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USER MANUAL

Flexible Joint Experiment

Set Up and Configuration

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This product meets the essential requirements of applicable European Directives as follows:

- 2006/95/EC; Low-Voltage Directive (safety)
- 2004/108/EC; Electromagnetic Compatibility Directive (EMC)

CONTENTS

1 PRESENTATION

The Quanser Rotary Flexible Joint module, pictured in Figure 1.1, consists of a rigid beam mounted on a flexible joint that rotates via a DC motor. The joint deflection is measured using a sensor. This module is designed to mount to a Quanser rotary servo plant (SRV02). The sensor shaft is aligned with the motor shaft. One end of a rigid link is mounted to the sensor shaft. The link rotation is counteracted by two extension springs anchored to the solid frame resulting in an instrumented flexible joint. The spring anchor points are adjustable to three locations to obtain various stiffness constants. Three types of springs are supplied with the system resulting in a total of 9 possible stiffness values. The link is also adjustable in length thus allowing for variations in inertia.

Figure 1.1: Rotary Flexible Joint system

This system is similar in nature to the control problems encountered in large geared robot joints where flexibility is exhibited in the gearbox. The Rotary Flexible Joint is an ideal experiment intended to model a flexible joint on a robot or spacecraft. This experiment is also useful in the study of vibration analysis and resonance. The SRV02 Rotary Flexible Joint module is equipped with a1024 line optical encoder to sense arm's angular position.

■ **Caution: This equipment is designed to be used for educational and research purposes and is not intended for use by the general public.** The user is responsible to ensure that the equipment will be used by technically qualified personnel only.

2 COMPONENTS

The Rotary Flexible Joint components are identified in Section 2.1. Some of those components are then described in Section 2.2.

2.1 Component Nomenclature

The components of the Rotary Flexible Joint module are listed in Table 2.1 below and labeled in Figure 2.1 and Figure 2.2.

ID #	Component	ID #	Component
1	ROTFLEX base	7	Springs
2	Thumbscrews	8	Adjustable load
3	ROTFLEX arm	9	Encoder connector
4	Arm sensor (Encoder)	10	ROTFLEX pivot
5	Base anchor points	11	Adjustable load anchor points
6	Arm anchor points	12	SRV02

