Industriële Wetenschappen

De brouwinstallatie

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DOSSIER GEINTEGREERDE PROEF 2022-2023

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Inhoudstafel

1. Technische fiches

1.1 Smart cart

Wireless Smart Cart [ME-1240 (Red) / ME-1241 (Blue)]

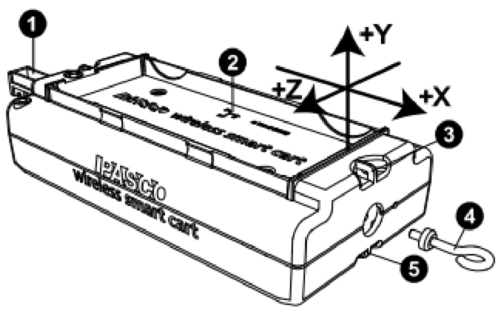
Introduction

The Wireless Smart Cart is a combination wireless *and* USB device that connects to a computer or tablet through Bluetooth, or to a computer or USB charger through an included micro USB cable. The Smart Cart has a durable ABS body, a three-position plunger, and nearly frictionless wheels. It includes built-in sensors which measure acceleration in three dimensions, position, velocity, and force. The Smart Cart also includes a gyroscope-type sensing element which can measure rotational motion. The Smart Cart can make its measurements on or off a dynamics track and transmit them wirelessly. For easy identification, the Smart Cart is available in red or blue.

The accessory tray on the top of the Smart Cart can hold any accessory designed for a PASCO cart except the Spring Cart Launcher (ME-6843). The Smart Cart has the same dimensions as other PASCO carts and can be used with any PASCO track. The Smart Cart can be stacked with any PASCO cart and has a mass of approximately 0.250 kilograms (250 grams). It has attachment points on the top and bottom of both ends, as well as Velcro® tabs for inelastic collisions on one end. The magnetic bumper, bumper attachment, and hook attachment fit into the threaded hole in the end of the Smart Cart opposite to the tabs.

The built-in sensors measure force in the range between -100 newtons (N) and +100 N, acceleration in the range between -16 g and +16 g (where g = ±9.8 m/s^2), and angular rotation rate up to ±145 degrees per second (dps). The cart measures force as a push or pull along its x-axis and measures acceleration in three dimensions (*x*, *y*, and *z*). PASCO Capstone or SPARKvue can also show the resultant acceleration. The encoder wheels on the Smart Cart measure velocity to a maximum of 3.0 meters per second; the wheels have a position resolution of 0.2 mm. The positive direction of motion is the same as the x-axis in the printed graphic representing the acceleration sensor's position.

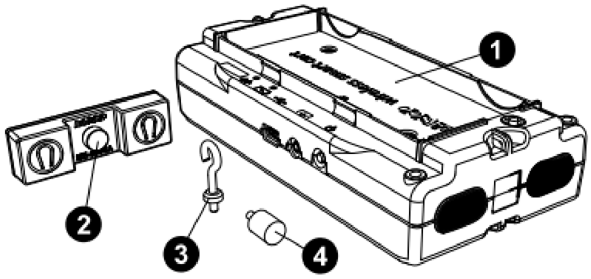
The Smart Cart is designed to optimize battery usage time and will turn off after about five minutes if not connected to the software. Since each Smart Cart has a unique device ID number, more than one can be connected to a computer or tablet at once.



1. Three-position plunger
2. Acceleration and gyro sensor position
3. Attachment point
4. Hook attachment
5. Attachment point

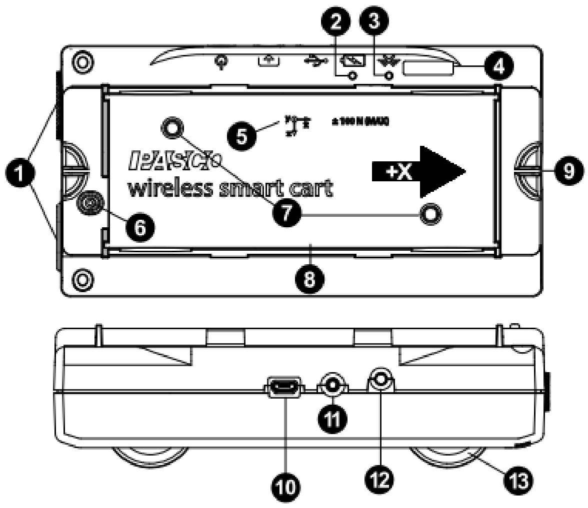
Equipment

Included equipment:



1. Wireless Smart Cart (ME-1240 or ME-1241)
2. Magnetic bumper
3. Bumper attachment
4. Hook attachment
5. Micro USB cable (not pictured)

Features:



1 Velcro® tab
Allows two carts to attach to each other in an inelastic collision.

2 Battery Status LED
Indicates the charge level and status of the cart's battery.

Battery LED	Status
Red blink	Low power
Yellow ON	Charging
Green ON	Fully charged

3 Bluetooth Status LED
Indicates the status of the cart's Bluetooth connection.

Bluetooth LED	Status
Red blink	Ready to pair
Green blink	Connected

NOTE: The Bluetooth LED will not light up if the sensor is connected to the software via micro USB cable.

4 Device ID
Use this to identify the cart when connecting via Bluetooth.

5 Accelerometer position
Indicates the position of the acceleration and gyro sensor within the cart, as well as the direction of the three dimensions of acceleration (the x-axis, y-axis, and z-axis).

6 Plunger release
Press to immediately release the plunger to its maximum extension.

7 Threaded holes (M5)
Use to secure accessories in place on top of the cart.

8 Accessory tray
Use to hold accessories mounted on the cart.

9 Attachment point
Use these points to tie a string to the cart for various experiments.

10 Micro USB port
Use with the included micro USB cable to connect the cart to a USB charger. The port and cable can also be used to directly connect the cart to a computer without the use of Bluetooth. This connection method is not supported by iOS.

11 Accessory port
Use to connect various accessories to the Smart Cart, enable data collection from them, and control them.

12 ON/OFF button
Press to turn the cart on. Press and briefly hold to turn the cart off.

13 Built-in wheel encoder
Used to automatically record position, velocity, and acceleration of the wheels during data collection.

Required equipment:

- Data collection software (PASCO Capstone *or* SPARKvue)

Initial step: Charge the battery

Charge the battery by connecting the USB port to any standard USB charger. The Smart Cart Charging Garage (ME-1243) allows up to five Smart Carts to be charged simultaneously, while also serving as a storage option for the cart and bumpers. The battery status light is solid yellow while charging. When fully charged, the light changes to solid green.

Get the software

You can use the Smart Cart with SPARKvue or PASCO Capstone software. If you're not sure which to use, visit pasco.com/products/guides/software-comparison.

SPARKvue is available as a free app for Chromebook, iOS, and Android devices. We offer a free trial of SPARKvue and Capstone for Windows and Mac. To get the software, go to pasco.com/downloads or search for **SPARKvue** in your device's app store.

If you have installed the software previously, check that you have the latest update:

SPARKvue
Go to Main Menu > **Check for Updates**

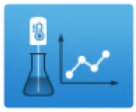
PASCO Capstone
Go to **Help** > **Check for Updates**.

The Wireless Smart Cart can also be used with the free PASCO program MatchGraph!, which can be downloaded at pasco.com/matchgraph.

Check for a firmware update

SPARKvue

1. Press the power button until the lights turn on.
2. Open SPARKvue.
3. Select **Sensor Data** on the Welcome Screen.



4. Select the sensor that matches your sensor's device ID. A notification appears if a firmware update is available. Click **Yes** to update the firmware.
5. Close SPARKvue.

PASCO Capstone

1. Press and hold the power button until the lights turn on.
2. Open PASCO Capstone.
3. Click **Hardware Setup**.

4. Select the sensor that matches your sensor's device ID. A notification appears if a firmware update is available. Click **Yes** to update the firmware.
5. Close Capstone.

Setting up the software

Collecting data from the Smart Cart requires PASCO Capstone, SPARKvue, or MatchGraph! software. The Smart Cart can be connected to any of these programs using either Bluetooth or a USB connection.

SPARKvue

To connect to SPARKvue using Bluetooth:

1. Turn on the Smart Cart. Check to make sure that the Bluetooth LED is blinking red.
2. Start SPARKvue, then select **Sensor Data** from the main menu.
3. From the list of available wireless devices, select the Smart Cart which matches the device ID (XXX-XXX) printed on your Smart Cart to connect to the cart.

To connect to SPARKvue using the micro USB cable:

1. Turn on the Smart Cart.
2. Start SPARKvue, then select **Sensor Data** from the main menu.
3. Connect the micro USB cable (included) from the micro USB port on the Smart Cart to a USB port on the computer, or into a powered USB hub connected to the computer. The cart will connect automatically.

Upon connecting to the Smart Cart, a list of available Smart Cart sensor measurements will automatically appear in the **Select Measurements for Templates** section.

To collect data with SPARKvue:

1. From the **Sensor Data** menu, after connecting to the Smart Cart, enable the desired measurements by clicking the checkboxes next to those measurements.
2. In the **Templates** section, select **Graph** to enter the Experiment Screen.
3. The Graph template will automatically populate the axes with the measurements you selected on the y-axis (or y-axes if you selected multiple measurements) and time on the x-axis. To change the quantity measured on an axis, click the buttons displaying the current measurement, then select the appropriate quantity from the list.
4. When you are ready, click **Start** to begin collecting data.

PASCO Capstone

To connect to Capstone using Bluetooth:

1. Turn on the Smart Cart.
2. Start Capstone, then select **Hardware Setup** from the **Tools** palette.
3. From the list of **Available Wireless Devices**, select the Smart Cart which matches the device ID (XXX-XXX) printed on your Smart Cart to connect to the cart.

To connect to Capstone using the micro USB cable:

1. Turn on the Smart Cart.
2. Start Capstone. If desired, select **Hardware Setup** from the **Tools** palette to verify the connection status.
3. Connect the micro USB cable (included) from the micro USB port on the Smart Cart to a USB port on the computer, or into a powered USB hub connected to the computer. The cart will connect automatically.

When connecting the Smart Cart to Capstone, the measurement of all sensors will be enabled by default. Any undesired measurements can be disabled through the **Data Summary** menu in the **Tools** palette.

To collect data from Capstone:

1. Double-click the **Graph** icon in the **Displays** palette to create a new Graph display.
2. On each axis, click **<Select Measurement>**, then choose the appropriate sensor measurement for your experiment from the list.
3. When you are ready, click **Record** to begin recording data.

MatchGraph!

To connect to MatchGraph! using Bluetooth:

1. Turn on the Smart Cart. Check to make sure that the Bluetooth LED is blinking red.
2. Start MatchGraph!. The **Sensor Not Found** window will open automatically.
3. Select **Choose Wireless Interface** from the bottom right corner of the **Sensor Not Found** window.
4. From the **Select Wireless Interface** list, select the Smart Cart which matches the device ID (XXX-XXX) printed on your Smart Cart to connect to the cart.

To connect to MatchGraph! using the micro USB cable:

1. Turn on the Smart Cart.
2. Connect the micro USB cable (included) from the micro USB port on the Smart Cart to a USB port on the computer, or into a powered USB hub connected to the computer.
3. Start MatchGraph!. The cart will connect automatically.

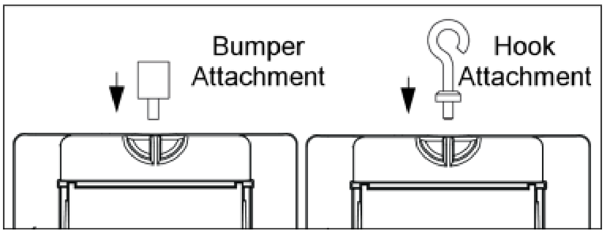
Note that MatchGraph! is only capable of tracking position and velocity data from the Smart Cart. Data from the cart's other measurements will not be collected.

To collect data from MatchGraph!:

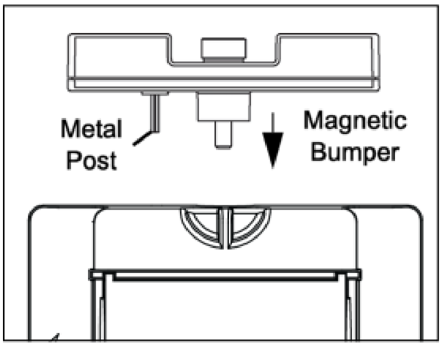
1. Select whether you want to track position or velocity data from the Smart Cart.
2. Choose a profile to be displayed by clicking **View All Profiles** at the top of the screen and selecting a profile from the list.
3. When you are ready, click **Record** to begin tracking data.

Connecting bumper and hook attachments

Screw the bumper or hook attachment into the threaded hole on the front end of the Smart Cart, as shown below.



The magnetic bumper has a metal post that fits in the small hole to the side of the threaded hole on the front end of the Smart Cart, as shown below. The post ensures that the magnetic bumper is mounted in the correct orientation.



Screwing any of these attachments into the threaded hole on the front end of the Smart Cart connects them to the Smart Cart's built-in Force Sensor, allowing measurements of the force on the cart to be collected.

IMPORTANT: If using the Smart Cart for collisions, do NOT use the rubber bumper, as the force of impact on the bumper may damage the internal force sensor. Instead, any of the following components can be used as a bumper for collision experiments:

- Light Spring Bumper (ME-9275)
- Bumper Accessory Set (ME-9884)
- Magnetic Bumper Set (ME-9885A)

Direction of acceleration

The acceleration sensing unit inside the Smart Cart is oriented so that the acceleration axes are aligned with the *x-y-z* arrows indicating the direction of positive acceleration.

In this orientation, the x-axis direction is 'along' the long axis of the Smart Cart; the y-axis direction is 'perpendicular' relative to the top of the Smart Cart; and the z-axis direction is 'perpendicular' to the long axis of the Smart Cart and parallel relative to the top of the cart.

Zero (tare) the sensors

At the beginning of an experiment, the measurement from the built-in force and acceleration sensors may not be zero when the force or acceleration is actually zero. This is a normal behavior that is corrected when you zero (or *tare*) the sensor using PASCO Capstone or SPARKvue. For information on zeroing a sensor in these programs, see the Capstone or SPARKvue online help and search for "**Zero sensor**".

Calibration

The Smart Cart is factory calibrated, so calibration is not necessary, especially if you are measuring a change in a measurement rather than absolute values. However, it is possible to calibrate the sensors if desired. For information on calibrating a Smart Cart, see the PASCO Capstone or SPARKvue online help.

NOTE: Zeroing of the acceleration sensor should **only** be performed if you are measuring acceleration on only a single axis, as zeroing the sensor will cause the measurements of acceleration on the other two axes to no longer report accurate values.

