Stress/Strain Apparatus

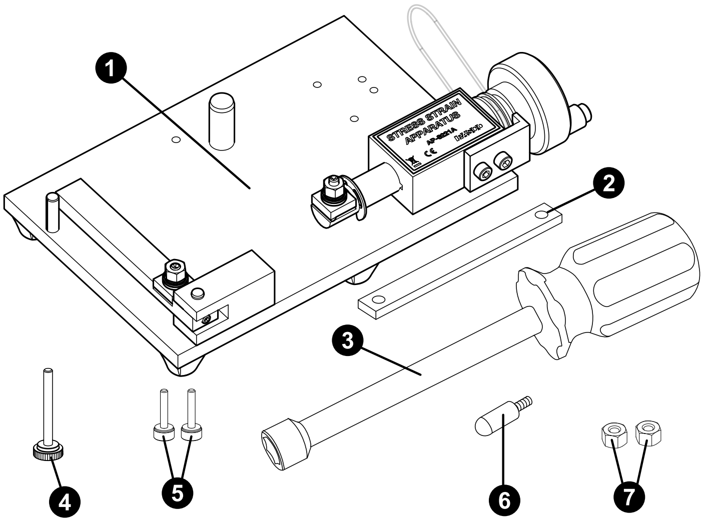
AP-8221A

Introduction

The Stress/Strain Apparatus illustrates the relationship between stress and strain for various materials. The apparatus measures the force applied to a test coupon and the resulting change in the coupon's length. PASCO Capstone data collection software can be used to generate a plot of force versus distance and a plot of stress versus strain.

The Stress/Strain Apparatus requires a rotary motion sensor, a force sensor, and PASCO Capstone software to record and analyze data. Depending on the chosen sensors, an analog or PASPORT interface may be required as well. Four types of metal test coupons and four types of plastic test coupons are included with the apparatus. Also included are a nut driver that fits over the hex nuts on the coupon clamps, a bar for calibrating the apparatus, and spare hex nuts for the coupon clamps.

Equipment



1. Stress/Strain Apparatus without Sensors (AP-8221A)
2. Calibration bar
3. Nut driver
4. Large thumbscrew for force sensor
5. 2× thumbscrews for rotary motion sensor
6. Attachment for force sensor
7. 2× replacement hex nuts

Required equipment (Wireless version):

- Wireless Force Acceleration Sensor (PS-3202)
- Wireless Rotary Motion Sensor (PS-3220)
- PASCO Capstone data collection software

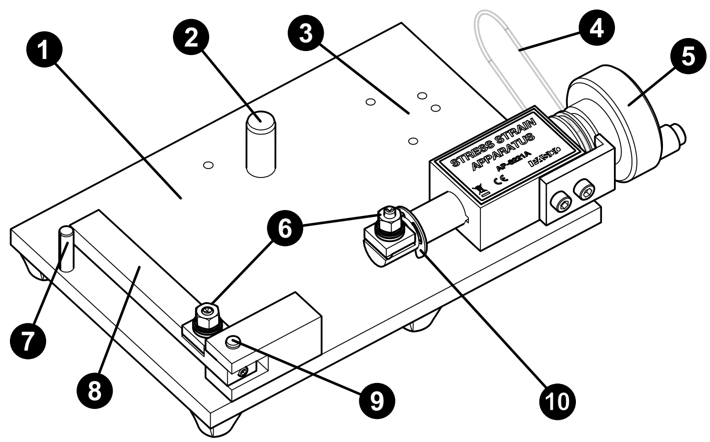
Required equipment (PASPORT version):

- PASPORT High Resolution Force Sensor (PS-2189)
- PASPORT Rotary Motion Sensor (PS-2120A)
- PASPORT interface, such as the 550 Universal Interface (UI-5001) or the 850 Universal Interface (UI-5000)
- PASCO Capstone data collection software

Recommended equipment:

