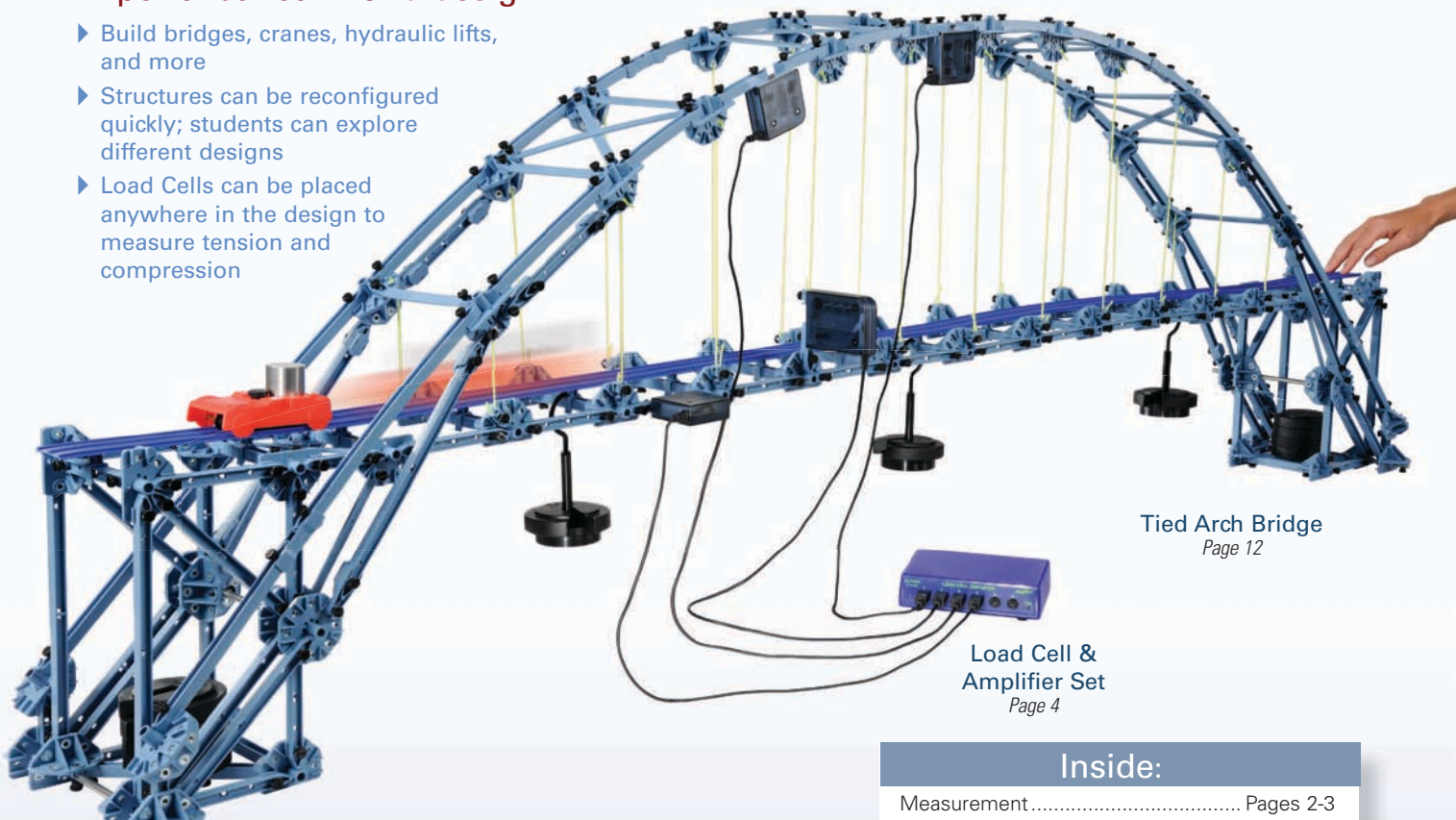


# STRUCTURES SYSTEM

## Imagine • Design • Build • Measure • Analyze

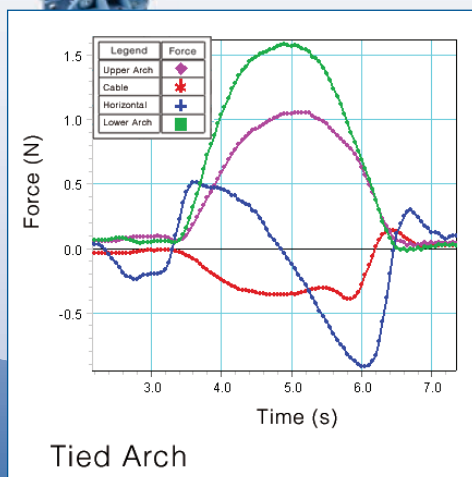
### Experience real-world design

- ▶ Build bridges, cranes, hydraulic lifts, and more
- ▶ Structures can be reconfigured quickly; students can explore different designs
- ▶ Load Cells can be placed anywhere in the design to measure tension and compression



Tied Arch Bridge  
Page 12

Load Cell &  
Amplifier Set  
Page 4



The PASCO Capstone™ graph shows changes in the compression and tension in the supporting members as the car traverses the bridge.

### Inside:

Measurement .....	Pages 2-3
Load Cells .....	Page 4
Truss Set .....	Page 5
Bridge Set .....	Pages 6-7
Advanced Set .....	Pages 8-9
Classic Statics .....	Page 10
Human Structures .....	Page 11
Large Structures Set .....	Page 12
Physics Structure Set .....	Page 13
Hydraulics .....	Page 14
Cast Beams .....	Page 15
Destructible Bridge Members .....	Page 16
Force and Displacement .....	Page 17
Bridges with Rigid Roadbeds .....	Page 18
Structures Resonance .....	Pages 19-21
National Instruments Structures .....	Page 21
Replacement Spares Sets .....	Pages 22-23

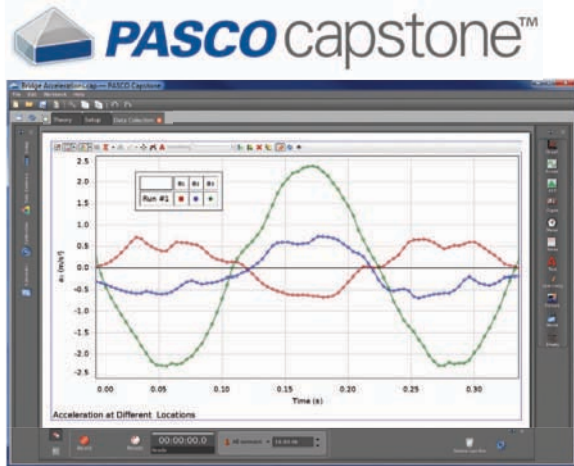
## 2 Data Acquisition and Display

### PASCO's All New Data Collection and Analysis Software

#### PASCO Capstone™ Software

- ▶ Compatible with All PASCO USB Interfaces

Whether you want your students to explore and create lab write-ups on their own, or you want to tailor a lab write-up with very specific instructions, PASCO Capstone™ has the power and flexibility to meet the needs of your lab.



**Order Information**

**PASCO Capstone Software**

Single User License..... UI-5401

Site License ..... UI-5400

For more information visit [www.pasco.com/capstone](http://www.pasco.com/capstone)

### Hand-held Computer with Interface

#### Xplorer GLX® PS-2002

- ▶ Built-in Voltage Sensor and two built-in Temperature Sensors, including probes
- ▶ Built-in speaker and microphone
- ▶ Dual Signal Generators
- ▶ Four PASPORT sensor ports
- ▶ Use as USB interface connected to computer
- ▶ Collect and analyze data away from the computer



**Order Information**

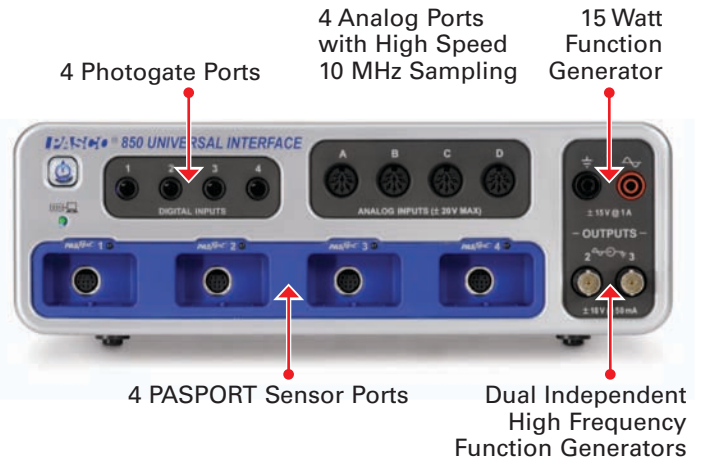
Xplorer GLX..... PS-2002

### It's fast! It's powerful! It's expandable!

#### 850 Universal Interface UI-5000

- ▶ Rugged Design
- ▶ Fully Compatible & Expandable
- ▶ An Incredible Value
- ▶ Runs on PASCO Capstone™

Introducing the most powerful educational lab interface in the world. Compatible with over 120 PASCO ScienceWorkshop® and PASPORT® Sensors.



**Order Information**

**850 Universal Interface ..... UI-5000**

For more information visit [www.pasco.com/850](http://www.pasco.com/850)

### Connect PASPORT Sensors to a Computer

#### USB Link PS-2100A

- ▶ Directly link one PASPORT sensor to a USB port
- ▶ Use multiple links for more sensors
- ▶ 1000 Hz maximum sampling rate with PASPORT sensors



**Order Information**

**USB Link ..... PS-2100A**

#### SPARKlink® PS-2009

- ▶ Two PASPORT sensor ports
- ▶ Simple USB connectivity to computer
- ▶ Built-in Temperature and Voltage Sensors with probes



**Order Information**

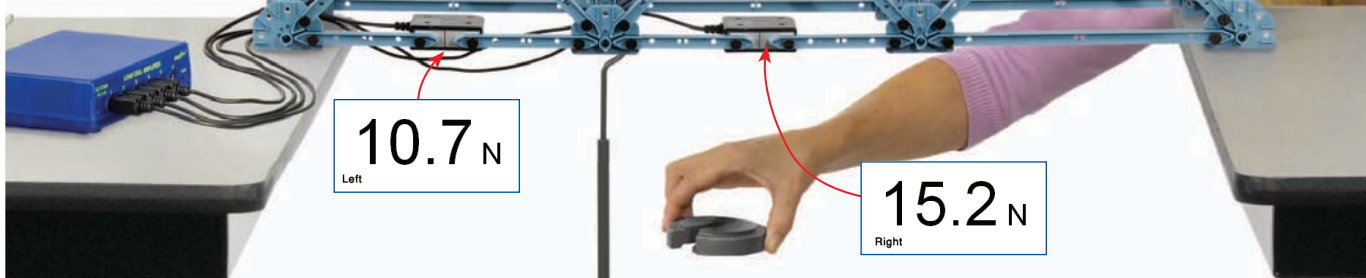
**SPARKlink..... PS-2009**

## Build bridges, cranes, catapults and roller coasters.

Experience real-world design building a large variety of structures. This reconfigurable system allows students to measure static and dynamic forces using load cells, and still have time to redesign and test again.

Numerical displays of load cell forces are generated in PASCO Capstone™ Software.  
(See page 2)

Load Cell & Amplifier Set  
(See page 4)

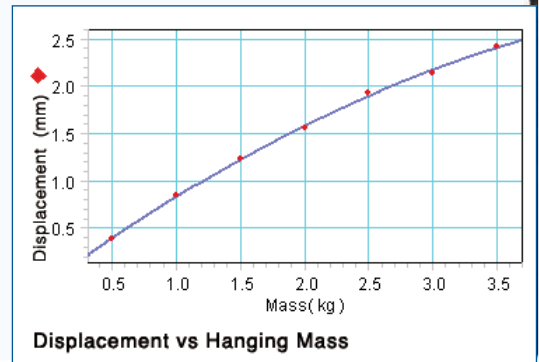


Xplorer GLX®  
Hand-held Computer  
(See page 2)

Large Slotted  
Mass Set

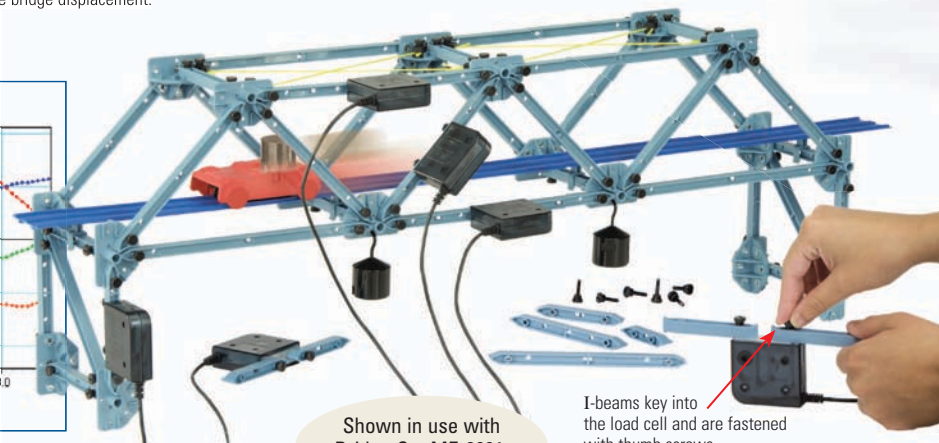
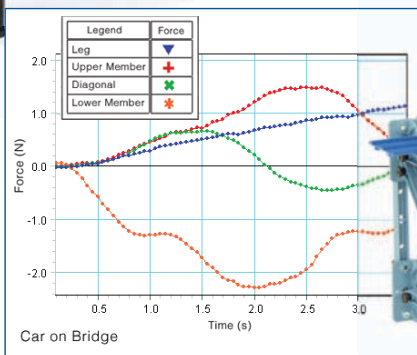


Graph shows displacement of bridge as a function of hanging mass.



Motion Sensor

Displacement of the bridge is measured by the Xplorer GLX and the Motion Sensor as the 1/2 kg masses are added to the mass hanger. See the PS-2204 Displacement Sensor (on page 17) for another way to measure bridge displacement.



Shown in use with Bridge Set ME-6991.  
(See pages 6-7)

I-beams key into the load cell and are fastened with thumb screws.

As the car crosses the bridge, the forces measured by each load cell are graphed in real-time in PASCO Capstone™. Notice the diagonal member (green trace) switches from compression to tension as the car passes by.



# 4 Load Cells and Amplifiers

## Choice of Load Cell Amplifiers:

### Load Cell Amplifier (6 ports)

PS-2198



This Load Cell Amplifier can accommodate up to six load cells and only needs a single PS-2100A USB Link (p. 2) to connect to the USB port on a computer. This is useful for doing an extensive analysis of a bridge by inserting six load cells at various points in the structure to see if theory matches reality.

The Amplifier accepts either the 100N load cell or the 5N load cell or a combination of both. The maximum data sample rate is 500 Hz for each port.