Accessories

A number of accessories are available for the Wireless Smart Cart. Links to these products can be found on the product page. In particular, certain accessories are designed specifically to be used with the Wireless Smart Cart, including:

- Smart Fan Accessory (ME-1242)
- Smart Ballistic Cart Accessory (ME-1245)
- Smart Cart Vector Display (ME-1246)
- Smart Cart Motor (ME-1247)

For instructions on mounting these accessories to the Smart Cart, see the manual for the product in question.

Troubleshooting

- If the Wireless Smart Cart loses Bluetooth connection and will not reconnect, try cycling the ON button. Press and briefly **hold** the button until the status LEDs blink in sequence, then release the button. Start the Smart Cart in the usual way.
- If the Smart Cart stops communicating with the computer software or tablet application, try restarting the software or application. If the problem remains, press and hold the ON button for 10 seconds, then release. Start the Smart Cart in the usual way.
- If the above problems do not solve the connection issue, turn Bluetooth off and back on for your computer, then retry.

About the battery

The Smart Cart's battery is partially charged at the factory. If the battery status LED blinks red, use the micro USB cable to connect the sensor to a USB port or a USB charger.

Maximizing battery life

One of the factors that affects battery life is the storage temperature. Therefore, avoid storing the Smart Cart in very cold or very hot environments.

Battery troubleshooting

If the Smart Cart battery will not charge, it may need to be replaced. Contact Technical Support for information about battery replacement.

Software help

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

SPARKvue

Software: Main Menu > Help

Online: help.pasco.com/sparkvue

PASCO Capstone

Software: Help > PASCO Capstone Help

Online: help.pasco.com/capstone

Specifications and accessories

Visit the product page at pasco.com/product/me-1240 or pasco.com/product/me-1241 to view the specifications and explore accessories. You can also download experiment files and support documents from the product page.

Experiment files

Download one of several student-ready activities from the PASCO Experiment Library. Experiments include editable student handouts and teacher notes. Visit pasco.com/freelabs/me-1240 or pasco.com/freelabs/me-1241.

Technical support

Need more help? Our knowledgeable and friendly Technical Support staff is ready to answer your questions or walk you through any issues.

Chat	pasco.com
Phone	1-800-772-8700 x1004 (USA) +1 916 462 8384 (outside USA)
Email	support@pasco.com

Regulatory information

Limited warranty

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

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Product end-of-life disposal

This electronic product is subject to disposal and recycling regulations that vary by country and region.
It is your responsibility to recycle your electronic equipment per your local environmental laws and regulations to ensure that it will be recycled in a manner that protects human health and the environment.
To find out where you can drop off your waste equipment for recycling, please contact your local waste recycle or disposal service, or the place where you purchased the product.
The European Union WEEE (Waste Electronic and Electrical Equipment) symbol on the product or its packaging indicates that this product must not be disposed of in a standard waste container.

CE statement

This device has been tested and found to comply with the essential requirements and other relevant provisions of the applicable EU Directives.

FCC statement

This device complies with part 15 of the FCC Rules.
Operation is subject to the following two conditions:
(1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Battery disposal

Batteries contain chemicals that, if released, may affect the environment and human health.
Batteries should be collected separately for recycling and recycled at a local hazardous material disposal location adhering to your country and local government regulations.
To find out where you can drop off your waste battery for recycling, please contact your local waste disposal service, or the product representative.
The battery used in this product is marked with the European Union symbol for waste batteries to indicate the need for the separate collection and recycling of batteries.

Patents

The Smart Cart (ME-1240 and ME-1241) is covered by U.S. Patent No. 10,481,173.

The Smart Fan Accessory (ME-1242) is covered by U.S. Patent No. 10,482,789.

1.2 Kracht sensor

Product Guide | 012-10237C

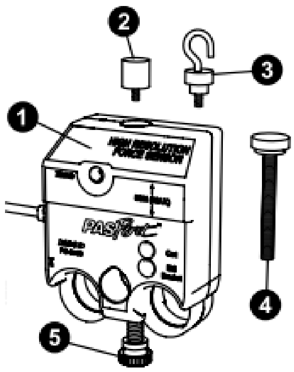
High Resolution Force Sensor (PS-2189)

Introduction

The High Resolution Force Sensor connects to a PASPORT interface and records force in the range of -50 N to +50 N at a rate of up to 1000 samples per second. High resolution, dynamic over-sampling, and low drift rate make this sensor well-suited for measuring very small changes in force.

Equipment

Included equipment:



1. **High Resolution Force Sensor**
2. **Bumper attachment**
3. **Hook attachment**
4. **Cart thumbscrew** (M5 × 45 mm)
   Use to secure the sensor to a PASCO cart.
5. **Rod clamp thumbscrew** (1/4-20 × 0.75 in.)
   Use to secure the sensor to a rod, such as the 120 cm Stainless Steel Rod (ME-8741).

Additional items required:

- PASPORT interface
- PASCO Capstone or SPARKvue data collection software

Get the software

You can use the sensor with SPARKvue or PASCO Capstone software. If you're not sure which to use, visit pasco.com/products/guides/software-comparison.

SPARKvue is available as a free app for Chromebook, iOS, and Android devices. We offer a free trial of SPARKvue and Capstone for Windows and Mac. To get the software, go to pasco.com/downloads or search for **SPARKvue** in your device's app store.

If you have installed the software previously, check that you have the latest update:

SPARKvue

Go to Main Menu > **Check for Updates**

PASCO Capstone

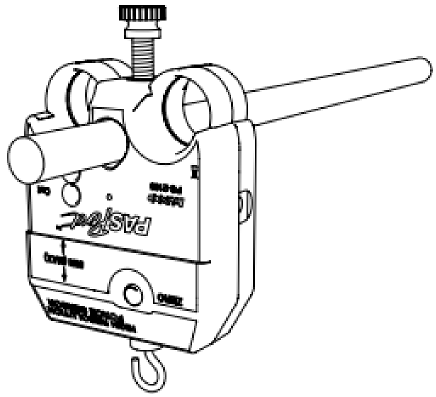
Go to **Help** > **Check for Updates**.

Set up the hardware

Sensor mounting

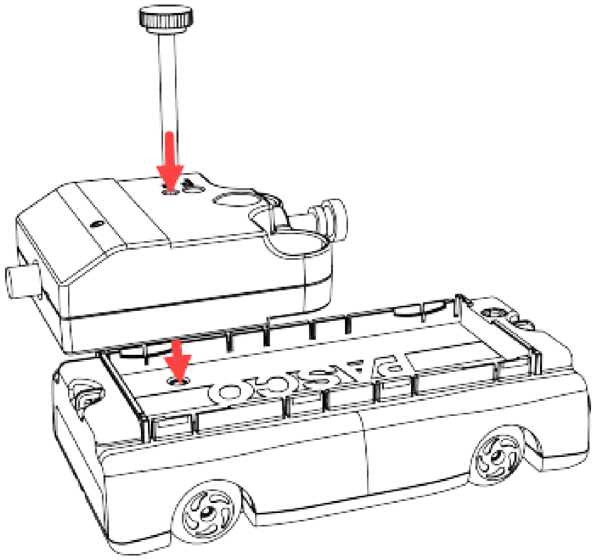
To mount the sensor on a rod:

1. Slide the sensor onto a rod, as shown below.
2. Tighten the thumbscrew to secure the sensor in place.



To mount the sensor on a PASCO cart:

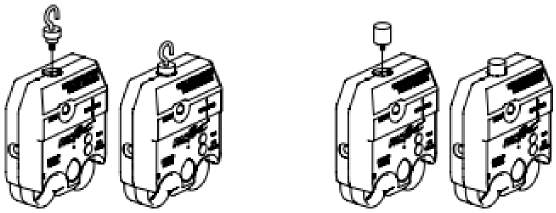
1. Align the hole labeled **Cart** on the sensor with one of the threaded holes in the accessory tray of the PASCO cart.
2. Insert the included cart thumbscrew through the **Cart** hole so that it extends into the threaded hole, as shown below.
3. Tighten the thumbscrew to secure the sensor in place.



PASCO 1

Connect bumper and hook attachments

Screw the bumper or hook into the sensor as shown below.



IMPORTANT: When performing experiments that involve a collision, **do NOT** use the rubber bumper with the Force Sensor, as this may damage the internal components. Instead, any of the following components can be used as a bumper for collision experiments:

- Light Spring Bumper (ME-9275)
- Bumper Accessory Set (ME-9884)
- Magnetic Bumper Set (ME-9885A)

Set up the software

SPARKvue

Connecting the sensor to SPARKvue:

1. Turn on SPARKvue, then click **Sensor Data**.
2. Turn on the PASPORT interface if needed, then connect your interface to SPARKvue. For more specific details, see the manual for your chosen interface and the SPARKvue online help.
3. Plug the High Resolution Force Sensor into one of the PASPORT ports on the interface. SPARKvue will automatically detect and identify the sensor.

Collecting data:

1. From the **Select Measurements for Templates** column, select the appropriate measurement for your experiment.
2. From the **Templates** column, click **Graph** to enter the experiment screen. The display will automatically plot your selected measurement on the y-axis and time on the x-axis.
3. When you are ready, click **Start** to begin recording data.

PASCO Capstone

Connecting the sensor to Capstone:

1. Turn on PASCO Capstone, then click **Hardware Setup** in the **Tools** palette.
2. Turn on the PASPORT interface if needed, then connect your interface to Capstone. For more specific details, see the manual for your chosen interface and the Capstone online help.
3. Plug the High Resolution Force Sensor into one of the PASPORT ports on the interface. Capstone will automatically detect and identify the sensor.

Collecting data:

1. Double-click the **Graph** icon in the **Displays** palette to create a Graph display.
2. Click each **<Select Measurement>** box and select an appropriate measurement for your experiment to assign that measurement to the associated axis.
3. When you are ready, click **Record** to begin recording data.

About the force measurement

Zeroing the sensor

Press the **ZERO** button on the sensor to adjust the sensor's output to zero. The sensor should always be zeroed before an experiment to ensure accurate values are collected.

Sample rate

By default, the sensor collects 20 samples per second. The sensor can collect data as fast as 1000 samples per second (or 2000 samples per second if using an 850 or 550 Universal Interface) and as slowly as one sample every 24 hours. The sample rate can be changed in the data collection software.

Dynamic over-sampling

Over-sampling reduces noise, produces slower data, and improves the measurement resolution. This effect is especially noticeable when very small force changes are measured. The degree of over-sampling depends on the sample rate. To increase the degree of dynamic over-sampling, lower the sample rate. Maximum over-sampling occurs at sample rates of 20 Hz and slower.

Software help

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

SPARKvue

Software: Main Menu > Help

Online: help.pasco.com/sparkvue

PASCO Capstone

Software: Help > PASCO Capstone Help

Online: help.pasco.com/capstone

Specifications and accessories

Visit the product page at pasco.com/product/PS-2189 to view the specifications and explore accessories. You can also download experiment files and support documents from the product page.

Experiment files

Download one of several student-ready activities from the PASCO Experiment Library. Experiments include editable student handouts and teacher notes. Visit pasco.com/freelabs/PS-2189.

Technical support

Need more help? Our knowledgeable and friendly Technical Support staff is ready to answer your questions or walk you through any issues.

Chat	pasco.com
Phone	1-800-772-8700 x1004 (USA) +1 916 462 8384 (outside USA)
Email	support@pasco.com

Regulatory information

Limited warranty

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Product end-of-life disposal

This electronic product is subject to disposal and recycling regulations that vary by country and region. It is your responsibility to recycle your electronic equipment per your local environmental laws and regulations to ensure that it will be recycled in a manner that protects human health and the environment. To find out where you can drop off your waste equipment for recycling, please contact your local waste recycle or disposal service, or the place where you purchased the product. The European Union WEEE (Waste Electronic and Electrical Equipment) symbol on the product or its packaging indicates that this product must not be disposed of in a standard waste container.

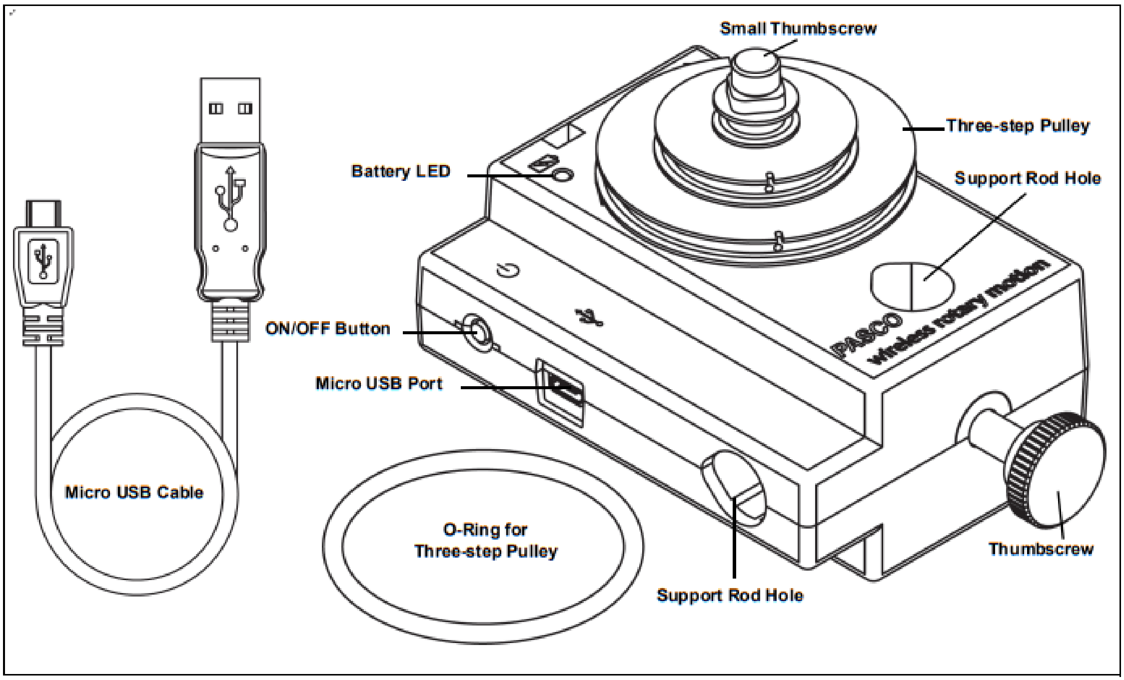
1.3 Ratatie sensor

PASCO

Reference Guide
013-15949A

Wireless Rotary Motion Sensor

PS-3220



Equipment Included	Equipment Included
Wireless Rotary Motion Sensor	Three-step Pulley
O-ring	Small Thumbscrew
Micro USB Cable (1 meter)	Thumbscrew

Required Item*	Part Number
PASCO Data Collection Software: Capstone or SPARKvue	see www.pasco.com

*See the PASCO catalog or the PASCO web site for more information.

www.pasco.com

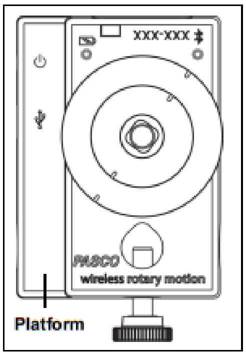
For downloadable experiments, go to www.pasco.com and enter PS-3220 in the Search window. Check under Resources.

