



USER MANUAL

IPO2 Linear Inverted Pendulum and IPO2 Linear Pendulum Gantry Experiments

Set Up and Configuration



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1 PRESENTATION

1.1 Description

The IP02 linear pendulum system can be configured in both a conventional single pendulum gantry (SPG), and single inverted pendulum (SIP) configuration as shown in Figure 1.1. Both systems consists of a single rod mounted on a linear cart whose axis of rotation is perpendicular to the direction of motion of the cart. The pendulums come in two different lengths: a 0.30 m (12") "medium" pendulum, and a 0.61 m (24") "long" pendulum.

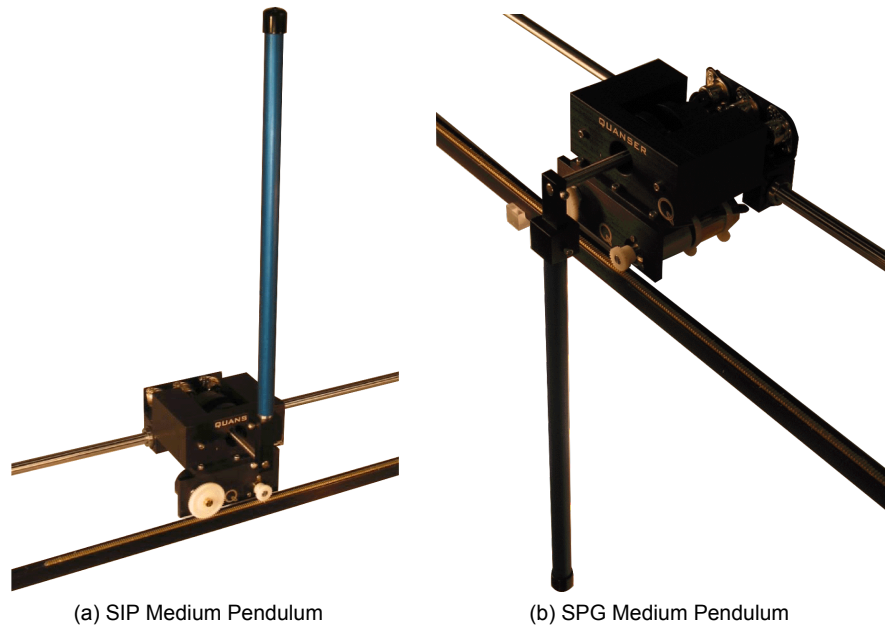


Figure 1.1: Quanser Single Pendulum

The IP02 is a solid aluminum cart. It is 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. The pendulum is instrumented using a quadrature incremental encoder. The pendulum is mounted in front of the cart to enable 360 degree free rotation. Please review [1] for a complete description of the IP02 system.



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 PENDULUM COMPONENTS

The SIP and SPG components are identified in Section 2.1.

2.1 SIP Component Nomenclature

The components listed in Table 2.1 below are labeled in Figure 2.1 and Figure 2.2. Both the SIP and SPG modules are comprised of two primary components: a medium pendulum (30.5 cm), and a long pendulum (61 cm).



Figure 2.1: Long pendulum



Figure 2.2: Medium pendulum

ID	Component	ID	Component
1	Medium length pendulum	4	Pendulum set screw (3/32")
2	Long length pendulum	5	Axis set screw (3/32")
3	Pendulum socket (T-fitting)		

Table 2.1: SIP and SPG Components

3 PENDULUM SPECIFICATIONS

Table 3.1 lists and characterizes the main parameters associated with the SIP and SPG. Some of these are used in the mathematical model.

Symbol	Description	Value
M_{pl}	Long Pendulum Mass (with T-fitting)	0.230 kg
M_{pm}	Medium Pendulum Mass (with T-fitting)	0.127 kg
L_{pl}	Long Pendulum Full Length (from Pivot to Tip)	0.6413 m
L_{pm}	Medium Pendulum Full Length (from Pivot to Tip)	0.3365 m
l_{pl}	Long Pendulum Length from Pivot to Center Of Gravity	0.3302 m
l_{pm}	Medium Pendulum Length from Pivot to Center Of Gravity	0.1778 m
I_{pl}	Long Pendulum Moment of Inertia, about its Center Of Gravity	$7.88 \times 10^{-3} \text{ kg.m}^2$
I_{pm}	Medium Pendulum Moment of Inertia, about its Center Of Gravity	$1.20 \times 10^{-3} \text{ kg.m}^2$
B_p	Viscous Damping Coefficient, as seen at the Pendulum Axis	0.0024 N.m.s/rad
g	Gravitational Constant on Earth	9.81 m/s^2

Table 3.1: SIP and SPG Specifications

4 SIP AND SPG SETUP

As discussed in Section 4.1, the Single Inverted Pendulum, and Single Pendulum Gantry modules require a specific workspace to avoid injury to the system or user. See Section 4.2 for instructions on how to assemble the Single Inverted Pendulum system.