**Order Information**

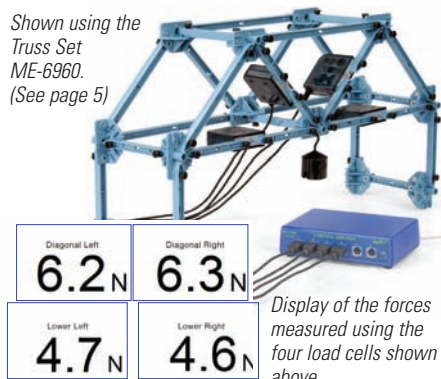
**Load Cell Amplifier (6 ports).....PS-2198**

*Required for Use:*

Load Cell 100N.....PS-2200

Load Cell 5N.....PS-2201

Shown using the Truss Set ME-6960. (See page 5)



Display of the forces measured using the four load cells shown above.

The top two numbers are the left and right diagonals and the bottom two numbers are the left and right horizontal forces.

**Also Available**

**Load Cell and Amplifier Set.....PS-2199**

**Set Includes**

- Load Cell Amplifier
- Load Cell 100N (qty 4)
- Instruction manual

### Dual Load Cell Amplifier

PS-2205



This Amplifier is for applications where only one or two load cells are needed, such as measuring the force on the track at the top of a roller coaster loop. If you only want to examine the forces in a bridge one at a time, you can move a single load cell around in the bridge.

The Amplifier accepts either the 100N load cell or the 5N load cell or a combination of both. The maximum data sample rate is 1000 Hz for each port.

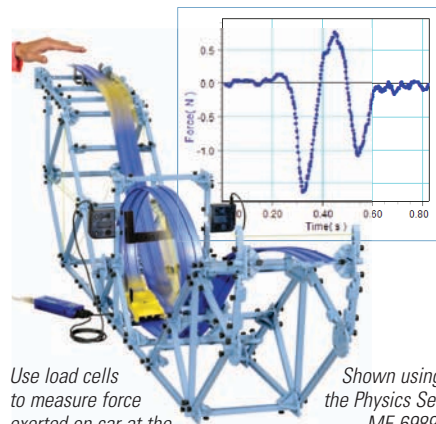
**Order Information**

**Dual Load Cell Amplifier.....PS-2205**

*Required for Use:*

Load Cell 100N.....PS-2200

Load Cell 5N.....PS-2201



Use load cells to measure force exerted on car at the top of the loop.

Shown using the Physics Set ME-6989. (See page 13)

**Also Available**

**Load Cell and Dual Amplifier Set.....PS-2206**

**Set Includes**

- Dual Load Cell Amplifier
- Load Cell 100N

### CI Load Cell Amplifier

CI-6464



This Amplifier allows users of the 850 Universal Interface and ScienceWorkshop Interfaces to collect data using the Structures System 100N and 5N Load Cells. This system has been successfully used at sample rates over 10,000 Hz.

A separate amplifier is required for each load cell.

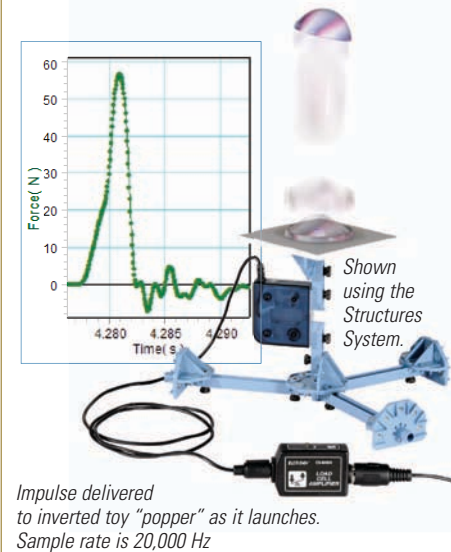
**Order Information**

**CI Load Cell Amplifier.....CI-6464**

*Required for Use:*

Load Cell 100N.....PS-2200

Load Cell 5N.....PS-2201



Shown using the Structures System.

Impulse delivered to inverted toy "popper" as it launches. Sample rate is 20,000 Hz

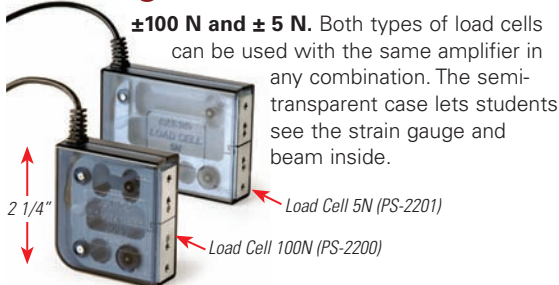
**Also Available**

**CI Load Cell and Amplifier Set.....CI-6465**

**Set Includes**

- CI Load Cell Amplifier
- Load Cell 100N

## Two ranges of Load Cells:



**±100 N and ± 5 N.** Both types of load cells can be used with the same amplifier in any combination. The semi-transparent case lets students see the strain gauge and beam inside.

### Load Cell 100N

PS-2200

#### Specifications (PS-2200)

- Range:** -100 N to +100 N
- Accuracy:** ±1% (± 1 N)
- Resolution:** 0.02 N
- Safe Overload:** -150 N to +150 N

**Order Information**

**100 N Load Cell.....PS-2200**

### Load Cell 5N

PS-2201

#### Specifications (PS-2201)

- Range:** -5 N to +5 N
- Accuracy:** ±1% (±0.05 N)
- Resolution:** 0.001 N
- Safe Overload:** -7.5 N to +7.5 N

**Order Information**

**5 N Load Cell.....PS-2201**

## Truss Set ME-6990

- ▶ Teach the basics of trusses
- ▶ Demonstrate the properties of I-Beams

Plastic I-Beams  
 Plastic Connectors  
 Steel Thumb Screws

Use the Truss Set to build a variety of structures to investigate the principles of trusses. The ABS plastic I-Beams fasten securely together using the provided connectors and thumb screws. Load cells can be inserted anywhere into the design by replacing one beam at a time. Students can load the truss by hanging weights.



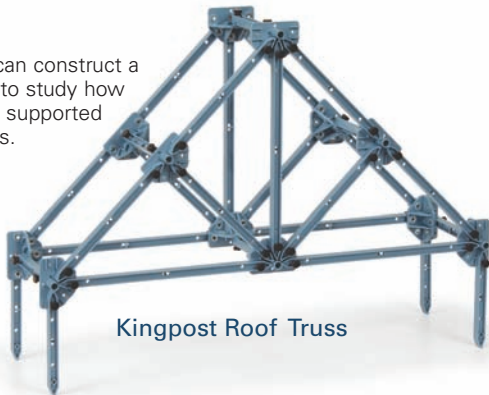
Measure the compression and tension in the I-Beam members by adding optional Load Cells.

Through Truss with Verticals

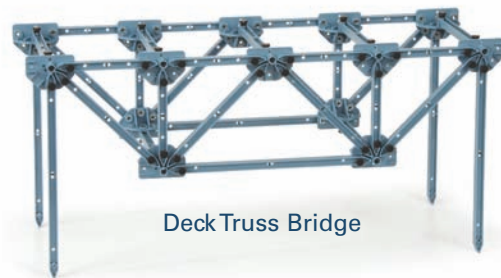


**Construction is easy:** I-Beams fit into the connectors and are secured with thumb screws. Thumb screws are also slotted so a screwdriver can be used.

Students can construct a roof truss to study how the roof is supported in buildings.



Kingpost Roof Truss



Deck Truss Bridge

### Truss Set Includes

One package each of Truss Set Members and Truss Set Screws  
 See pages 22-23 for details.

### Order Information

Truss Set .....ME-6990

#### Recommended

Load Cell & Amplifier Set  
 (includes four load cells).....PS-2199

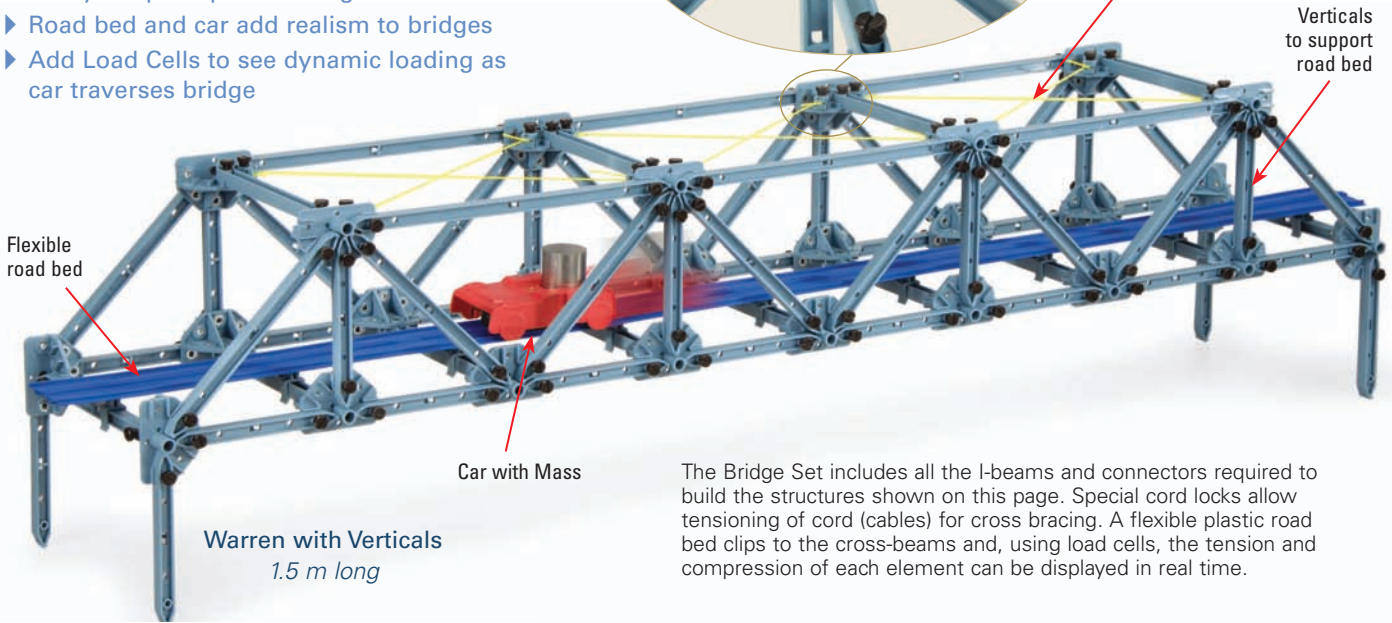


# 6 The Bridge Set

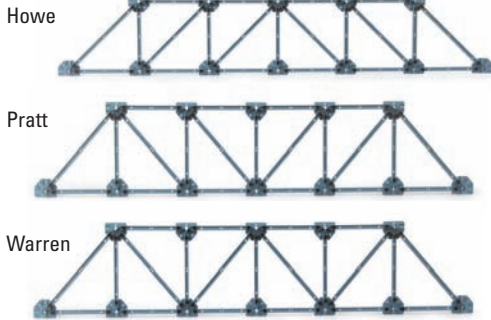
## Bridge Set ME-6991

- ▶ Study the principles of bridge construction
- ▶ Road bed and car add realism to bridges
- ▶ Add Load Cells to see dynamic loading as car traverses bridge

Flexible road bed



The Bridge Set includes all the I-beams and connectors required to build the structures shown on this page. Special cord locks allow tensioning of cord (cables) for cross bracing. A flexible plastic road bed clips to the cross-beams and, using load cells, the tension and compression of each element can be displayed in real time.

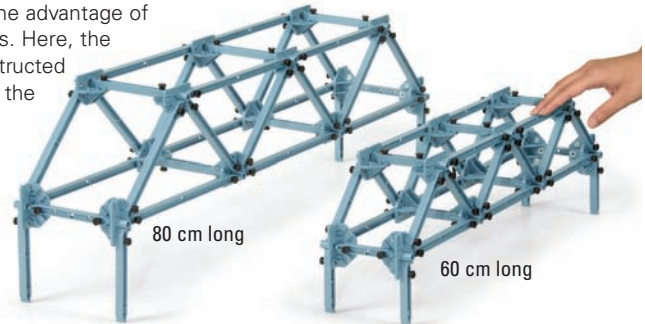


Students can build several types of fundamental bridges, including Howe, Pratt, and Warren bridges.

### Build different scale bridges

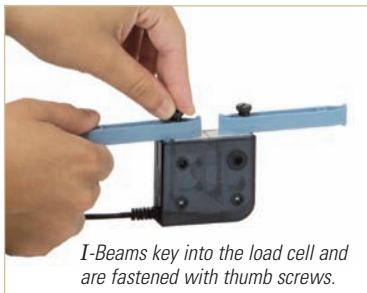
Students will learn the advantage of building taller bridges. Here, the larger bridge is constructed with a #4 I-beam on the diagonal, while the smaller bridge uses a #3 I-beam on the diagonal.

Both of these bridges can be built with the ME-6991 Bridge Set.

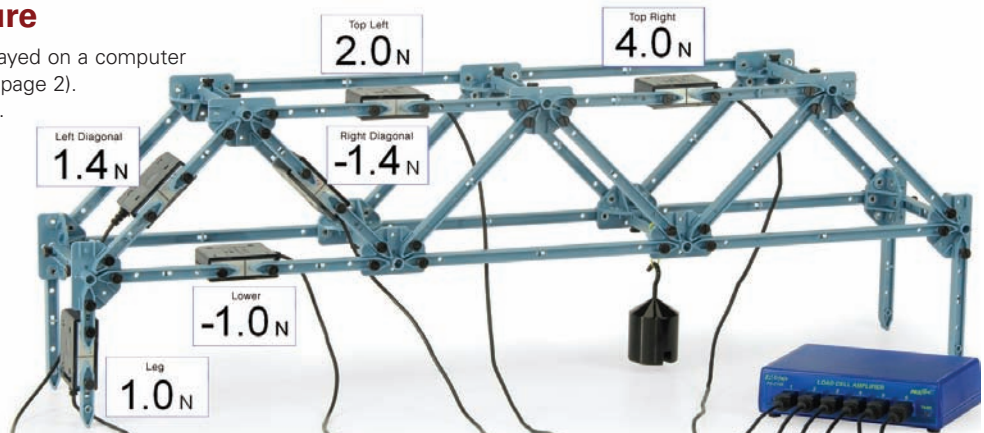


### Add load cells to measure Static Forces anywhere in the structure

Forces measured by Load Cells are displayed on a computer using PASCO Capstone™ Software (see page 2). A positive value represents compression.

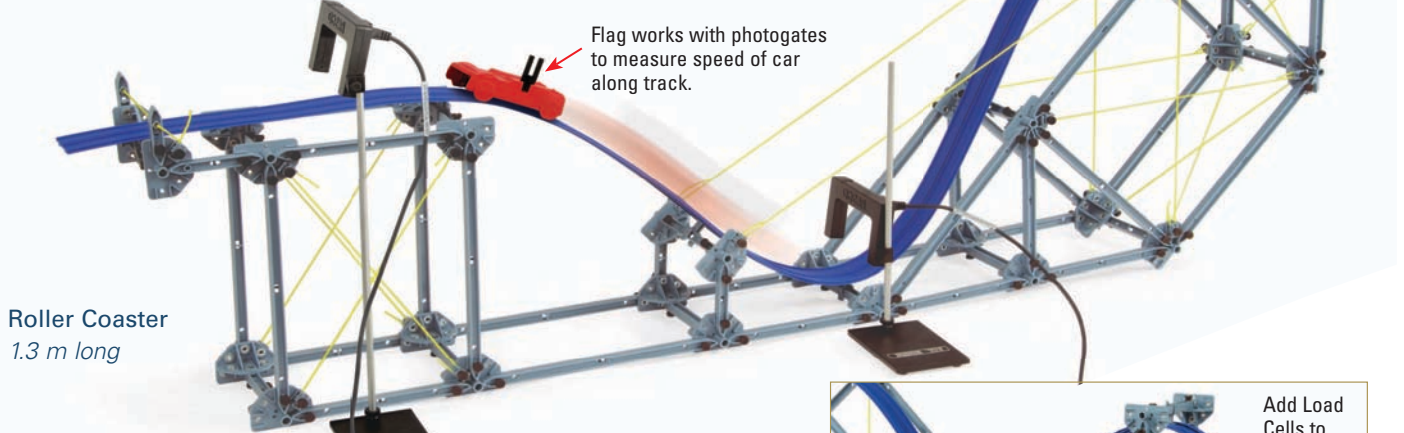


I-Beams key into the load cell and are fastened with thumb screws.



