU KNOW

#### Materials:

small candle; matches; steel, copper, brass, aluminum and glass rods, each about 1/4 in. in diameter and about 6 in. long; 5 small, different-colored buttons; a metal bottle cap or jar lid; laboratory tongs; a steel-can tripod provided by your teacher; burner (or alcohol lamp); stopwatch, watch with second hand or watch or timer that displays seconds; graph paper or computer program with graphing capabilities; safety glasses; container of water

**Process:** Follow these steps.



**Caution:** Tie back long hair; wear safety glasses. Keep a container of water nearby. Know the location of the fire extinguisher. Hot wax can burn, wear heat protective gloves.

1. Clear your work area and place the fireproof mat where you will work. Place two blocks of paraffin side by side as shown in Fig. 1. Push the blocks together tightly and evenly.
2. Light the candle and slowly and carefully run the flame along the top joint as shown in Fig. 2. Move the flame slowly enough to just melt the edges of the blocks and keep the candle tilted enough to allow the melted candle wax to drip into the seam.
3. Without touching the blocks, repeat the process at both side seams.
4. Blow out the candle. Allow the paraffin to cool for two minutes, then carefully and gently turn the blocks over. Repeat the process on the bottom seam.
5. Allow the paraffin blocks to cool for one minute, then carefully set aside to cool completely.
6. Place the second set of blocks side by side as shown in Fig. 1. Push the blocks together tightly and evenly. Open the C-clamps so that you can fit them quickly and easily over the blocks as shown in Fig. 3. Put the open clamps aside.
7. Hold the paraffin blocks with tongs as shown in Fig. 4. Have your welding partner stand ready with the C-clamps. Simultaneously, dip both blocks into the hot water so that the edges to be joined are below the surface but not touching the bottom. Wait 30 seconds.

8. Quickly remove the blocks, place them on the mat with edges to be joined touching. Help your partner quickly put the clamps in place and tighten them just until the wax at the joining edge begins to deform. Try to tighten both clamps evenly. Leave the clamps on until the block is totally cool.

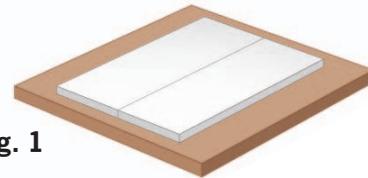


Fig. 1

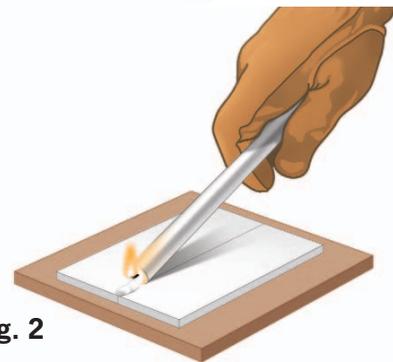


Fig. 2



Fig. 3

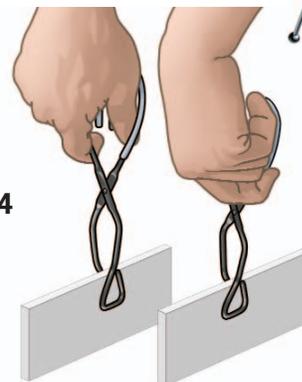


Fig. 4

## WELDING TO JOIN (page 2 of 2)

**Questions & Predictions** Predict and record answers to these questions. Observe and measure for Evidence & Proof below.

1. What welding process did you model in Steps 2-4? What key terms or phrases in the definition of the process actually tell you that Steps 2-4 model that process?

2. What welding process did you model in Steps 7-8? What key terms or phrases in the definition of this process actually tell you that Steps 7-8 model that process?
3. Predict whether the deformation bonding joint will show equal resistance, greater resistance or less resistance to an equal amount of tensile (pulling) force that the fusion joint will show. Record and explain your predictions.

## EVIDENCE & PROOF

### Materials:

candle in holder;  
heavy nail long enough to go through a paraffin block;  
metric ruler; several small weights,  
sinkers or heavy washers;  
balance scale; drink carton bucket used in Workshop 8;  
2 C-clamps; matches; fireproof mat; tongs;  
heat protective gloves;  
safety glasses; container of water

**Process:** Follow these steps. Compare your results with your predicted answers to the questions.



**Caution:** Tie back long hair; wear safety glasses. Keep a container of water nearby. Know the location of the fire extinguisher. Hot wax can burn, wear heat protective gloves.

1. Measure and mark a line 1 1/4 in. from the edge of one model. Draw an X at the center of the line as shown in Fig. 5. Repeat for the other model.
2. Light the candle. Use tongs to heat the nail as shown in Fig. 6. Still using the tongs to hold the nail, force the hot nail to make a hole in the blocks at the X's.
3. Clamp the fusion welding model to the back of a chair and attach the "bucket" by running the cord handle through the hole, as shown in Fig. 7.
4. Add small weights into the bucket, one at a time. Record the mass of each weight added. Continue until the joint breaks. Note the last amount the joint supported before it broke.
5. Repeat Steps 3-4 with the other model.