- Replacement Test Coupons (Full Set) (AP-8217A)
- Digital Calipers (SE-8710)

Features



1. Platform
2. Force sensor post
3. Rotary motion sensor mounting holes
4. Belt
5. Crank
6. Coupon clamps
7. Lever arm stop
8. Lever arm
9. Pivot
10. Plunger

Get the software

PASCO Capstone is required to properly use this product. We offer a free trial of Capstone for Windows and Mac. To get the software, go to pasco.com/downloads. If you have installed the software previously, check that you have the latest update by clicking the **Help** tab and selecting **Check for Updates**.

Theory

A stress-strain tensile test measures the amount of stretching force applied to a sample of material and the amount of stretch of that material. **Stress** (σ) is the ratio of force (*F*) per unit of cross-sectional area (*A*). **Strain** (ε) is the ratio of the change of length (*l*) compared to the original length (*L*). A stress-strain curve is a graphical representation of the load applied and the deformation of the sample. The curve varies from material to material. See Figure 1 for an example of this curve.

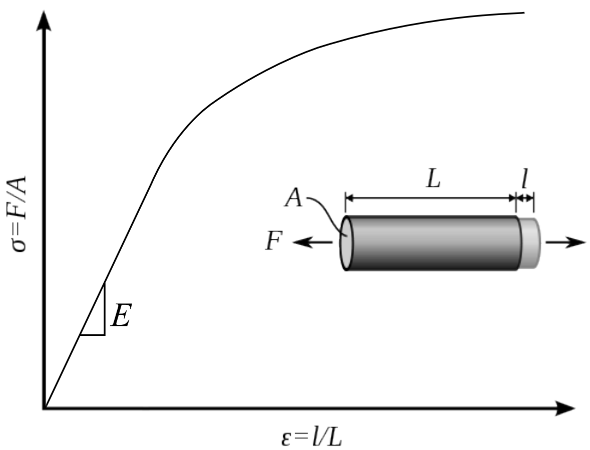


Figure 1: Stress-strain curve.

Ductile materials like metal have a linear stress-strain relationship up to a point. The slope of the linear part of the stress-strain curve is called "Young's modulus" or the modulus of elasticity (*E*) and is a property used to characterize materials.

About the apparatus

The lever arm on the Stress/Strain Apparatus is a Class III lever that transmits the applied force to the force sensor. The length of the lever arm from the pivot to the force sensor attachment is five times the length of the lever arm from the pivot to the coupon clamp that is part of the lever arm. The force applied to the test coupon is five times more than the force measured by the force sensor. Therefore, any experiment using the Stress/Strain Apparatus must include a calculation which multiplies the measured force by five.

About the coupons

Two sets of coupons are available for the Stress/Strain Apparatus: the Plastic Test Coupons (AP-8222) and the Metal Test Coupons (AP-8223). The Plastic Test Coupons set contains four types of color-coded samples, with 10 pieces of each sample provided. The plastic coupons are attached to rectangular plastic rails called "sprues", from which each sample should be cut using scissors or a knife. The Metal Test Coupons includes five different types, with 10 pieces of each type provided. The metal samples are stored in sample containers which prevent the coupons from being bent or creased, and which are labeled with the material and thickness of the contained samples.

The Plastic Test Coupons consist of the following materials:

- Orange: High impact polystyrene (HIPS)
- Black: Nylon 6 (15% glass fiber reinforced)
- Blue: Acrylonitrile butadiene styrene (ABS)
- White: Polypropylene (PP)

The Metal Test Coupons consist of the following materials and thicknesses:

- Cold-rolled steel, 0.003"
- Annealed steel, 0.003"
- Aluminum, 0.003"
- Brass (thick), 0.005"
- Brass (thin), 0.003"

