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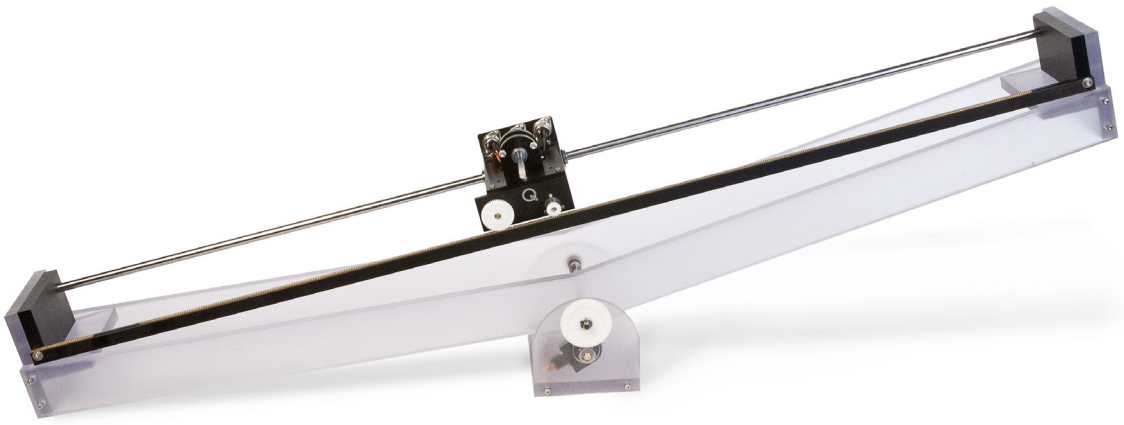
USER MANUAL

Seesaw Experiment

Set Up and Configuration



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

CONTENTS

1 PRESENTATION

1.1 Description

As illustrated in Figure 1.1, the SEESAW-E module is designed to accommodate the IP02 system, which is to say that the IP02 cart and track can be placed on top of the SEESAW-E. The SEESAW-E module is shown in Figure 1.1, below, and consists of two long arms hinged onto a support fulcrum. The system is manufactured of precisely machined polycarbonate with a durable matte finish. The seesaw can tilt freely about a rotation (a.k.a. pivot) axis mounted on an instrumented fulcrum. In order to measure the seesaw tilt angle, the rotation axis is coupled to an encoder through a pinion-and-anti-backlash-gear system. The resulting gear ratio is 3:1. The SEESAW-E module uses a 1024-line quadrature optical encoder to sense the position angle.

As previously mentioned, the IP02 cart-and-rack system can easily be placed on top of the seesaw. The powered cart can then travel freely along the length of the SEESAW-E. The IP02 is a solid aluminum carts. They are driven by a rack and pinion mechanism using a 6-Volt DC motor, ensuring consistent and continuous traction. Such cart slides along a stainless steel shaft using linear bearings. The cart position is measured using a sensor coupled to the rack via an additional pinion. Please review Reference [1] for a complete description of the IP02 systems.

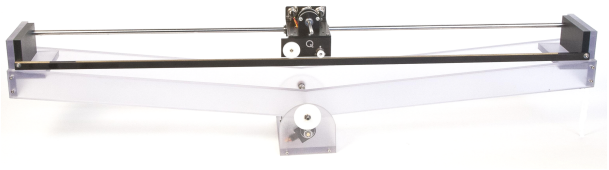


Figure 1.1: IP02 on the SEESAW-E

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.

1.2 Experiment Overview

Quanser values itself for the modularity of its experiments. This modular philosophy facilitates the change from one experimental setup to another with relative ease of work.

Table 1.1, below, provides a list of the Quanser linear motion experiments using the SEESAW-E module. Quanser's basic linear motion servo plant is the IP02. The seesaw can be used in combination with other Quanser modules, as described in Table 1.1.

Experiment Name	Experiment Description
Linear Flexible Joint Cart on SEESAW-E (SEEFLEX)	Design of a control system to balance a seesaw using a flexible structure mounted on top of it.
Single Inverted Pendulum on a double SEESAW-E (SEEPEN)	Design of a control system to balance an inverted pendulum on top of a double seesaw (MIMO system).