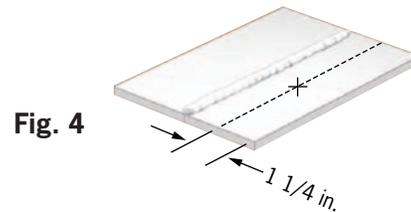


Fig. 4

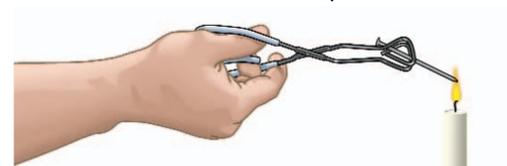


Fig. 5

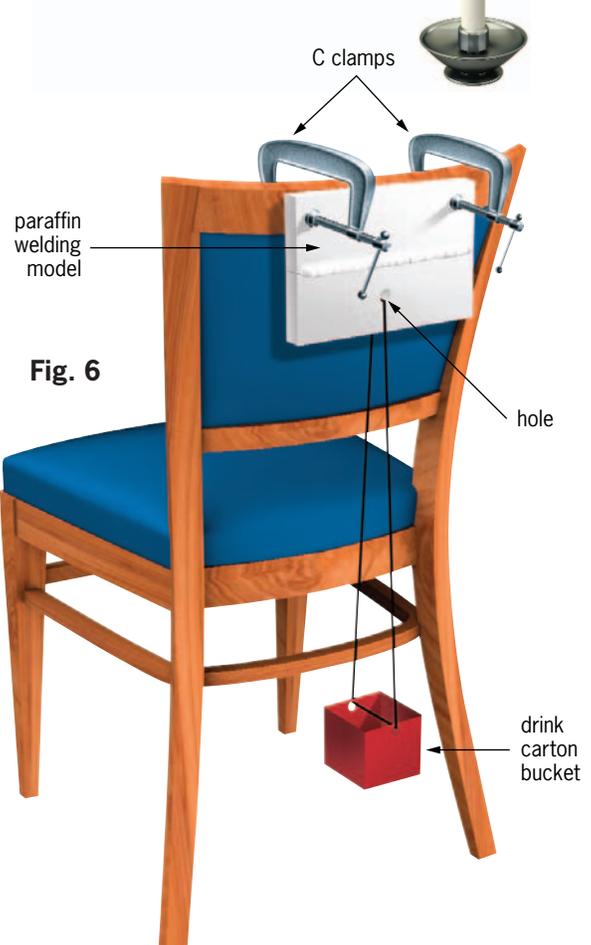


Fig. 6

## CONCLUSIONS & INFERENCE

Were your predictions correct? Why? If anything unexpected happened during your investigation, describe it and explain why you think it happened.

Do you think you can make dependable inferences about real metal welded joints from these wax models? Why?



## 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 them 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.

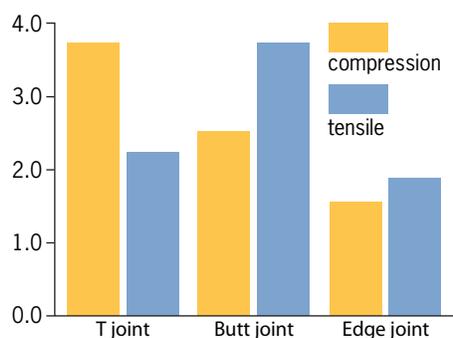
Spend some time discussing predictions. Make the point that science is as much about recognizing when one is wrong as about proving oneself right.

### 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.

## TEAMWORK: THE KEY TO TECHNOLOGY (page 1 of 2)

The image of scientists shutting themselves up in their labs to work in isolation on secret projects is for the most part a myth. On a day-to-day basis, scientists, engineers and technicians—such as welders—work as members of teams. Science and technology teams work at many tasks to provide a world to suit people's needs and wants. These tasks include research, design, craftsmanship, finance, manufacturing, management, quality control, marketing and service.

In scientific activity, the team's objective may be simply to gather information to help answer a specific question. In engineering, the objective may be to find a solution to a particular problem. A technical team's objective may be to produce a finished product that meets high standards. In all teamwork, the key to success is cooperation and respect for one another's ideas and abilities. Study after study shows that teams come up with better ideas than individuals working along.

### APPLYING WHAT YOU KNOW

In this activity, you will work with others as a team. Your team's mission is to plan, organize and carry out investigations to meet the following team objectives: Rank the five model joints constructed in Workshop 6 according to their ability to resist tensile (pulling) stress. (Rank the model with the ability to resist the most stress as #1.) Also rank the models according to their ability to resist compression (pushing) stress. Present your data in an easy to understand format.