Table 2.1: Listing of ROTFLEX Components

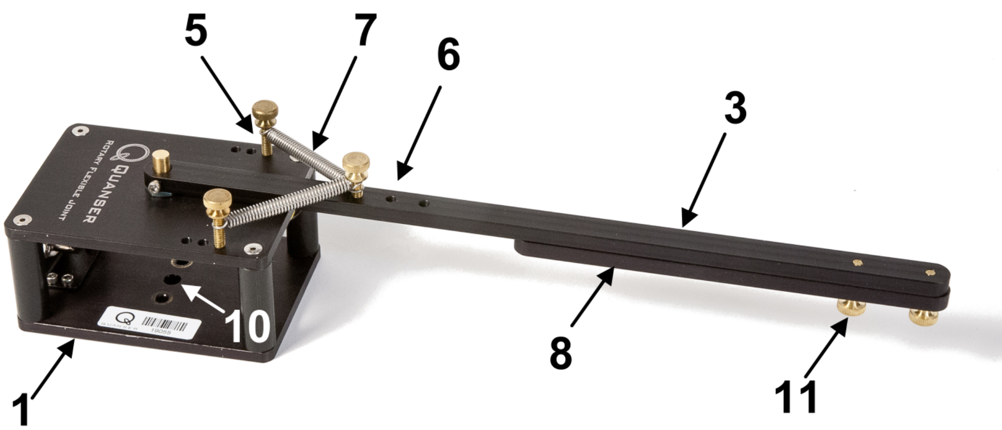


Figure 2.1: ROTFLEX Components - Top View

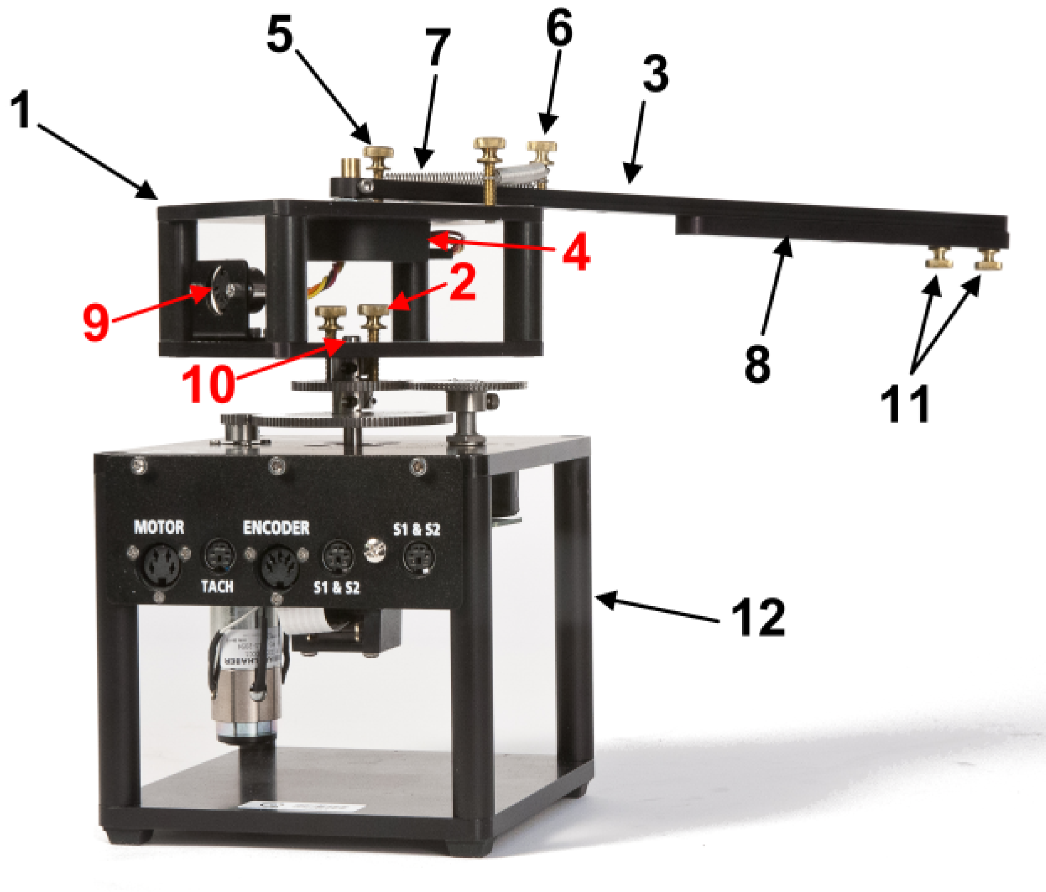


Figure 2.2: ROTFLEX Components - Back View when installed on SRV02

2.2 Component Description

2.2.1 Encoder

The ROTFLEX option comes with an optical encoder used to measure the arm's angular position. The model used is a US Digital Optical Kit Encoder. It offers high resolution (4096 counts in quadrature), and measures the relative angle of the arm. The internal wiring of the encoder and the 5-pin DIN connector on the ROTFLEX module is illustrated in Figure 2.3.

■ **Caution:** The Encoder sends a digital signal and should be directly connected to a Quanser terminal board using a standard 5-pin DIN cable. **DO NOT connect the encoder signal to the amplifier**.

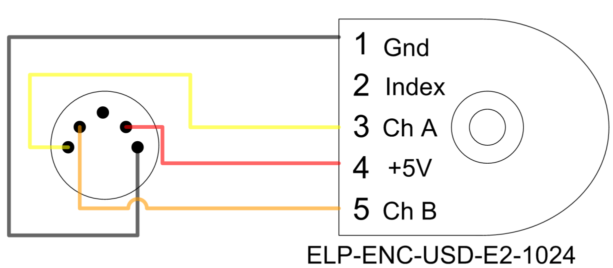


Figure 2.3: Encoder Wiring

3 SYSTEM SPECIFICATIONS

Table 3.1, below, lists and characterizes the main parameters associated with the ROTFLEX module. Some of the parameters listed in Table 3.1 are used in the mathematical model.

Symbol	Description	Value	Unit
	Module Dimensions	10 x 8 x 5	cm^3
L_1	Main arm length	29.8	cm
L_2	Load arm length	15.6	cm
	Distance between joint to middle of load arm		
d_{12}	Arm Anchor Point 1	21.0	cm
d_{12}	Arm Anchor Point 2	23.5	cm
d_{12}	Arm Anchor Point 3	26.0	cm
	Module body mass	0.3	kg
m_1	Main arm mass	0.064	kg
m_2	Load arm mass	0.03	kg
K_{enc}	Encoder resolution (in quadrature mode)	4096	Counts/Rev
K_1	Spring #1 stiffness	187	N/m
K_2	Spring #2 stiffness	313	N/m
K_3	Spring #3 stiffness	565	N/m

Table 3.1: Rotary Flexible Joint specifications.