Table 1.1: IP02 Based Experiments Involving the SEESAW-E Module

2 COMPONENTS

2.1 Components Nomenclature

Table 2.1 provides a list of all the principal elements composing the SEESAW-E system. Each of these elements is located and identified, through a unique identification (ID) number, as represented in Figure 2.1 and Figure 2.2, above.

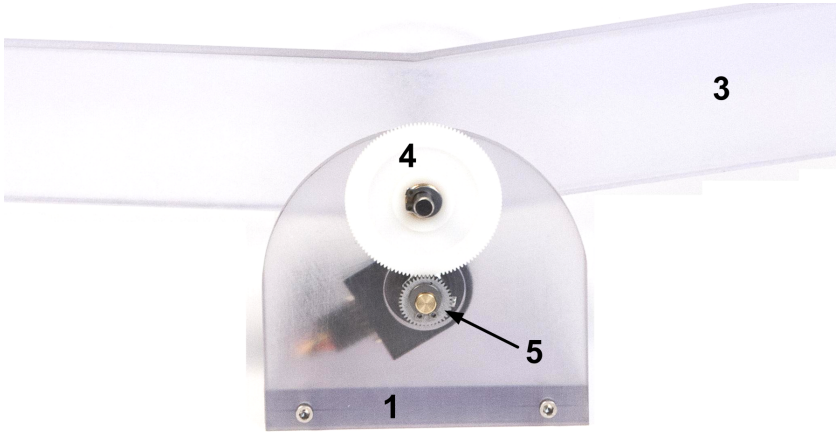


Figure 2.1: SEESAW-E Nomenclature

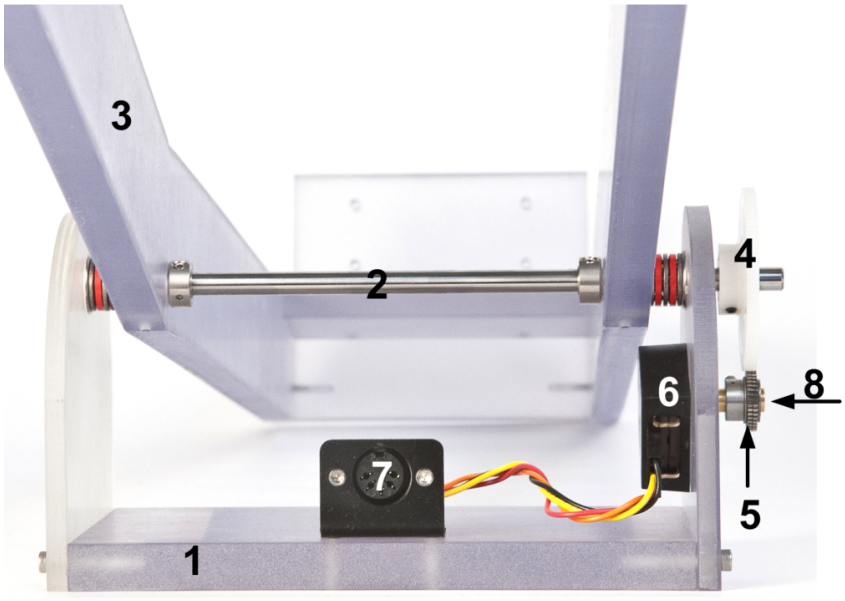


Figure 2.2: SEESAW-E Fulcrum Close-Up

ID	Component	ID	Component
1	Support Fulcrum	2	Pivot Axis
3	SEESAW-E Arm	4	SEESAW-E Position Pinion
5	Encoder Anti-Backlash Gear	6	Encoder
7	Encoder Connector	8	Encoder Shaft

Table 2.1: 2 DOF Robot components.

2.2 Space Requirement

When mounted on the SEESAW-E module, the IP02 systems require an overall space of 44-inch long by 16-inch high by 8-inch deep, as characterized in Table 2.2, below.

