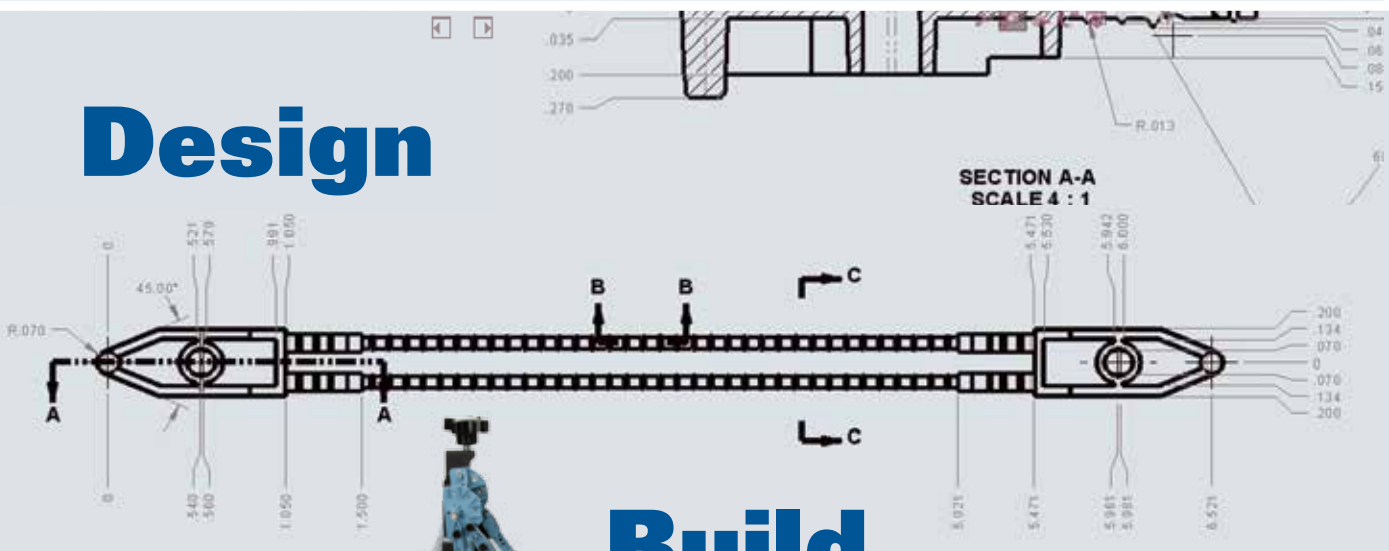


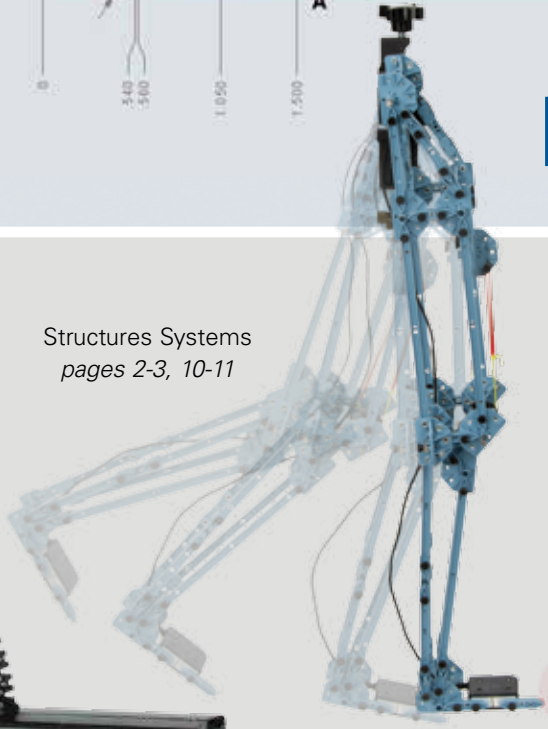


# Engineering Education

## Design



## Build



Structures Systems  
pages 2-3, 10-11

## Test



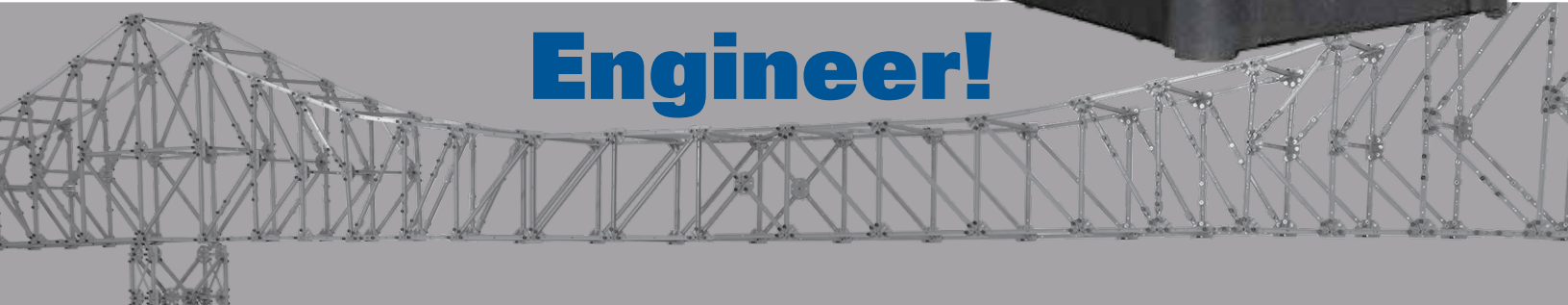
Materials Testing  
pages 4-9



Load Cells  
pages 3 and 10

## Iterate...

## Engineer!



# Design with PASCO Structures

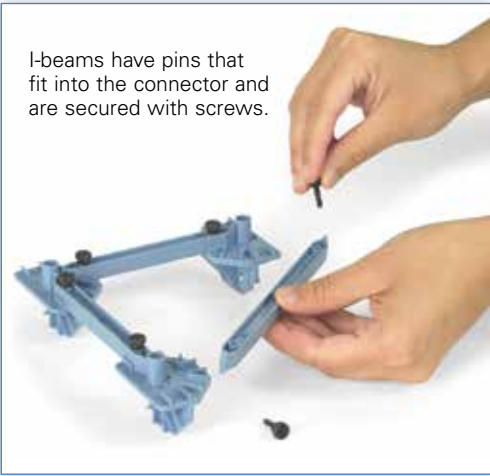
Use PASCO's Structures System as building blocks for your new designs.


- ▶ Build real-world structures.
- ▶ Measure loads anywhere in the structure.
- ▶ Students go beyond the basics and make their own designs.