+1 916 462 8384
support@pasco.com

800-772-8700
www.pasco.com

Equipment used with the sensor	Equipment used with the sensor
Rotational Inertia Accessory Kit (ME-3420) (includes Ring and Disk Set (ME-3419), Pendulum Accessory (ME-8969), and Super Pulley with Clamp (ME-9444B))	
Physical Pendulum Set (ME-9633)	Track String Adapter (ME-6569)
Rotating Platform (ME-8951)	Centripetal Force Pendulum (ME-9821)
Gyroscope Mounting Bracket (ME-8963)	Polarization Analyzer (OS-8533A)
Dynamics Track Mount Accessory (CI-6692)	Three-Axis Gyroscope (ME-8960)
Three-Step Pulley Accessory (CI-6693)	

Introduction



The PASCO Wireless Rotary Motion Sensor is a versatile position and motion measuring device. It measures angles to a resolution of 0.18°, and detects the direction of motion. Markings on the outside of the case indicate which is the default positive direction. The maximum speed is between 20 and 80 revolutions per second.

The sensor comes with a removable three-step pulley (10 millimeter (mm), 29 mm, and 48 mm diameters), and a rubber "O"-ring that fits into the largest diameter step. The three-step pulley can be placed large-diameter down or large-diameter up on the shaft. A tab on the inside of the pulley matches a notch on the outside of the shaft. The pulley has a notch and a small hole in the outer edge of the largest and second largest steps for attaching a string. One side of the sensor has a platform for mounting a Super Pulley with Table Clamp (optional).

Using the Sensor

The sensor is designed to work with PASCO data collection software to measure position, velocity, and acceleration. Use it to study optics, dynamics, centripetal force, or motion of a pendulum.

Data Collection Software

PASCO Capstone	SPARKvue
• Mac OS X	• Mac OS X
• Windows	• Windows
	• iOS
	• Android
	• Chromebook

See the PASCO web site at

www.pasco.com/software

for help in selecting the right PASCO software and to check for the latest versions.

Software Help

See the SPARKvue Help or PASCO Capstone Help for information about collecting, displaying, and analyzing data.

- In SPARKvue, select the HELP button (?) in any screen including the Home Screen.
- In PASCO Capstone, select **PASCO Capstone Help** from the **Help** menu, or press **F1**.

Bluetooth SMART Compatibility

For more information about wireless compatibility, see the PASCO website at:

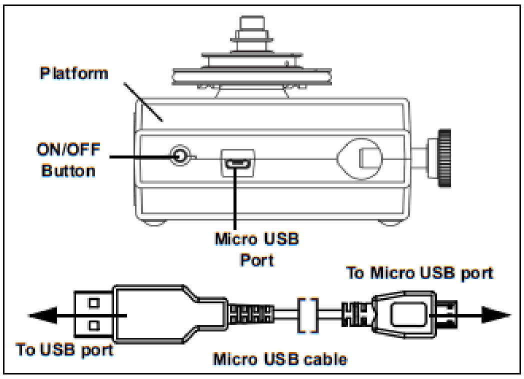
www.pasco.com/compatibility

Platform	Bluetooth SMART Compatibility
iOS	iPad 3 and later iPhone 4S and later iPod touch 5 and later
SPARK LX / LXi	All models
Android	Android 4.4 and later
Chromebook	Chrome OS (requires PS-3500 Adapter*)
Mac OS X	Models introduced July 2011 or later*
Windows	Windows 7 and later (requires PS-3500 Adapter*)

See Appendix B for more information about the PS-3500 Adapter and Mac OS X models.

Initial Step: Charge the Battery

- **Connect the Cable**: Use the Micro USB Cable to connect the micro USB port on the side of the sensor to a USB **port** or USB **charger** such as the PASCO PS-2575 USB Single Port Charger. Charging begins automatically. The charger circuit inside the sensor turns itself off when the unit is fully charged. The battery status LED will shine yellow as the battery is charging, and will shine green when the battery is charged. The battery is partially charged at the factory. Initial charging time may be three hours or longer depending on the power source and the condition of the battery.



ON/OFF Information

To turn the sensor on, press the ON button. The status LEDs will blink. To turn the sensor off, press and **hold** the ON button for a moment until the status LEDs stop blinking. The sensor puts itself to sleep after one hour of inactivity if connected, and after several minutes if not connected.

LED Information

The Bluetooth and the Battery Status LEDs operate as follows:

For a wireless Bluetooth connection:

Bluetooth LED	Status
Red blink	Ready to pair
Green blink	Connected
Yellow blink	Logging*

Battery LED	Status
Red blink	Low power

For a micro USB cable connection to a USB *port*:

Bluetooth LED	Status
OFF	--
OFF	--
Yellow blink	Logging*

Battery LED	Status
Yellow ON	Charging
Green ON	Charged

For a micro USB cable connection to a USB *charger*:

Bluetooth LED	Status
Red blink	Ready to pair
Green blink	Connected
Yellow blink	Logging*

Battery LED	Status
Yellow ON	Charging
Green ON	Charged

***Logging**: PASCO wireless sensors can either stream live data to a compatible device or log data (save it to the sensor's memory). The data can then be uploaded to the device for display and analysis at a later time. Logging capability supports long-term or remote data collection while not connected to the device.

Note: The latest versions of SPARKvue and PASCO Capstone support logging. Check the PASCO Web page at:

www.pasco.com/software

for the latest software version.

Set Up the Software

SPARKvue

Connecting the Sensor to a Tablet or a Computer via Bluetooth

- For SPARKvue, select the Bluetooth icon. In the **Wireless Devices** list. The sensors are ordered by proximity to the device. Select the correct address that matches the Device ID XXX-XXX number found on the sensor. Select **Done**.

Connecting the Sensor to a Computer with the Micro USB Cable

- Connect the micro end of the included Micro USB Cable into the micro USB port on the side of the sensor. Connect the other end of the Micro USB Cable to a USB port on the computer, or into a powered USB hub connected to the computer.

- In the SPARKvue Home Screen, select a measurement from the list under the sensor's name. A graph of the measurement versus time opens.

Collecting Data

- Select the Start button to begin collecting data.

PASCO Capstone

Connecting the Sensor to a Tablet or a Computer via Bluetooth

- For PASCO Capstone, select **Hardware Setup** in the Tools palette. In **Hardware Setup** the sensors are ordered by proximity to the device. Select the address that matches the Device ID XXX-XXX number on the sensor.

Select a display in the main window or from the **Display** palette. In the display, use the **<Select Measurement>** menu to pick a measurement to be shown.

Connecting the Sensor to a Computer with the Micro USB Cable

- Connect the micro end of the included Micro USB Cable into the micro USB port on the end of the sensor. Connect the other end of the Micro USB Cable to a USB port on the computer, or into a powered USB hub connected to the computer.
- In PASCO Capstone, select a display in the main window or from the **Displays** palette. In the display, use the **<Select Measurement>** menus to pick the measurement to be shown.

Collecting Data

- Select **Record** to begin recording data.

Troubleshooting the Sensor

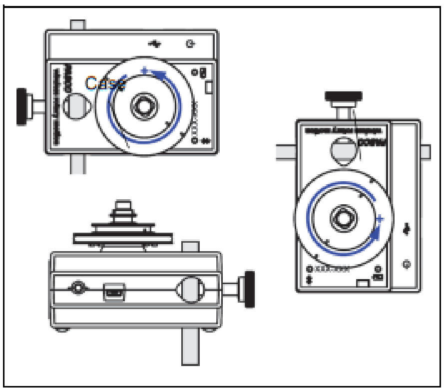
- If the sensor loses Bluetooth connection and will not reconnect, try cycling the ON button. Press and briefly ***hold*** the button until the status LEDs blink in sequence, and then release the button. Start the sensor in the usual way.
- If the sensor stops communicating with the computer software or tablet application, try restarting the software or application. If the problem remains, press and **hold** the ON button for 10 seconds and then release. Start the sensor in the usual way.
- Turn Bluetooth off and then back on. Retry.

Mounting the Wireless Rotary Motion Sensor

The sensor case has two support rod holes that fit rods up to 12.7 mm in diameter, such as the ME-8736 45 cm Stainless Steel Rod, and the case can be put on the support rod using either of the support rod holes.

It is possible to mount the Wireless Rotary Motion Sensor horizontally on a support rod with the Three-step Pulley facing up or facing sideways. You can mount the sensor vertically with the pulley facing forward.

When mounted on a track as shown, a Rotary Motion Sensor could be used to measure the motion of a PASCO Cart as it is pulled by a string suspended over the Three-step Pulley of the sensor and attached to a hanging mass.



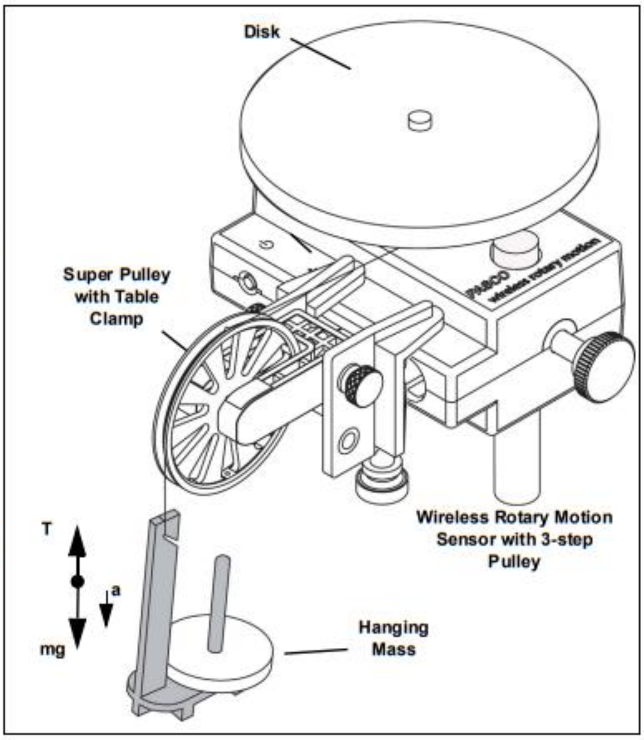
Attaching Accessories to the Wireless Rotary Motion Sensor

Using the Disk from the Disk and Ring Set (ME-3419)

For rotational inertia experiments, mount the Wireless Rotary Motion Sensor with the Disk horizontal. The underside of the Disk has a square shaped indent that fits the square-shaped top of the 3-Step Pulley. Mount a Super Pulley with Clamp (ME-9448B) on the platform at the side of the sensor. To provide a known torque, wrap a string around one of the steps of the 3-step Pulley. Arrange the end of the string over the Super Pulley and attach a hanging mass.

Adjust the Super Pulley on the platform so that the string is tangent to the step on the 3-step Pulley on the sensor.

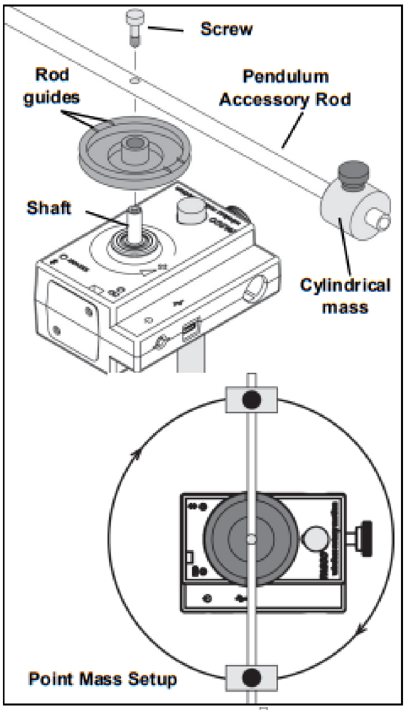
Perform a conservation of angular momentum experiment by dropping a second Disk onto the first Disk as it is rotating. Alternately, attach one of the Ring Alignment Devices to the first Disk and then drop the Ring onto the first disk.(See the suggested experiments.)



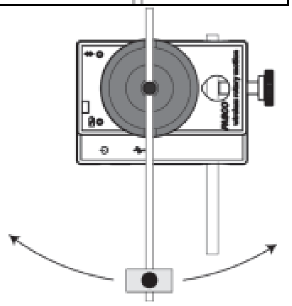
Attaching the Pendulum Accessory Rod (part of ME-8969 Pendulum Accessory) to the Wireless Rotary Motion Sensor

To mount the rod of the Pendulum Accessory to the Wireless Rotary Motion Sensor, orient the 3-step Pulley so that the large diameter step is away from the sensor case. The large diameter step has two pair of rod guides opposite each other on the top edge. Align the rod with the rod guides and use the captive screw in the center of the rod to attach the rod and pulley onto the sensor's shaft.

Point Mass Setup Attach the center of the rod to the 3-step Pulley and shaft and mount the cylindrical masses at the ends of the rod to investigate the rotational inertia (moment of inertia) of point masses.



Pendulum Setup Attach the end of the rod to the 3-step Pulley and shaft. Mount a cylindrical mass on the rod to use the rod as a pendulum. Investigate the period of oscillation of the pendulum when the amount of mass or the position of the mass is changed. Investigate the period of oscillation as the amplitude of the swing is changed.