**Process:** Follow these steps.

#### Step One: Think It Through

1. What investigations have you already done that allow you to measure, with reasonable accuracy, an object's resistance to tensile or compression stress?

---

2. How can you measure differences in ability to resist tensile stress in the model joints?

---

3. How can you measure differences in ability to resist compression stress in the model joints?

---

4. What materials will you need to carry out the investigation?

---

5. What safety equipment should be worn during the investigation? Why?

---

6. How can you clearly present the data you gather about compression and tensile strengths of the five joints?

---

#### Model joints from Workshop 6

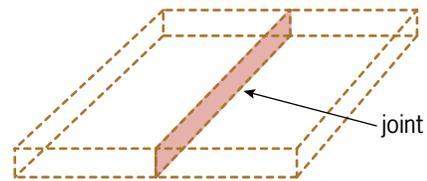


Fig. 1 Butt joint

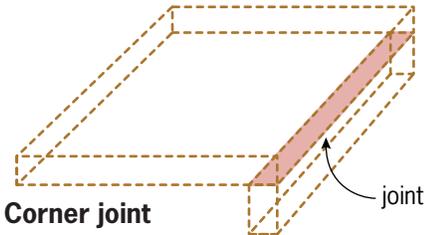


Fig. 2 Corner joint

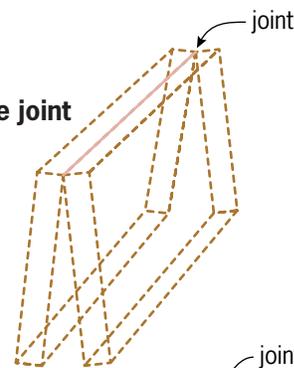


Fig. 3 Edge joint

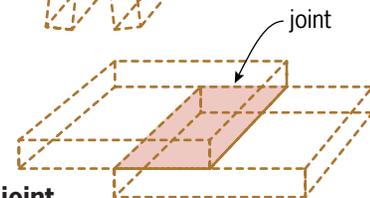


Fig. 4 T joint

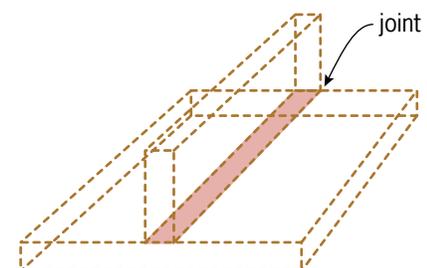


Fig. 5 Lap joint

## TEAMWORK: THE KEY TO TECHNOLOGY (page 2 of 2)

### Step Two: Predict What Will Happen

1. Of the five joints you constructed, which do you expect to have the greatest resistance to each kind of stress?

\_\_\_\_\_

The least resistance?

\_\_\_\_\_

2. Of the five joints you constructed, which do you expect to have similar compression strength?

\_\_\_\_\_

Tensile strength?

\_\_\_\_\_

3. Which of the joints, if any do you think will have the same rank in both tests?

\_\_\_\_\_

\_\_\_\_\_

### Step Three: Get Organized

1. What tasks must be performed to meet the team's objectives? (Example: design investigations, gather materials, conduct investigations, record data, analyze data, draw graph, write report clean up)

\_\_\_\_\_

2. What roll will each team member play?

\_\_\_\_\_

3. What is the project deadline?

\_\_\_\_\_

4. How much time will you allow for each task?

\_\_\_\_\_

5. Who has responsibility for making sure the team keeps on schedule?

\_\_\_\_\_

### Step Four: The Process

1. State specific questions that will give you answers to the questions in the team objectives. (Example: How much pulling mass can each joint resist before it breaks?)

\_\_\_\_\_

2. Check your investigation plans against these requirements for an accurate investigation:

- a. Items to be tested for various properties should be as similar as possible.

- b. Identical tests must be used to test various items for the same property.

- c. Information gathered must be expressed in terms of quantity or amount.

- d. Measurements must be carefully read and accurately recorded.

3. Carry out your investigation according to team plans, and assignments. Prepare your graphs, reports and so forth.

### Step Five: Review Your Work

1. Were your predictions correct? \_\_\_\_\_

Why? \_\_\_\_\_

\_\_\_\_\_

2. Did you meet each of the team's objectives? \_\_\_\_\_

Why? \_\_\_\_\_

\_\_\_\_\_

3. Did your team work successfully? \_\_\_\_\_

Why? \_\_\_\_\_

\_\_\_\_\_

4. If you were assigned a similar objective, what would you do differently?

\_\_\_\_\_

Why? \_\_\_\_\_

\_\_\_\_\_

### CONCLUSIONS & INFERENCES

Do you think that your team's ranking of the model joints could be applied to actual joints of the same type? Why? Do you think

that the benefits and problems your team experienced were similar to those experienced by actual technology teams? Why?