Let your students' imaginations run wild with these simple I-beam building blocks. Unlike the toys sold by other companies, the PASCO Structures System has a great deal of flexibility, allowing students to expand on what they learn about basic structures. They learn about pinned connections and can actually measure the forces anywhere in their structures using our reusable load cells that can be moved to different locations.

Start with the Truss Set (ME-6990) with five different length I-beams and then graduate to a more advanced set, such as the Large Structures Set (ME-7003), which has different types of connectors that allow for angles other than 45 and 90 degrees, axles and wheels, and flexible I-beams. For complete information on the contents of kits, go to [www.pasco.com/trysttructures](http://www.pasco.com/trysttructures)

I-beams have pins that fit into the connector and are secured with screws.





**Order Information**

Truss Set.....	ME-6990
Bridge Set .....	ME-6991
Advanced Set.....	ME-6992B
Large Set.....	ME-7003
Human Set.....	ME-7001

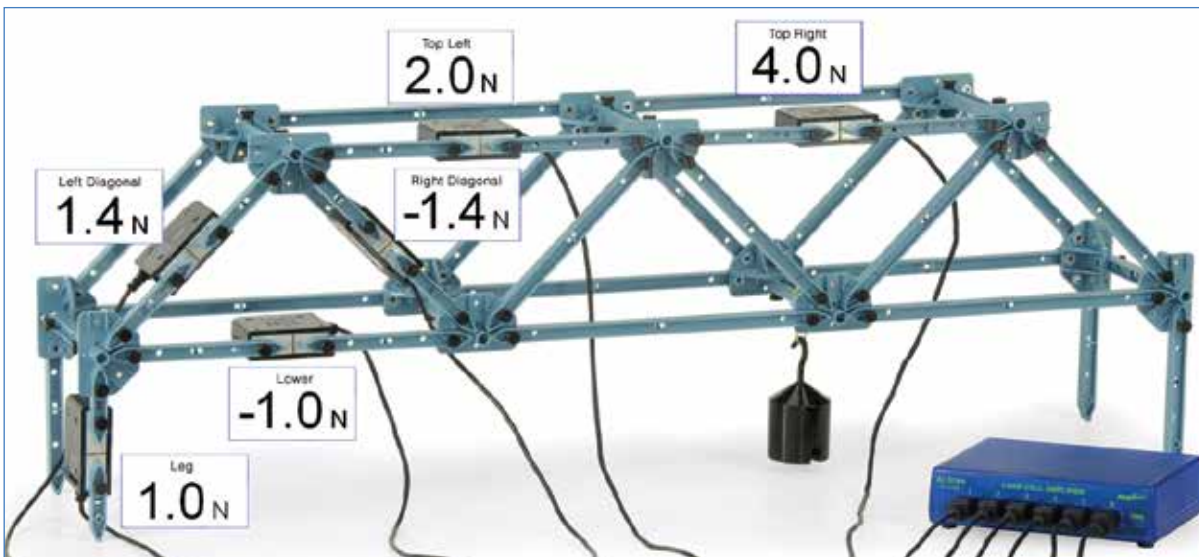
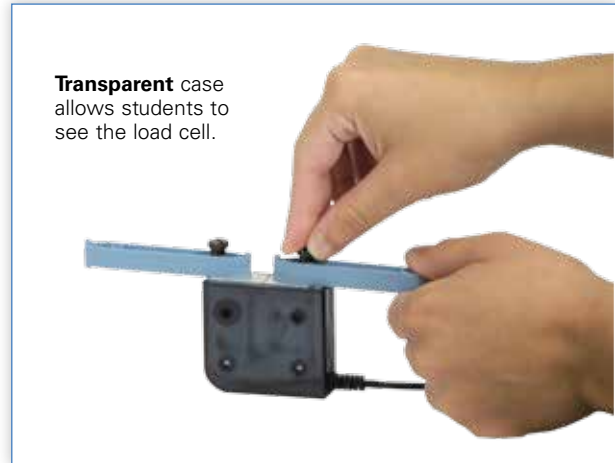
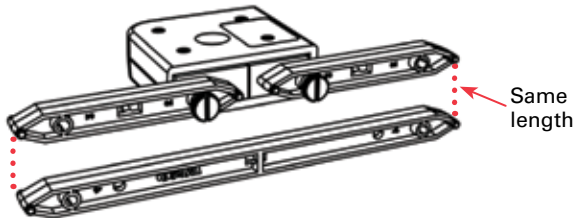
*For Load Cells, see next page.*

# Test with Load Cells

## Test the loads in your structure.

- ▶ Place the load cells at any location in your structure.
- ▶ Available in two ranges:  $\pm 100\text{ N}$  and  $\pm 5\text{ N}$

This system is designed so any single member can be removed and replaced with a load cell attached to two shorter members, making it possible to insert a load cell and move it around without having to rebuild.



The load cell readings are displayed in PASCO Capstone software. When all the screws in the bridge are loosened, the bridge connections rest on the I-beam pins and the resultant forces cancel at any point.



PS-2206 includes Dual Load Cell Amplifier and one 100 N Load Cell.



PS-2201 5 N Load Cell

PS-2200 100 N Load Cell



PS-2199 includes a 6-port Load Cell Amplifier and four 100 N load cells.

### Order Information

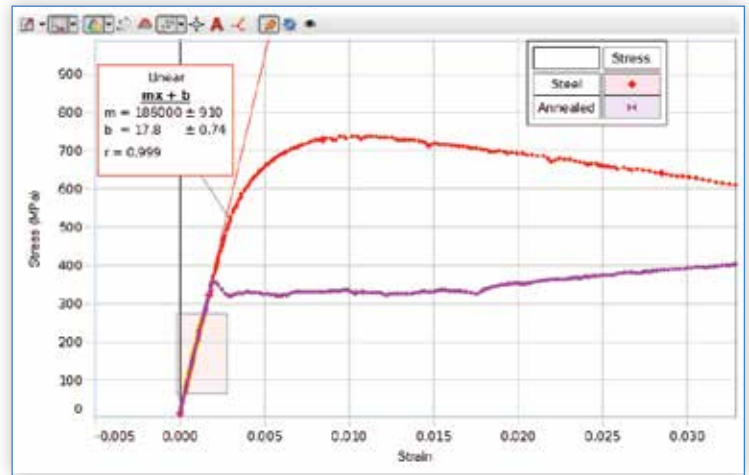
Load Cell and Dual Amplifier Set (includes 1 load cell).....	PS-2206
Load Cell and Amplifier Set (includes 4 load cells).....	PS-2199
<i>Required:</i>	
PASPORT Interface such as AirLink.....	PS-3200
PASCO Capstone Software Single License.....	UI-5401
<i>Recommended:</i>	
100 N Load Cell.....	PS-2200
5 N Load Cell.....	PS-2201
Hooked Mass Set.....	SE-8759

# Test with PASCO Materials Tester

## Test materials and beams using the PASCO Materials Testing System.

- ▶ Low cost and compact enough to fit into any lab
- ▶ Hand crank lets students feel the force.
- ▶ PASCO Capstone software is used to calibrate and measure.
- ▶ Adapters allow structures I-beams to be tested.