Equipment setup

Part 1: Attach the rotary motion sensor

1. If you are using the PASPORT Rotary Motion Sensor, remove the rod clamp from the sensor.
2. Place the three step pulley onto the shaft of the rotary motion sensor with the largest pulley on the outside. If using the PASPORT Rotary Motion Sensor, the pulley should be on the "clockwise positive" side of the sensor.
3. Place the rotary motion sensor onto the platform such that the middle pulley is aligned with the groove on the crankshaft and the cord (if the sensor has one) points away from the crankshaft. If you are using the PASPORT Rotary Motion Sensor, the sensor's longest side will be flat against the platform (see Figure 2). If you are using the Wireless Rotary Motion Sensor, the sensor will be standing upright (see Figure 3).
4. Insert the two thumbscrews included with the apparatus up through the appropriate mounting holes on the bottom of the platform, then screw the thumbscrews into the threaded holes on the rotary motion sensor. Note that you will need to use different holes depending on which rotary motion sensor you are using.
5. Seat the belt so that it slots over the middle step of the pulley and the groove on the crankshaft.

Part 2: Attach the force sensor

1. Remove the hook or bumper from your chosen force sensor, then replace it with the force sensor attachment included with the Stress/Strain Apparatus.
2. Place the force sensor onto the apparatus platform by aligning the sensor's support rod mounting hole with the force sensor post on the platform.
3. Insert the long thumbscrew through the hole on the sensor marked **Cart**, then screw the thumbscrew into the threaded hole in the platform.
4. Tighten the force sensor's setscrew against the force sensor post.

With both sensors in position, the setup should resemble what is shown in Figure 2 (if using the PASPORT Rotary Motion Sensor) or Figure 3 (if using the Wireless Rotary Motion Sensor).

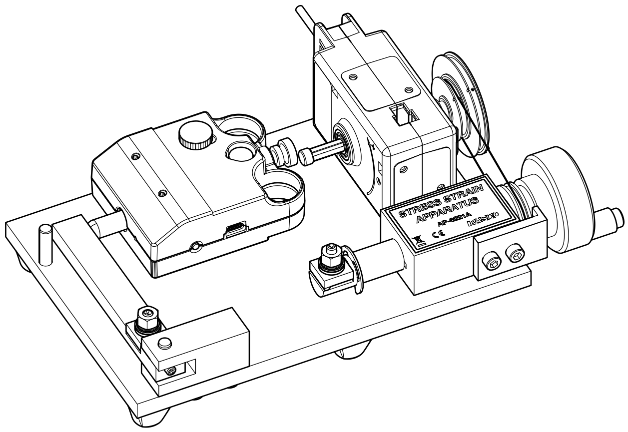


Figure 2: Platform with force sensor and PASPORT Rotary Motion Sensor mounted.

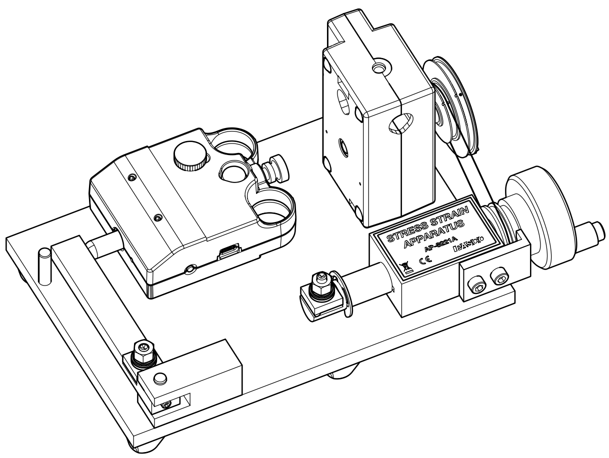


Figure 3: Platform with force sensor and Wireless Rotary Motion Sensor mounted.

Part 3: Clamp down the apparatus (*optional*)

To prevent the apparatus from moving during data collection, use a large C-clamp to clamp the apparatus platform to the edge of your bench or table. One side of the platform has three feet. In order to avoid bending the platform, position the clamp directly over the center foot.