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 Workspace

When creating a workspace for the pendulum modules, it is important to keep in mind that the single pendulum is mounted in front of that cart in such a way that it can operate freely over a 360-degree range. Therefore, you should ensure that the pendulum does not collide with any objects while it swings/rotates. Note that the pendulum will swing even while the cart is at one of the extremities of the track! In such a configuration (i.e. when the pendulum rod goes from the inverted to the gantry position and vice-versa), the systems require an overall space of 2.19 m long by 1.27 m high (0.56 m below table and 0.71 m above) by 0.3 m deep. The clearance needed to avoid collisions is characterized in Figure 4.1.

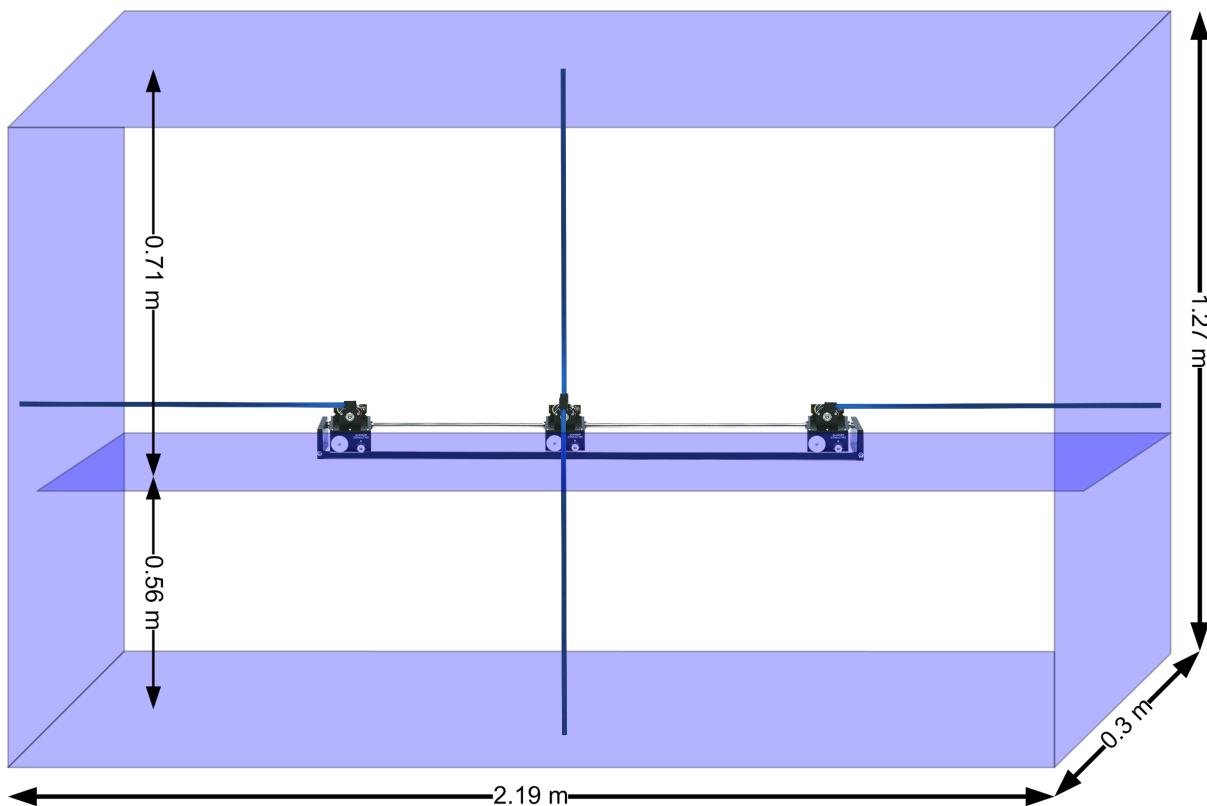


Figure 4.1: Pendulum Workspace

4.2 Assembly

4.2.1 Default SIP and SPG Configuration

The setup procedure for the default SIP configuration, is as follows:

1. Insert the long pendulum rod inside its T-fitting (i.e. component #3), as shown in Figure 4.2. Ensure that it sits properly. Tighten the pendulum set screw #4, as required.