With the PASCO Materials Testing System, your students can test the tensile strength of the plastic materials used in making the I-beams in the PASCO Structures System, as well as testing bending and buckling of the I-beams themselves.



PASCO Capstone software is included for real-time display of data as it is collected. Here Young's Modulus for steel and annealed steel is found by taking the slope of a line.



An I-beam from the PASCO Structures System buckles as it is compressed in the Materials Tester.



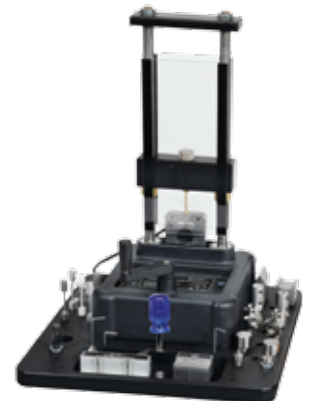
Stress lines show in a transparent I-beam made from an optically active plastic as it is compressed between two crossed polarizers.



A three-point bending test is performed on a plastic I-beam from the PASCO Structures System.



A concrete beam, simulated by pouring plaster of paris into a form with plastic rebar using the PASCO Structures Cast Beam Set, undergoes a bending test.



### Download 22 Free Materials Testing Labs at [pasco.com/testmts](http://pasco.com/testmts)

ME-8244 includes testing machine on storage base with accessories for tensile testing, three- and four-point bending, shear, compression, and photoelasticity, as well as tensile samples of various materials, flat coupons, and I-beam samples. For exact contents, see [www.pasco.com/testmts](http://www.pasco.com/testmts)

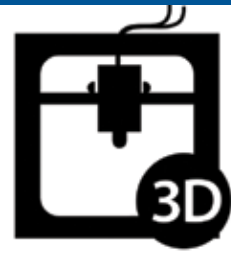
#### Order Information

- Comprehensive Materials Testing System..... ME-8244
- Materials Testing Machine ..... ME-8236

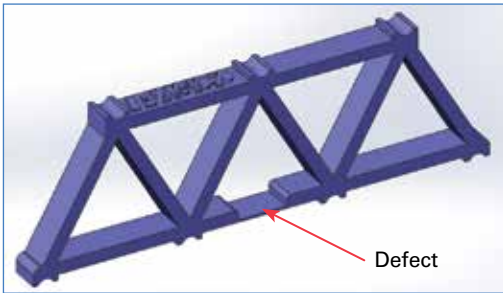
# Iterate Using PASCO 3D Files

Explore how defects affect strength: Modify our 3D files and 3D print your own structural components.

- ▶ Do It Yourself: Download free 3D designs at [pasco.com/freedy](http://pasco.com/freedy)
- ▶ Introduce defects and 3D print new structural components.
- ▶ Test defective trusses in the PASCO Materials Tester.



PASCO has made some of our designs available in the form of Solid Works™ and .stl files, so you can modify them and print them on your own 3D printer. This gives your students a starting point for their own investigations and new design ideas.



Truss with Intentional Defect



Regular I-beam from the PASCO Structures System



Truss with Support Points for PASCO Materials Tester



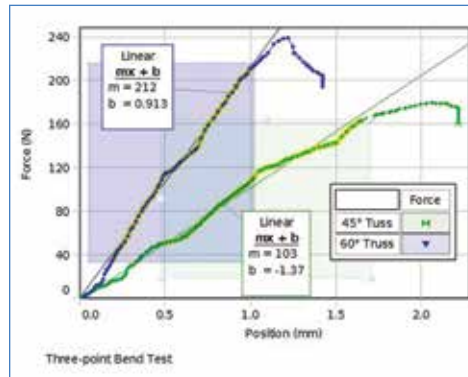
Rectangular Box Cross-section Beam



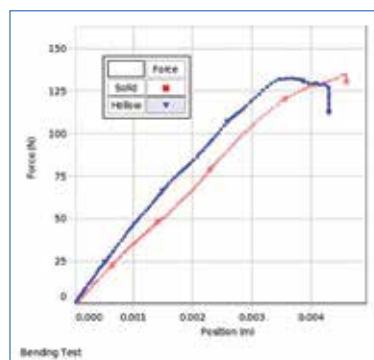
Do column buckling, 3-point bending, 4-point bending, tensile, and compression.



Truss Buckles under Compression in Materials Tester



Box Cross-section Beam Bends in Three-point Test



# Materials Testing System

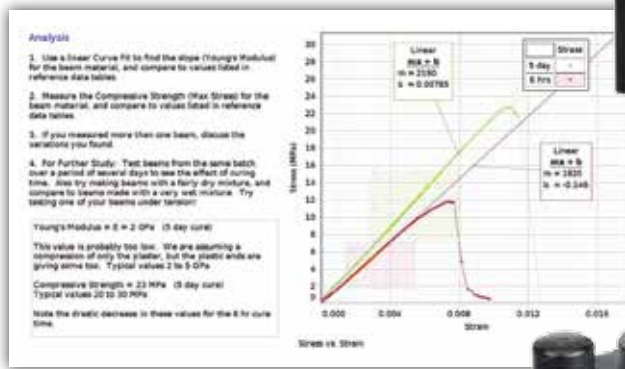
## Comprehensive Materials Testing System

With this one system, your students can investigate:

- ▶ Compression and tensile testing
- ▶ Column buckling
- ▶ Three- and four-point bending
- ▶ Shear testing
- ▶ Stress lines with photoelasticity

System includes everything needed to study material testing: Testing machine with attachments, test samples, and computer software. PASCO Capstone Workbooks include setup instructions, theory, and detailed analysis questions.