## Design your own Roller Coaster

PASCO's Bridge Set allows students to design and build their own roller coaster for detailed studies of conservation of energy and centripetal force. The flexible track is perfect for building hills, valleys and even a loop! Car with low friction ball bearing wheels minimizes energy losses. Measure the speed of the car using photogates or a Motion Sensor.



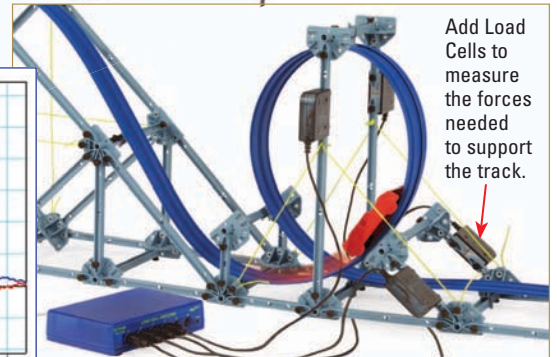
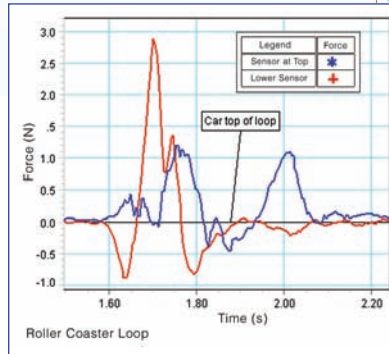
Roller Coaster  
1.3 m long

Mini Car Starter Bracket

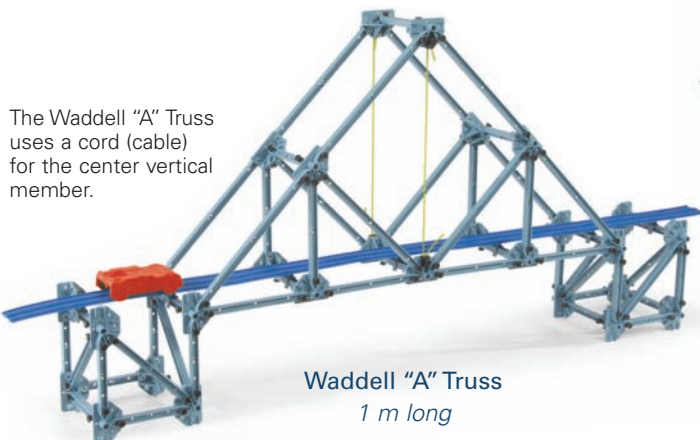
Flag works with photogates to measure speed of car along track.

Position Accessory Photogate anywhere along the track to measure speed.

PASCO Capstone™ graph shows support forces exerted on the track as the car goes up and over the loop.



Add Load Cells to measure the forces needed to support the track.



The Waddell "A" Truss uses a cord (cable) for the center vertical member.

Waddell "A" Truss  
1 m long



Deck Truss  
80 cm long

### Bridge Set Includes

Two packages each of Truss Set Members and Truss Set Screws  
One package each of Roadbed Spares and Cord Lock Spares  
See pages 22-23 for details.

### Order Information

Bridge Set.....	ME-6991	p. 6
Load Cell & Amplifier Set (includes four load cells).....	PS-2199	p. 4
Shown in use with		
Accessory Photogate.....	ME-9204B	

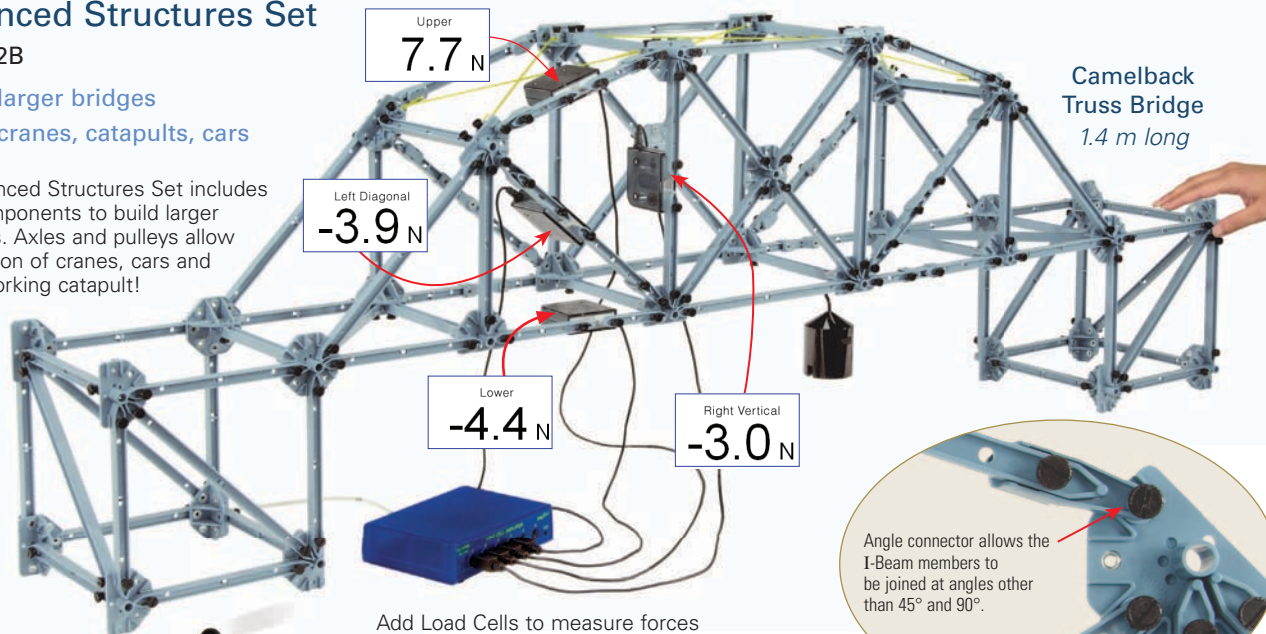


## Advanced Structures Set

ME-6992B

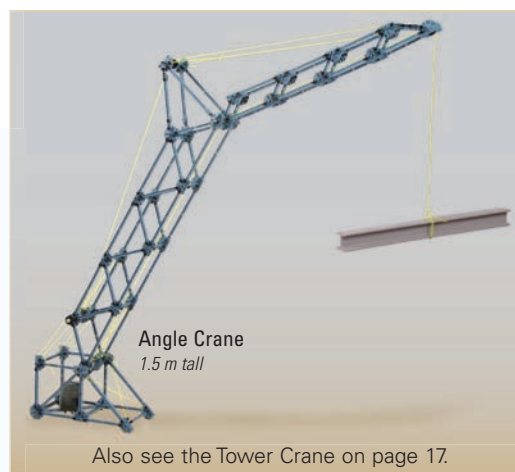
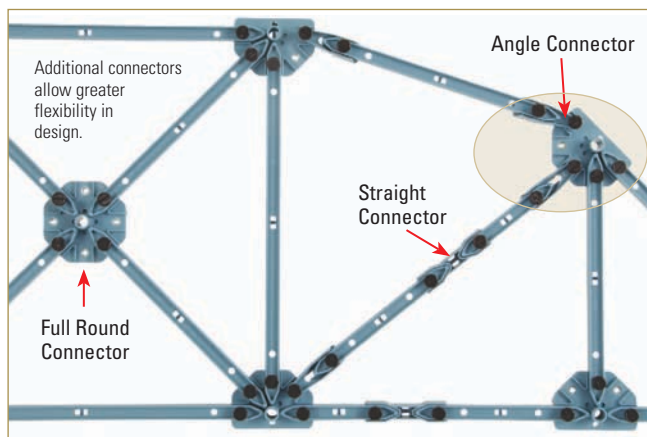
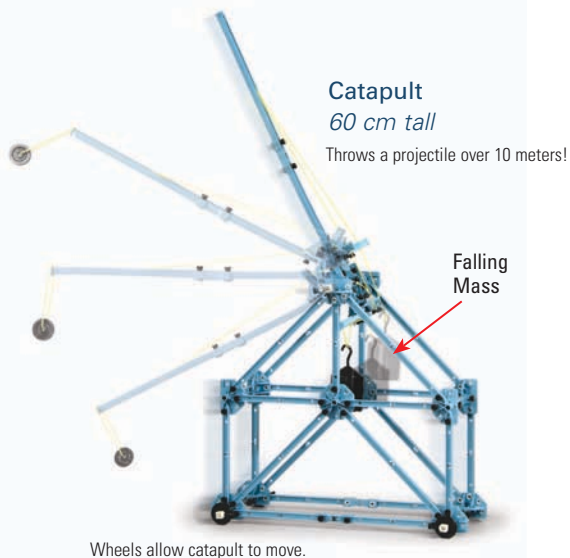
- ▶ Build larger bridges
- ▶ Build cranes, catapults, cars

The Advanced Structures Set includes more components to build larger structures. Axles and pulleys allow construction of cranes, cars and even a working catapult!



Add Load Cells to measure forces anywhere in the structure.

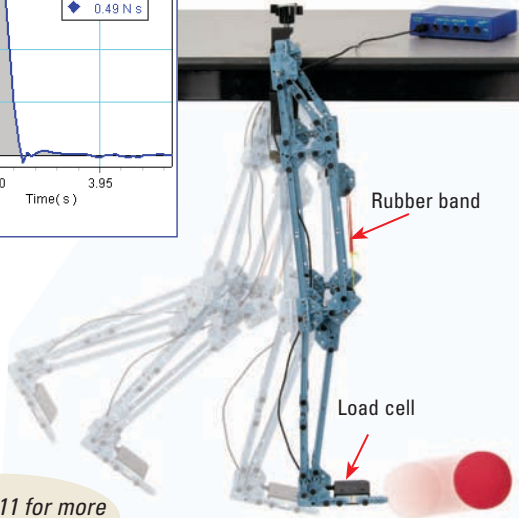
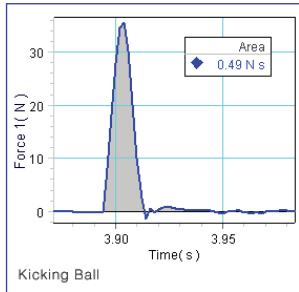
Angle connector allows the I-Beam members to be joined at angles other than 45° and 90°.





## Human Leg Model

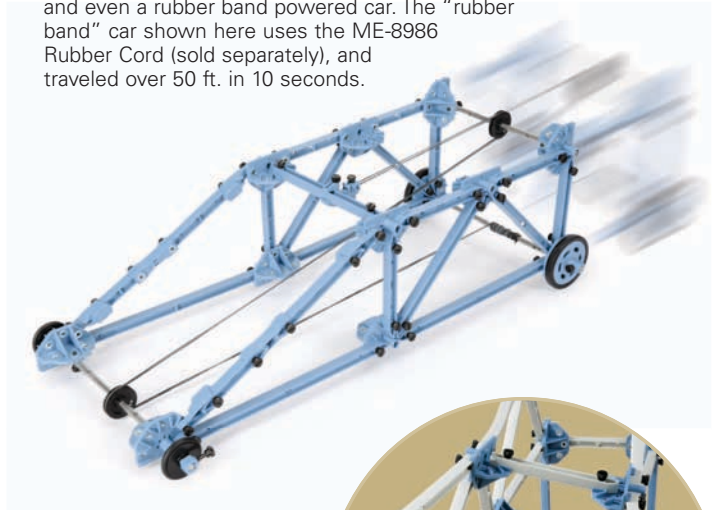
The articulated leg shown below uses a rubber band (not included) for the quadriceps and has a load cell on the foot to measure the force that the “toe” exerts on the ball. The impulse (area under the curve) is equal to the resulting momentum of the ball.



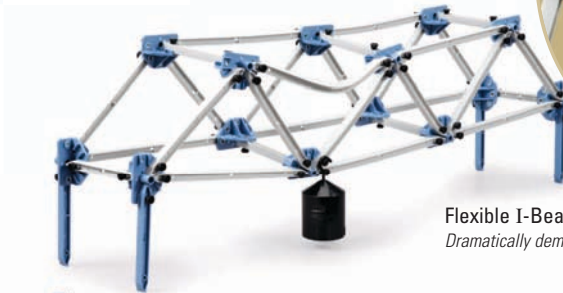
See page 11 for more Human Structures.

## Rubber Band Car

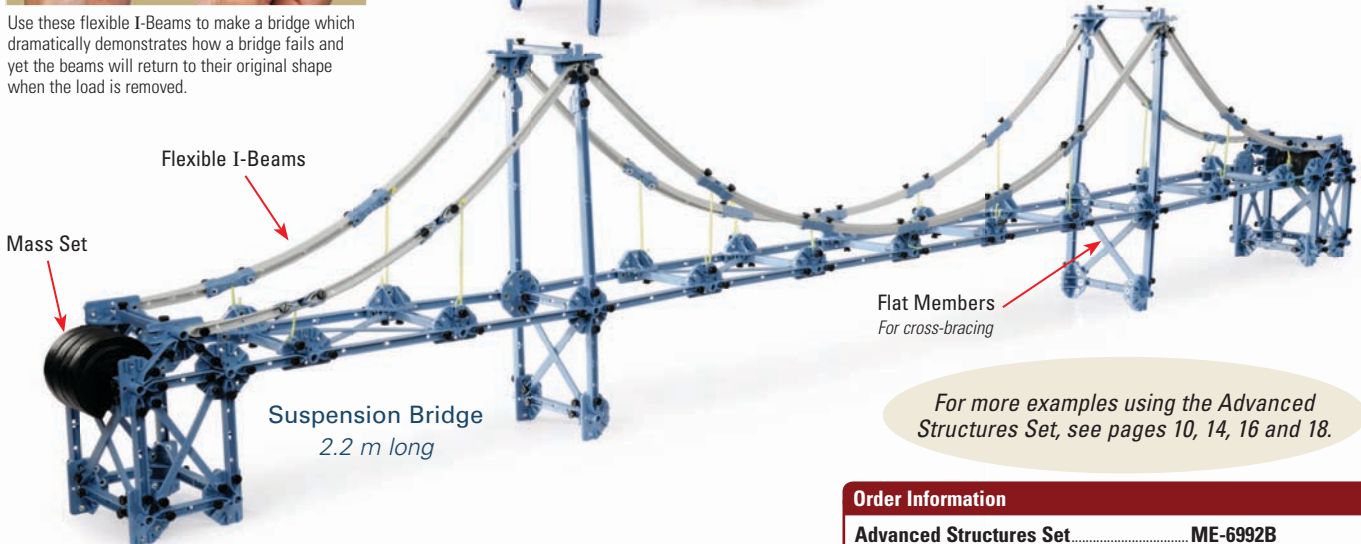
The axles, pulleys and wheels in this set allow students to build a working catapult, a car with rubber band suspension, and even a rubber band powered car. The “rubber band” car shown here uses the ME-8986 Rubber Cord (sold separately), and traveled over 50 ft. in 10 seconds.