Part 4: Connect the sensors

To finish setup, you will need to connect the sensors from Parts 1 and 2 to PASCO Capstone data collection software. The procedure for doing so differs based on the sensors used:

- PASPORT sensors: Plug the sensors into a PASPORT interface, then connect the interface to Capstone.
- Wireless Sensors: Connect the sensors directly to Capstone using Bluetooth or the included mini USB cable.

> **NOTE:** If you are using the Wireless Rotary Motion Sensor, you will need to switch the sign of its measurements so that clockwise rotation is positive. To do so, select the **Properties** icon next to the Wireless Rotary Motion Sensor in the Hardware Setup tool, then check the box next to **Change sign**.

For more information on connecting the sensors to the software, see the relevant product manuals and the Capstone online help.

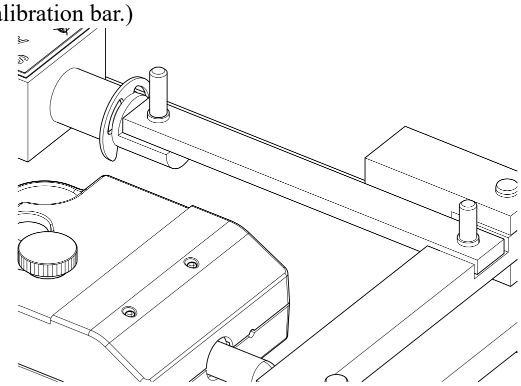
Calibrate the apparatus

As you turn the crank during the experiment, force will be applied to the test coupon, causing it to stretch. However, this applied force will also cause the apparatus platform and the force sensor to deform slightly. The displacement recorded by the rotary motion sensor will be the combination of the coupon stretching and the deformation of the rest of the apparatus. Therefore, to obtain the most accurate data possible, you will need to compensate for this deformation in the software.

Regardless of how much the coupon stretches, the deformation of the rest of the apparatus is constant for a given force. You can measure this deformation directly by using the calibration bar, which does not stretch significantly, instead of a coupon. The resulting displacement is due entirely to the deformation of the apparatus. Once properly configured, the Calibration tool in Capstone uses this information to subtract the displacement due to deformation from the total stretch during a coupon test, leaving only the stretch of the coupon itself.

Once you have mounted the sensors and connected them to Capstone as described previously, select **Calibration** from the Tools palette and follow the instructions below to create a new calibration:

1. Select **Stress-Strain Apparatus: Compliance Calibration** as the measurement to be calibrated, then click **Next**.
2. If you have multiple force sensors or rotary motion sensors connected to Capstone, select the ones connected to the Stress-Strain Apparatus, then click **Next**.
3. Select **Create New Calibration**, then click **Next**.
4. For each coupon clamp, remove the nut, washers, clamp top, and spring from the bolt. Place the calibration bar onto the posts for the coupon clamps, all the way down onto the smooth base of the bolts (see below), then select **Next**. (Do not use the nuts to secure the calibration bar.)



5. Record a smooth run of data using the following procedure:
    a. Turn the crank so that the lever arm does not touch the force sensor, as shown in Figure 4, then zero the force sensor by pressing the **Zero** button in Capstone (for the Wireless Force Acceleration Sensor) or by pressing the **ZERO** button on the sensor body (for the PASPORT Force Sensor).
    b. Click **Record**, then slowly begin to turn the crank clockwise until the lever arm is just barely touching the force sensor attachment.
    c. Once the force measurement on the display reaches about 5 N of force, click **Stop**. This will preload the bar with a small amount of force, removing slack and improving the quality of data.