**Download 22 Free Materials Testing Labs at [pasco.com/testmts](http://pasco.com/testmts)**



## Comprehensive Materials Testing System Includes:

- Testing Machine (with Safety Shields and Calibration Rod)
- Tensile Samples (10 of each): Aluminum, Brass, Annealed Steel, Steel, Acrylic, Polyethylene
- Bending Accessory
- Four-point Bending Load Anvil
- Photoelasticity Accessory (with photoelastic beams)
- Shear Accessory (with Shear Samples)
- Storage Base
- Structures Beam Fixture
- Thin Beams
- Cast Spares
- Compression Accessory (with Compression Samples)
- Flat Coupon Fixture
- Plastic Flat Coupons
- Metal Flat Coupons
- Clevis Grip
- 10-32 Adapter
- USB Link
- PASCO Capstone Software Single User License

## Order Information

Comprehensive Materials Testing System ..... ME-8244

Clear Safety Shields

Tensile Samples

Three-point Bending

Four-point Bending

### System Storage Base

Sturdy plastic base provides convenient storage for accessories. Use a C-clamp on the corner of the base to temporarily secure the Materials Testing Machine to the lab bench.

Calibration Rod

Structures Beam Fixture

Clevis Grip

Flat Coupon Fixture

Compression Accessory

10-32 Adapter

Bending Support Anvil

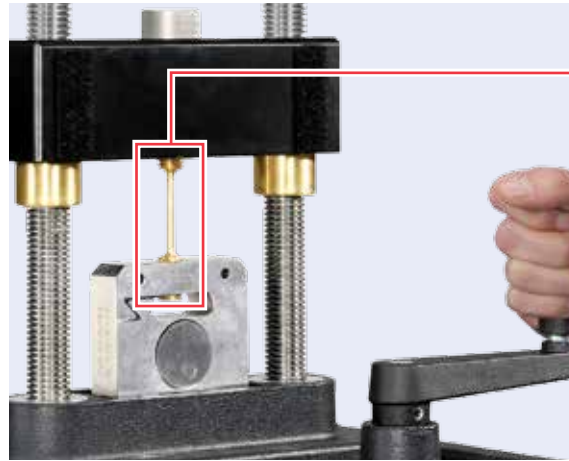
Shear Accessory

# Tensile Testing

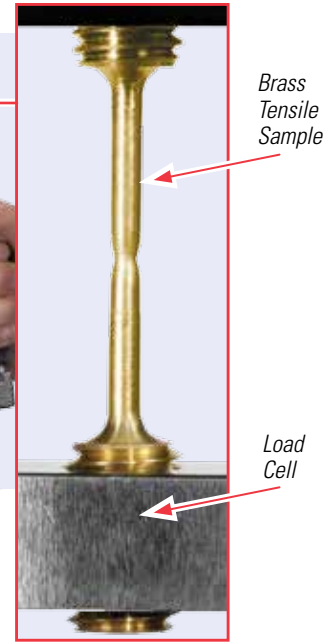
## Tensile Samples

Investigate material properties including:

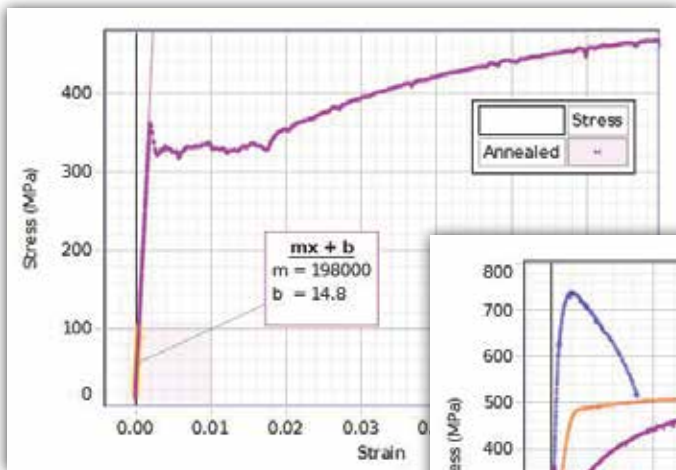
- ▶ Young's Modulus
- ▶ Tensile Strength
- ▶ Yield Strength
- ▶ Ductility
- ▶ Modulus of Resilience



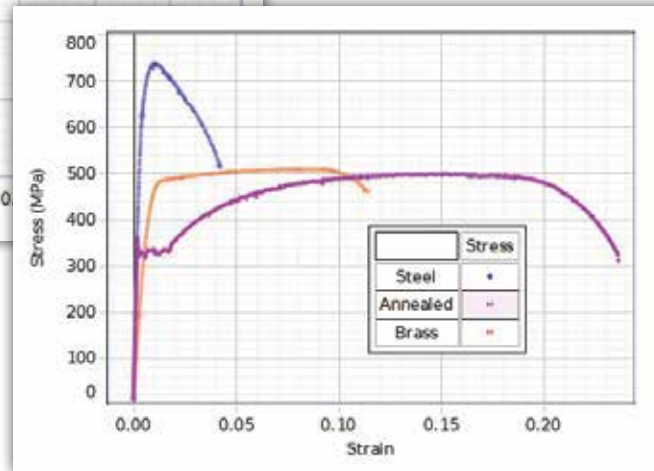
The deformation can be seen as the brass sample is stretched.



Detailed graphs in PASCO Capstone software allow students to investigate the material properties of various samples and measure Young's Modulus, as well as the Tensile Strength and Yield Strength for the material. The software is included in the Comprehensive Materials Testing System (ME-8244).

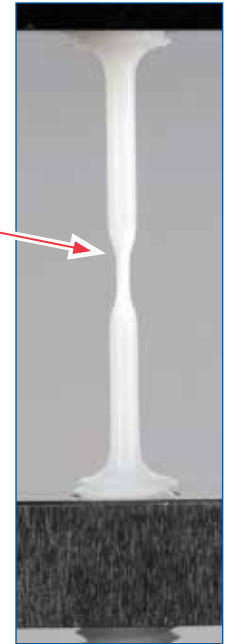


A linear fit is applied to find Young's Modulus for annealed steel.



Tensile stress versus strain is plotted in PASCO Capstone software for steel, annealed steel, and brass.

Polyethylene Tensile Sample



These "Tensile" samples can also be tested under compression. Measure the elastic modulus for both tension and compression. Investigate column buckling and the Euler Column Equation.

Measure the critical load needed to buckle the sample.