Use these flexible I-Beams to make a bridge which dramatically demonstrates how a bridge fails and yet the beams will return to their original shape when the load is removed.



**Flexible I-Beams**  
Dramatically demonstrate structural failure



**Suspension Bridge**  
2.2 m long

For more examples using the Advanced Structures Set, see pages 10, 14, 16 and 18.

### Advanced Structures Set Includes

Three packages of Truss Set Members and four packages of Truss Set Screws  
One package each of Flexible I-Beams, Cord Lock Spares, Axle Spares, Round Connector Spares, Angle Connector Spares, Flat Beams, Structures Rod Clamps, and Force Platform Structures Bracket  
See pages 22-23 for details.

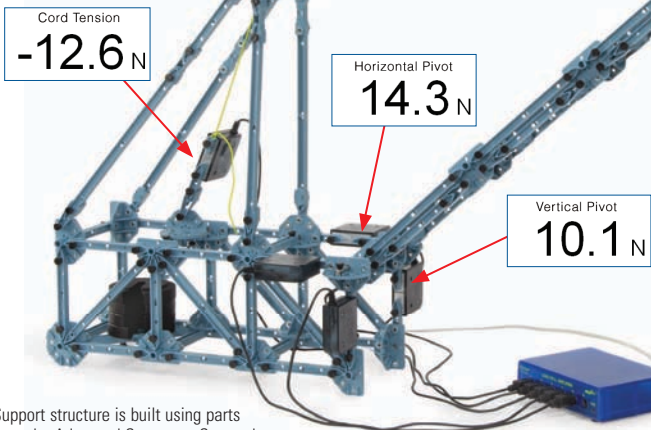
### Order Information

<b>Advanced Structures Set</b> .....	<b>ME-6992B</b>
<i>Shown in use with:</i>	
Load Cell & Amplifier Set (includes four load cells).....	PS-2199
Hooked Mass Set.....	SE-8759
Large Slotted Mass Set.....	ME-7566
Motion Sensor.....	PS-2103A
Rubber Cord (spool of 30 m).....	ME-8986

# 10 Classic Statics Using the Advanced System

## Forces on a Boom

Vary all parameters including length and angle of the boom. Directly measure the horizontal and vertical forces exerted by the pivot (axle) on the boom, and the tension in the supporting cord.

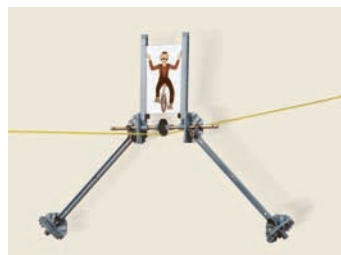


Support structure is built using parts from the Advanced Structures Set, and uses 1/2 kg masses from the ME-7566 Large Slotted Mass Set (sold separately) for counter balance.



## Teeter Totter

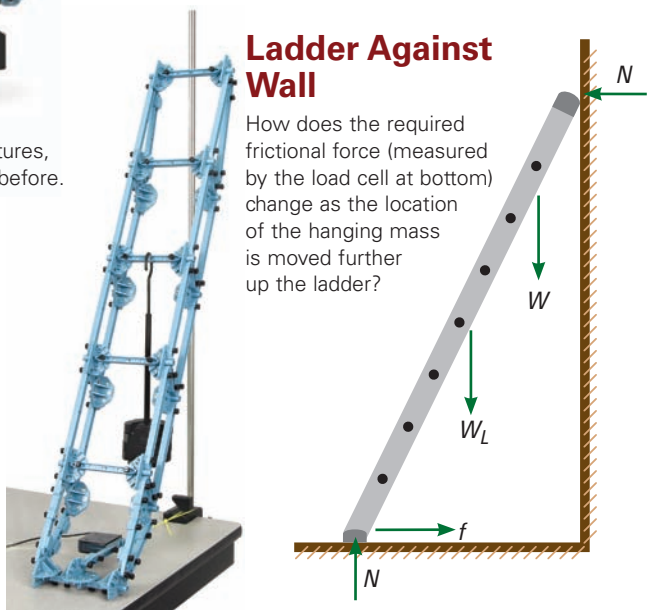
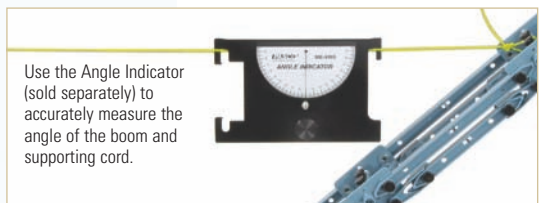
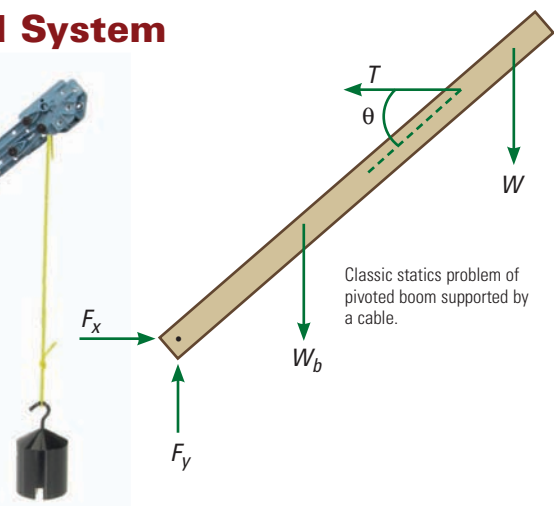
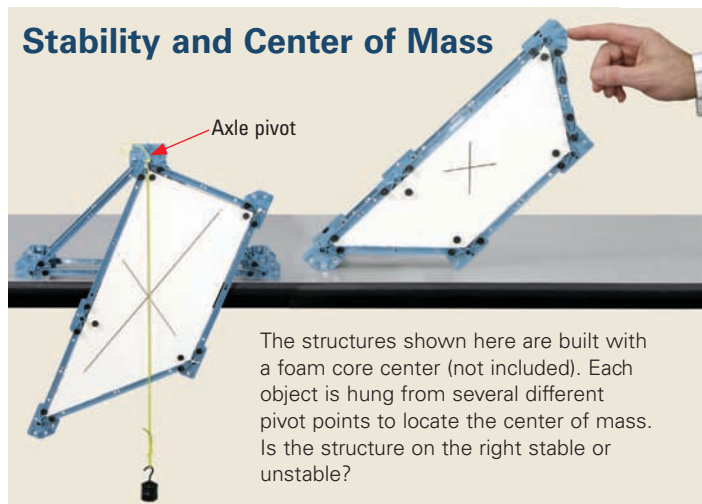
Take "meter stick" torque to a new level! By building their own unique structures, students learn about center of mass, torque, and static equilibrium as never before.



## A Lesson in Balance

Circus performer not included!

## Stability and Center of Mass



Order Information		
Advanced Structures Set.....	ME-6992B	p. 8-9
<i>Shown in use with:</i>		
Load Cell & Amplifier Set (includes four load cells).....	PS-2199	p. 4
Additional 100 N Load Cell.....	PS-2200	p. 4
Hooked Mass Set.....	SE-8759	
Large Slotted Mass Set.....	ME-7566	
Angle Indicator.....	ME-9495A	
Mass and Hanger Set.....	ME-8979	
Large Table Clamp.....	ME-9472	
Steel Rod (90 cm).....	ME-8738	



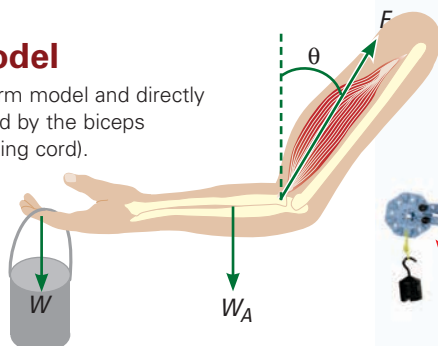
## Human Structures Set

ME-7001

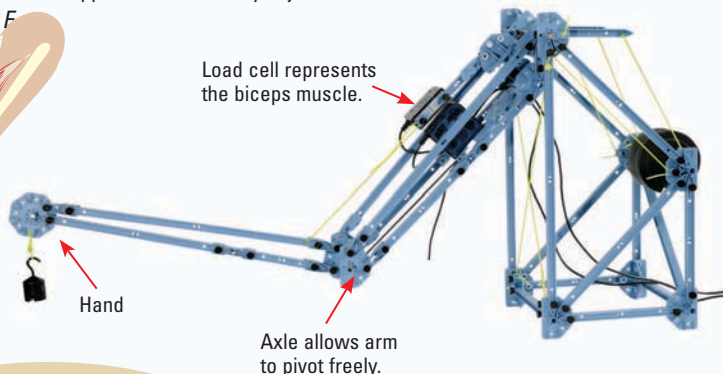
- ▶ Build models that represent real life examples.
- ▶ Bring homework problems to life!

### Human Arm Model

Students build a realistic arm model and directly measure the forces exerted by the biceps muscle (tension in supporting cord). Vary the length and angle of upper and lower arm, as well as the point of attachment of the muscle.



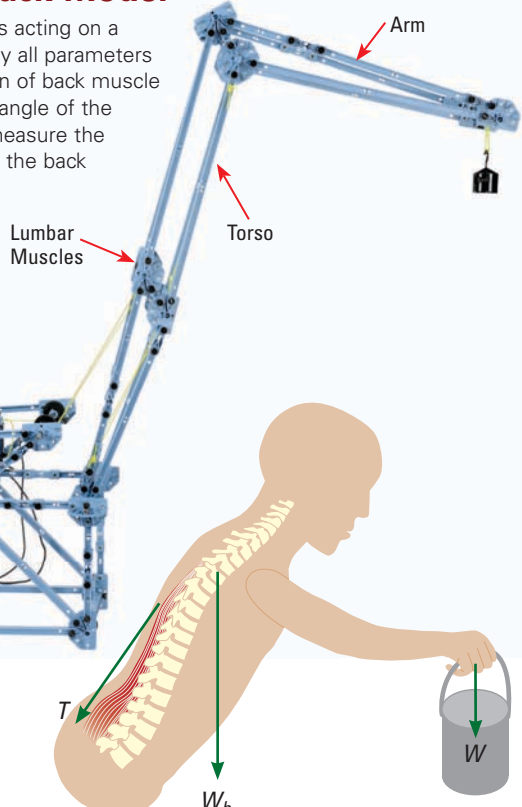
Support Structure allows the angle of the upper arm to be easily adjusted.



Construct all three models concurrently with this set.

### Human Back Model

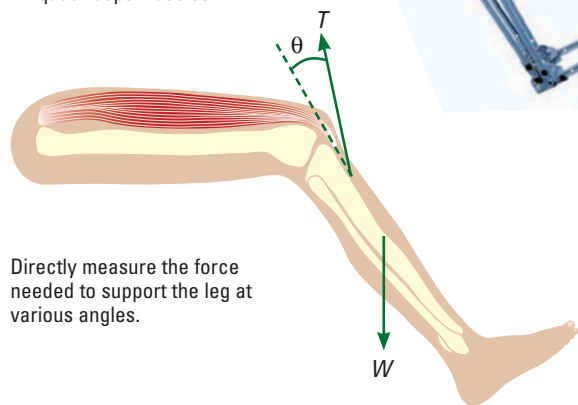
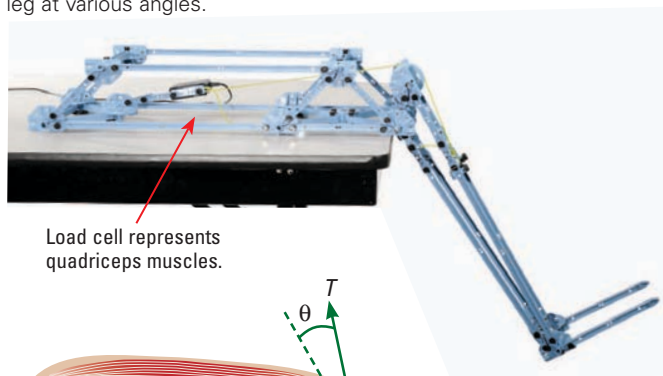
Model the forces acting on a human back. Vary all parameters including position of back muscle attachment and angle of the torso. Directly measure the force exerted by the back muscles.



Load cells directly measure forces exerted on back model.

### Human Leg Model

The leg model shown below uses a load cell for the quadriceps muscle to directly measure the force needed to support the leg at various angles.



Directly measure the force needed to support the leg at various angles.

### Human Structures Set Includes:

- Five packages of Truss Set Screws
- Two packages of Truss Set Members
- Two packages of Connector Spares
- One package each of #6 I-Beam Spares, Cord Lock Spares, Axle Spares, Round Connector Spares, Angle Connector Spares, roll of rubber cord.

See pages 22-23 for details.

### Order Information

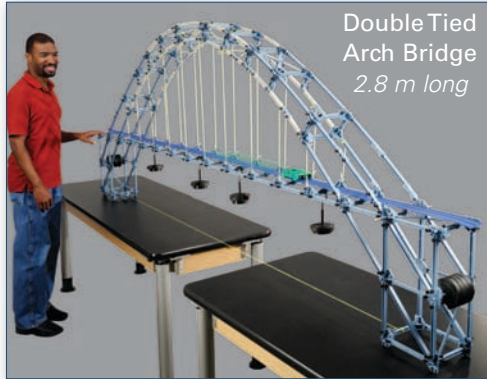
<b>Human Structures Set</b> .....	<b>ME-7001</b>
<i>Shown in use with:</i>	
Load Cell & Amplifier Set (includes four load cells).....	PS-2199
Hooked Mass Set.....	SE-8759
Large Slotted Mass Set.....	ME-7566

# 12 Large Structures Set

## Large Structures Set

ME-7003

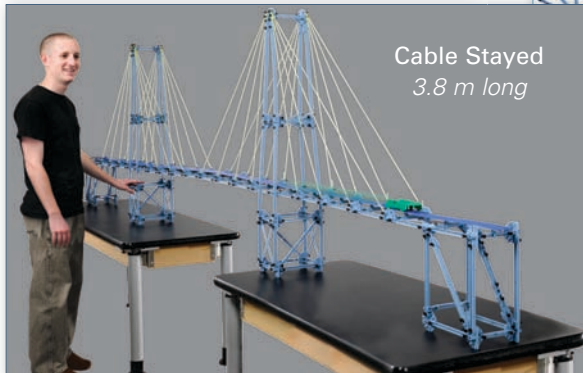
The Large Structures Set includes all the components contained in the Advanced Structures Set (ME-6992B) plus additional parts to build even bigger structures. It also includes the Mini Cars with plastic track to build roller coasters and to add realistic roadbeds to your bridges.