Description	Value	Unit
Overall SEESAW-E plus IP02 System Length	1.12	m
Overall SEESAW-E plus IP02 System Height	0.40	m
Overall SEESAW-E plus IP02 System Depth	0.20	m

Table 2.2: Overall Dimensions of the SEESAW-E plus IP02 System Space Requirements

2.3 Component Description

2.3.1 SEESAW-E Encoder

The SEESAW-E tilt angle is measured with one optical encoder, which is represented in Figure 2.1 and Figure 2.2, above, by component #6. The encoder model used in the SEESAW-E is a US Digital S1 single-ended optical shaft encoder. It offers a high resolution of 4096 counts per revolution (i.e. 1024 lines per revolution with two channels in quadrature).

The internal wiring diagram of the SEESAW-E encoder is depicted in Figure 2.3. The standard 5-pin DIN connector shown in Figure 2.3 is also pictured as component #7 in Figure 2.2.

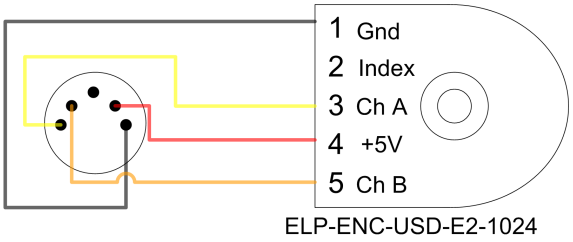


Figure 2.3: Wiring Diagram of the SEESAW-E Encoder

3 SPECIFICATIONS

Table 3.1, below, lists and characterizes the main parameters associated with the Quanser's SEESAW-E module. These parameters are particularly useful for the mathematical modeling and simulation of the SEESAW-E system(s).

Symbol	Description	Value	Unit
M_{SW}	Mass of the one-SEESAW-E plus one IP02 Track System	3.6	kg
K_{gs}	SEESAW-E Geartrain Gear Ratio	3	
D_T	Distance from Pivot to the IP02 Track	0.125	m
D_C	Distance from Pivot to the Center Of Gravity of the one SEESAW-E plus one IP02 Track System	0.058	m
J_{SW}	Moment of Inertia of SEESAW-E plus IP02 Track System, about its Center Of Gravity	0.395	kg-m^2
B_{SW}	Viscous Damping Coefficient as seen at the Seesaw Pivot Axis	≈ 0	N-m-s/rad
g	Gravitational Constant on Earth	9.81	m/s^2
K_{E_SW}	SEESAW-E Encoder Resolution	0.0015	rad/count
$\grave{e}_{range}$	SEESAW-E Approximative Angular Range on a Flat Surface	± 11.5	$\circ$

Table 3.1: SEESAW-E system specifications.

4 SYSTEM SETUP

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

Figure 4.1, below, illustrates an IP02 cart-and-rack system mounted on top of a SEESAW-E, in the default configuration, and his is the configuration used in the SEESAW-E laboratory

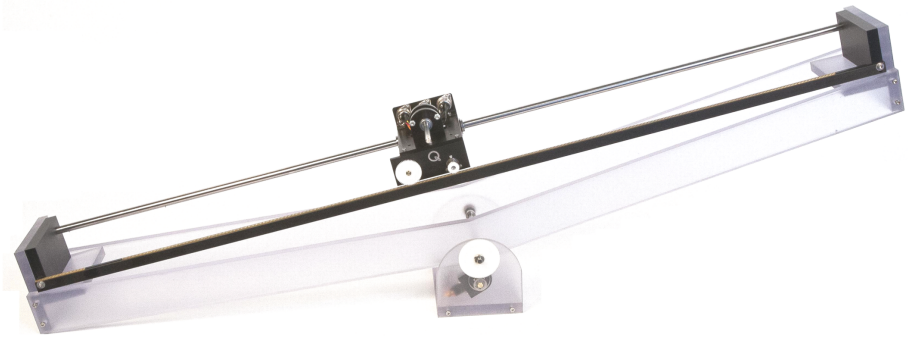


Figure 4.1: Configuration of the IP02 and SEESAW-E System

Note: The default configuration consists of the cart without its additional weight on it. Also the pendulum rod itself is not used and should be removed. Lastly, the IP02 rack should be located on top of the SEESAW-E in such a way that all the system's pinions face the same side, as shown in Figure 4.1

Follow these procedure to setup the Quanser SEESAW-E module in default configuration.