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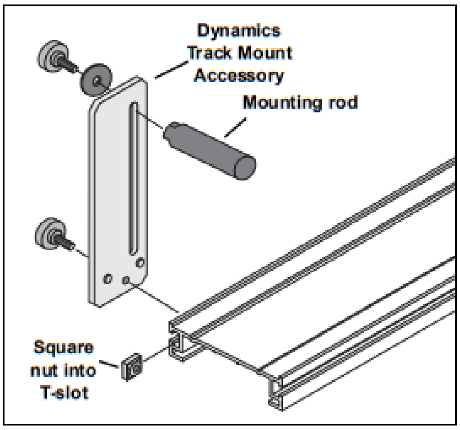
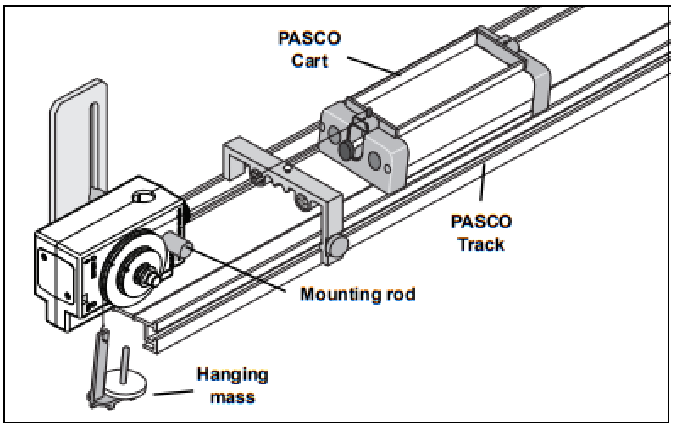
Mounting the Wireless Rotary Motion Sensor on a PASCO Track

The sensor can also be mounted on the short rod that is part of the Dynamics Track Mount Accessory (CI-6692).

Slide the square nut of the Dynamics Track Mount Accessory into the T-slot on the side of the track. Adjust the position of the mounting rod.on the Dynamics Track Mount Accessory.

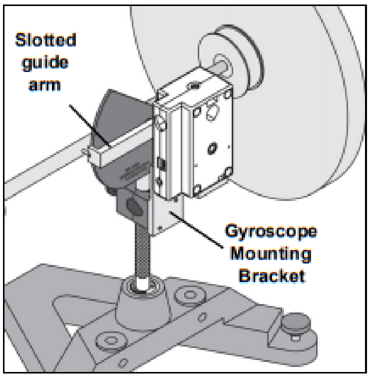
When mounted on the track as shown, the Wireless Rotary Motion Sensor could be used to measure the motion of a PASCO Cart as it is pulled by a string suspended over the Three-step Pulley of sensor and attached to a mass hanger.





See the PASCO web site at www.pasco.com for more information.

Mounting the Wireless Rotary Motion Sensor to a Gyroscope



Use the Gyroscope Mounting Bracket (ME-8963, available separately) to mount the Wireless Rotary Motion Sensor to the Three-Axis Gyroscope (ME-8960). Remove the gyroscope assembly from the vertical shaft of the large "A" base. Mount the Gyroscope Mounting Bracket onto the vertical shaft. Remove the three-step pulley from the Wireless Rotary Motion Sensor, and mount the sensor on the Gyroscope Mounting Bracket with the thumbscrews included with the bracket. Mount the slotted guide arm onto the shaft of the Wireless Rotary Motion Sensor. Replace the gyroscope assembly on the vertical shaft.

See the PASCO web site at www.pasco.com for more information.

Experiments

Experiments for the Wireless Rotary Motion Sensor in electronic format are available to download from the PASCO web site.

www.pasco.com

Go to the web site, enter PS-3220 in the Search window, and check under Resources.

Three suggested experiments are:

- Rotational Inertia of a Point Mass
- Rotational Inertia of Disk and Ring
- Conservation of Angular Momentum.

Specifications

Item:	Value
Three-step Pulley	10, 29 and 48 mm diameter
Sensor Dimensions	9 cm by 6.5 cm by 4 cm, 6.35 mm diameter shaft
Resolution	±0.09° or 0.0078 mm 0.02 mm (linear) and 0.09° (angular) at 2,000 points per revolution

Item:	Value
Rotational Resolution	0.00157 radian
Maximum Rotation Rate	30 rotations per second
Optical Encoder	Bidirectional, indicates direction of motion, 4,000 divisions/rotation

Technical Support

For assistance with any PASCO product, contact PASCO at:

Address:	PASCO scientific 10101 Foothills Blvd. Roseville, CA 95747-7100	Web:	www.pasco.com
Phone:	+1 916-462-8384 (worldwide) 877-373-0300 (U.S.)	Email	support@pasco.com

Check the PASCO website for the latest version of the instruction manual.

www.pasco.com/manuals

Product End of Life Disposal Instructions:

This electronic product is subject to disposal and recycling regulations that vary by country and region. It is your responsibility to recycle your electronic equipment per your local environmental laws and regulations to ensure that it will be recycled in a manner that protects human health and the environment. To find out where you can drop off your waste equipment for recycling, please contact your local waste recycle/disposal service, or the place where you purchased the product.

The European Union WEEE (Waste Electronic and Electrical Equipment) symbol (to the right) and on the product or its packaging indicates that this product **must not** be disposed of in a standard waste container.

Appendix A: Bluetooth SMART Compatibility

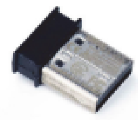
Check the PASCO Web page at

www.pasco.com/compatibility

for the latest information on Bluetooth SMART compatibility.

Platform	Bluetooth SMART Compatibility
iOS	iPad 3 and later iPhone 4S and later iPod touch 5 and later
SPARK Element	All models
Android	Android 4.3 and later
Chromebook	Chrome OS (requires PS-3500 Adapter*)
Mac OS X[1]	Models introduced July 2011 or later
Windows 7 and 8	Requires PS-3500 Adapter*
Windows 10	Bluetooth SMART compatible

*The PS-3500 USB Bluetooth 4.0 Adapter, when connected to a USB port, allows up to three Bluetooth SMART devices, such as this PASCO wireless device, to connect to Windows computers, Chromebooks, and older Macintosh computers.



PS-3500 USB Bluetooth 4.0 Adapter

Note: The PS-3500 USB Bluetooth 4,0 Adapter is the only adapter we can currently recommend. Many other Bluetooth 4.0 adapters are available but this adapter has a specific design that enables in-app pairing of Bluetooth SMART sensors.

[1]To check the Mac computer's Bluetooth compatibility, do the following:

- Click the (Apple) Menu.
- Select *About This Mac*
- Click the *More Info*... button.
- Click the *System Report*... button.
- Select *Bluetooth* from the sidebar on the left, underneath *Hardware*.
- Scan down the list of information until you find “LMP Version”.
- If your Mac is equipped with Bluetooth SMART, the LMP Version will show **0x6**. (Anything lower than **0x6** means an older version of Bluetooth. Your device will need the PS-3500 USB Bluetooth 4.0 Adapter.)

[1]The Mac Mini and MacBook Air were updated with Bluetooth SMART support in 2011. The MacBook Pro was updated in 2012. The Mac Pro that debuted in December 2013 has Bluetooth SMART support.

Exception: Before you upgrade to El Capitan (Mac OS X 10.11.x), if you have a Macintosh with LMP version “0x4” that requires the PS-3500 USB Bluetooth 4.0 Adapter, please contact PASCO Technical Support for further instructions.

Experiment 1: Rotational Inertia of a Point Mass

Equipment Required*	Equipment Required*
Wireless Rotary Motion Sensor (PS-3220	Base and Support Rod (ME-9355)
PASCO Data Collection Software	Mass and Hanger Set (ME-8979)1
Rotational Inertia Accessory Kit (ME-3420)	Triple Beam Balance (SE-8723)
Calipers (SF-8711)	Paper clips (for masses <1g)

*See the PASCO Web site at www.pasco.lcom for more information

Purpose

The purpose of this experiment is to find the rotational inertia of a point mass experimentally and to verify that this value corresponds to the calculated theoretical value.

Theory

Theoretically, the rotational inertia, I, of a point mass is given by I = MR2, where M is the mass, and R is the distance the mass is from the axis of rotation. Since this experiment uses two masses equidistant from the center of rotation, the total rotational inertia will be

$$I_{total} = M_{total}R^2$$

where $M_{total} = M_1 + M2$, the total mass of both point masses.

To find the rotational inertia experimentally, a known torque is applied to the object and the resulting angular acceleration is measured. Since $\tau = I\alpha$,,

$$I = \tau/\alpha$$

where α is the angular acceleration, which is equal to a/r (a = linear acceleration), and τ is the torque caused by the weight hanging from the thread that is wrapped around the 3-step Pulley.

$$\tau = rT$$

where *r* is the radius of the chosen pulley about which the thread is wound, and *T* is the tension in the thread when the apparatus is rotating.

Applying Newton's Second Law for the hanging mass, m, gives

$$\Sigma F = mg - T = ma$$

(see Figure 1.1). Solving for the tension in the thread gives:

$$T = m(g - a)$$

After the angular acceleration of the mass (m) is measured, the torque and the linear acceleration can be obtained for the calculation of the rotational inertia.

Equipment Setup

1. Attach a mass on each end of the rod (part of the Rotational Inertia lAccessory Kit) equidistant from the rod center. You may choose any radius you wish.

2. Tie one end of a thread to a Mass Hanger and tie the other end to one of the levels of the 3-step Pulley on the Wireless Rotary Motion Sensor (WRMS).

3. Mount the rod and masses to the pulley on the Wireless Rotary Motion Sensor. Please note the orientation of the 3-step Pulley.

4. Mount the WRMS on a support rod. Make sure that the support rod does not interfere with the rotation of the rod and masses. See Figure 1.1.

5. Mount the Super Pulley with Clamp (part of the ME-3420) on the platform of the Wireless Rotary Motion Sensor.

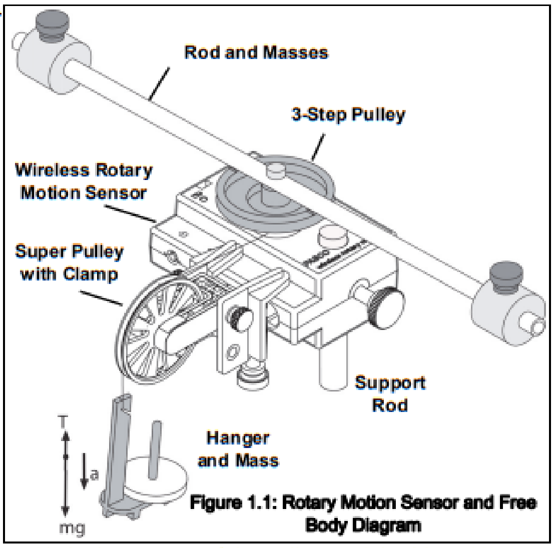


Figure 1.1: Rotary Motion Sensor and Free Body Diagram

6. Drape the thread over the Super Pulley such that the thread is in the groove of the pulley and the Mass Hanger hangs freely (see Figure 1.1).

Note: The Super Pulley with Clamp must be adjusted at an angle, so that the thread runs in a line tangent to the point where it leaves the 3-step Pulley and straight down the middle of the groove on the clamp-on Super Pulley.

7. Adjust the Super Pulley height so that the thread is level with the 3-step pulley.

Procedure

Part 1: Measurements for the Theoretical Rotational Inertia

1. Weigh the two masses from the ends of the thin rod to find the total mass M_{total} and record the value in Data Table 1.

2. Measure the distance from the axis of rotation to the center of the masses and record this radius in Data Table 1.

Data Table 1: Theoretical Rotational Inertia

Total Mass	
Radius	

Part 2: Measurement for the Experimental Method

A. Finding the Acceleration of the Point Masses and Apparatus

1. In the data collection software, create an experiment to measure the angular velocity (in radians per second) versus time (in seconds) of the point masses and apparatus.

- In PASCO Capstone, for example, drag the Graph icon from the Displays palette to the workbook. Select “Angular Velocity (rad/s)” for the vertical axis, and “Time (s)” for the horizontal axis.

- Click the Hardware Setup icon in the Tools palette to open the “Hardware Setup” panel. In the panel, click the properties button (it looks like a gear wheel in the lower right corner).

- In the Properties window for Linear Accessory, select the size of the 3-step Pulley you are using. The default setting is "Large Pulley (Groove)". Click OK.

2. Put a 50-g mass on the Mass Hanger and turn the 3-step Pulley to wind up the thread so the hanger is just below the Super Pulley. Hold the 3-step Pulley.

3. Click Record to begin recording data, and release the 3-step Pulley, allowing the hanger to fall.

4. Caution! Click Stop to end data recording BEFORE the hanger reaches the floor or the thread completely unwinds from the 3-step Pulley.

5. In the Graph display, select the region of the data that represents when the Point Masses and Apparatus were accelerating.

6. In the display, select "Linear" from the curve fit menu.

The slope, m, of the linear fit represents the angular acceleration (a) for the Point Mass and Apparatus

7. Record the value of the slope, m, as the angular acceleration in Data Table 2.

8. Using calipers, measure the diameter of the pulley about which the thread is wrapped and calculate the radius. Record the radius in Data Table 2.

In the previous procedure, the apparatus is rotating and contributing to the total rotational inertia. The next step is to find the rotational inertia of the apparatus by itself so that this rotational inertia can be subtracted from the total.

B. Finding the Acceleration of the Apparatus Alone

1. Take the point masses off the ends of the rod.
2. Repeat the procedure from Part A for finding the angular acceleration of the apparatus alone.

- You may need to decrease the amount of hanging mass so that the apparatus does not accelerate too fast for smooth data collection.
- Remember that the value of the slope, m, is the angular acceleration.

3. Record the data in Data Table 2.

Data Table 2: Experimental Rotational Inertia Data

	Point Masses and Apparatus	Apparatus Alone
Hanging Mass		
Slope, m		
Radius		

Calculations

1. Calculate the experimental value of the rotational inertia of the point masses and apparatus together and record the calculation in Data Table 3.
2. Calculate the experimental value of the rotational inertia of the apparatus alone and record the calculation in Data Table 3.
3. Subtract the rotational inertia of the apparatus from the total rotational inertia of the point masses and apparatus together. Record this in Data Table 3 as the rotational inertia of the point masses alone.
4. Calculate the theoretical value of the rotational inertia of the point masses and record the calculation in Data Table 3.
5. Calculate the percent difference to compare the experimental value to the theoretical value, and record the percent difference in Data Table 3.

Data Table 3: Results

Component	Rotational Inertia
Point Masses and Apparatus Combined	
Apparatus Alone	
Point Masses (experimental value)	
Point Masses (theoretical value)	
Percent Difference	

Experiment 2: Rotational Inertia of Disk and Ring

Equipment Required*	Equipment Required*
Wireless Rotary Motion Sensor (PS-3220	Base and Support Rod (ME-9355)
PASCO Data Collection Software	Mass and Hanger Set (ME-8979)1
Rotational Inertia Accessory Kit (ME-3420)	Triple Beam Balance (SE-8723)
Calipers (SF-8711)	Paper clips (for masses <1g)

***See the PASCO Web site at www.pasco.lcom for more information**

Purpose

The purpose of this experiment is to experimentally find the rotational inertia of a ring and a disk and verify that these values correspond to the calculated theoretical values.