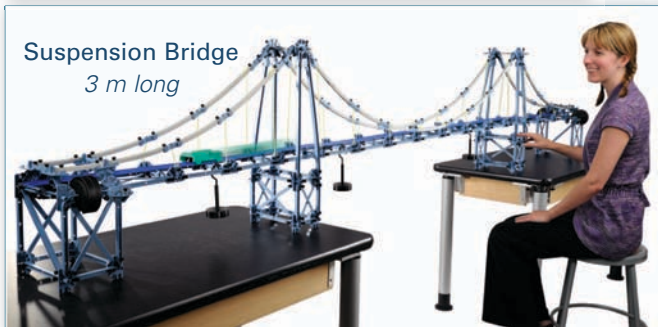
Double Tied Arch Bridge  
2.8 m long



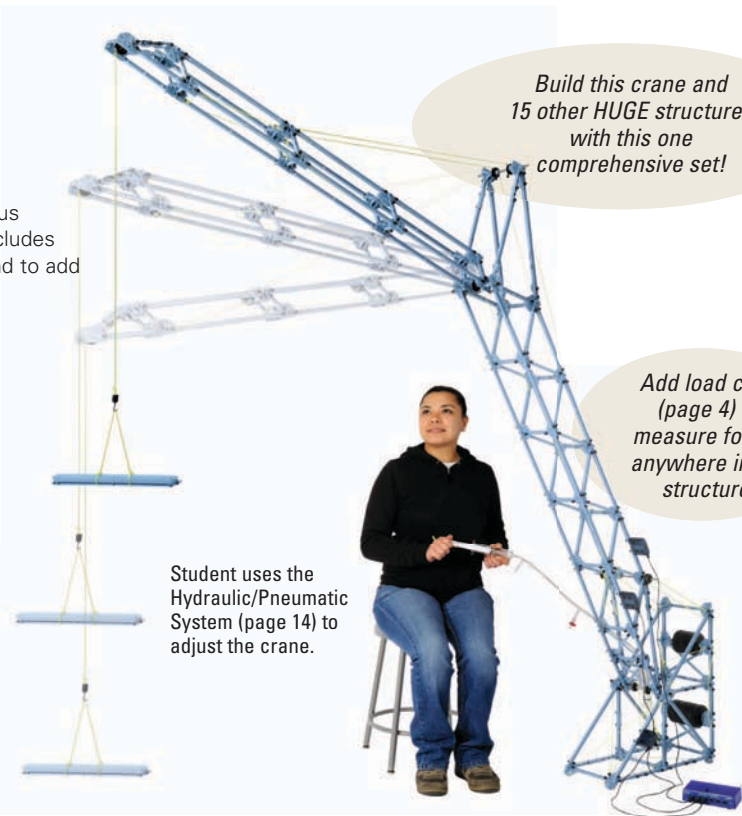
Arch Truss  
2 m long



Cable Stayed  
3.8 m long



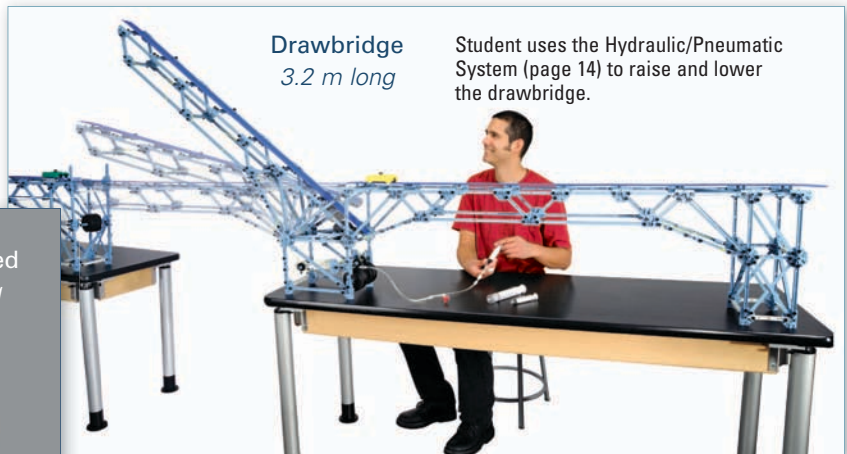
Suspension Bridge  
3 m long



Build this crane and 15 other HUGE structures with this one comprehensive set!

Add load cells (page 4) to measure forces anywhere in the structure.

Student uses the Hydraulic/Pneumatic System (page 14) to adjust the crane.



Drawbridge  
3.2 m long

Student uses the Hydraulic/Pneumatic System (page 14) to raise and lower the drawbridge.

### Large Structures Set Includes:

- Six packages of Truss Set Screws
- Three packages of Truss Set Members
- Two packages of Connector Spares
- One package each of #6 I-Beam Spares, Flexible I-Beams, Cord Lock Spares, Axle Spares, Round Connector Spares, Angle Connector Spares, Flat Beams, Structures Rod Clamps, Mini Car Track Spares, Force Platform Structures Bracket, and one each Green Car, Yellow Car, 9.1 m Track, and Starter Bracket

### Order Information

<b>Large Structures Set</b> .....	<b>ME-7003</b>	
Load Cell & Amplifier Set (includes four load cells).....	PS-2199	p. 4
Hydraulic/Pneumatic Structures.....	ME-6984	p. 14
Slotted Mass Set.....	ME-7589	
Required:		
Interface.....		p. 2



## Physics Structures Set

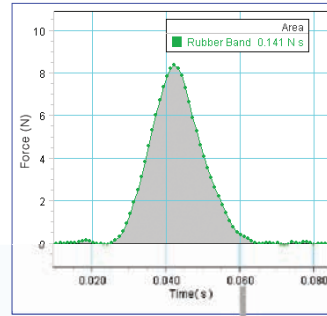
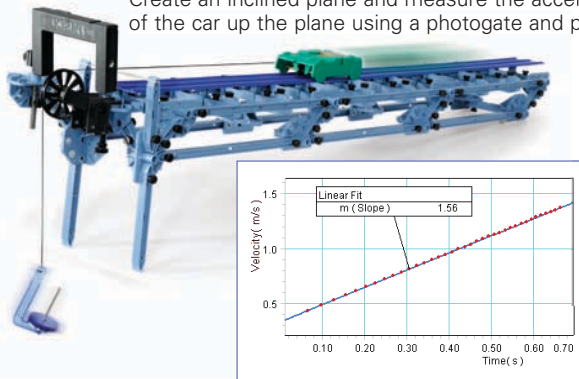
ME-6989

- ▶ With One Comprehensive Set, Study Kinematics, Momentum, Energy, and Rotation
- ▶ Build Over 20 Unique Apparatus For Learning Physics
- ▶ Over 10 Copy-Ready Experiments Included

The **Physics Structures Set** has been designed to maximize the number of different structures students can build to study and verify physics concepts. Sensors can be used to measure force, position, velocity, and acceleration. Literally in minutes, students can create their own unique apparatus to explore and measure physical quantities.

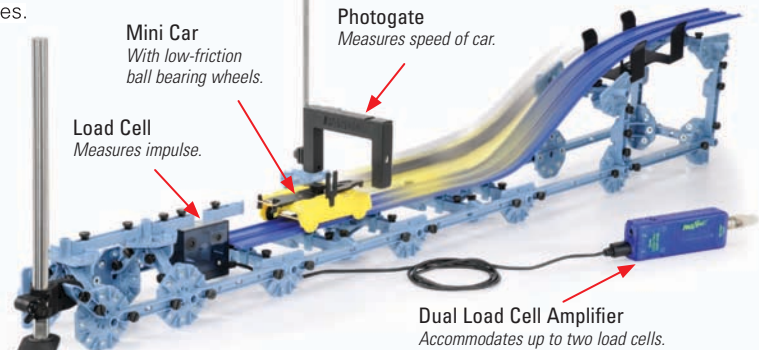
### Newton's Second Law

Create an inclined plane and measure the acceleration of the car up the plane using a photogate and pulley.



### Impulse and Change in Momentum

The car goes down the hill and collides with the load cell attached to the track. The area under the force vs. time curve gives the impulse and the photogate measures the speeds so the change in momentum can be calculated.



**Mini Car**  
With low-friction ball bearing wheels.

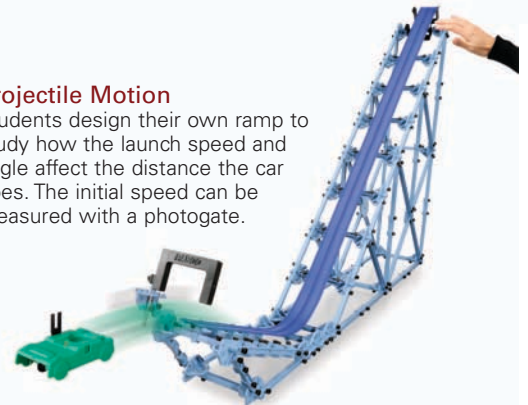
**Photogate**  
Measures speed of car.

**Load Cell**  
Measures impulse.

**Dual Load Cell Amplifier**  
Accommodates up to two load cells.

### Projectile Motion

Students design their own ramp to study how the launch speed and angle affect the distance the car goes. The initial speed can be measured with a photogate.



**Clamp-on Super Pulley**

**Spring Set**

### Hooke's Law and Oscillations

The car hooked to two springs oscillates back-and-forth. Masses can be attached to the car over the pulley to cause a displacement and thus determine the effective spring constant using Hooke's Law.

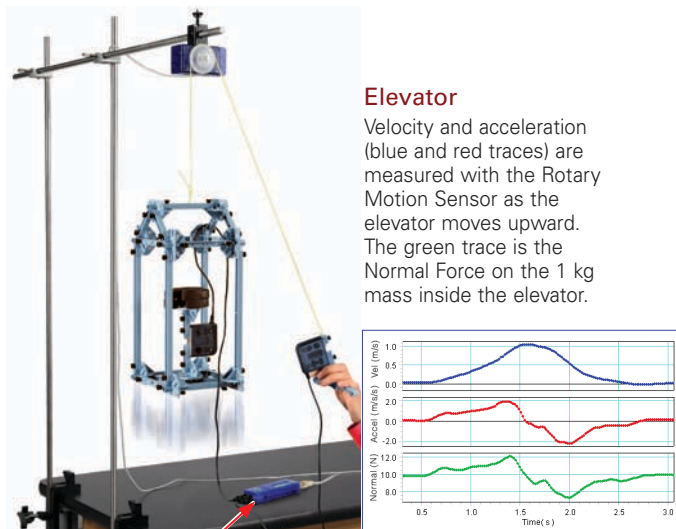
### Physics Structures Set Includes

Structures Rod Clamp, Spring Set Members (two packages), Truss Set Screws (two packages), Cord Lock Spares, Full Round Spares, Connector Spares, Axle Spares, Angle Connector Spares and a roll of thread, Super Pulley with Clamp, Light Duty Spring Set, six PASTrack fasteners, 3 m Flexible Road Bed, 24 Road Bed Clips, two Track Coupler Collision Brackets with rubber bands and clay, yellow car and green car, each with ballast mass and flag, starter bracket and instruction manual.

See pages 22-23 for details.

### Elevator

Velocity and acceleration (blue and red traces) are measured with the Rotary Motion Sensor as the elevator moves upward. The green trace is the Normal Force on the 1 kg mass inside the elevator.



**Dual Load Cell Amplifier**

### Order Information

**Physics Structures Set** ..... **ME-6989**

Shown in use with:

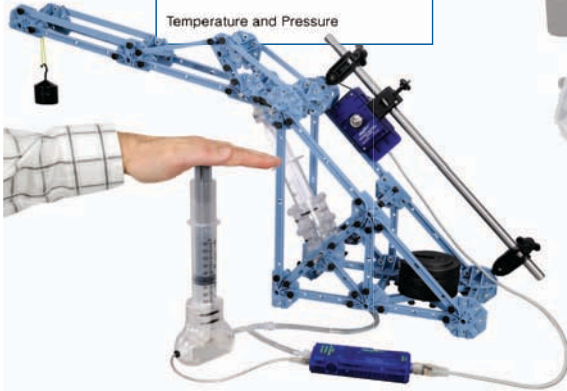
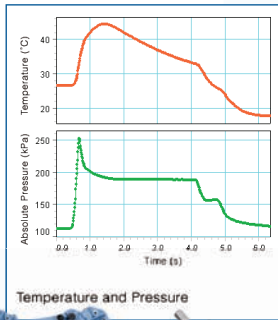
Load Cell Amplifiers.....	p. 4
5 N Load Cell.....	PS-2201 p. 4
100 N Load Cell.....	PS-2200 p. 4
Photogate Head (2).....	ME-9498A
Rotary Motion Sensor .....	PS-2120A
Mass and Hanger Set .....	ME-8979
Large Slotted Mass Set .....	ME-7566
Aluminum Table Clamp .....	ME-8995
60 cm Long Threaded Rod .....	ME-8977

# 14 Investigate Hydraulics

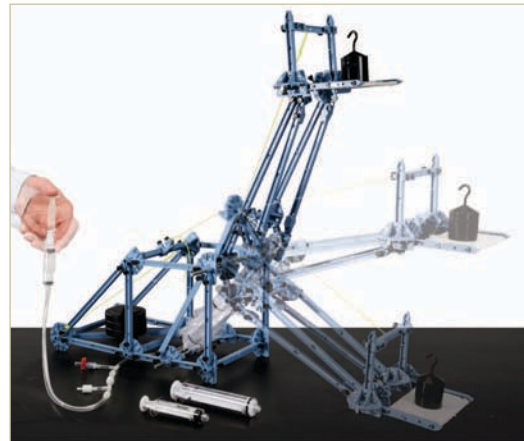
## Hydraulic and Pneumatic Structures

ME-6984

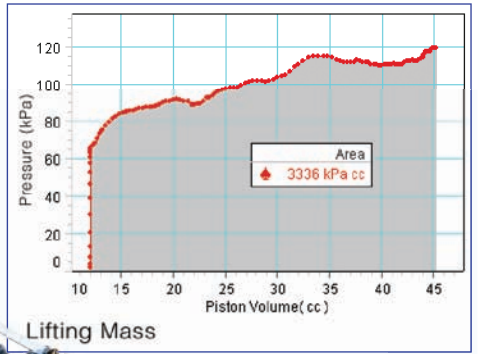
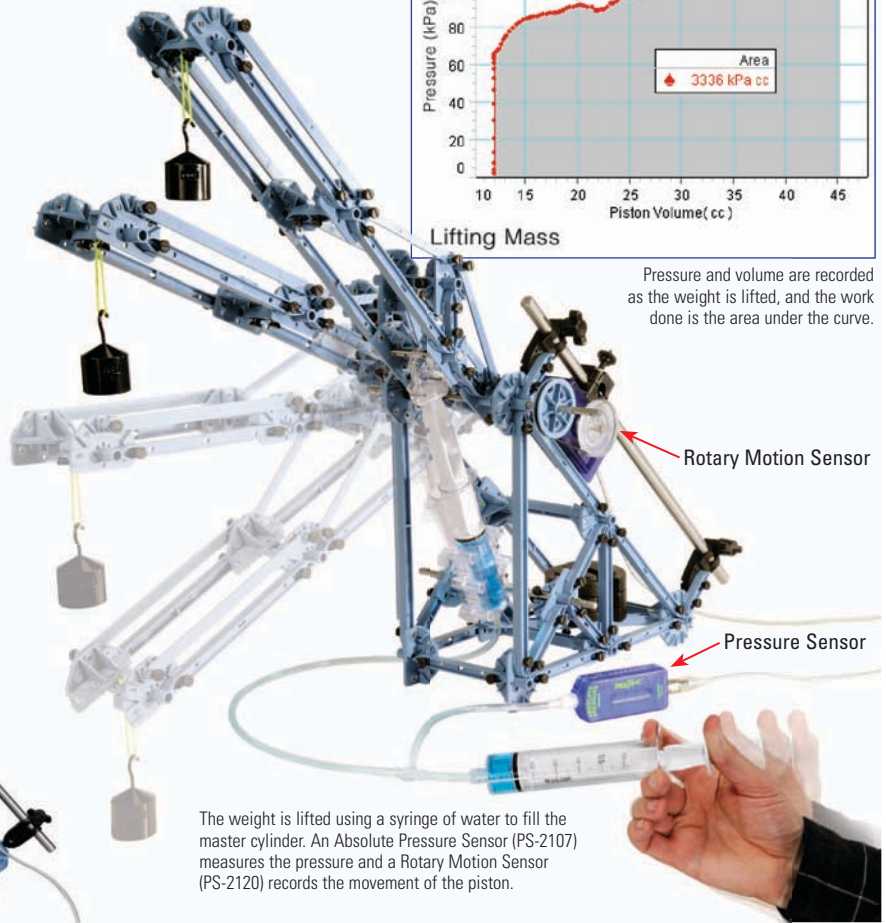
Add a hydraulic/pneumatic ram to make your structures move and do work. Not only will students see the cranes and jacks in action, they can directly measure the pressure and volume to calculate how much work was done.