1. Do not mount the pendulum rod on your IP02 cart. Remove it if necessary. See Reference [1].
2. Do not place the additional weight on your P02 cart. Remove it if necessary. See Reference [1].
3. Loosen the four screws on both end of the SEESAW-E. As shown in Figure 4.3

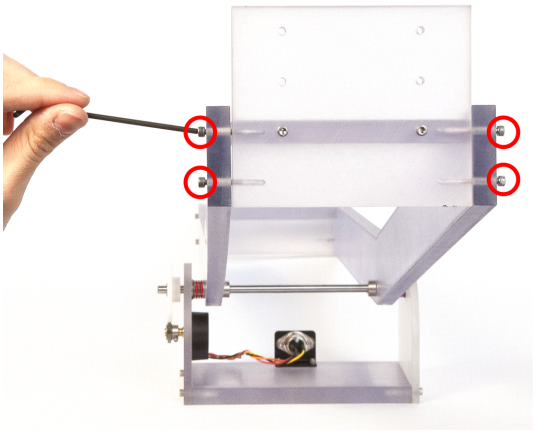


Figure 4.2: Adjustment screws

4. Place the IP02 cart and rack system on top of your SEESAW-E module. Make sure to locate the rack in such a way that IP02 cart pinions are on the same side as the SEESAW-E gears, as shown in Figure 4.1. Turn the rack around if necessary.

5. Tighten the four screws at on each end of the SEESAW-E to secure the IP02 rack from sliding.

Figure 4.3: Adjustment screws

5 WIRING PROCEDURE

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

1. **Power Amplifier:** Quanser VoltPAQ, or equivalent.
2. **Data Acquisition Device:** Quanser Q1-cRIO, Q2-USB, QPID/QPIDe, NI DAQ, or equivalent.
3. **Linear Plant:** Quanser IP02 module and SEESAW-E.

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

See the corresponding documentation for more information on these components. The required cables are described in Section 5.1 and the procedure to connect the above components is given in Section 5.2.

5.1 Cable Nomenclature

Table 5.1, below, provides a description of the standard cables used in the wiring of the SEESAW-E experiment.

Cable	Type	Description
 (a) RCA Cable	2xRCA to 2xRCA	This cable connects an analog output of the data acquisition (DAQ) device 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 (DAQ) device (to the encoder counter). Namely, these signals are: +5 VDC power supply, ground, channel A, and channel B

Table 5.1: Cables used to connect SRV02 to amplifier and DAQ device

5.2 Typical Connections

This section explains how to connect the SEESAW-E plant to the amplifier and the data acquisition device. See Reference [1] for more information about the IP02 Base Unit.

The connections are given in Table 5.2 and illustrated in Figure 5.1. The detailed wiring procedure is given below.

Cable #	From	To	Signal
1	Data Acquisition (DAQ) Device: Analog Output #0	Amplifier Command connector	Control signal to the amplifier.
2	Amplifier "To Load" connector	IP02 "Motor" connector	Power leads to the DC motor of IP02.
3	Data Acquisition (DAQ) Device: Encoder Input #0	IP02 Cart Connector	Cart encoder position measurement.
4	Data Acquisition (DAQ) Device: Encoder Input #1	SEESAW-E Encoder connector	SEESAW-E angle encoder measurement.