Theory

Theoretically, the rotational inertia, I, of a ring about its center of mass is given by:

$$I = \frac{1}{2}M(R_1^{\,2} + R_2^{\,2})$$

where *M* is the mass of the ring, *R1* is the inner radius of the ring, and *R2* is the outer radius of the ring. See Figure 2.1.

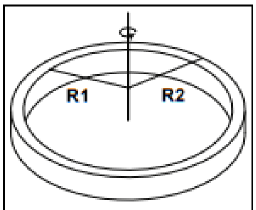


Figure 2.1: Ring about center of mass

The rotational inertia of a disk about its center of mass is given by:

$$I = \frac{1}{2}MR^2$$

where *M* is the mass of the disk and *R* is the radius of the disk. See Figure 2.2. To find the rotational inertia experimentally, a known torque is applied to the object and the resulting angular acceleration is measured, Since $\tau = I\alpha$,

$$I = \frac{\tau}{\alpha}$$

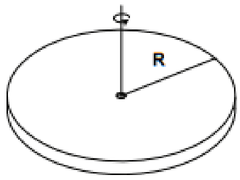


Figure 2.2: Disk about center of mass

where α is the angular acceleration, which is equal to *a/r* (*a* = acceleration), and τ is the torque caused by the weight hanging from the thread that is wrapped about the 3-step Pulley on the Rotary Motion Sensor. The torque is given by:

$$\tau = rT$$

where *r* is the radius of the pulley step about which the thread is wound, and *T* is the tension in the thread when the apparatus is rotating.

Applying Newton's Second Law for the hanging mass, *m*, gives:

$$\Sigma F = mg - T = ma$$

See Figure 2.3. Solving for the tension in the thread gives:

$$T = m(g - a)$$

Once the angular acceleration is measured, the radius and the linear acceleration, *a*, can be obtained for the calculation of the torque.

Procedure

Measurements for the Theoretical Rotational Inertia

1. Weigh the ring and the disk to find their masses and record these masses in Data Table 1.
2. Measure the inside and outside diameters of the ring and calculate the radii, R_1 and R_2. Record in Data Table 1.
3. Measure the diameter of the disk and calculate the radius, R, and record into Data Table 1.

Data Table 1: Theoretical Rotational Inertia.

Mass of ring	
Mass of disk	
Inner radius of ring	
Outer radius of ring	
Radius of disk	

Setup

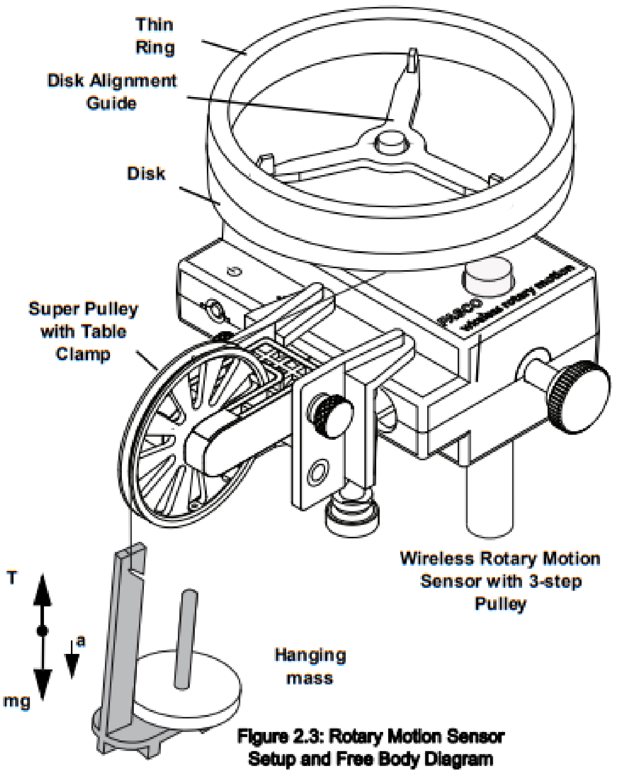


Figure 2.3: Rotary Motion Sensor Setup and Free Body Diagram

1. Mount the Wireless Rotary Motion Sensor (WRMS) on a support rod.
2. Mount the Super Pulley with Clamp on the side of the WRMS as shown in Figure 2.3.
3. Tie one end of a thread to a Mass Hanger and the other end of the thread to one of the levels of the 3-step Pulley on the RMS.
4. Drape the thread over the Super Pulley such that the thread is in the groove of the Super Pulley and the Mass Hanger hangs freely.
5. Adjust the Super Pulley with Clamp to an angle so that the thread runs in a line tangent to the point where it leaves the 3-step Pulley and is straight down the middle of the groove on the Super Pulley.
6. Remove the thumbscrew from the 3-Step Pulley. Place the disk directly on the square-shaped top of the 3-step Pulley as shown in Figure 2.3.
7. Place one of the disk alignment guides on the disk. Replace the thumbscrew to the 3-Step Pulley so that the disk alignment guide is firmly held in place.
8. Place the thin ring on the disk alignment guide on top of the disk as shown in figure 2.3..

Procedure

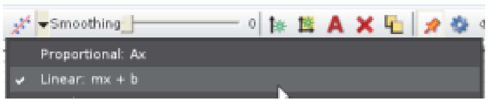
Measurements for the Experimental Method

A. Finding the Acceleration of the Ring and Disk

1. In the data collection software, create an experiment to measure the angular velocity (in radians per second) versus time (in second) of the ring and disk.

- In PASCO Capstone, for example, drag the Graph icon from the Displays palette to the workbook. Select "Angular Velocity (rad/s)" for the vertical axis, and "Time (s)" for the horizontal axis.
- Click the Hardware Setup icon in the Tools palette to open the "Hardware Setup" panel. In the panel, click the properties button (it looks like a gear wheel in the lower right corner).
- In the Properties window for Linear Accessory, select the size of the 3-step Pulley you are using. The default setting is "Large Pulley (Groove)". Click OK.

2. Put a 50-g mass on the Mass Hanger and turn the 3-step Pulley to wind up the thread so the hanger is just below the Super Pulley. Hold the 3-step Pulley.
3. Click Record to begin recording data, and release the 3-step Pulley, allowing the hanger to fall.
4. Caution! Click Stop to end data recording BEFORE the hanger reaches the floor or the thread completely unwinds from the 3-step Pulley.
5. In the Graph display, select the region of the data that represents when the ring and disk were accelerating.
6. In the Graph display, select "Linear" from the curve fit menu.



The slope, m, of the linear fit represents the angular acceleration (α) for the Point Mass and Apparatus

7. Record the value of the slope, m, as the angular acceleration in Data Table 2.

Data Table 2: Experimental Rotational Inertia Data

	Ring and Disk Combined	Disk Alone
Hanging Mass		
Slope, m		
Radius		

C. Finding the Acceleration of the Disk Alone

1. In "Finding the Acceleration of Ring and Disk," both the disk and the ring are rotating; therefore, it is necessary to determine the acceleration and the rotational inertia of the disk by itself so this rotational inertia can be subtracted from the total, leaving only the rotational inertia of the ring.
2. Take the ring off the apparatus and repeat the steps under "Finding the Acceleration of the Ring and Disk" for the disk alone. Record the results in Data Table 3.

Calculations

3. Calculate the experimental value of the rotational inertia of the ring and disk together, and record the value in Data Table 3.

4. Calculate the experimental value of the rotational inertia of the disk alone and record the value in Data Table 3.

5. Subtract the rotational inertia of the disk from the total rotational inertia of the ring and disk, and record this as the rotational inertia of the ring alone.

6. Use a percent difference to compare the experimental values to the theoretical values.

Data Table 3: Results

Item	Rotational Inertia
Ring and Disk	
Disk alone	
Ring alone	
Percent difference for the disk	
Percent difference for the ring	

Experiment 3: Conservation of Angular Momentum

Equipment Required*	Equipment Required*
Wireless Rotary Motion Sensor (PS-3220	Base and Support Rod (ME-9355)
PASCO Data Collection Software	Mass and Hanger Set (ME-8979)1
Mini-Rotational Accessory (CI-6691)	Triple Beam Balance (SE-8723)
Calipers (SF-8711)	Paper clips (for masses <1g)

***See the PASCO Web site at www.pasco.lcom for more information**

Purpose

A non-rotating thin ring is dropped onto a rotating disk, and the final angular speed of the system is compared with the value predicted using the principle of the conservation of angular momentum.

Theory

When the ring is dropped onto the rotating disk, there is no net torque on the system since the torque on the ring is equal and opposite to the torque on the disk. Therefore, there is no change in angular momentum; angular momentum (L) is conserved.

$$L = I_i\omega_i = I_f\omega_f$$

where I_i is the initial rotational inertia and ω_i is the initial angular speed of the disk and I_f is the final rotational inertia and ω_f is the final angular speed of the disk and the ring together.

The rotational inertia of a disk is given as:

$$I_i = \frac{1}{2}M_1R^2$$

and the final rotational inertia of a disk and ring together is:

$$I_f = \frac{1}{2}M_1R^2 + \frac{1}{2}M_2(r_1^{\ 2} + r_2^{\ 2})$$

where M_1 is the mass of the disk, M_2 is the mass of the ring, R is the radius of the disk, and r_1 and r_2 are the inner and outer radii of the ring.

Based on this, the final rotational speed is given by:

$$\omega_f = \frac{M_1R^2}{M_1R^2 + M_2(r_1^{\ 2} + r_2^{\ 2})}\omega_i$$

Setup

1. Mount the Wireless Rotary Motion Sensor to a support rod. Remove the thumbscrew from the 3-Step Pulley. Place the disk directly on the square-shaped top of the 3-step Pulley as shown in Figure 3.1.

2. Place one of the disk alignment guides on the disk. Replace the thumbscrew to the 3-Step Pulley so that the disk alignment guide is firmly held in place.

3. .In the data collection software, create an experiment to measure the angular velocity (in radians per second) versus time (in second) of the disk before and after the ring is dropped on top of it.

- In PASCO Capstone, for example, drag the Graph icon from the Displays palette to the workbook. Select "Angular Velocity (rad/s)" for the vertical axis, and "Time (s)" for the horizontal axis.

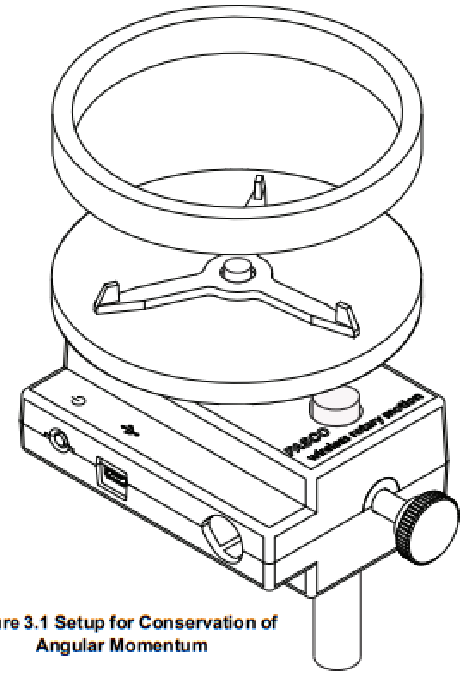


Figure 3.1 Setup for Conservation of Angular Momentum

Procedure

1. Hold the thin ring just above the disk alignment guide that is on the top of the disk.
2. Give the disk a spin with your hand and click Record to begin recording data.
3. After about 25 data points have been recorded, drop the thin ring onto the spinning disk. See Figure 3.1.
4. Click Stop to end data recording after the disk and ring have made a few rotations.
5. In the Graph display, select the region of the data that represents when the ring was dropped onto the disk.
6. In the Graph display, select the data analysis tool that shows the coordinates of any point in the plot of data and move the cursor to the data point that is immediately before the collision. Record the Angular Velocity at this point as the initial angular velocity in the Data Table.
7. Move the cursor to the data point immediately after the collision. Record the Angular Velocity at this point as the final angular velocity in the Data Table.
8. Weigh the ring and disk and record their masses. Measure the inner and outer radii of the ring, and the radius of the disk. Record these values in the Data Table.

Analysis

1. Calculate the theoretical value for the final angular velocity and record this value in the Data Table.
2. Calculate the percent difference between the experimental and theoretical values of the final angular velocity and record it in the Data Table.

Questions

1. How does the experimental result for the final angular velocity compare with the theoretical value for the final angular velocity?

2. What percentage of the rotational kinetic energy was "lost" during the collision? Calculate the energy lost and record the results in the Data Table.

$$\%\ \text{KE lost} = \left(\frac{\frac{1}{2} I_i \omega_i^2 + \frac{1}{2} I_f \omega_f^2}{\frac{1}{2} I_i^2 \omega_i^2} \right)$$

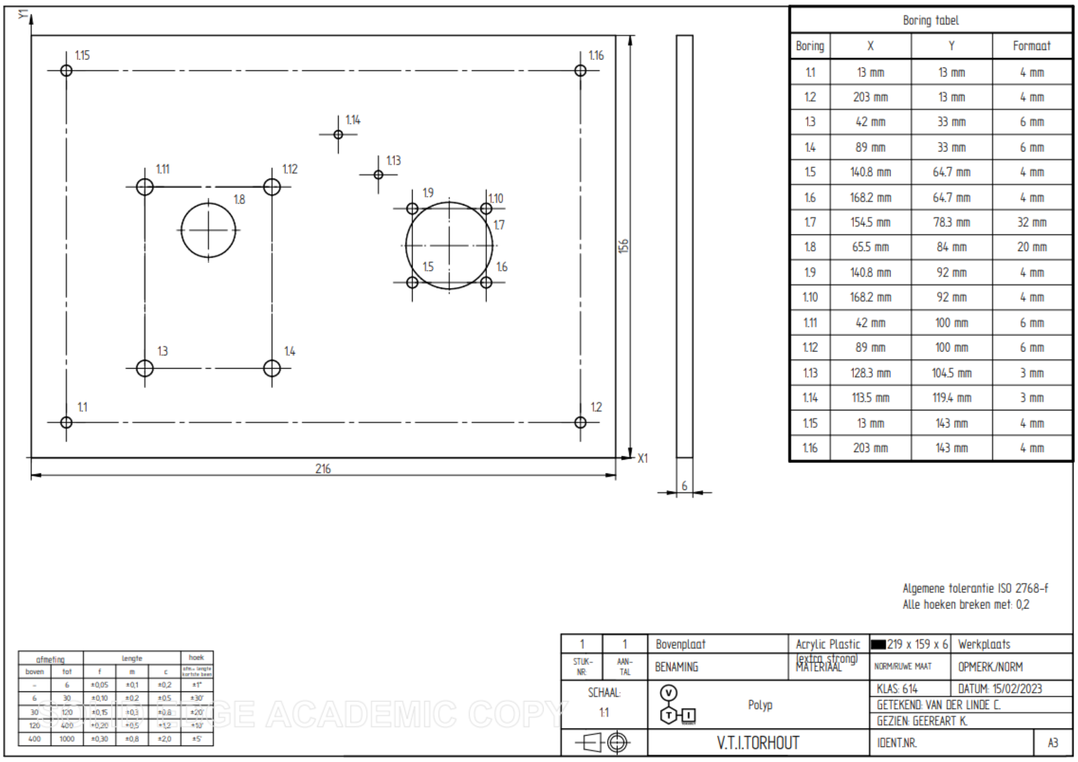
.Data Table: Data and Results

Initial angular velocity	
Final angular velocity (experimental value)	
Mass of disk (M1)	
Mass of ring (M2)	
Inner radius of ring (r1)	
Outer radius of ring (r2)	
Radius of disk (R)	
Final angular velocity (theoretical value)	
Percent difference between experimental and theoretical values	
Percent of kinetic energy lost	