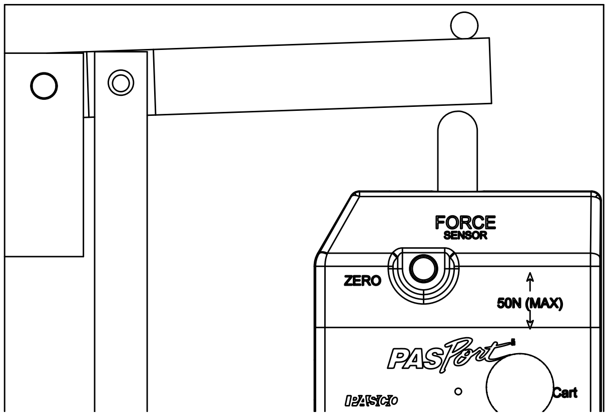
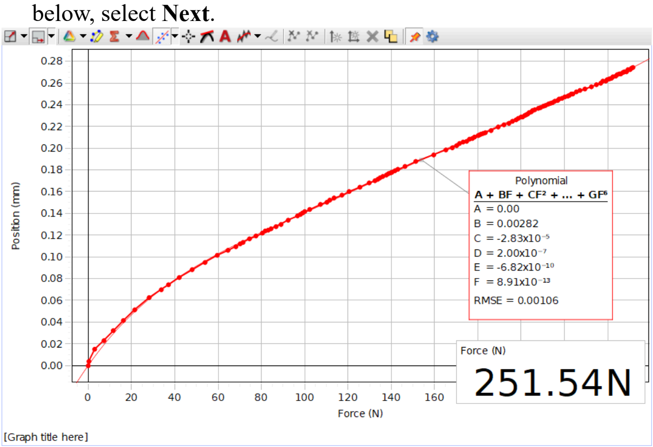


Figure 4: Lever arm in the appropriate starting position.

d. Zero the force sensor again, then begin recording again, turning the crank slowly to stretch the apparatus.

e. When the force reaches about 240 N, stop recording. For best results, continue smoothly turning the crank until *after* recording has stopped, as stopping the rotation while data is being collected will introduce slight errors into the calibration.

f. Once you have obtained data resembling what is shown below, select **Next**.



6. A polynomial fit with six terms will automatically be applied to your data run. In the Curve Fit Editor, you may change the number of coefficients and lock coefficients to specified values. You may also add a selection to the graph to restrict the data points used to determine the polynomial fit. There is usually no need to adjust the fit beyond its initial value. Once you are satisfied with the polynomial, select **Next**.

7. Enter a name for the calibration, then select **Finish**.

In addition to creating a new calibration, Step 3 of the Calibration process allows you to perform the following actions:

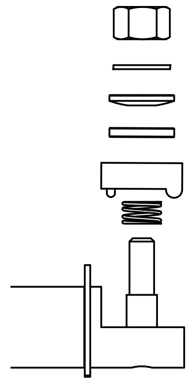
- **Use Calibration**: Select and enable a calibration that has already saved in the Capstone file. If the dropdown menu is blank and inaccessible, there are no saved calibrations in the file.
- **Use Raw Values**: Temporarily disable calibration for the experiment.
- **Manage Existing Calibration**: Rename or delete a calibration stored in the Capstone file.

Data collection

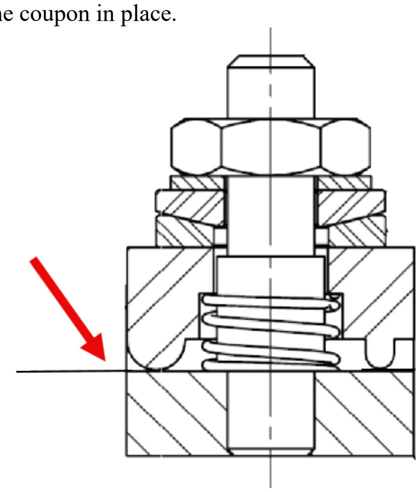
1. Create a graph display of **Applied Force** versus **Change in Length**. (Do NOT use the regular force and position measurements!)