Figure 4.2: Insert the long pendulum rod inside its T-fitting

2. If you are setting up the SPG configuration, place the additional mass on top of the IP02 cart before proceeding.
3. On the IP02, attach the single pendulum, pointing downwards, at the tip of the IP02 cart's pendulum axis, as shown in Figure 4.3. Tighten set screw #5 as necessary. As a remark, it is reminded that in this configuration, the pendulum is free to rotate over a 360-degree range in front of the cart.

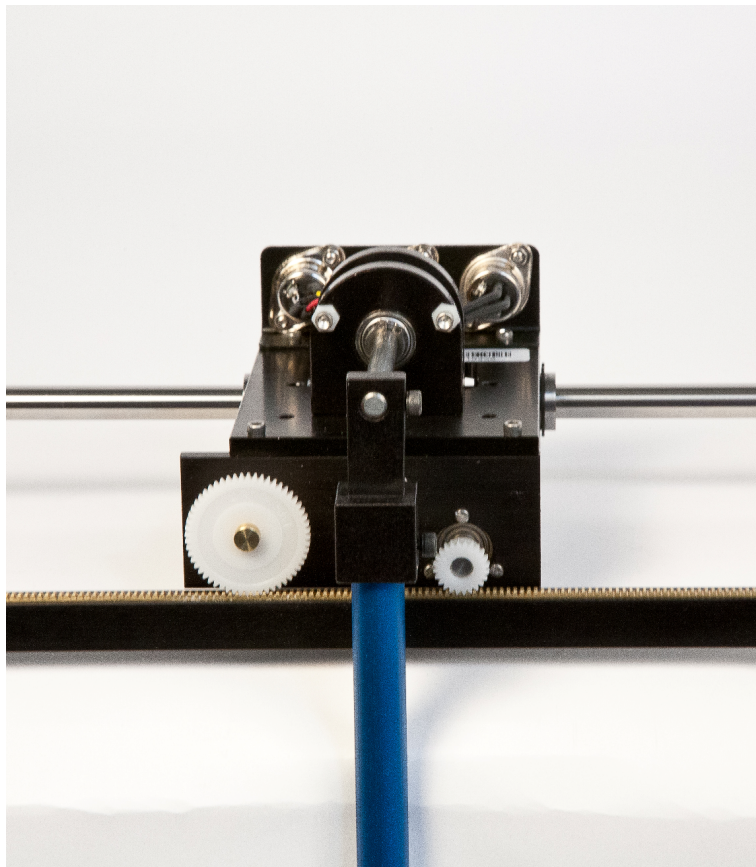


Figure 4.3: Attach the pendulum pointing downwards

4. We highly recommend that you can clamp the track down to the table using its end plates.
5. Wire up the IP02 cart as per dictated in the IP02 User Manual [1], where the Quanser's standard wiring conventions are fully described. No further electrical cabling is required in setting up the pendulum, as all the connections are done at the IP02 level.

Note: The SPG default configuration is the same as the SIP default configuration, but with the additional mass placed on top of the IP02 base unit cart.

4.2.2 Other Configurations

Four other configurations using the medium and long pendulums are possible, outlined as follows:

1. An IP02 cart without its additional weight and in front of which the medium pendulum is attached, pointing downwards.
2. An IP02 cart with its additional weight and in front of which the medium pendulum is attached, pointing downwards.
3. An IP02 cart without its additional weight and on top of which the long pendulum is mounted, pointing upwards. In order to install the pendulum in this configuration, slide the T-fitting (i.e. component #3) all the way back on the IP02 cart pendulum axis, so that the pendulum sits on top of the cart in the "inverted" position. In this configuration, the angular range of motion of the inverted pendulum is mechanically constrained by two plastic washers to $\pm 32^\circ$ from the upright position. This setup is very similar to that of with the IP01.
4. An IP02 cart without its additional weight and on top of which the medium pendulum is mounted, pointing upwards.

REFERENCES

[1] Quanser Inc. *IP02 User Manual*, 2009.

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