2. Technische tekeningen

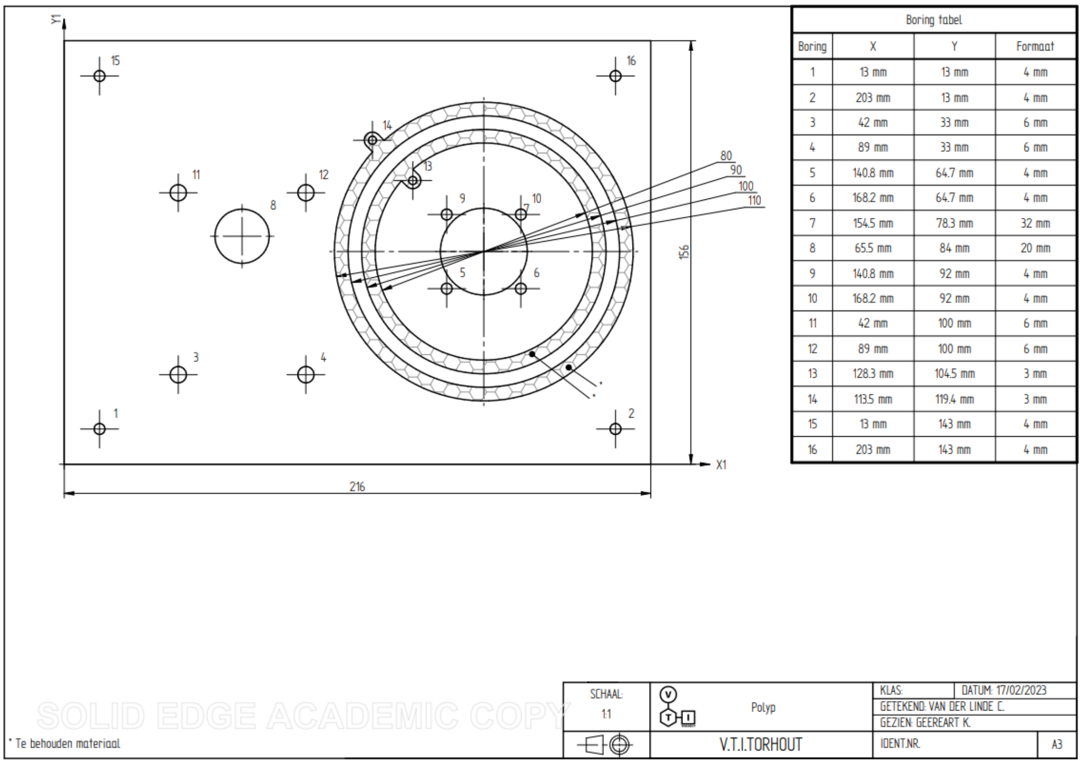
2.1 Volledige polyp

2.2 Bovenplaat



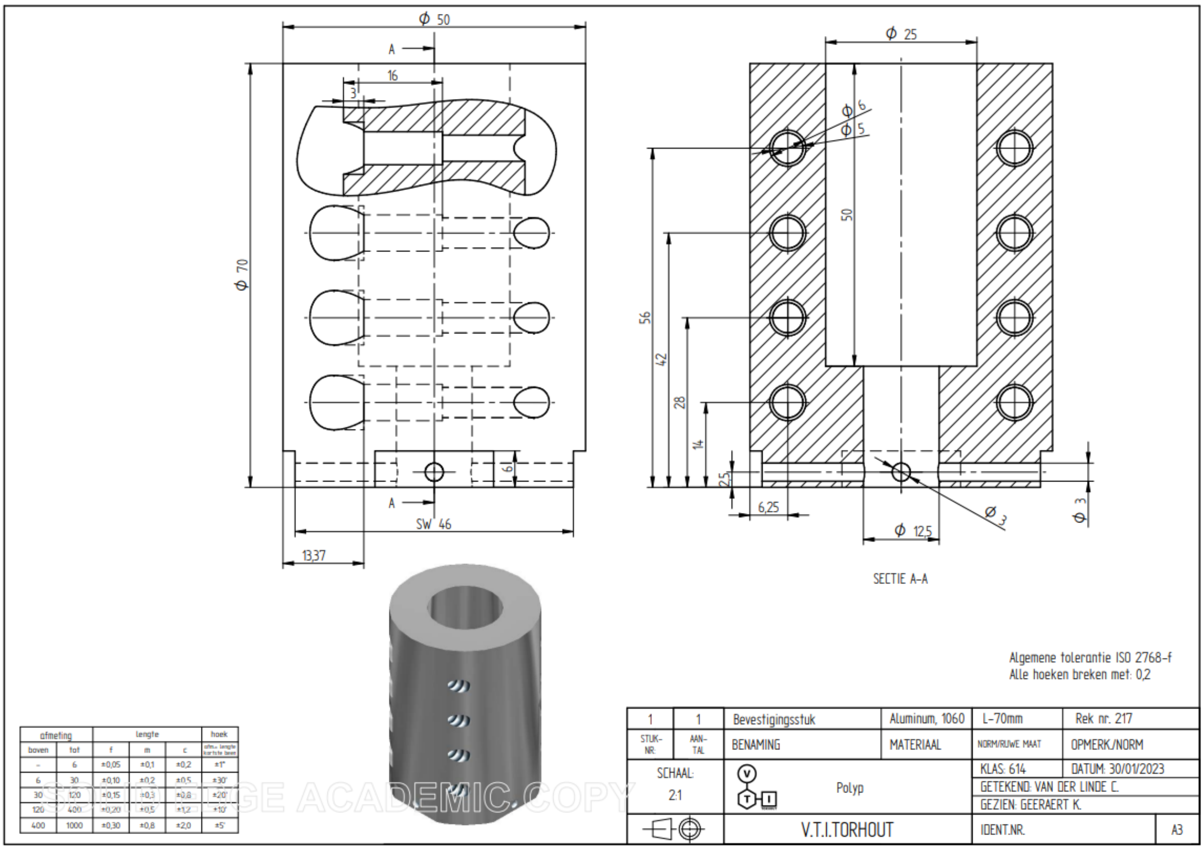
Boring tabel			
Boring	X	Y	Formaat
1.1	13 mm	13 mm	4 mm
1.2	203 mm	13 mm	4 mm
1.3	42 mm	33 mm	6 mm
1.4	89 mm	33 mm	6 mm
1.5	140.8 mm	64.7 mm	4 mm
1.6	168.2 mm	64.7 mm	4 mm
1.7	154.5 mm	78.3 mm	32 mm
1.8	65.5 mm	84 mm	20 mm
1.9	140.8 mm	92 mm	4 mm
1.10	168.2 mm	92 mm	4 mm
1.11	42 mm	100 mm	6 mm
1.12	89 mm	100 mm	6 mm
1.13	128.3 mm	104.5 mm	3 mm
1.14	113.5 mm	119.4 mm	3 mm
1.15	13 mm	143 mm	4 mm
1.16	203 mm	143 mm	4 mm

2.3 Bevestiging as

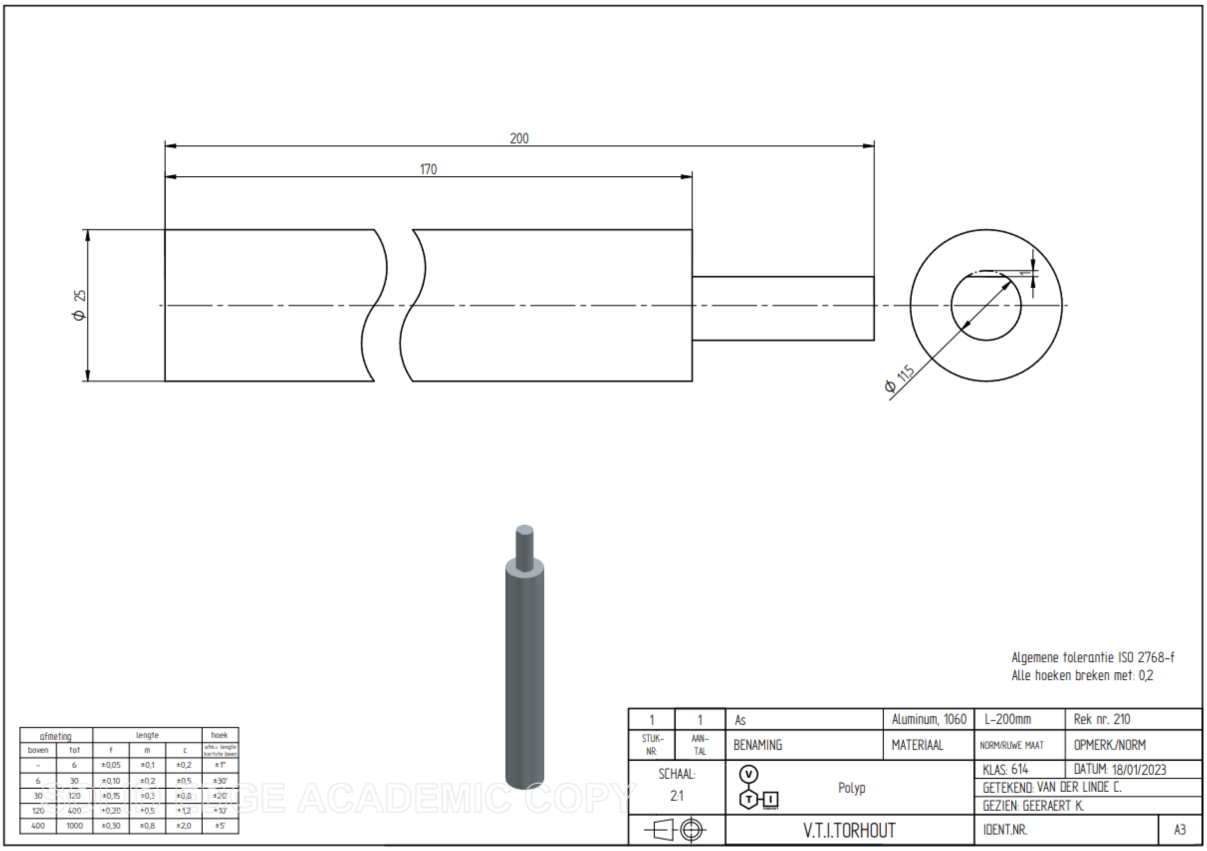


Boring tabel			
Boring	X	Y	Formaat
1	13 mm	13 mm	4 mm
2	203 mm	13 mm	4 mm
3	42 mm	33 mm	6 mm
4	89 mm	33 mm	6 mm
5	140.8 mm	64.7 mm	4 mm
6	168.2 mm	64.7 mm	4 mm
7	154.5 mm	78.3 mm	32 mm
8	65.5 mm	84 mm	20 mm
9	140.8 mm	92 mm	4 mm
10	168.2 mm	92 mm	4 mm
11	42 mm	100 mm	6 mm
12	89 mm	100 mm	6 mm
13	128.3 mm	104.5 mm	3 mm
14	113.5 mm	119.4 mm	3 mm
15	13 mm	143 mm	4 mm
16	203 mm	143 mm	4 mm

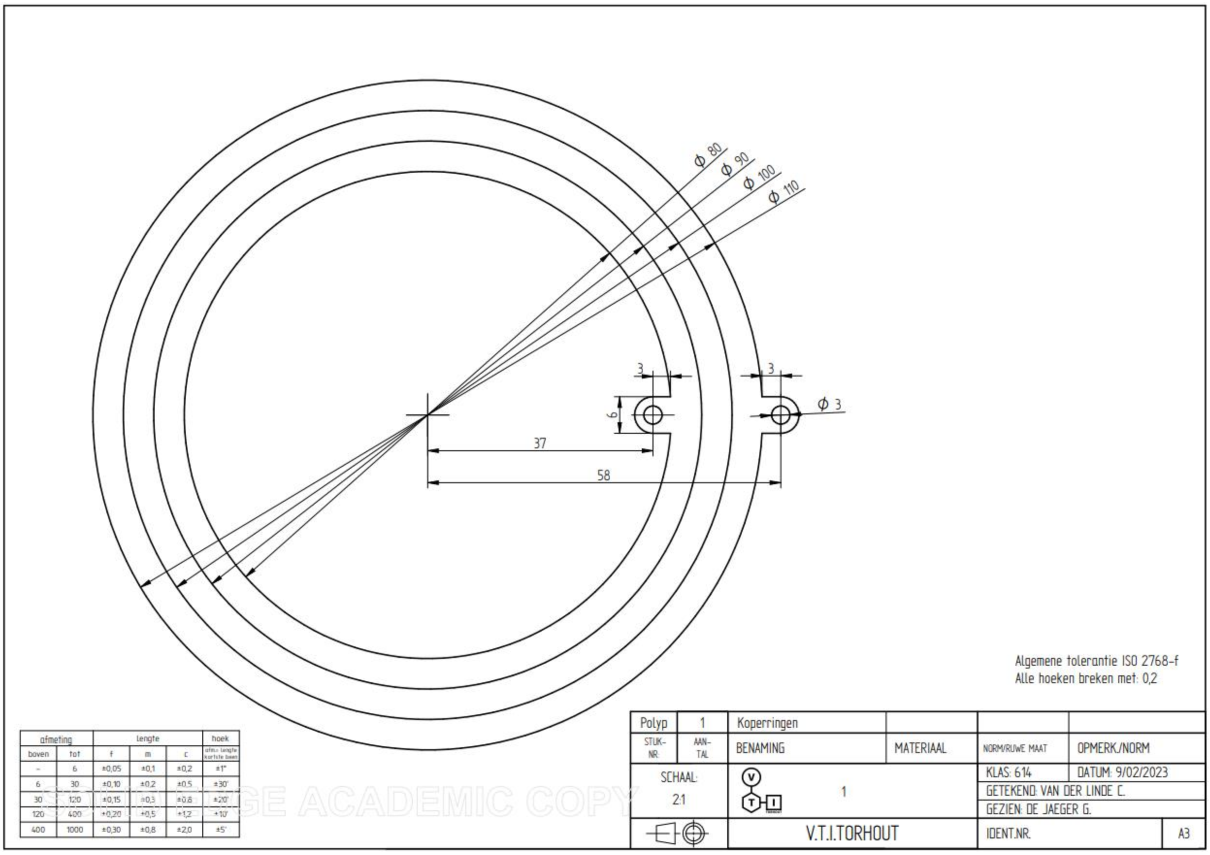
2.4 Bevestiging as



2.5 As



2.6 Sleepringen



3. Stukkenlijst en prijsberekening

Totaalprijs: € 1.195,03

3.1 prijs filament

NAAM	GEWICHT (Gram)	aantal	Totaal gewicht (g)	prijs per stuk	totaal prijs
spoor met stop	32,6	4	130,4	€ 1,57	€ 6,28
spoor	19	2	38	€ 0,91	€ 1,83
as snelheidmeter	13	2	26	€ 0,63	€ 1,25
houder rotatiesensor	54,5	3	163,5	€ 2,62	€ 7,87
houder arduino as	65,1	3	195,3	€ 3,13	€ 9,40
test stuk arduino houder	9,8	1	9,8	€ 0,47	€ 0,47
bevestiging sleepring	6,4	6	38,4	€ 0,31	€ 1,85
test stuk as	0,5	1	0,5	€ 0,02	€ 0,02
bevestiging stuk sleepcontact	0,6	12	7,2	€ 0,03	€ 0,35
arm polyp	47	3	141	€ 2,26	€ 6,79
houder motor	42,26	1	42,26	€ 2,03	€ 2,03
houder arduino	15,18	1	15,18	€ 0,73	€ 0,73
			807,54		€ 38,88