Figure 3.1 is a model depicting the Rotary Flexible Joint system. The ROTFLEX module has been designed to allow many configurations. As shown in Figure 3.1, there are three anchor positions on the arm as well as three anchor positions on the body. The force exerted by the springs can be varied by attaching the springs in different anchor points. The ROTFLEX system is also supplied with three sets of springs of different stiffness constants (values shown in Table 3.1). The secondary load arm attaches underneath the main arm and can be connected to different anchor points, allowing the total arm length to be changed.

The spring anchor locations, variable load length, and springs with different stiffnesses allows for many configurations.

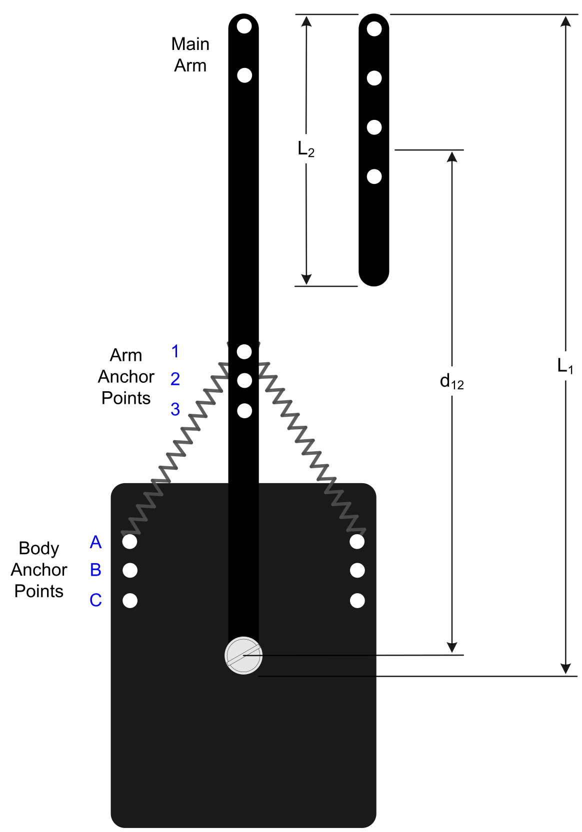


Figure 3.1: Rotary Flexible Joint Module

4 SYSTEM SETUP

The Rotary Flexible Joint module requires minimal assembly. The ROTFLEX system contains the following components:

- Quanser ROTFLEX module
- 3 sets of springs with differents stiffnesses (in Table 3.1).
- Encoder cable

See Section 4.1 for instructions on how to assemble the Rotary Flexible Joint system. Then, go through the procedure discussed in Section 4.2 to change the springs if desired.

■ **Caution:** If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

4.1 Assembly

1. Before starting, ensure the Quanser Rotary Servo (SRV02) is setup in the high-gear configuration, as discussed in SRV02 User Manual [1].
2. Slide middle hole on the bottom of the ROTFLEX module base onto the load shaft of the SRV02.
3. Fasten the ROTFLEX module on the top of the gears using the two thumbscrews, as shown in Figure 4.1 (highlighted in red).

Figure 4.1: Attach ROTFLEX to SRV02 using thumb screws

4.2 Changing the Springs

The following is the procedure to properly insert a new set of springs or change spring anchor locations. In order to maintain proper system dynamics, the springs and anchor positions should be symmetric. Do not use springs of different stiffness values and make sure both body anchor points are the same.

Note: *Using the stiffest set of springs might require extra effort to insert into the anchor points*.

1. Take both springs (make sure they are of the same pair) and insert the thumbscrew through the ends of both springs. Screw the thumbscrew into the desired point on the anchor arm (ID #6) in Figure 2.1.
2. Turn the arm towards you and screw in one side's thumbscrew into the desired base anchor point (ID #5) in Figure 2.1.
3. Finally, pull the arm toward the other base anchor point (you will feel some resistance from the other spring). Screw the remaining thumbscrew into the desired base anchor point. Make sure this anchor point is the same point the other spring is in.

5 WIRING PROCEDURE

The following is a listing of the hardware components used in this experiment:

- **Power Amplifier:** Quanser VoltPaq-X1, or equivalent.
- **Data Acquisition Board:** Quanser Q2-USB, Q8-USB, QPID, QPIDe, or equivalent supported DAQ.
- **Rotary Servo Plant:** Quanser SRV02, SRV02-T, SRV02-E, SRV02-EHR, or SRV02-ET.
- **Rotary Flexible Joint:** Quanser ROTFLEX Module.