Tensile Samples (set of 10 each)



### Order Information

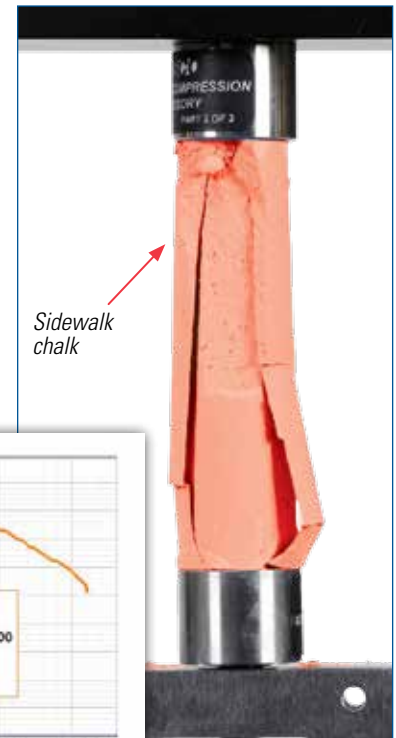
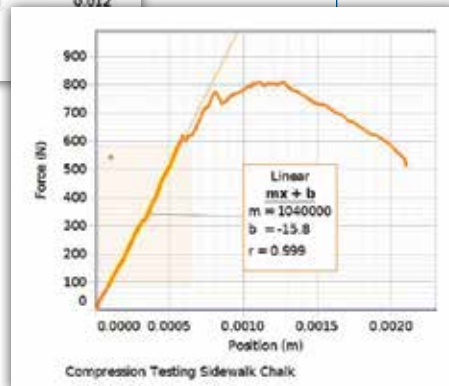
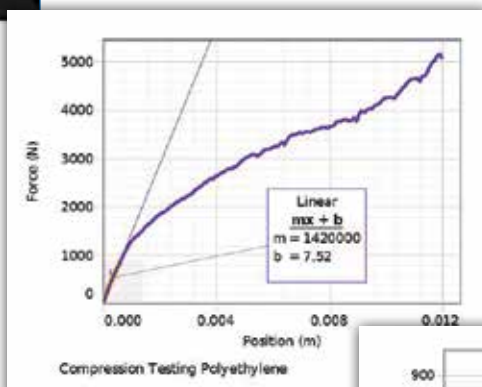
- Tensile Sample Aluminum (10).....ME-8231
- Tensile Sample Brass (10).....ME-8232
- Tensile Sample Annealed Steel (10).....ME-8233
- Tensile Sample Steel (10).....ME-8243
- Tensile Sample Acrylic (10).....ME-8234
- Tensile Sample Polyethylene (10).....ME-8235

All of these samples are included in the Comprehensive Materials Testing System (ME-8244).

# Design Iterate Build Test Engineer! Compression & Shear Testing

## Compression Accessory

This one-inch diameter platform provides a sturdy base to investigate compression of a variety of materials. It is shown here in a compression test on one of the included polyethylene test samples.



Compression test of "sidewalk" chalk.



Compression Accessory (ME-8247) includes the platform and 20 polyethylene cylinders (ME-8248), 1.3 cm dia. x 2 cm long.

ME-8247 is included in the Comprehensive Materials Testing System (ME-8244).

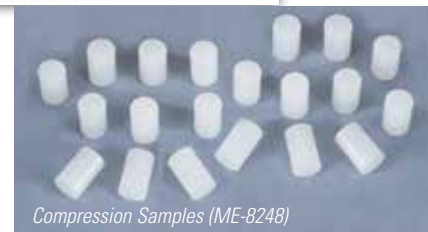
### Order Information

Compression Accessory.....ME-8247

Replacement Supplies:

Compression Samples (20).....ME-8248

(1.3 cm dia. x 2 cm long polyethylene cylinders)

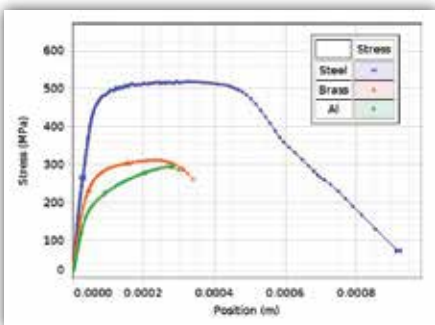


Compression Samples (ME-8248)

## Materials Shear Accessory

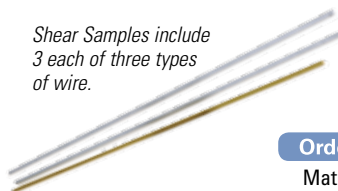
Perform shear tests for a variety of wires.

Accessory accepts diameters of 1/16", 3/32", 1/8", and 5/32". The Shear Accessory includes the ME-8240 Shear Samples, three each of 1/8" diameter, 12" long, aluminum, brass and mild steel.

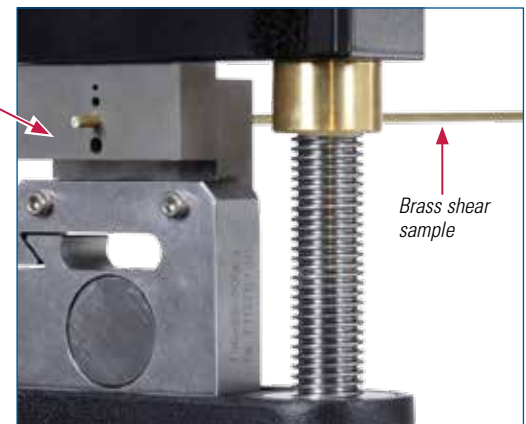


The PASCO Capstone graph shows shearing of steel, brass, and aluminum rods, all having an 1/8" diameter. The shear strength of each material is measured.

Shear Samples include 3 each of three types of wire.



Materials Shear Accessory



Shown shearing a brass wire..



Materials Shear Accessory (ME-8239) includes: Shearing Block and Shear Samples (ME-8240)

ME-8239 is included in the Comprehensive Materials Testing System (ME-8244).

### Order Information

Materials Shear Accessory.....ME-8239

Replacement Supplies:

Shear Samples (set of 9).....ME-8240



# Tensile Testing of Flat Samples

## Flat Coupon Fixture

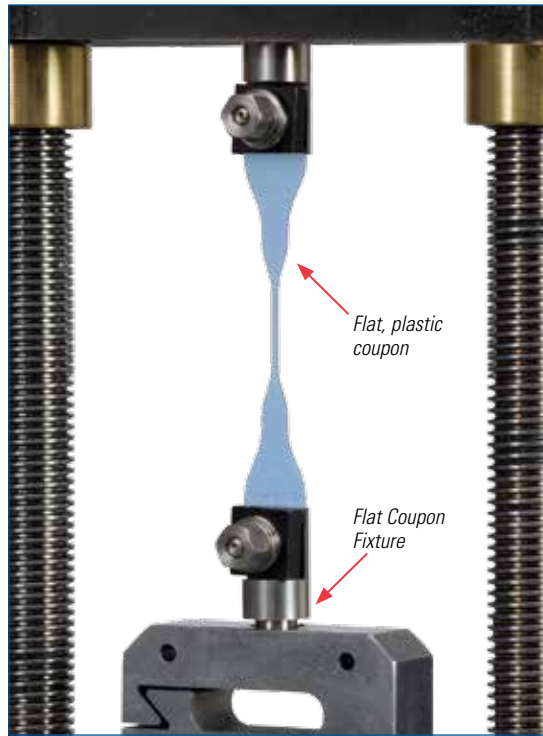
Tensile test any thin, flat material such as paper or foil. Designed to be used with the AP-8222 and AP-8223 flat coupons.