prijs per rol filament	€ 30,00	/kg
Prijs eli/h printen	€ 0,07	/h
Uur per Kg printen	108	h/kg
prijs printer	€ 490,00	
levensduur printer	5000	h
	€ 0,10	prijs/h

3.2 Prijs Mdf

NAAM	DIKTE (mm)	Oppervlakte (mm²)	aantal	Prijs per stuk	totaal prijs
Grondplaat	3	35200	2	€ 0,33	€ 0,67
Schijf sleepcontacten	3	25600	1	€ 0,32	€ 0,32
				TOTAAL	€ 0,98

slijtage berekening	
printtijd/dag (h)	2
prijs	€ 9.000,00
levensduur (j)	10
slijtage prijs/j	€ 900,00
slijtage prijs/d	€ 2,47
slijtage prijs/h	€ 1,23
slijtage prijs/min	€ 0,02

prijs/plaat/mm dikte	€ 1,11	/plaat/mmdikte
oppervlakte plaat	0,6	m²
prijs/mm²/mm dikte	€ 0,00	/mm²/mm dikte
eli prijs/laser beurt	€ 0,07	/keer
slijtage	€ 0,21	/keer

3.3 Prijs onderdelen

arduino				
aantal	onderdeel	prijs	totaal	
2	arduino	€ 3,33	€ 6,66	https://nl.aliexpress.con
1	joystick shield	€ 3,46	€ 3,46	https://nl.aliexpress.con
2	NRF	€ 2,55	€ 5,10	https://opencircuit.shop
1	jumperdraden	€ 0,20	€ 0,20	https://nl.aliexpress.con
1	batterij	€ 1,29	€ 1,29	https://nl.aliexpress.con
1	batterij houder	€ 1,89	€ 1,89	https://nl.aliexpress.con
		tot	€ 18,60	

motor				
aantal	onderdeel	prijs	totaal	
1	profielen	€ 20,56	€ 20,56	https://www.123-3d.nl/1
8	hoekjes profiel	€ 3,00	€ 24,00	https://www.123-3d.nl/1
1	as	€ 5,12	€ 5,12	https://www.aluminium\
1	motor	€ 1.070,50	€ 1.070,50	https://benl.rs-online.co
1	plexiplaat	€ 2,20	€ 2,20	https://kunststofplaten.l
1	kabels	€ 0,75	€ 0,75	https://gigatek.be/nl/ele
1	messingplaat	€ 19,99	€ 19,99	https://www.conrad.be/
1	touwtje	€ 0,03	€ 0,03	https://shingyo.nl/produ
3	borsteltjes	€ 0,72	€ 2,16	https://www.bol.com/be
1	krachtsensor	200	€ 200,00	https://www.vosinstrum
1	rotatiesensor	321,64	€ 321,64	https://www.vosinstrum
1	smart cart	€ 319,13	€ 319,13	https://www.vosinstrum
		tot	€ 1.123,13	

	bouten en moeren				
soort	aantal	onderdeel	prijs	totaal	
	10	M3 moer	€ 0,03	€ 0,25	https://www.rvspaleis.nl
6kant	8	M3X8	€ 0,05	€ 0,40	https://www.rvspaleis.nl
	16	M4 borgmoer	€ 0,04	€ 0,58	https://www.rvspaleis.nl
	32	M4 rondel	€ 0,01	€ 0,32	https://www.rvspaleis.nl
6kant	16	M4X20	€ 0,08	€ 1,20	https://www.rvspaleis.nl
rond	8	M5X35	€ 0,15	€ 1,20	https://www.rvspaleis.nl
	8	M6 moer	€ 0,05	€ 0,40	https://www.rvspaleis.nl
	4	M6 rondel	€ 0,02	€ 0,08	https://www.rvspaleis.nl
rond	8	M6X35	€ 0,21	€ 1,68	https://www.rvspaleis.nl
6kant	5	M6X25	€ 0,11	€ 0,55	https://www.rvspaleis.nl
rond	32	M6X8	€ 0,15	€ 4,80	https://www.rvspaleis.nl
	2	M12 borgmoer	€ 0,32	€ 0,64	https://www.rvspaleis.nl
6kant	1	M12X100	€ 1,34	€ 1,34	https://www.rvspaleis.nl
			tot	€ 13,44	

4. Logboeken

4.1 Logboek Wout Crevits

Datum	Actie	Omschrijving Resultaat	Tijd
01/09/2022	Brainstormen	Beslissen wat onze GIP zal zijn en al wat ideeën uitwisselen over dit project zoals de theorie en realisering.	2u
05/09/2022	Brainstormen	Verder uitwerken van ideeën: sleepcontacten, motoren, middenstuk, etc.	2u
06/09/2022	Brainstormen en PPT	Al een eerste versie maken van onze PowerPoint en nog wat verder denken over hoe we alles zullen maken en realiseren.	1u
08/09/2022	Vragen en brainstormen	Verder werken aan de PPT en vragen stellen aan leerkrachten of alles wel kan.	1u
12/09/2022	PPT	Onze PPT afwerken en verdelen om ons klaar te maken voor de presentatie	2u
12/09/2022	Presentatie #1	Eerste presentatie voor jury, proberen zoveel als mogelijk te onthouden en alle opmerkingen en vragen gebruiken om ons project beter te maken.	2u
13/09/2022	Overlopen vragen	Overlopen van vragen en opmerkingen van de jury met mr. Vansteenlandt.	1u

15/09/2022	Bespreken van ideeën en verder brainstormen	Verder besproken hoe we alles gaan doen aan de hand van de vragen van de jury. Met in het bijzonder eerst het sleepcontact.	1u
19/09/2022	Eerste tekening en verder denken	De eerste 3D tekening werd gemaakt nl. het sleepcontact, er werd hierbij overlegd met mr. Geeraert	2u
Vanaf 20/09/2022	Motor	Motor zoeken en uittesten met Mr Geeraert	7u
29/09/2022	3D tekeningen	Eerste 3D tekening van slepertje en motor.	2u
03/10/2022	Verder tekenen	Verder getekend aan de GIP en overlegd hoe we alles zullen ontwerpen	2u
06/10/2022	Opzoeken	Overleg met Mr Vansteenlandt over alle krommen en hoe de krachten zullen gemeten worden.	2u
10/10/2022	Motor en ESC	ESC bij gelijmd om te beschermen en motor getest (Werkt). Verder overlegd over het opmeten van de krachten (Sensor/Karretje??)	2u
13/10/2022	Koppelstuk	Koppelstuk getekend	1u
26/10/2022	Site	Werken aan site	4u
28/10/2022	Site	Werken aan site	4u
07/11/2022	Site	Werken aan site	2u
10/11/2022	Geogebra	Geogebra werkblad gemaakt om cycloïden te onderzoeken	2u
14/11/2022	Site	Werken aan site en helpen denken met Corneel en Robbe	2u

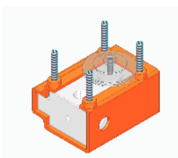
21/11/2022	Presentatie	Gewerkt aan presentatie	2u
24/11/2022	Presentatie	Gewerkt aan presentatie	1u
28/11/2022	Draadloze communicatie en presentatie	Gewerkt aan de presentatie en de draadloze communicatie proberen te laten werken	2u
29/11/2022	Presentatie	Presentatie GIP	2u
05/12/2022	Communicatie en site	Gewerkt aan site i(1u) en draadloze communicatie met potentiometer besturen (1u)	2u
09/01/2023	Werken aan programma	Gewerkt aan programma en aan de shields om de snelheid van de motor te besturen.	2u
12/01/2023-17/01/2023	Werken aan programma	Programma van motor verder maken en problemen oplossen	4u
23/01/2023	Programma afmaken	Programma GIP is zo goed als afgewerkt	2u
26/01/2023	Video-analyse Capstone	Videoanalyse en berekeningen rond capstone	4u
06/03/2023	Site	Site afgewerkt	2u
07/03/2023	Metingen	Metingen gedaan en programma is af	2u
09/03/2023	Testen capstone en PPT	Powerpoint en testen met capstone.	2u
13/03/2023	PPT voorstelling	Aan Powerpoint voor presentatie werken en opzoeken wat we allemaal gaan zeggen.	4u
28/03/2023	Fritzing en constructie	Constructie verder gemaakt en elektrisch schema in Fritzing	4u
29/03/2023	Code	Code opkuisen en tekstjes voor GIP-boek ivm code schrijven	2u

30/03/2023	GIP-boek en overleg	Overleggen met Dhr. Geeraert over volgende stappen en schrijven aan GIP-boek.	

4.2 Logboek Robbe Ryckeboer

Datum	Actie	Omschrijving Resultaat	Tijd
01/09/2022	Brainstormen Gip	We gaan een polyp maken.	2u
05/09/2022	Informatie polyp opzoeken	Verschillende manieren uitdenken of het gaat werken of niet. En al een paar schetsen maken.	3u
06-12/09/2022	PowerPoint	PowerPoint maken voor 1e presentatie + inoefenen.	4u
08/09/2022	Brainstormen cilinder roteren	We gaan het via sleepcontacten doen en willen dat eerst testen.	1u
13/09/2022	Bespreken 1e presentatie	Evaluatie bespreken, de tips en opmerkingen van de jury overlopen.	2u
19/09/22	Bedenken maten sleepcontact	Buitenste cirkel 135mm.	10min
19/09/22	Bespreken tandwieloverbrenging	Aan uiteinde as motor moet ook een lager die aan motor hangt zodat 1 stevig stuk is en niet kan afbuigen.	40min
19/09/22	Bespreking dataversturing	Niet via bluetooth of wifi want hebben niet zo veel dat doorgestuurd moet worden, doen het via 2,4 Ghz, en een denkvraag: hoe snel moet het draaien?, De sleepringen onder of boven de tandwielen?	50min

20/09/22	Meating met Jeff	Kracht sensor heeft lim van 50N, de rotatie sensor heeft geen lim. Capstone heeft geen video lengte lim.	50min
26/09/22	Motor bespreking met Geeraert	Hebben onze ideeën voor de motor besproken met meneer en meneer is met ons op school een geschikte motor gaan uitzoeken. Die motor hebben we besproken en gaan de as rechtstreeks op de motor kunnen monteren. Dit zorgt ervoor dat we waarschijnlijk geen tandwielen nodig gaan hebben. Dus minder risico. We kregen ook een esb electronic speed controller mee om uit te testen.	2u
27/09/22	Solderen en uittesten esc electronic speed controller en motor	We ondervonden dat de esb electronic speed controller defect is en moeten een andere vinden. Eventueel die van de grote drone.	1u30min
29/09/22	Schets arm	Schetsen op solid edge een vorm voor de arm en op papier hoe gemonteerd moet worden.	1u
3/10/22	1e versie arm	1e versie van de arm is af met gaten in voor gewicht maar met versteveging.	1u
3/10/22	Brainstormen monteren pasco sensor	Hoe aan arm monteren? Karretjes moeten aan die sensor hangen. Hoe sensor monteren?	1u
6/10/22	Pasco sensor tekenen	Pasco sensor getekent in solid edge	1u

6/10/22	Bespreking meting	We gaan het autotje gebruiken om de meting uit te voeren, zo kunnen we ook makkelijk de straal bepalen	30min
6/10/22	Bespreken arm	Hoe monteren	20 min
10/10/22	Esc controller afwerken	Solderen esc controllor en dicht lijmen	20min
10/10/22	Test motor	Constructie gemaakt en motor uitgetest, met potentio meter voltage aangepast. 24V nemen we als maximum.	30min
10/10/22	Meten as motor	De as van de motor is 12,45mm	10min
10/10/22	Bespreken met Geeraert en de Jeager pasco sensoren	Het karretje is geen goed iedee, we gaan de gewone pasco gebruiken. We moeten ook de softweare bekijken. We kunnen wel karretje ook doen maar dan 2 aparte opstellingen.	50min
17/10/22	Box bedenken	Rechthoekig Geen houten buitenkant Nog wachten met constructie, eerst sensor motor arduino juist zetten. Daarna de box want anders constant aanpassen.	2u
18/10/22	Proefopstelling met sensors uittesten	We experimenteerden eens met de sensoren en het programma.	2u
26/10/22	Rotatie sensor tekenen + overleg hoe bevestigen + tekenen bevestiging	In een bakje makkelijk uit te halen en vast met draadstang 	4u