An Ideal Gas Law Syringe (TD-8596A), which has an internal thermistor, is used to pump air into the cylinder. A Pressure/Temperature Sensor (PS-2146) records the air pressure and temperature while the Rotary Motion Sensor (PS-2120) records the movement.



Valves are used with the syringe to pump up this fork lift. The use of different size syringes shows how a smaller force requires a greater number of pumps to do the same amount of work as a larger force.



Pressure and volume are recorded as the weight is lifted, and the work done is the area under the curve.

The weight is lifted using a syringe of water to fill the master cylinder. An Absolute Pressure Sensor (PS-2107) measures the pressure and a Rotary Motion Sensor (PS-2120) records the movement of the piston.



This scissor lift uses pulleys to change the mechanical advantage.



### Includes

- Master Cylinder
- Pressure Sensor "T"
- Check Valves and Tubing
- 10 ml Syringe
- 20 ml Syringe
- 60 ml Syringe
- Drive belt for Rotary Motion Sensor (Not shown)

### Order Information

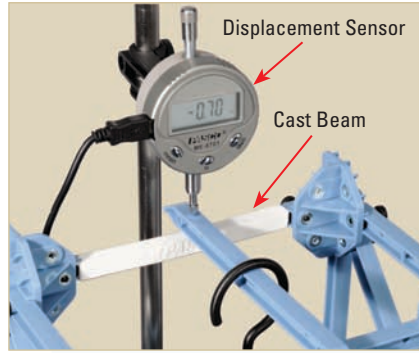
<b>Hydraulic/Pneumatic Structures</b> .....	<b>ME-6984</b>
<i>Required</i>	
Advanced Structures Set .....	ME-6992B
Steel Rod (45 cm) .....	ME-8736
Absolute Pressure Sensor .....	PS-2107
Rotary Motion Sensor .....	PS-2120A
Pressure/Temperature Sensor .....	PS-2146
Ideal Gas Law Syringe .....	TD-8596A
<i>Not shown but required for data collection</i>	
Interface and PASCO Capstone™ Software .....	page 2



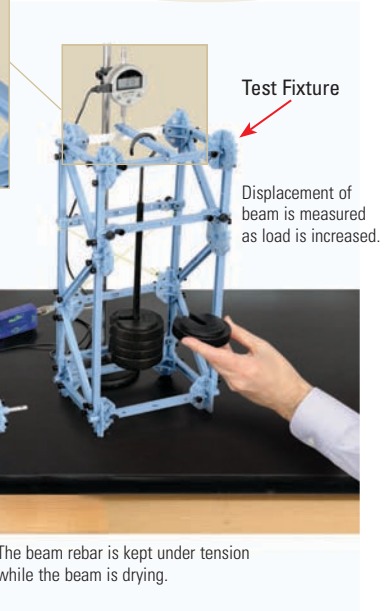
## Cast Beam Structures Set

ME-7009

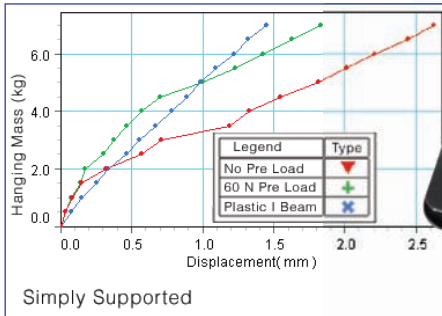
Make your own cast beams which look like pre-stressed concrete beams. Test them and you'll find they perform like them, too. These beams are cast with a mixture of sand and plaster of Paris (not included). The rebar is made of the same plastic used for the I-beams. Students can explore how the strength of the beam is affected by the amount of tension put on the rebar, the mixture of sand and plaster of Paris, or using one or two rebar.



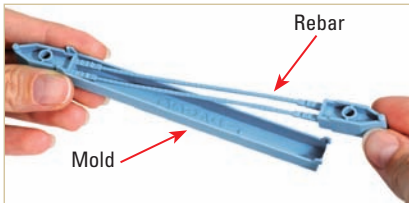
Both the tension fixture and the test fixture can be built concurrently with this set.



The graph of hanging mass versus displacement shows the relative strengths of three beams: One cast beam made with no pre-load; one cast beam made with 60 N of pre-load; and one normal plastic I-beam. Notice that the traces for the cast beams show discontinuities when the beams cracked. Also notice that the pre-loaded cast beam is stronger than the plastic I-beam until the cast beam cracks.



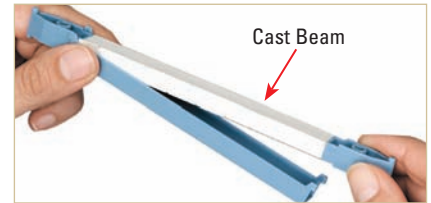
Simply Supported



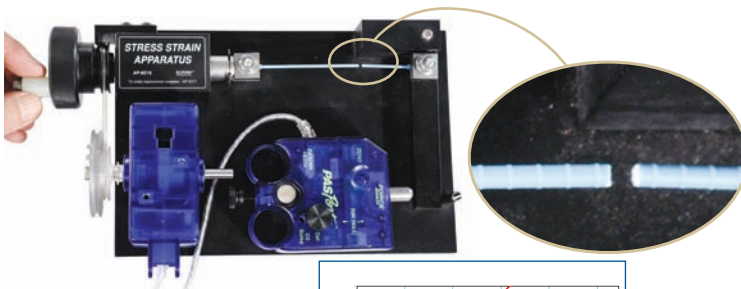
**Step 1:** The rebar with connecting ends snaps into the plastic mold.



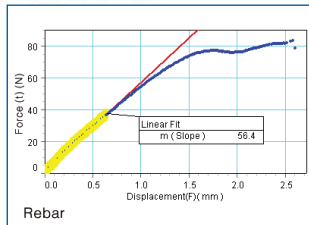
**Step 2:** Insert rebar into tensioning apparatus and pour a mixture of sand and plaster of Paris into the mold.



**Step 3:** After it dries, it is easy to remove the flexible plastic mold from the cast beam.



**Measure Young's Modulus for the rebar.**  
The connecting ends can be cut off from the rebar allowing the rebar to fit into the Stress/Strain Apparatus (AP-8213).



## Cast Beam Spares ME-6983

Consumable replacement parts for Cast Beams. These can also be used with the Advanced Structures Set (page 8).

### Includes

- 10 Reusable Plastic Molds
- 30 Rebar with Connectors



### Order Information

Cast Beam Spares ..... ME-6983

### Order Information

- Cast Beam Structures Set ..... ME-7009
- Also shown
- Displacement Sensor ..... PS-2204
- Stress/Strain Apparatus with Sensors ..... AP-8213A
- Large Slotted Mass Set ..... ME-7566
- Small Round Base ..... ME-8974A
- 60 cm Threaded Rod ..... ME-8977
- Not shown but required for data collection
- Interface and PASCO Capstone™ Software ..... page 2

## Cast Beam Structures Set Includes

One package each of Truss Set Members, Cord Lock Spares, Axle Spares, Round Connector Spares, Angle Connector Spares and two packages of Truss Set Screws

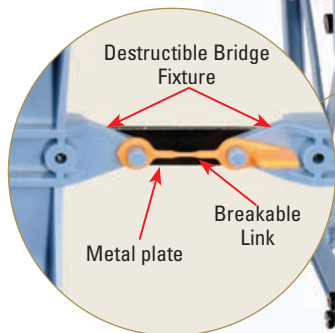
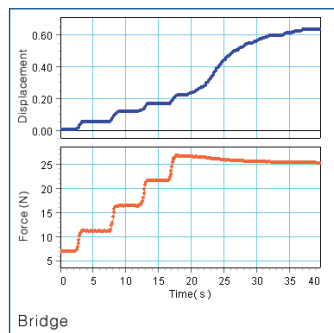
See pages 22-23 for details.

# 16 Destructible Bridge Members

## Destructible Bridge Members

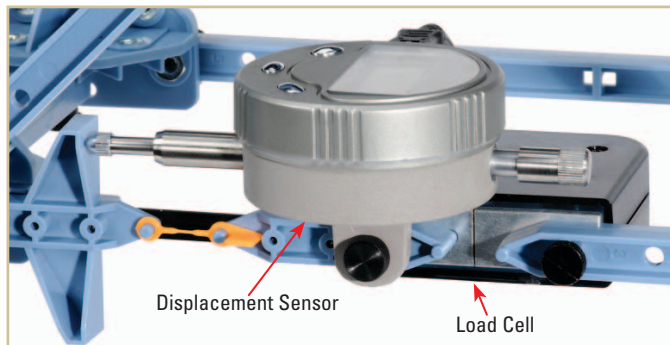
ME-7004

Because the standard blue I-beams are so strong, it requires too much weight to break them. To investigate structural failure, we have created a bridge member that is weaker, and has a fail-safe mechanism so the bridge will not catastrophically collapse. In addition, you can measure the tension and the displacement during the failure.



The black metal plate of the Destructible Bridge Fixture allows the Breakable Link to stretch and fail but keeps the bridge from falling down completely.

As each weight is added, the stretch of the Breakable Link is measured with the Displacement Sensor and the tension in the member is measured with the Load Cell. The tension decreases when the link is in the final stage of failure.



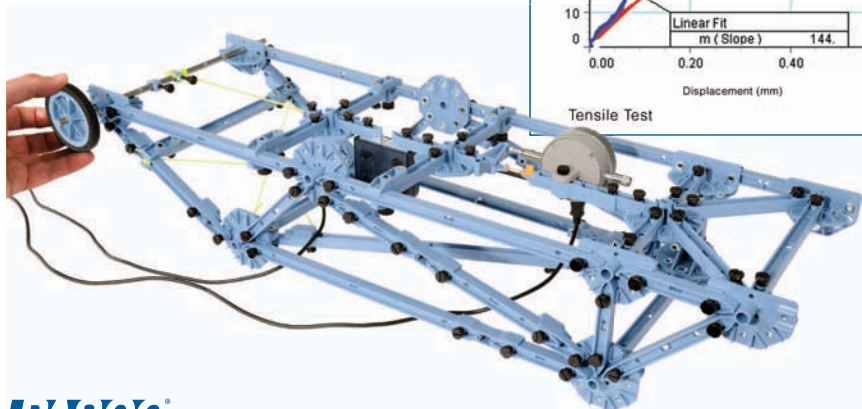
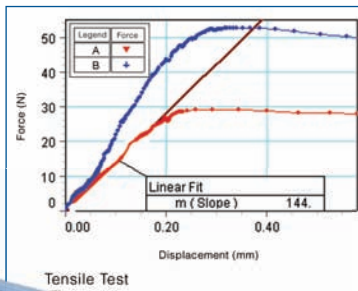
The Destructible Bridge Fixture is reusable. A broken link can be easily replaced with a new one by simply sliding it onto the posts.

### Includes:

- Destructible Bridge Fixtures (2)
- Breakable Links (100 each of two different strengths)



A tensile stress tester can be constructed from the Advanced Structure Set. Using a 100 N Load Cell and the Displacement Sensor, Young's Modulus for the material can be determined.



### Order Information

**Destructible Bridge Members**.....ME-7004

*Required:*

Advanced Structures Set.....ME-6992B p. 8

Load Cell & Amplifier Set (includes four load cells)....PS-2199 p. 4

Displacement Sensor.....PS-2204

Large Slotted

Mass 2 kg Set.....ME-7589

*Not shown but required for data collection:*

Interface.....p. 2

PASCO Capstone™ Software.....p. 2

*Recommended:*

Destructible Bridge

Members Spares.....ME-7005 p. 22

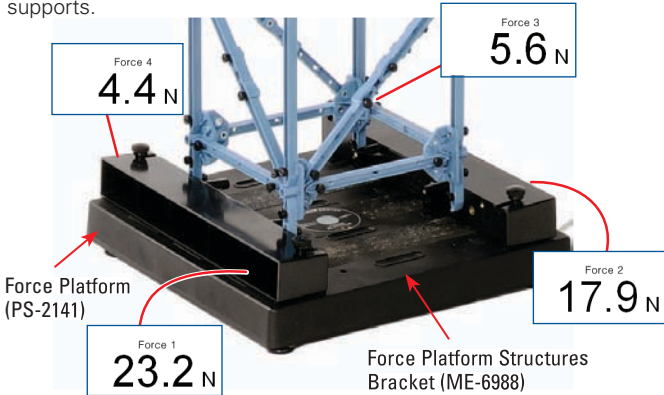


## Measure support forces with a Force Platform

### Force Platform

PS-2141

Measure the support forces of a crane by connecting it to a Force Platform (PS-2141) using the special Force Platform Structures Bracket (ME-6988). The Force Platform is supported by four individual load cells which combine to measure the total vertical force on the platform. These four readings can also be viewed separately, to measure the unequal forces on the crane supports.

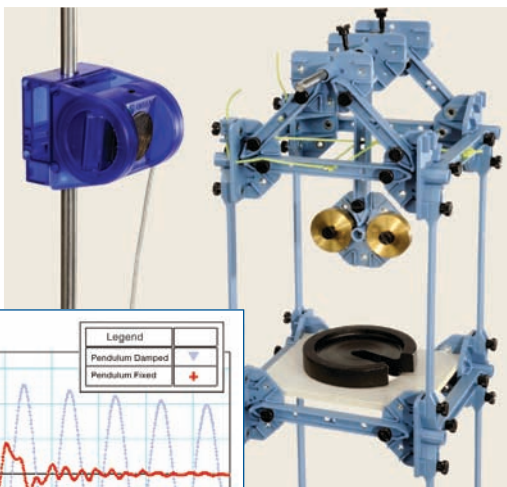


Tower Crane  
2.3 m tall

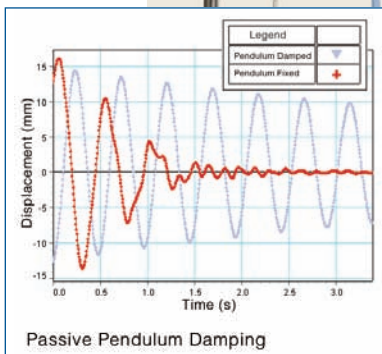
Order Information	
Force Platform.....	PS-2141
Force Platform Structures Bracket.....	ME-6988A

## Measure passive damping with a Motion Sensor

This building frame is built with an Advanced Structures Set using the Flat Beams. A pendulum with drag caused by strings is suspended from the top of the building. The Motion Sensor is positioned to record the oscillation of the building.