Table 5.2: Quanser SEESAW-E and IP02 connections

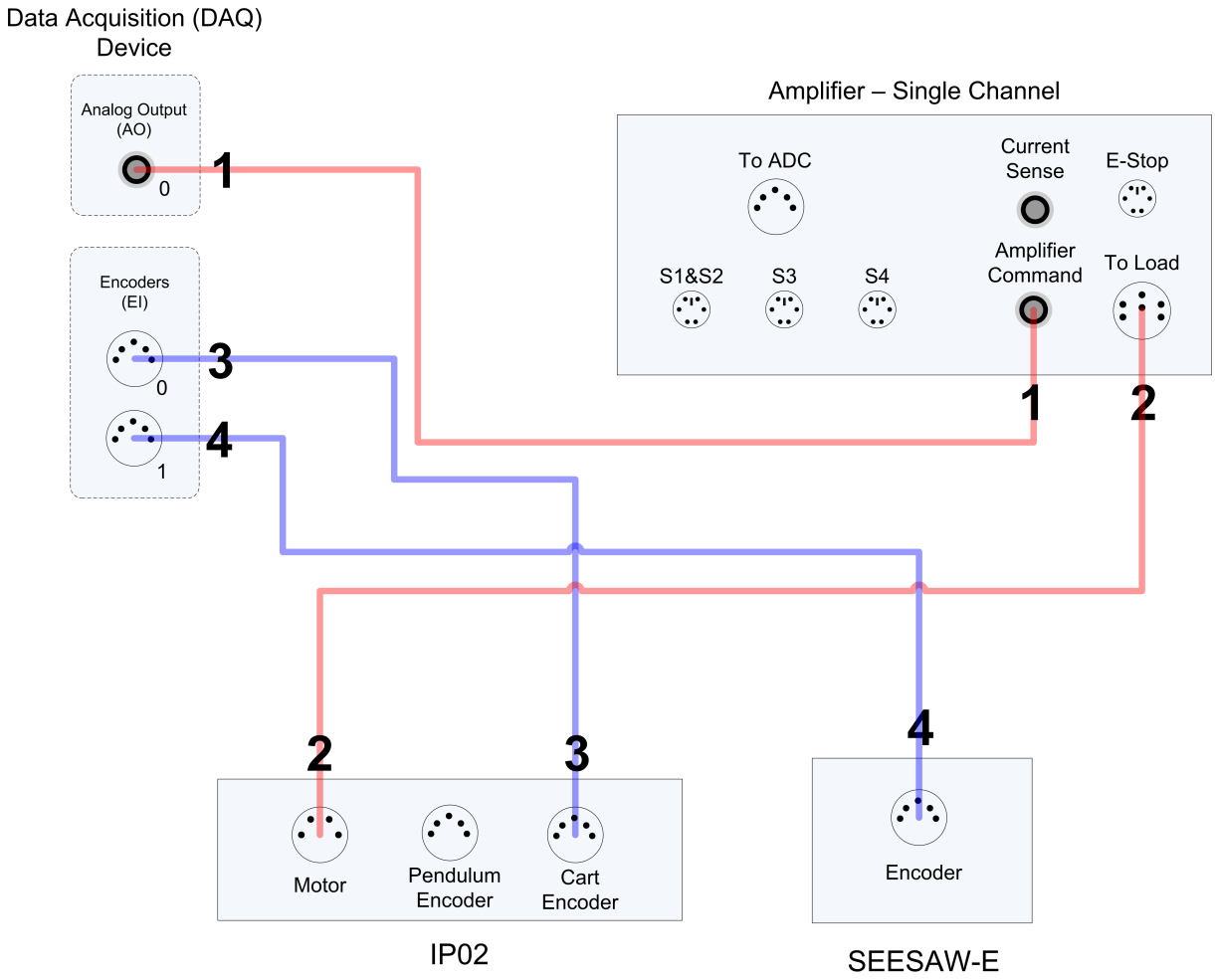


Figure 5.1: SEESAW-E and IP02 connection diagram

The follow describes in detail the wiring procedure of the SEESAW-E and IP02 to a amplifier and DAQ::

1. It is assumed that the data acquisition (DAQ) device is already installed as discussed in its respective User Manual.
2. Make sure everything is powered off before making any of these connections. This includes turning off your PC and the amplifiers.

3. Connect one end of the 2xRCA to 2xRCA cable from the Analog Output Channel #0 on the data acquisition (DAQ) device to the Amplifier Command connector on the amplifier. See cable #1 shown in Figure 5.1. This carries the attenuated IP02 motor voltage control signal, V_m/K_a, where K_a is the amplifier gain.