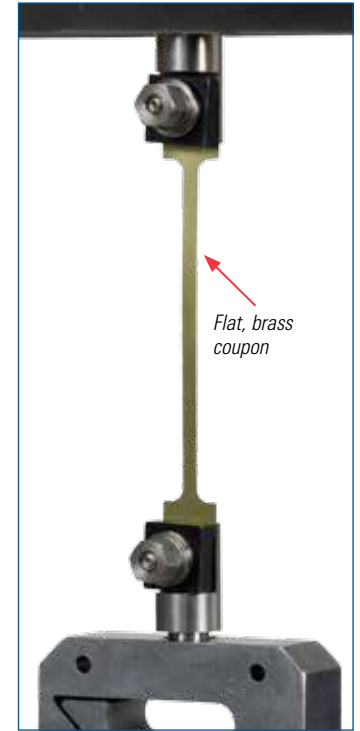
Plastic set (AP-8222)



Metal set (AP-8223)



Shown using the Flat Plastic Test Coupons (AP-8222).



Shown using the flat brass coupon from the AP-8223 Metal Set.



Flat Coupon Fixture (ME-8238) includes:  
Two clamps and a wrench

### Order Information

Flat Coupon Fixture.....ME-8238

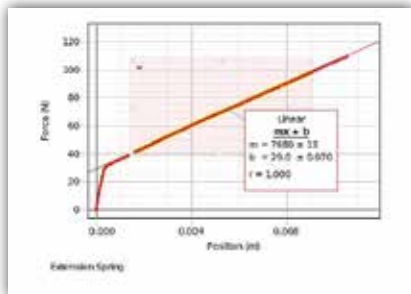
Plastic Test Coupons (40 coupons).....AP-8222

Metal Test Coupons (50 coupons).....AP-8223

ME-8238 and the test coupons are included in the Comprehensive Materials Testing System (ME-8244).

## Clevis Grip

This generic pin and clevis adapter allows the user to tensile test a wide variety of samples with hooked ends or through-holes. It is shown here testing an extension spring (not included).



Clevis Grip (ME-8245)  
Pin diameter is 0.187 in.  
Max width of sample is .300 in



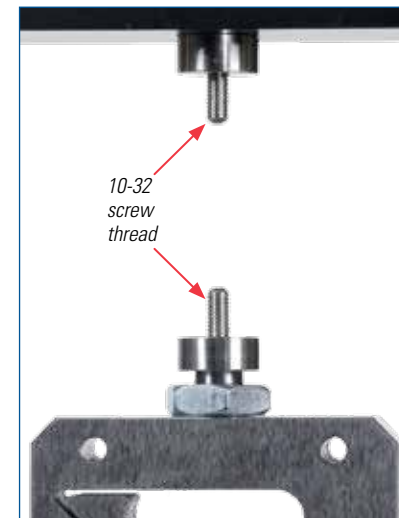
### Order Information

Clevis Grip.....ME-8245

Included in the Comprehensive Materials Testing System (ME-8244).

## 10-32 Adapter

Allows use of grips and attachments from other vendors that require a 10-32 male thread.



### Order Information

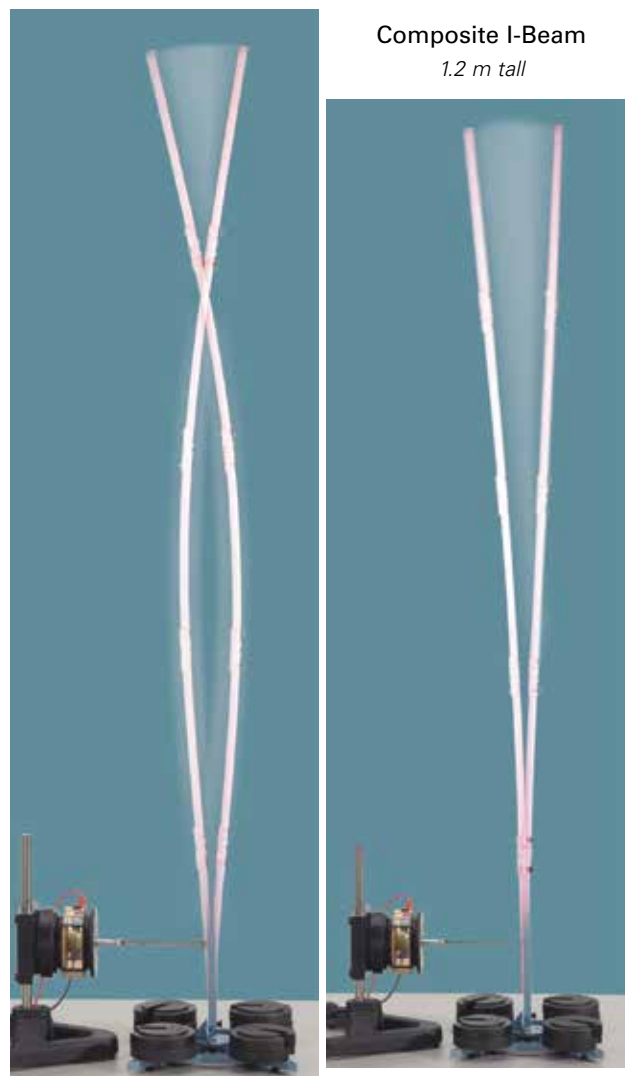
10-32 Adapter.....ME-8246

Included in the Comprehensive Materials Testing System (ME-8244).