The cables required to setup the ROTFLEX system is described in Section 5.1 and the procedure to connect the above components is given in Section 5.2.

■ **Caution:** When using a Quanser VoltPAQ power amplifier, **make sure you set the Gain to 1**!

5.1 Cable Nomenclature

Table 5.1, below, provides a description of the standard cables used in the wiring of the ROTFLEX system.

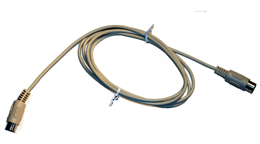
Cable	Type	Description
 (a) RCA Cable	2xRCA to 2xRCA	This cable connects an analog output channel of the data acquisition terminal board to the power module for proper power amplification.
 (b) Motor Cable	4-pin-DIN to 6-pin-DIN	This cable connects the output of the power module, after amplification, to the desired DC motor on the servo.
 (c) Encoder Cable	5-pin-stereo-DIN to 5-pin-stereo-DIN	This cable carries the encoder signals between an encoder connector and the data acquisition board (to the encoder counter). Namely, these signals are: +5 VDC power supply, ground, channel A, and channel B

Table 5.1: Cables required for setup

5.2 Typical Connections

This section describes the typical connections used to connect the Quanser Rotary Flexible Joint system to a data acquisition device and a single-channel power amplifier. The connections are given in Table 5.2 and illustrated in Figure 5.1. The connection procedure details is given below as well.

Cable #	From	To	Signal
1	Terminal Board: Analog Output #0	Amplifier "Command" Conector	Control signal to the amplifier.
2	Amplifier "To Load" Connector	SRV02 "Motor" Connector	Power leads to the SRV02 DC motor.
3	Terminal Board: Encoder Input #0	SRV02 "Encoder" Connector	Servo load shaft angle measurement.
4	Terminal Board: Encoder Input #1	ROTFLEX "Encoder" Connector	Flexibe joint angle measurement.