4. Connect the 4-pin-stereo-DIN to 6-pin-stereo-DIN from "To Load" on the amplifier to the Motor connector on the IP02. See connection #2 shown in Figure 5.1. The cable transmits the amplified voltage that is applied to the IP02 motor and is denoted V_m.

5. Connect the 5-pin-stereo-DIN to 5-pin-stereo-DIN cable from the IP02 Cart Encoder connector to Encoder Input # 0 on the data acquisition (DAQ) device, as depicted by connection #3 in Figure 5.1. This carries Cart position measurements.

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

6. Connect the 5-pin-stereo-DIN to 5-pin-stereo-DIN cable from the SEESAW-E Encoder connector to Encoder Input # 1 on the data acquisition (DAQ) device, as depicted by connection #4 in Figure 5.1.

6 TESTING AND TROUBLESHOOTING

This section describes some functional tests to determine if your SEESAW-E system is operating normally. It is assumed that the SEESAW-E system is connected as described in the Section 5.2. To carry out these tests, it is preferable if the user can use a software such as QUARC® or LabVIEW™ to read sensor measurements and feed voltages to the motor. Alternatively, these tests can be performed with a signal generator and an oscilloscope.

6.1 IP02 Motors and Sensors

See [1] for more information on testing and troubleshooting the IP02 separately.

6.2 SEESAW-E Encoder

6.2.1 Testing

Follow this procedure to test the SEESAW-E encoder:

1. Measure Encoder Input Channel #1.
2. Move the SEESAW-E arm up and down. This movement should gives encoder counts at a rate of 4096 counts per revolution (in quadrature mode).

   Note: Some data acquisition systems do not measure in quadrature and, in this case, one-quarter of the expected counts are received. 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.

6.2.2 Troubleshooting

If the encoder is not measuring properly, go through this procedure:

1. Check that the data acquisition device is functional, e.g. ensure it is properly connected, that the fuse is not burnt.
2. 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

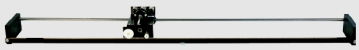
To obtain support from Quanser, go to http://www.quanser.com/ and click on the Tech Support link. Fill in the form with all the requested software and hardware information as well as a description of the problem encountered. Also, make sure your e-mail address and telephone number are included. Submit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

REFERENCES

[1] Quanser Inc. *IP02 User Manual*, 2012.

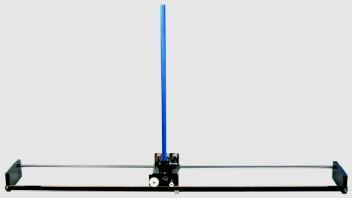
Nine linear motion plants for teaching fundamental and advanced controls concepts

IP02 Base Unit

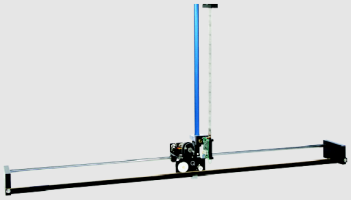


Seesaw

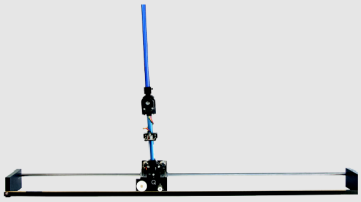
Linear Pendulum



Linear Flexible Inverted Pendulum

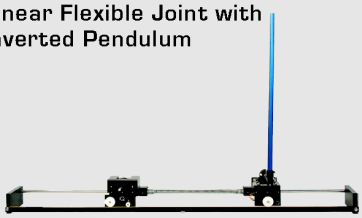


Linear Double Inverted Pendulum

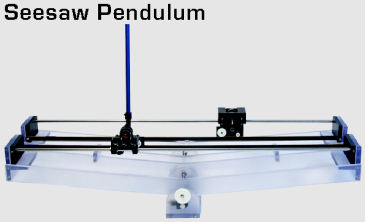


Linear Flexible Joint

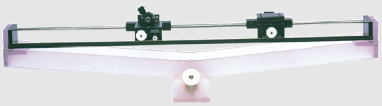
Linear Flexible Joint with Inverted Pendulum



Seesaw Pendulum



Linear Flexible Joint on Seesaw



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