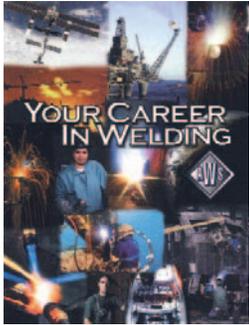
## WE NEED YOUR FEEDBACK!

Would you like to help improve future editions of Engineering Your Future? You can contribute valuable feedback by visiting [www.Weld-Ed.org](http://www.Weld-Ed.org) and clicking on the "Engineering Your Future" link. There you'll find six simple questions designed to improve the content and functionality of this resource.

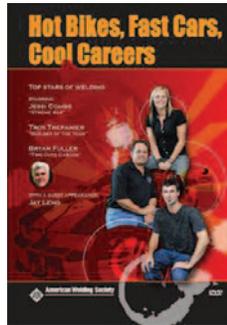
Your five-minute feedback could impact a career!

## ADDITIONAL CAREER RESOURCE PUBLICATIONS

NOTE: All of these FREE resources are located online at [www.CareersInWelding.com](http://www.CareersInWelding.com) under the "Welding Publications" link.



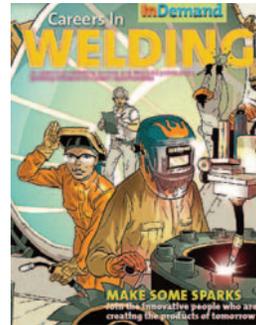
Your Career  
in Welding book



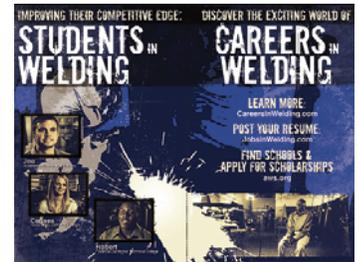
Hot Bikes, Fast Cars,  
Cool Careers DVD



Ironman comic book



Careers in Welding  
"In Demand" magazine



Students in Welding DVD

## CAREER RESOURCES ONLINE

[CareersInWelding.com](http://CareersInWelding.com)

[JobsInWelding.com](http://JobsInWelding.com)

[Weld-Ed.org](http://Weld-Ed.org)

[facebook.com/WeldEd.org](https://facebook.com/WeldEd.org)

[facebook.com/CareersInWelding](https://facebook.com/CareersInWelding)

[twitter.com/welded2](https://twitter.com/welded2)



Helmet postcard



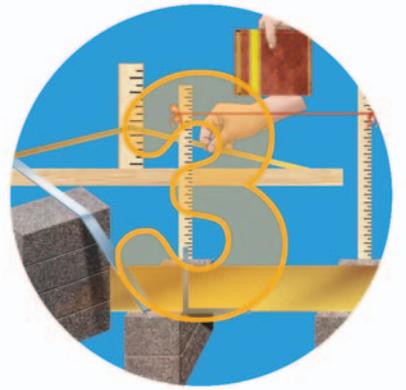
Torch postcard

## CAREERS IN WELDING MOBILE TOUR 2012



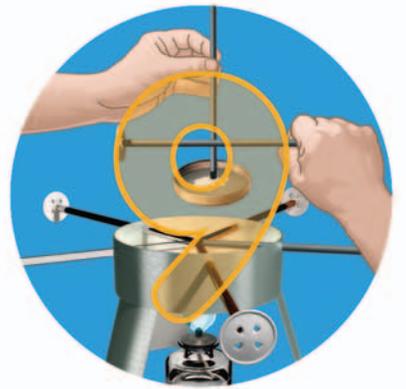
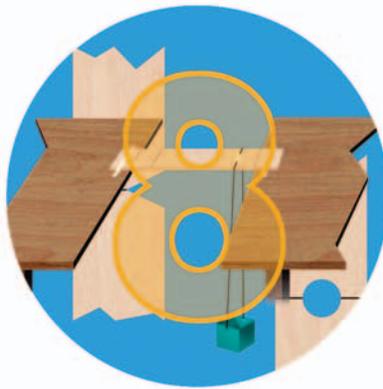
A nationwide educational outreach program that hits the road in 2012 to attract students and second-career adults to the many opportunities available in the welding field. The hands-on exhibit features interactive displays and

virtual reality arc welding simulators that enables the public to learn about the various career paths in welding. Track the tour at [www.explorewelding.com](http://www.explorewelding.com)



# ENGINEERING YOUR FUTURE

## TEACHER'S GUIDE



Weld-Ed Center • Lorain County Community College • 1005 N. Abbe Road • Elyria, OH 44035



American Welding Society



National Center for Welding Education and Training