Table 5.2: ROTFLEX system connections

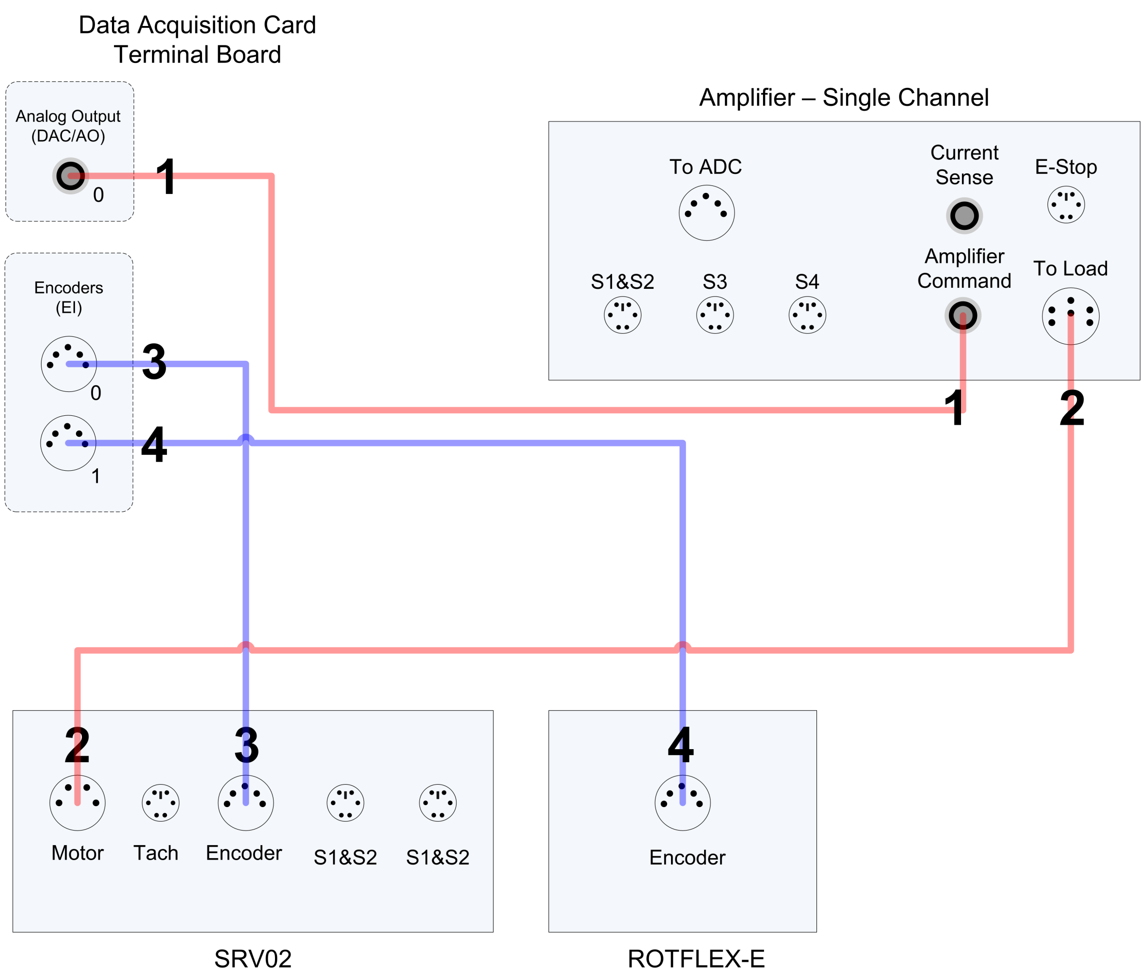


Figure 5.1: ROTFLEX system connections diagram

Follow these steps to connect the ROTFLEX system:

1. It is assumed that the Quanser DAQ board is already installed as discussed in [2]. If another data-acquisition device is being used, e.g. NI M-Series board, then go to its corresponding documentation and ensure it is properly installed.

2. Make sure everything is powered off before making any of these connections. This includes turning off your PC and the amplifier.

3. Connect one of the connectors on the 2x RCA to 2x RCA cable from the *Analog Output Channel #0* on the terminal board to the *Amplifier Command* Connector on the Quanser amplifier. See cable #1 shown in Figure 5.1.

4. Connect the 4-pin-stereo-DIN to 6-pin-stereo-DIN from *To Load* connector on the amplifier to the *Motor* connector on the SRV02. See connection #2 shown in Figure 5.1. The cable transmits the amplified voltage that is applied to the SRV02 motor.

5. To use the encoder to measure the load gear angle connect the 5-pin-stereo-DIN to 5-pin-stereo-DIN cable from the *Encoder* connector on the SRV02 panel to *Encoder Input Channel #0* on the terminal board, as depicted by connection #3 in Figure 5.1. This carries the load shaft angle measurement by the encoder.

   ■ **Caution:** Any encoder should be directly connected to the Quanser terminal board (or equivalent) using a standard 5-pin DIN cable. **DO NOT connect the encoder cable to the amplifier!**

6. Connect the connector on the ROTFLEX directly to *Encoder Input Channel #1* on the terminal board, as depicted by connection #4 in Figure 5.1. It carries the arm angle measured by the encoder.

6 TESTING AND TROUBLESHOOTING

This section describes some functional tests to determine if your ROTFLEX is operating normally. It is assumed that the system is connected as described in the Section 5.2, above. Software such as QUARC®or LabVIEW™ can be used to test the sensor readings and apply voltages to the motor. Alternatively, these tests can be performed with a signal generator and an oscilloscope.

6.1 SRV02 Motor and Sensors

Please refer to [1] for information on testing and troubleshooting the SRV02 separately.

6.2 Testing the ROTFLEX Arm Angle Sensor

Follow this procedure to test the ROTFLEX encoder:

1. Measure *Encoder Input Channel #1* using, for instance, the QUARC software.
2. Rotate the ROTFLEX arm, component #3 in Figure 2.1, slightly back-and-forth and verify that your are obtaining a reading.
3. If it is measuring, make sure it is reading the correct angle. For example, rotate the arm 30 degrees and ensure you are reading 30 degrees, which is about 341 counts in quadrature mode, in the software.

   Note: Some data acquisition systems do not measure in quadrature and, in this case, one-quarter of the expected counts are received, i.e. 1024 counts. In addition, some data acquisition systems measure in quadrature but increment the count by 0.25 (as opposed to having an integer number of counts). Make sure the details of the data-acquisition system being used is known. The counters on the Quanser DAQ boards measure in quadrature and therefore a total of four times the number of encoder lines per rotation, e.g. a 1024-line encoder results in 4096 integer counts for every full rotation.