# Shake Test with Mechanical Driver

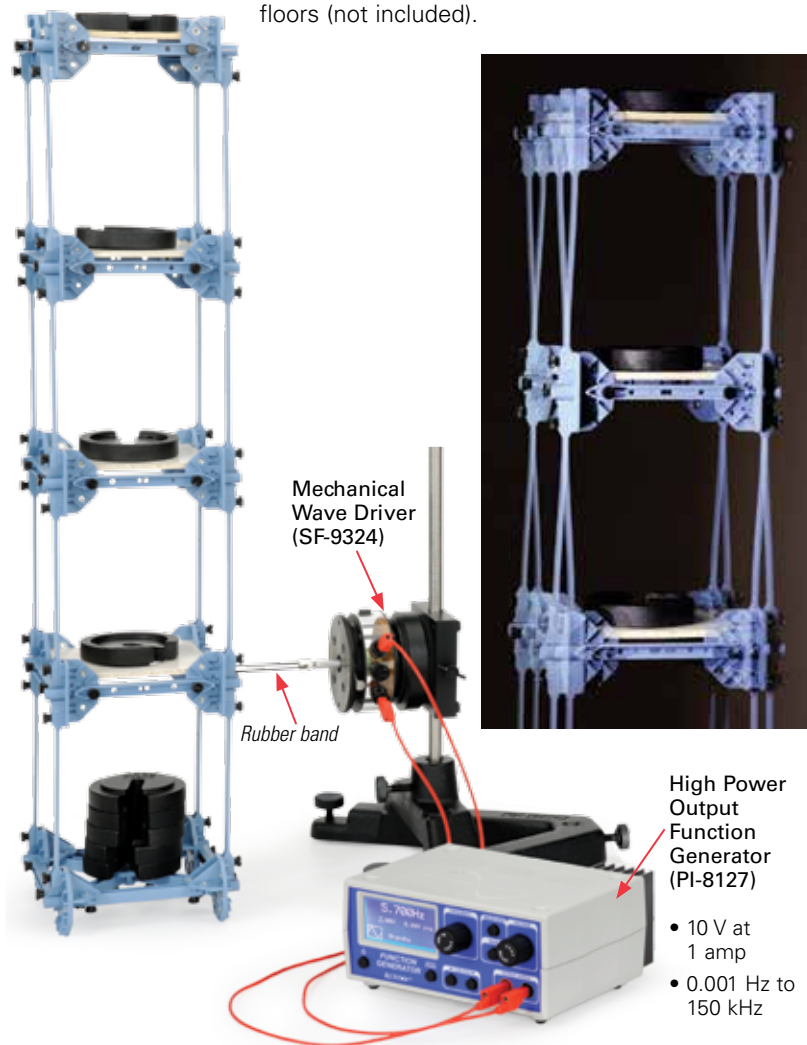
## Structures Resonance

PASCO's Structures System is perfect for demonstrating resonance in complex systems. The plastic I-Beams clearly show two different bending moments and can be connected together to build a variety of structures.



The long plastic I-Beam is constructed of components from the Advanced Structures Set. It is driven using the Mechanical Wave Driver and the Function Generator, demonstrating the harmonics.

**Shaking Tower**  
75 cm tall



Mechanical Wave Driver (SF-9324)

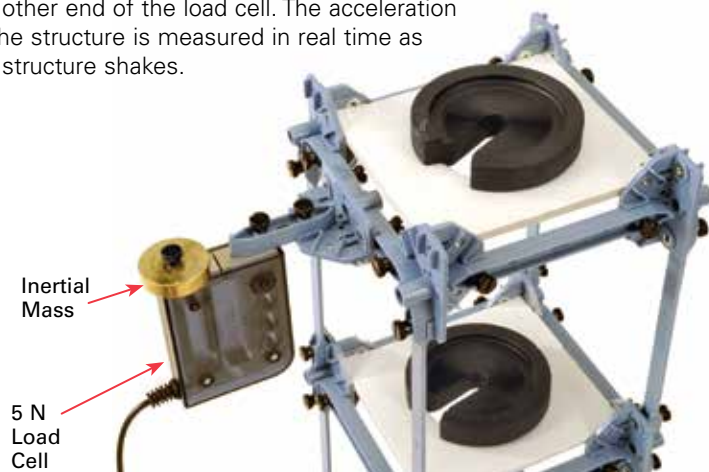
Rubber band

High Power Output Function Generator (PI-8127)

- 10 V at 1 amp
- 0.001 Hz to 150 kHz

## Measure acceleration with a 5 N Load Cell

Connect one end of a load cell to the structure and attach a mass to the other end of the load cell. The acceleration of the structure is measured in real time as the structure shakes.