See page 19 for more examples using the Shaking Tower.



The gray graph (in PASCO Capstone™ Software) shows the oscillation without the pendulum. The red graph shows the damping caused when the pendulum is allowed to oscillate.

Order Information		
Advanced Structures Set.....	ME-6992B	p. 8
Motion Sensor.....	PS-2103A	
Large Slotted Mass Set.....	ME-7566	

## Measure bridge deflection with a Displacement Sensor

### Displacement Sensor

PS-2204

The PS-2204 Displacement Sensor measures the travel of a spring-loaded indicator pressed against a bridge as the bridge is loaded. It consists of a PASPORT sensor which plugs into the included Digital Indicator, a digital travel indicator which has its own digital LED readout and can be used as a stand-alone device. When the PASPORT sensor is plugged into an interface, the reading can be recorded.



### Specifications

- Maximum Travel:** 10 mm
- Maximum Sample Rate:** 5 Hz
- Resolution:** 0.013 mm (0.0005 in)



Order Information	
Displacement Sensor.....	PS-2204
<i>Shown in use with:</i>	
Hooked Mass Set.....	SE-8759
Small "A" Base.....	ME-8976
60 cm long Steel Rod (threaded).....	ME-8977
<i>Required:</i>	
Interface.....	p. 2

# 18 Explore Bridges with Rigid Roadbeds

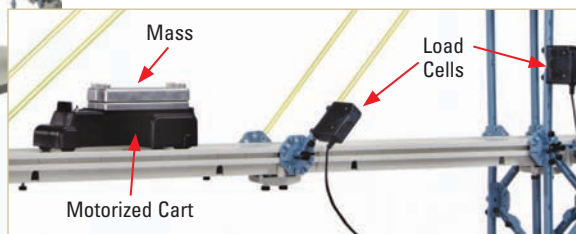
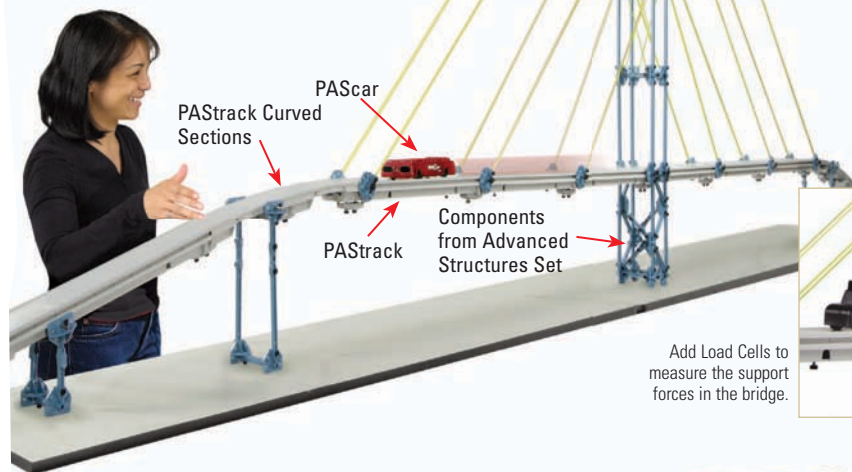
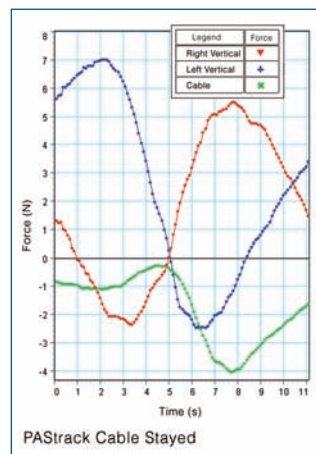
Combine the rigid, plastic PAStack sections with components from the Structures System to build truss and cable-stayed bridges with realistic rigid decks.

## PAStack Cable-Stayed Bridge

The cable-stayed bridge shown here was constructed using components from the Advanced Structures Set and two ME-6997 Round Connector Spares sets. The roadbed uses four sets of curved PAStack and four sets of curved PAScar. The bridge is built starting with the center column and working symmetrically outward, always keeping the bridge in balance. As each 50 cm section of rigid deck is added to each side, new supporting cable is added.

Cable-Stayed Bridge  
1.5 m Tall

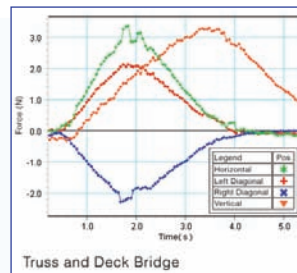
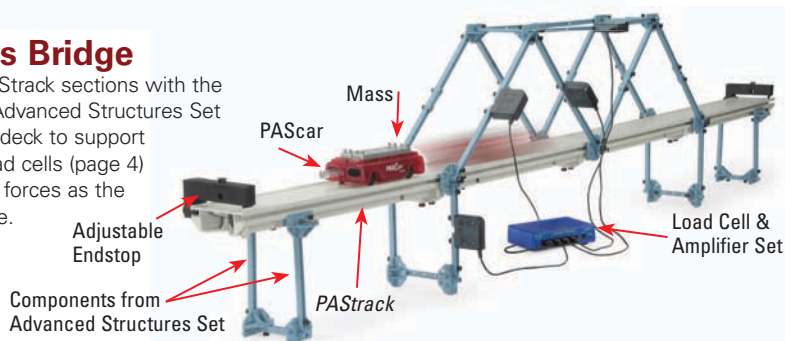
PASCO Capstone™ graph shows the change in tension and compression of the supporting members as the Motorized Cart moves across the span.



Add Load Cells to measure the support forces in the bridge.

## PAStack Truss Bridge

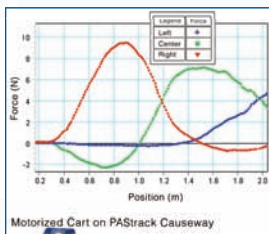
Combine the plastic PAStack sections with the components from the Advanced Structures Set (page 8) to build a rigid deck to support dynamics carts. Use load cells (page 4) to directly measure the forces as the cart traverses the bridge.



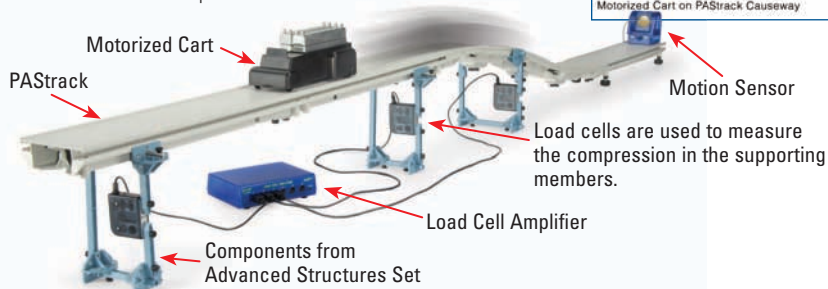
Load cells are used to measure the tension and compression in the members.

## Dynamics Track Support Reactions

Combine the plastic PAStack sections with the components from the Advanced Structures Set (page 8) to measure the support reactions as the Motorized Cart climbs the hill. The Load Cell and Amplifier Set (page 4) directly measures the forces in the structure as the Motion Sensor measures the carts position.



Force vs. Position of the cart for each of the support forces as the Motorized Cart climbs the hill.



### Equipment Shown

Advanced Structures Set.....	ME-6992B	p. 8
PAScar (set of 2).....	ME-6950	
PAStack (2 sections).....	ME-6960	
Curved PAStack.....	ME-6841	
Motorized Cart.....	ME-9781	
250g Mass.....	ME-6756	
Adjustable Endstop.....	ME-8971	
Round Connector Spares.....	ME-6997	p. 22
Load Cell & Amplifier Set (includes four load cells).....	PS-2199	p. 4
Motion Sensor.....	PS-2103A	
PASCO Capstone™ Software.....		p. 2
Interface.....		p. 2



## Structures Resonance

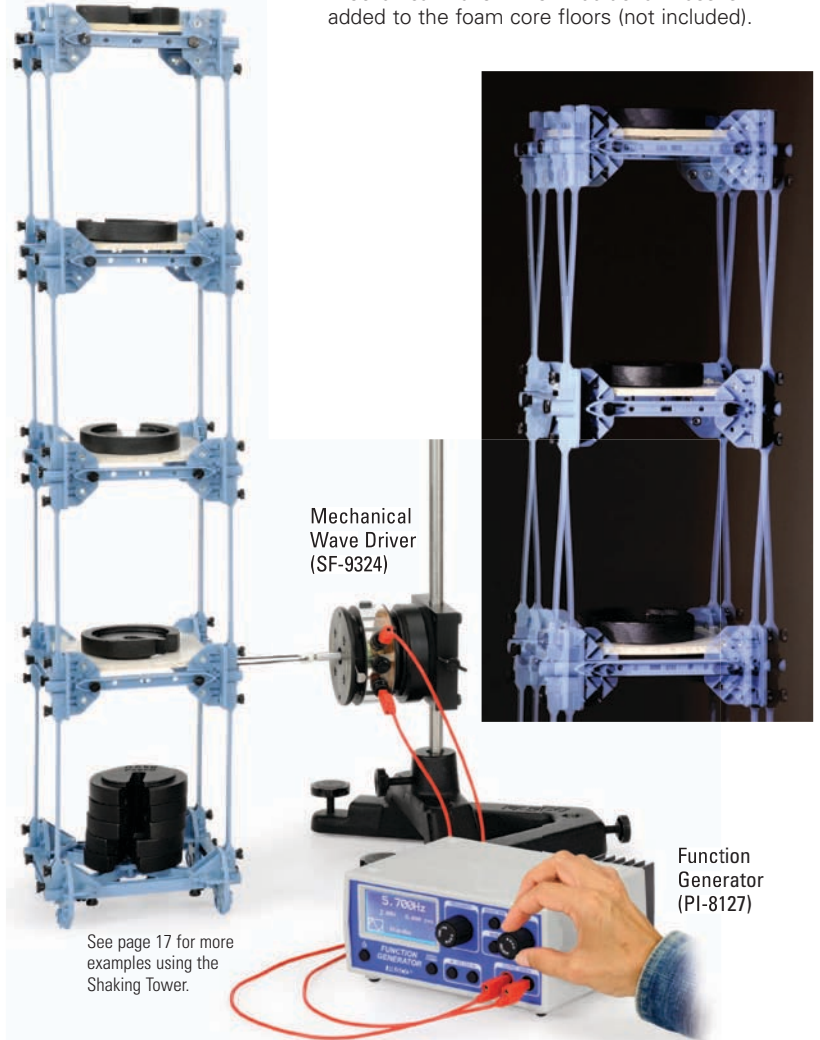
PASCO's Structures System is perfect for demonstrating resonance in complex systems. The plastic I-Beams clearly show two different bending moments, and can be connected together to build a variety of structures.



Composite I-Beam  
1.2 m tall

The long plastic I-Beam is constructed of components from the Advanced Structures Set (page 8). It is driven using the SF-9324 Mechanical Wave Driver and the PI-8127 Function Generator, demonstrating the three lowest harmonics.

Shaking Tower  
75 cm tall



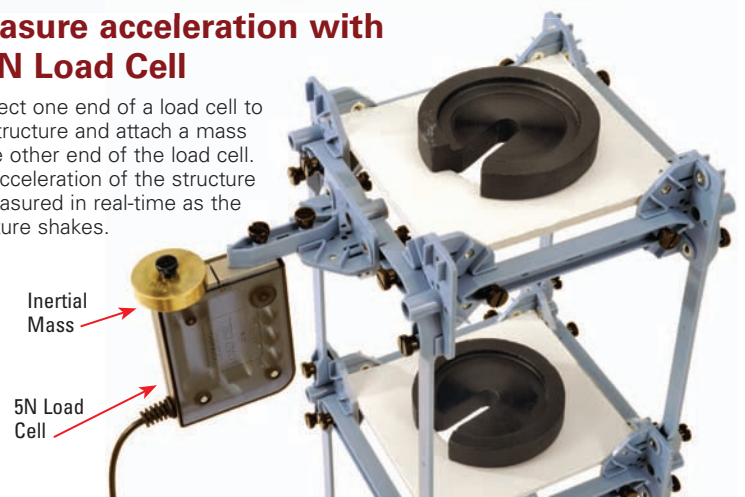
Mechanical Wave Driver (SF-9324)

Function Generator (PI-8127)

See page 17 for more examples using the Shaking Tower.

## Measure acceleration with a 5N 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.



### Equipment Shown:

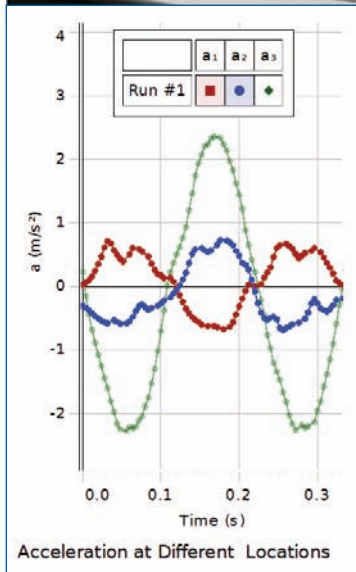
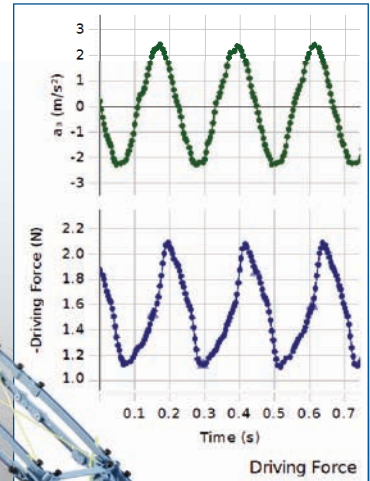
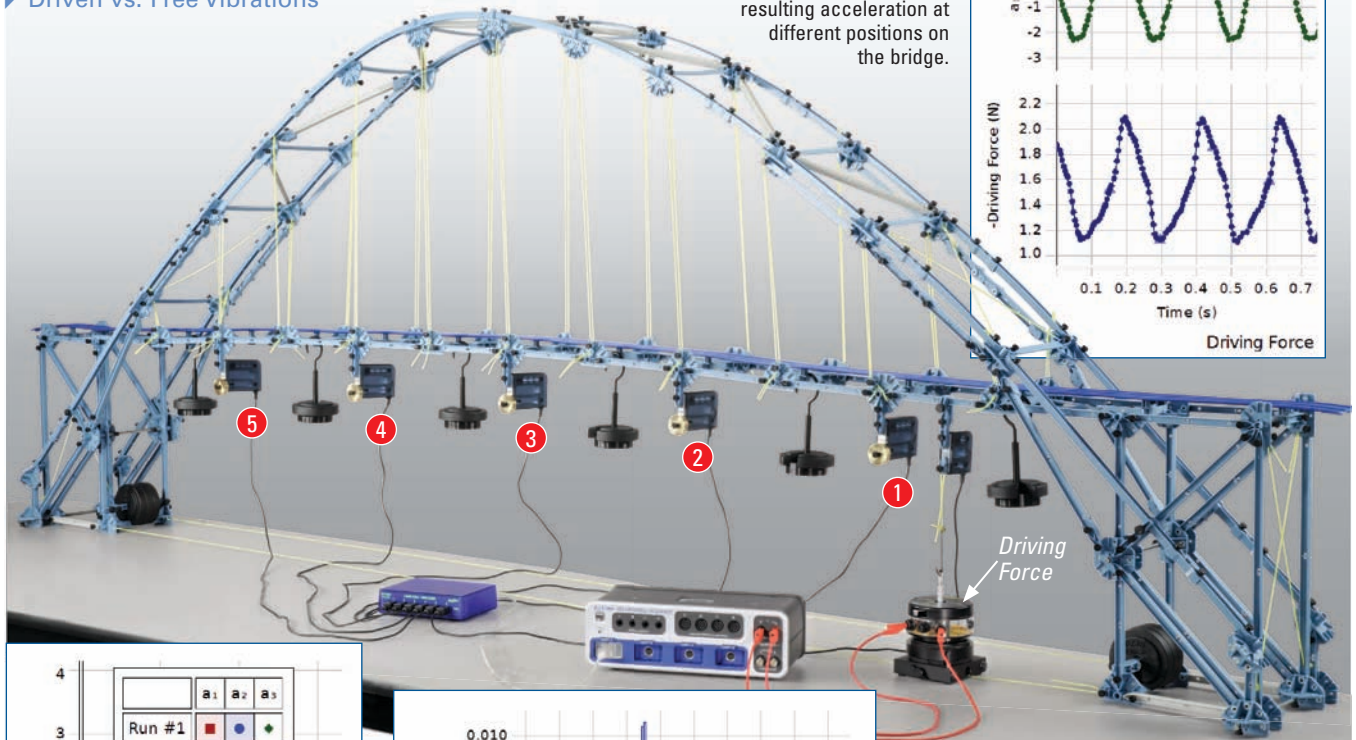
Advanced Structures Set	ME-6992B	p. 8
Function Generator	PI-8127	
Mechanical Wave Driver	SF-9324	
Large Slotted Mass Set	ME-7566	
5 N Load Cell	PS-2201	p. 4
45cm Stainless Steel Rod	ME-8736	
Large Rod Base	ME-8735	