6.3 Troubleshooting

Follow the steps below if the encoder on the ROTFLEX model is not measuring properly: If the encoder is not measuring properly, go through this procedure:

- Check that the data-acquisition board is functional, e.g. ensure it is properly connected, that the fuse is not burnt.
- Check that both the A and B channels from the encoder are properly generated and fed to the data-acquisition device. Using an oscilloscope, there should be two square waves, signals A and B, with a phase shift of 90 degrees. If this is not observed then the encoder may be damaged and need to be replaced. Please see Section 7 for information on contacting Quanser for technical support.

7 TECHNICAL SUPPORT

To obtain support from Quanser, go to http://www.quanser.com/ and click on the Tech Support link. Fill in the form with all the requested software and hardware information as well as a description of the problem encountered. Also, make sure your e-mail address and telephone number are included. Submit the form and a technical support representative will contact you.

REFERENCES

[1] Quanser Inc. *SRV02 User Manual*, 2009.

[2] Quanser Inc. *Q2-USB Data-Acquisition System User's Guide*, 2010.

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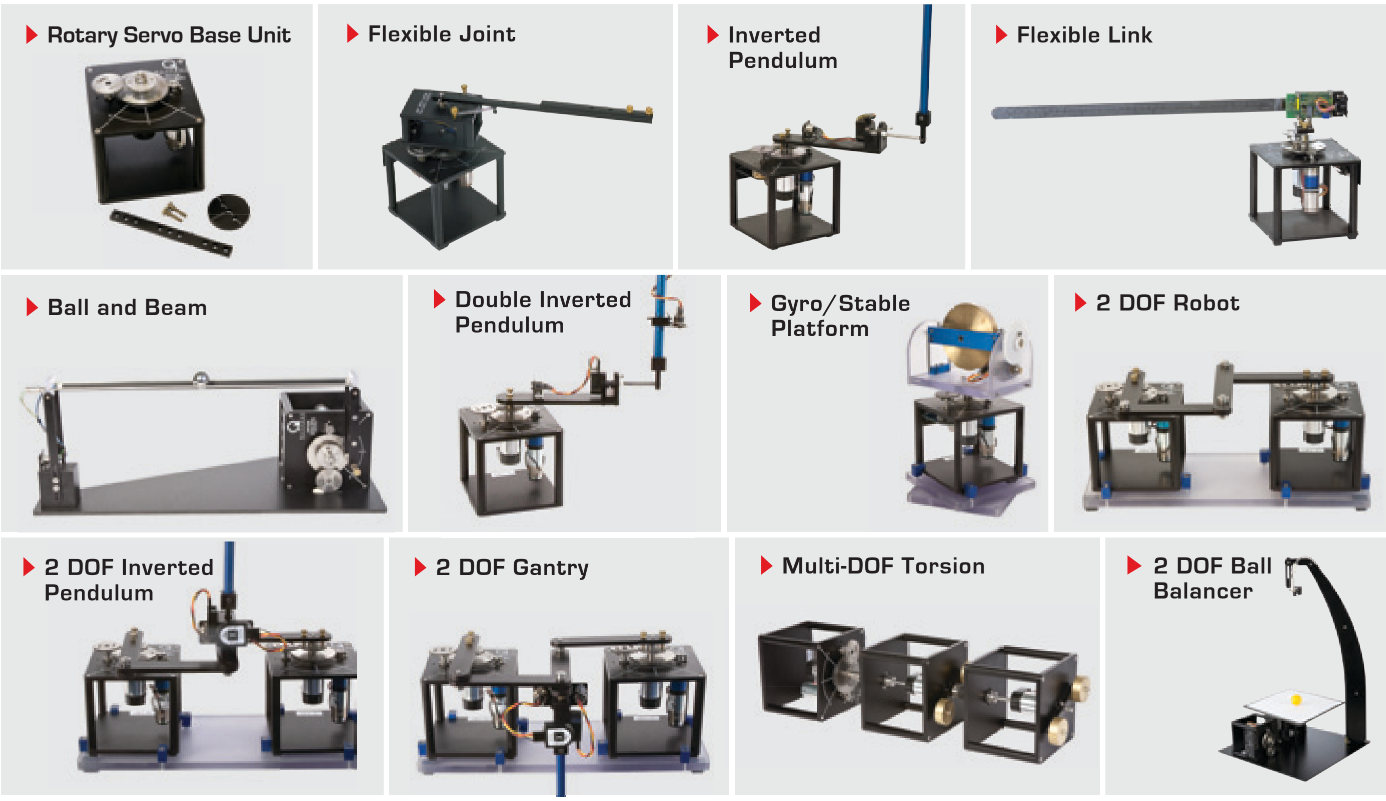

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