### Order Information

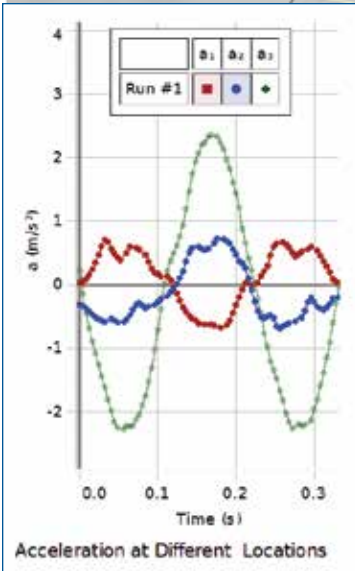
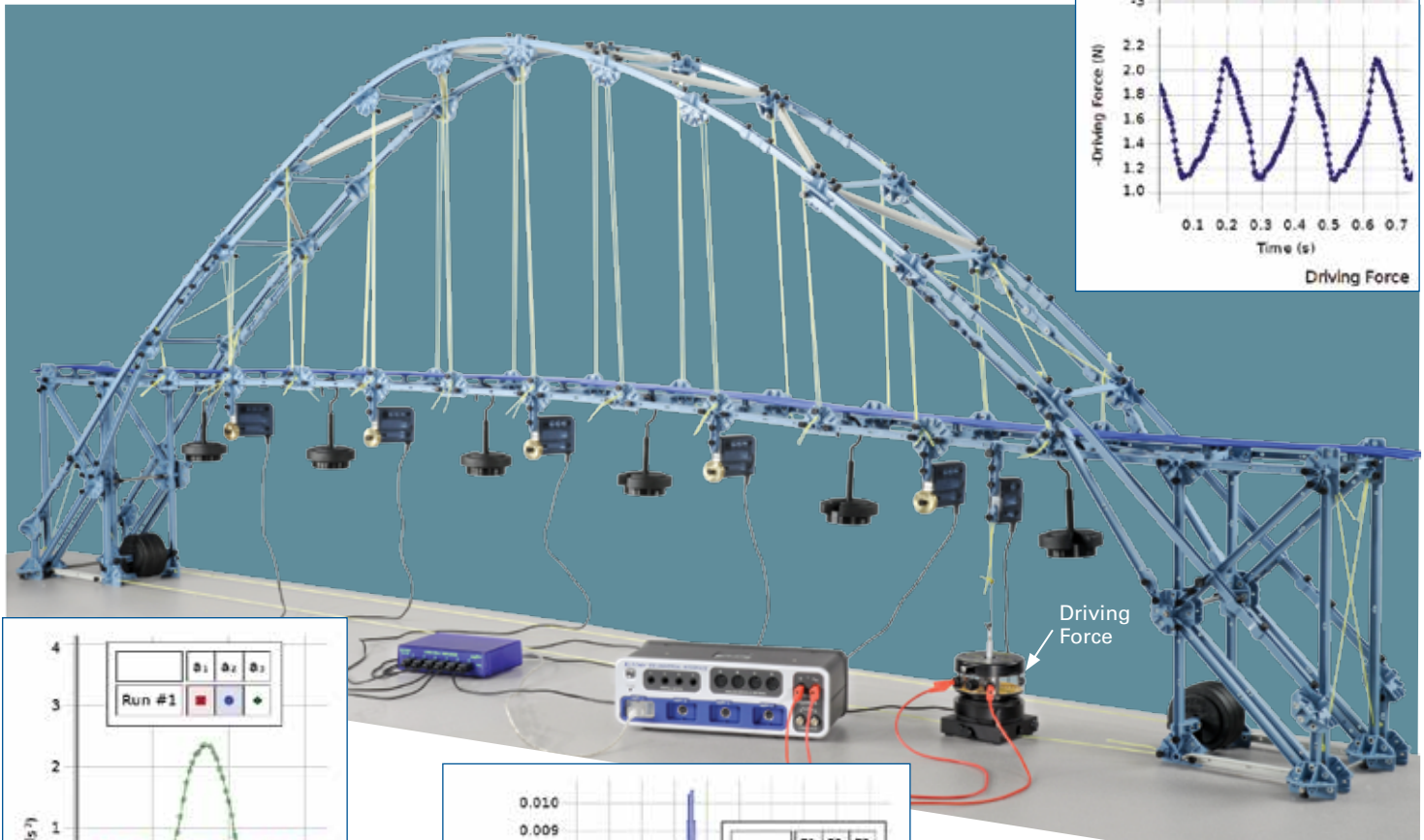
Advanced Structures Set .....	ME-6992B
Function Generator.....	PI-8127
Mechanical Wave Driver .....	SF-9324
Large Slotted Mass Set.....	ME-7566
5 N Load Cell.....	PS-2201
45 cm Stainless Steel Rod .....	ME-8736
Large Rod Base.....	ME-8735

# Test Vibrations with Load Cells

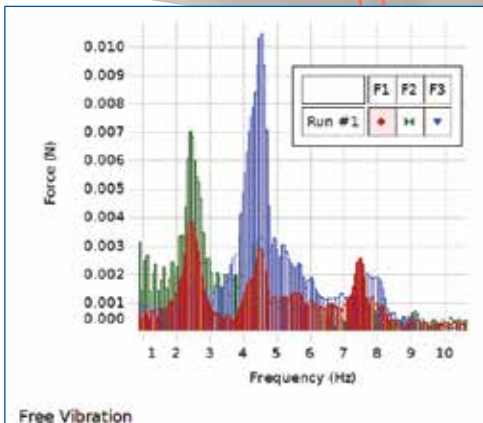
## Bridge Vibrations

### Concepts:

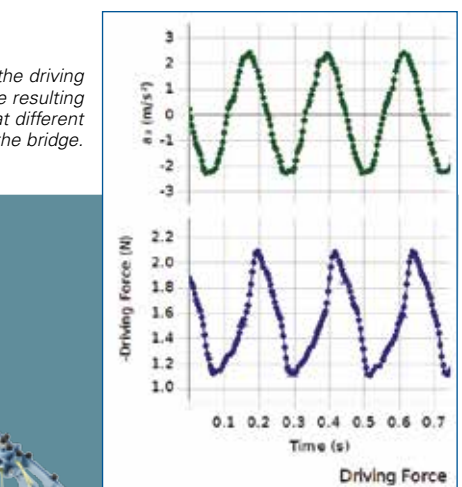
- ▶ Study resonance in complex systems
- ▶ Compare driven vs. free vibrations



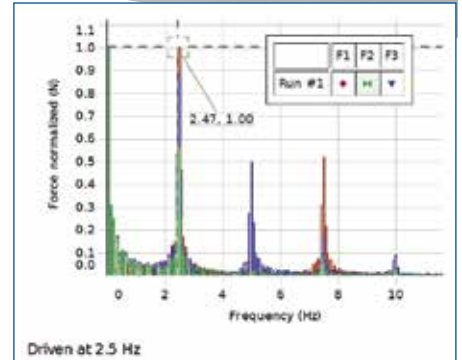
5 N Load Cells are used to measure the oscillations of the bridge at different positions.



The bridge is struck by hand and allowed to freely oscillate. The FFT (using PASCO Capstone) shows several resonant frequencies.



Compare the driving force to the resulting acceleration at different positions on the bridge.



The resonance of the bridge is characterized by driving the bridge at different resonant frequencies. Note how different the amplitudes are at different locations on the bridge.

### Download This Experiment

The FREE experiment files include instructions in Microsoft Word™, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at [www.pasco.com/freeCapstoneExperiments](http://www.pasco.com/freeCapstoneExperiments)

### Experiment Includes

Large Structures Set	ME-7003	4 mm Banana Plug Cords	SE-9750
Load Cell Amplifier	PS-2198	Rubber Cord	ME-8986
100 N Load Cell	PS-2200	Large Slotted Mass Set (4)	ME-7589
5 N Load Cell (5)	PS-2201	Short Mass Hanger (2)	ME-7590
Mechanical Wave Driver	SF-9324	20 g Masses (3 sets of 6)	ME-8983

### Order Information

Bridge Vibrations .....	EX-5548
<i>Required:</i>	
850 Universal Interface .....	UI-5000
PASCO Capstone Software Single License .....	UI-5401

# Design, Build, Test, Iterate... Engineer!

Have a 3D Printer? Use our designs! Download at [pasco.com/freediya](http://pasco.com/freediya)



#### Giant Demonstration Smart Cart:

3D print a big facade that snaps onto a Smart Cart to give you an operational giant Smart Cart. For more information, go to [pasco.com/gosmartcart](http://pasco.com/gosmartcart)



#### I-Beam for PASCO's Structures System:

Print your own variation of our design and test it in your structure. See page 5.



#### Truss:

Change angles and thickness in these small trusses designed to undergo a three-point or four-point bending test in the PASCO Materials Tester. See page 5.