2. Remove the calibration bar from the coupon clamps.

3. For each of the coupon clamps, replace the spring, clamp top, concave washer, convex washer, flat washer, and hex nut onto the bolts *in that order*, as shown below. Keep the hex nuts slightly loose for now.



4. Place one end of the test coupon under one of the clamp tops at the position indicated by the red arrow below, oriented so that the coupon points toward the other clamp. Make sure the clamp top's feet hold the coupon in place.



> **NOTE:** The plastic test coupons have ridges on their top sides. Place the coupon end under the clamp top with the ridged side facing upwards.

5. Adjust the crank until the opposite end of the coupon slides easily under the other clamp.

6. Tighten the nuts on both clamps using the nut driver. When no force is applied to the coupon, as little twist as possible should be visible in the coupon.

> **IMPORTANT:** The clamps should hold the coupon tightly enough that it will not slip when force is applied. However, over-tightening the nuts **will** damage the bolts. When in doubt, err on the side of under-tightening.

7. Turn the crank counterclockwise to pull the lever arm away from the force sensor, creating a small gap between the end of the force sensor attachment and the lever arm. (See Figure 3.)
8. Click **Record**, then begin turning the crank clockwise. Just before the lever arm comes in contact with the Force sensor, begin turning the crank very slowly. When you observe on the plot that the material has been stretched beyond the elastic region, you can begin turning the crank faster.
9. When you have finished collecting data, click **Stop**.

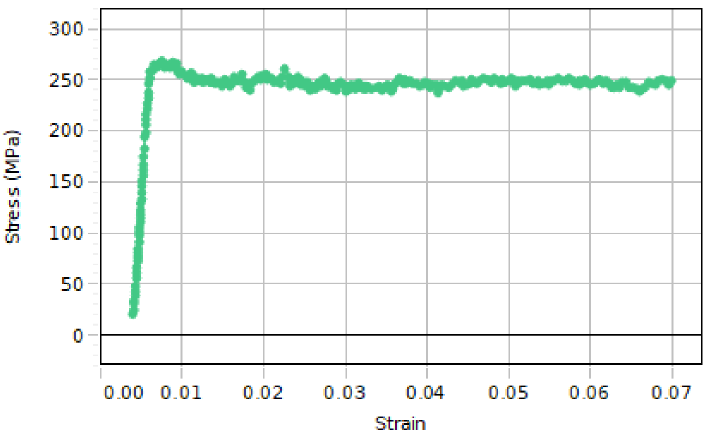
> **NOTE:** If the coupon breaks, it should break near the middle of the coupon. If the coupon breaks near one of the ends, it was likely twisted slightly when it was mounted, which may harm the accuracy of the data.

Data analysis

Once you have obtained the Applied Force and Change in Length data from the previous section, follow the steps below to create a plot of stress versus strain for your sample:

1. Select **Calculator** in the Tools palette.
2. Enter the following calculations into the Calculator tool:
   - Stress=[Applied Force, Ch B (N)]/Area
   - Strain=[Change in Length, Ch B (mm)]/L_0

   For the first calculation, set the units of Stress to MPa. For the second calculation, set Strain to be unitless.
3. For the values of **Area** and $\mathbf{L_0}$, enter the cross-sectional area of your sample (in mm^2) and the length of the straight portion of the sample (in mm) respectively.
4. Edit the graph display to plot Stress versus Strain, as shown below.



Software help

The SPARKvue, PASCO Capstone, and chemvue Help provide information on how to use this product with the software. You can access the help from within the software or online.

Software: Help > PASCO Capstone Help

Online: help.pasco.com/capstone

Experiment files

Download one of several student-ready activities from the PASCO Experiment Library. Experiments include student handouts and teacher notes. Visit pasco.com/freelabs/AP-8221A.

Technical support

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Limited warranty

For a description of the product warranty, see the Warranty and Returns page at www.pasco.com/legal.