## Study Vibrational Modes in Complex Bridges

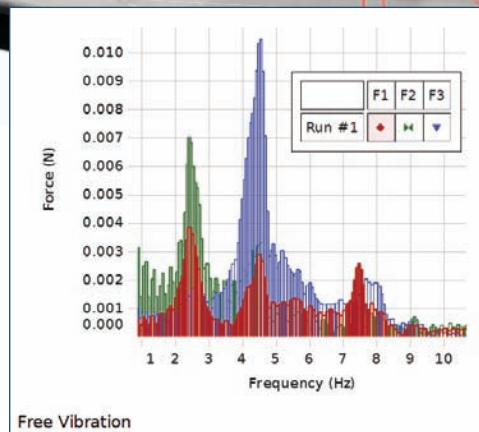
Concepts:

- ▶ Resonance in Complex Systems
- ▶ Driven vs. Free Vibrations

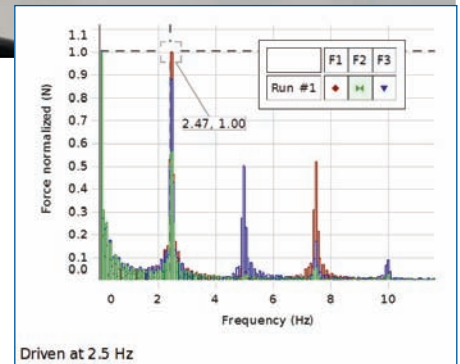
Students compare the driving force to the resulting acceleration at different positions on the bridge.



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



The bridge is struck by hand and allowed to freely oscillate. The FFT (using PASCO Capstone™) shows that there are several resonant frequencies. Note how different the amplitudes are at different locations 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.

### 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

### 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/CapstoneExperiments](http://www.pasco.com/CapstoneExperiments).

### Order Information

<b>Bridge Vibrations</b> .....	<b>EX-5548</b>
<i>Required:</i>	
850 Universal Interface.....	p. 2
PASCO Capstone Software.....	p. 2



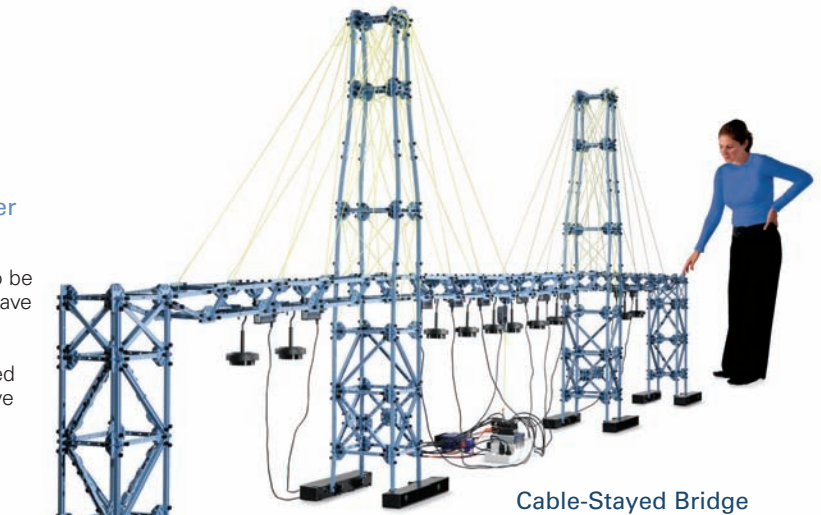
# National Instruments Structures Sets

ME-7006 Non-Driven Set

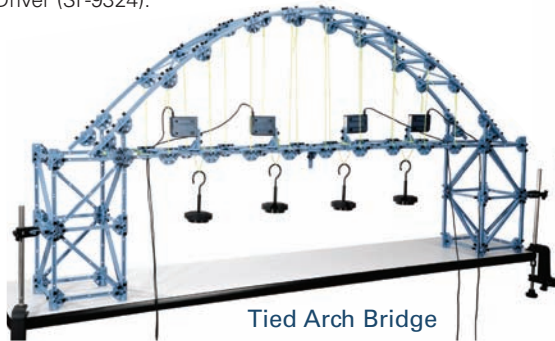
ME-7007 Driven Set

- ▶ Study Methods for Determining Bridge Health
- ▶ Build Tied Arch Bridge with Either Set
- ▶ Build Cable-Stayed Bridge with ME-7007 Set
- ▶ Amplifier Gives NI Output Signal Enough Power to Run the Driver

These two structures sets have been specially designed to be used with National Instruments interfaces. The load cells have an RJ50 male connector to connect to the NI 9237 Analog Input Module. To make the bridge shake in the ME-7007 set, the output of the NI 9263 is amplified with the included Instrument Amplifier (PI-2212) to drive the Mechanical Wave Driver (SF-9324).



Cable-Stayed Bridge



Tied Arch Bridge

## ME-7006 NI Structures Set (not driven)

The smaller set (ME-7006) has all the plastic I-beams, connectors, and four 5 N load cells, required to build and test the tied arch bridge shown on this page. The load cells act as sensitive accelerometers. When the bridge is struck with a hammer, the resulting vibrations can be recorded and analyzed in an FFT.



## ME-7007 NI Driven Structures Set

The larger set (ME-7007) has all the plastic I-beams and connectors required to build either the tied arch bridge or the cable-stayed bridge shown on this page. Ten 5 N load cells are provided to measure the accelerations at various points along the bridge and one 100 N load cell is attached to the driver to measure the driving force. In addition to striking the bridge with a hammer, the bridge oscillation is driven using the Mechanical Wave Driver at different frequencies to find the resonant frequencies of the bridge. The resulting vibrations can be recorded and analyzed in an FFT. Then a single I-beam is removed to weaken the bridge and the analysis is repeated to determine how the vibrations of the bridge at various points change.

The Mechanical Driver, which is basically a speaker with a driving rod, is connected by a string to the load cell attached to the bridge roadbed.



The NI 9263 outputs a sine wave which is amplified by the Instrument Amplifier (PI-2212) and fed into the Mechanical Wave Driver (SF-9324).

Part	Description	ME-7007	ME-7006
ME-6993	Truss Set Members	8 sets	3 sets
ME-6994	Truss Set Screws (75/set)	14 sets	5 sets
ME-6987	Flat Structures Members	1 set	1 set
ME-7002	Connector Spares	3 sets	2 sets
ME-6997	Full Round Connector Set	2 sets	1 set
ME-6996	Cord Lock Spares	2 sets	1 set
ME-7590	Short Mass Hanger	6 ea.	4 ea.
ME-7589	Slotted Mass Set, 2 kg	4 ea.	2 ea.
ME-6988A	Force Platform Structure	4 sets	2 sets
PS-2201-NI	Load Cell, 5 N	10 ea.	4 ea.
PS-2200-NI	Load Cell, 100 N	1 ea.	
PI-2212	Instrumentation Amplifier	1 ea.	
SE-9750	4 mm Banana Plug Cords (5)	1 set	
SF-9324	Mechanical Wave Driver	1 ea.	
ME-6999A	Angle Connectors	2 sets	



## Order Information

NI Structures Set	ME-7006
NI Driven Structures Set	ME-7007
Instrument Amplifier	PI-2212
5 N Load Cell	PS-2201-NI
100 N Load Cell	PS-2200-NI

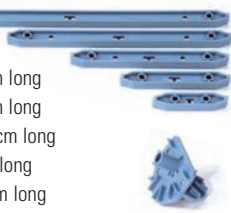
# 22 Replacement & Spares Sets

## Truss Set Members

ME-6993

### Includes

- I-beam #5 (8) 24 cm long
- I-beam #4 (18) 17 cm long
- I-beam #3 (18) 11.5 cm long
- I-beam #2 (8) 8 cm long
- I-beam #1 (8) 5.5 cm long
- Connectors (14)



<b>Order Information:</b>	
Truss Set Members.....	ME-6993

## Truss Set Screws

ME-6994

### Includes

- 75 screws.
- All components in the Structures System use this same 6-32 thumb screw.



<b>Order Information:</b>	
Truss Set Screws.....	ME-6994

## Connectors Spares

ME-7002

- Set of 14 connectors used to join truss members. This is the same connector included in the Truss Set ME-6990.



<b>Order Information:</b>	
Connector Spares.....	ME-7002

## Angle Connector Spares

ME-6999A

### Includes

- Sliding connectors (12),
- Angle connectors (24),
- Straight connectors (24).



<b>Order Information:</b>	
Angle Connector Spares.....	ME-6999A

## Round Connector Spares

ME-6997

### Includes

- Round connectors (6)
- Flat connectors (6)
- Six bolts with nuts.



<b>Order Information:</b>	
Round Connector Spares.....	ME-6997

## Cord Lock Spares

ME-6996

### Includes

- 32 cord-tensioning clips and a spool of yellow cord.



<b>Order Information:</b>	
Cord Lock Spares.....	ME-6996
Yellow Cord (2 pack).....	ME-9876

## Axle Spares

ME-6998A

- Includes drive wheel with rubber tire (4), pulleys with "O" rings (12 each), axles (two each of three lengths), spacers (12) and collets (24).



<b>Order Information:</b>	
Axle Spares.....	ME-6998A

## Destructible Bridge Members Spares

ME-7005

- Consumable replacement Breakable Links for the Destructible Bridge Members ME-7004. Each sprue contains 10 each of two different diameter links, giving a total of 200 links.



<b>Order Information:</b>	
Destructible Bridge Members Spares.....	ME-7005

## Force Platform Structures Bracket

ME-6988A

### Includes

- Brackets (2)
- Screws (4)



<b>Order Information:</b>	
Force Platform Structures Bracket.....	ME-6988A

## Flexible I-Beams

ME-6985

### Includes

- Flex I-beam #5 (10) 24 cm long
- Flex I-beam #4 (18) 17 cm long
- Flex I-beam #3 (18) 11.5 cm long



<b>Order Information:</b>	
Flexible I-Beams.....	ME-6985

## Flat Beams

ME-6987

### Includes

- 2x3 beams 12 cm long
- F4 beams 17 cm long
- 3x4 beams 19 cm long



<b>Order Information:</b>	
Flat Beams.....	ME-6987

## #6 I-Beam Spares

ME-7008

- Longer beam to supplement the Truss Set ME-6990.
- Has the same cross section as the shorter beams.



- Includes 24 of the #6 I-beams, 35 cm long.

<b>Order Information:</b>	
#6 I-Beam Spares.....	ME-7008

## Cast Beam Spares

ME-6983

- Consumable replacement parts for Cast Beams ME-7009. Includes 10 Reusable Plastic Molds and 30 Rebar with Connectors. These can also be used with the Advanced Structures Set ME-6992B.



<b>Order Information:</b>	
Cast Beam Spares.....	ME-6983



## Roller Coaster Track (9.1 m)

ME-9814

Longer replacement roll of flexible plastic track for use with the Bridge Set ME-6991, Physics Structures Set ME-6989, Large Structures Set ME-7003, and Roadbed Spares ME-6995.



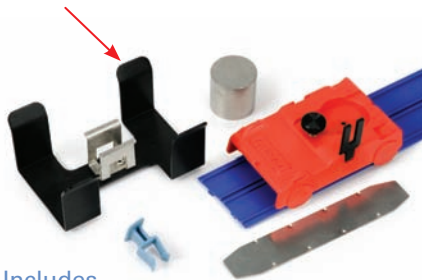
### Order Information:

Roller Coaster Track ..... ME-9814

## Roadbed Spares

ME-6995

*Starter Bracket*



### Includes

Flexible roadbed (3 m)  
Roadbed clips (24)  
Car with flag  
Extra mass, mini car starting bracket, and track couplers (2).

### Order Information:

Roadbed Spares ..... ME-6995

## Mini Car Starter Bracket

ME-9856



### Order Information:

Mini Car Starter Bracket ..... ME-9856

## Mini Car

Red Mini Car ME-9834

Green Mini Car ME-9839

Yellow Mini Car ME-9840



### Includes

M5 screw

### Order Information:

Red Mini Car ..... ME-9834

Green Mini Car ..... ME-9839

Yellow Mini Car ..... ME-9840

## Mini Car Collision Bumpers

ME-9844



### Includes

Two each of bumper and 6-32 screw

### Order Information:

Mini Car Collision Bumpers ..... ME-9844

## Mini Car Track Spares

ME-6974



### Includes

Two gates  
Two track couplers  
One bag (24) of roadbed clips

### Order Information:

Mini Car Track Spares ..... ME-6974

## Mini Car Collision Spares

ME-6973



### Includes

Two gates

One each of ballast mass, track coupler, bag (24) of roadbed clips, thread, clay and rubber bands

### Order Information:

Mini Car Collision Spares ..... ME-6973

## Hydraulic and Pneumatic Structures

ME-6984



### Includes

Master Cylinder  
Pressure Sensor "T"  
Check Valves and Tubing  
Syringes (10, 20, 60 ml)  
Drive Belt for Rotary Motion Sensor (Not shown)

### Order Information:

Hydraulic/Pneumatic Structures ..... ME-6984

## Structures Rod Clamps

(Set of 2)

ME-6986



Connects structure members to 1/2 inch rod.

### Order Information:

Structures Rod Clamps (2) ..... ME-6986

# STRUCTURES SYSTEM

*Connect your students to the real world!*



This model of the Louisville 2nd Street Bridge was built using the PASCO Structures System. The section shown here is approximately 4m long.