27/10/22	Rotatie sensor	Voor de rotatie sensor extra vesteging maken en foutjes hertekenen.	2u
27/10/22	Box ontwerpen en tekenen	Box rond sensoren en motor ontwerpen en bedenken.	2u
07/11/22	Uitleg solid edge	Uitleg gekregen van mnr Geeraert over assembly in solid edge en uitgeprobeerd, hebben assembly sensor opnieuw gedaan via zijn betere methode.	2u
14/11/22	Batterij	Batterij uitgekozen en beginnen tekenen, deze hebben we nodig zodat de arduino nooit zonder stoom geraakt.	1u
14/11/22	samenstelling	Bespreken hoe we de samenstelling gaan realiseren	1u
17/11/22	krachtsensor	Meeting krachtsensor bespreken	30min
17/11/22	Centripetale krachten	Berekening maximale massa die de krachtsensor aan kan R=0,08m en bij 60tr/min ⇨ V= 0,5m/s ⇨ m(max) = 16kg dit is voor horizontaal opheffen! Dus wij moeten het nog anders berekenen	50min
21/11/22	powerpoint	Gip presentatie voorbereiden	1u
21/11/22	karretjes	Baan karretjes bedenken + beginnen tekenen	1u
24/11/22	karretjes	Testopstelling karretjes tekenen (is nog een schets voor in powerpoint) want hebben de rails nog niet ontvangen van mevr.	1u

27/11/22	Oefenen Gip	Oefenen Gip presentatie + laatste details afwerken	2u
05/12/22	Asm karretjes aan passen	We kregen een paar stukken van vorig jaar en passen deze nu toe in onze tekening	1u
05/12/22	Totale asm	Totale asm sleepcontacten in asm steken	10min
05/12/22	Uitleg pattern + uitvoeren op bouten asm karretjes	Uitleg gekregen over pattern om in asm snel alle bouten juist te steken.	40min
09/01/23	Proefopstelling 2	Tekenen 2e proefopstelling Er moet een blok onder komen dat het niet kan kantelen	1u
09/01/23	Probleem as	De as van motor is 11,5 en we gaan over naar een van 30, deze word dan weer afgeslepen van boven tot 11,5 dus waarom 30? Twijfelen tussen alles aanpassen of zo houden. Want misschien voor stevigheid toch houden. En voor bouten en moeren makkelijker te kunnen steken	20min
09/01/23	printen	Printen rails	10min
12/01/23	Slicen en tekenen stukken proef 2		30min
16/01/23	Proefopstelling 2 verzamelen	stukken proef 2 printen en bouten, en vloten gaan zoeken	1u
16/01/23	bestellen	Borgmoeren aanvragen	10min
16/01/23	lazeren	Plaat proef 2 lijzeren	10min
16/01/23	Bespreken as	Bespreken en aanpassen as + gaan kijken in werkplaats	30min

19/01/23	Arm polyp	Arm aanpassen en kijken hoe printen	40min
23/01/23	Bevestiging sleepcontacten	Tekenen, printen en aanpassen als te dun of te dik tot correct past	1u 30min
26/01/23	Bouten en moeren verzamelen	Uitzoeken welke bouten en moeren allemaal nodig en gaan zoeken	1u
26/01/23	Test programma sensoren	Test gedaan op de looping en binnen gelezen in het programma. De kracht en rotatiesensor eens binnengelezen	1u
30/01/23	Koppelstuk en profielen werkplaats	In werkplaats koppelstuk en profielen tekenen + aanvragen om te maken	1 u 20min
30/01/23	Plaat sleepringen halen	Geschikte plaat voor sleepringen gaan zoeken + overleggen hoe realiseren	30 min
06/02/23	Profiel kader maken	Profiel kader is binnen gekomen, moesten de bouten nog verzinken dus hebben gaten gemaakt.	40 min
06/02/23	Assembleren proef karretjes	Proef met karretjes geassembleerd (rails en bevesteging aan as vastgebout met borgmoeren)	1u
13/02/23	GIP dossier	Info verzamelen	1u
14/02/23	GIP dossier	Titels indelen in dossier	4u
16/02/23	Stukken tekenen, printen, lazeren en verzamelen	Arm, houder arduino, houder motor, bevesteging sleepcontacten, bevestegingschijf, test rotatie as, en bevesteging stuk	6u30min
16/02/23	assembleren	Kader assembleren en aanpassen	30min

27/02/23	Koppelstuk moter en as maken	Stuk gaan ophalen en gaten in boren. Dan uittesten en stuk errond 3d printen	2u
02/03/23	Plaat frezen	Plaat frezen gaan vragen en uitleggen	30min
06/02/23	Test programma	Met looping capstone testen	30min
06/02/23	Koppelstuk motor	Nog eens vragen aan iemand anders hoe mogelijk	30min
06/02/23	printen	Stukken tekenen en 3d printen	1u
20/03/23	Frezen sleepringen	Freezen met Geeraert	1u30min
20/02/23	Spoor monteren	Spoor vervangen door nieuwe versie	10min
21/03/23	Meeting uitleg pasco	Bellen voor uitleg	1u
21/03/23	Assembleren kader	Kader met motor aanpassen en assembleren	1u
24/03/23	montage	Monteren polyp	2u
28/03/23	Kuisen sleepringen	Resten materiaal weg kuisen met disolvent	40 min
28/03/23	Rotatie houder	Hertekenen en printen	30 min
28/03/23	dossier	Dossier sensoren	40 min
28/03/23	sleepcontacten	Solderen en hersolderen sleepcontacten	1u
28/03/23	Testen polyp	Motor en servo laten draaien tegelijk, onze polyp werkt!	20min
29/03/23	Gip dossier	Gip dossier	1u
29/03/23	montage	Montage	40min
30/03/23	As rotatiesensor	Tekenen	1u
30/03/23	Prijsberekening PLA	Prijsberekening PLA	2u
30/03/23	Gip dossier	Gip dossier	40min

17/04/23	As rotatiesensor	printen	20min
17/04/23	Hoeksnelheid en motor	Vragen aan mnr Geeraert Zelf opzoeken naar formule Uitleg via exel	50min
17/04/23	Gip dossier	Gip dossier	30min
20/04/23	prijsberekening	Prijsberekening laser cutter	2u
24/04/23	prijsberekening	Opzoeken onderdelen zoals profielen, arduino,… en in exel verwerken	2u
25/04/23	prijsberekening	Bouten, moeren, plexi	1u30min
25/04/23	Krachten berekening	Fk en Fn berekening	20min
04/05/23	Stukken printen	Arm tekenen en printen	1u
04/05/23	testopstelling	Testopstelling voorbereiden	1u
04/05/23	Houder batterij	Bespreken houder batterij	20min
08/05/23	Houder batterij	Printen	10 min
08/05/23	Assembleren	Assembleren polyp houders	50min
08/05/23	Houder gsm	Bedenken en tekenen	1u
20/05/23	Handleiding prusa slicer	Handleiding schrijven voor de prusa slicer	1u 45min
22/05/23	Prusa slicer	Handleiding schrijven voor prusa slicer	1u
22/05/23	Prijsberekening	Prijsberekening motor opzoeken en paar aanpassingen	30 min
22/05/23	Bijlagendossier	Balansverslag invullen	1u
23/05/23	Prijsberekening	Prijsberekening afronden	1u

23/05/23	Bijlagendossier	Bijlagendossier invullen	1u
28/05/23	Berekening tekening	Tekening met vectoren karretje	1u
30/05/23	Bijlagendossier	Bijlagendossier invullen	30min
30/05/23	Shield	Opzoeken shield en gegevens	30min
30/05/23	3D-printen	Opzoeken 3D-printen geschiedenis,…	1u
30/05/23	MDF	Opzoeken en verwerken gip dossier	2u
01/06/23	plexiglas	Opzoeken en verwerken gip dossier	2u
02/06/23	Rexroth profielen	Opzoeken en verwerken gip dossier	2u
04/06/23	batterij	Opzoeken en verwerken gip dossier	2u
04/06/23	Dossier	In orde zetten en aanpassen titels	1u
05/06/23	Booglengte	Tekening maken via geogebra	1u
05/06/23	Epicycloïde	Tekening maken via geogebra	1u
05/06/23	Dossier	Aanpassingen document	30min
06/06/23	Mech studie	Tekeningen maken voor in dossier	1u
06/06/23	Matterialen studie	Document verbeteren	1u
06/06/23	PC plexi	Opzoeken en verwerken gip dossier	1u
06/06/23	Battery shield	Opzoeken en verwerken gip dossier	2u
07/06/23	Gip dossier	Gip dossier afwerken	3u

4.3 Logboek Corneel van der Linde

Datum	Actie	Omschrijving Resultaat	Tijd

01/09/2022	Brainstormen GIP	- Bespreken van de Ideeën en kiezen welk project je graag zou doen. Wij maken een Polyp.	2u
05/09/2022	Brainstormen GIP	- We zoeken informatie op over de GIP Bv: hoe het werkt, welke soorten zijn er… - We maken ook een paar schetsen.	3u
06/09/2022	PowerPoint	- Het maken van de PowerPoint voor de start vergadering.	1u
08/09/2022	PowerPoint	- Afwerken van de PowerPoint. - Dia verdeling.	1u
12/09/2022	Presentatie	- De PowerPoint inoefenen. - Ons project voorstellen aan de jury in de startvergadering.	2u
13/09/2022	Evaluatie presentatie	- Evaluatie bespreken. - Vragen en opmerkingen van de jury overlopen.	1u
19/09/2022	Definitieve ideeën bedenken	- Data overbrenging bespreken met meneer Geeraert. We zullen gebruik maken van de 2,4 KHz frequentie om Data door te sturen. - We kregen ook nog enkele zaken waar we eens moesten over denken: 1) Waar komen de sleepringen te liggen, op de bovenste plaat of onder de tandwielen? 2) Aan welke snelheid zal onze Polyp moeten draaien? - Bespreking tandwielen, met welke overbrenging zullen we werken en hoe zullen we dit stevig realiseren?	2u
22/09/2022	Afspraak met Jeff (PASCO)	- Bespreken met Jeff van de PASCO sensoren welke sensoren we kunnen	1u

		gebruiken en hoe we ze kunnen toepassen op de Polyp.	
26/09/2022	GIP les	- Bespreken en brainstormen over de definitieve sleepcontacten. De sleepcontacten zullen onder op de tandwielen zitten, ze zullen - Bespreken met meneer Geeraert welke hoofdmotor er zal gebruikt worden. Er word geen gebruik meer gemaakt van tandwielen, want we hebben een motor gevonden die aan een laag genoeg toerental een voldoende grote kracht kan leveren.	2u
26/09/2022	Tekenen	- Teken van motor en rotatiesensor op Solid Edge.	1u
27/09/2022	Motor testen	- We maken een proefopstelling waarmee we onze motor kunnen testen, deze zal aangestuurd worden via een ESC (Electronic Speed Controller). De motor werkte wel niet omdat de ESC stuk was.	1u
6/10/2022	Bespreking metingen	- We hebben besloten om het karretje (van Pasco) te gebruiken om de krachtmetingen uit te voeren.	1u
10/10/2022	Motor opstelling afgewerkt	- We hebben de ESC op punt gezet, hierna hebben we de opstelling gemaakt en de motor laten draaien. Om de snelheid van de motor aan te passen werken we met een potentiometer.	1u
10/10/2022	Bespreking Pasco sensoren	- De meting die we zouden doen met de karretjes (van Pasco) moet worden aangepast, eerst gingen de karretjes los op een rail staan en als de Polyp begon	1u

		met draaien zouden deze naar buiten bewegen. Dit vond meneer Geereart geen goed idee omdat het voor een onevenwicht zou zorgen in de opstelling en zo niet zou werken.	
1710/2022	Brainstormen box (onderkant constructie)	- We kwamen tot het besluit dat we in een Assembly eerst alle componenten op de positie zetten moesten zetten hoe ze in de constructie moesten komen. Hierdoor kunnen we zo veel mogelijk materiaal en onnodige ruimte in de constructie besparen. - Ook hebben we gekozen om de buitenwanden uit plexiglas te maken.	1u
18/10/2022	Proefopstelling Pasco sensoren	- We hebben de krachtsensor en het karretje van Pasco getest. Al deze sensoren hebben we ingelezen in het programma Capstone.	1u
26/10/2022 27/10/2022	De gehele box (onderkant Polyp) ontwerpen	- Het ontwerpen van de onderkant van de Polyp, dus de montage motor, montage rotatiesensor, het frame tekenen enz.	2u
05/12/2022	Uitleg, printen	- Uitleg over Solid Edge, hoe je makkelijk met een pattern verschillende gaten cut (bevestigingsstuk as). Het printen van de arm en de bevestigingsstukjes voor de sleepcontacten.	2u
09/01/2023	Bespreking as, Stukken verzamelen	- Bespreking om de as van 30mm in te perken naar 25mm omdat de nuttige lengte maar 11,5mm is. Het verzamelen van stukken, bouten en moeren. Ook ben ik gaan kijken naar de werkplaats welke ruwe materialen er ter beschikking zijn.	2u

12/01/2023	Werktekeningen	- Het tekenen van de werktekeningen voor de as en het bevestigingsstuk van de as. Hulp aan de hand van mnr Geeraert zijn video's.	1u
16/01/2023	Werktekening verbeteren	- De werktekeningen laten verbeteren door mnr Geeraert en aanpassen waar nodig. Met deze tekeningen naar de werkplaats gaan en ze laten construeren.	2u
19/01/2023	Printen	- Het printen van de arm. Ook is de as geconstrueerd.	30min
23/01/2023	Technisch tekenen	- Met mvr De Jaeger mijn ASM overlopen, alle relaties nakijken en relaties toevoegen waar nodig. Nu zou de ASM geschikt zijn om er een 3D animatie van te maken. Ook maakte ik een werktekening van de profielen zodat deze op maat konden gezaagd worden.	1,5u
26/01/2023	Sensoren	- Capstone is geïnstalleerd op de computers dus we kunnen ermee testen, we testte de rotatiesensor, de krachtsensor, het karretje en de videoverwerking (aan de hand van de looping).	2uur
30/01/2023	Aanpassen stuk, bespreking sleepringen	- De frees kon de gaten in het bevestigingsstuk niet maken door machinale beperkingen, ze waren te klein. Ik paste ze aan van M4 naar M5 en maakte er een nieuwe werktekening van, hierna kon deze meteen gefabriceerd worden. We bespraken de sleepringen met mnr Geeraert.	1uur
06/02/23	Assembleren	- Kader van de Polyp in elkaar steken.	1 uur

06/02/23	Assembleren	- As en koppelstuk assembleren, ook de opstelling met de karretjes testen en in elkaar steken .	1 uur
14/02/23	GIP dossier	- Verzamelen van info over mechanica voor in GIP dossier. Plakken van de plaat waaruit de sleepringen gefreesd zullen worden.	3 uur
16/02/23	Stukken verzamelen	- Stukken printen (arduino houder, houder motor en rotatie as). Lazeren grondplaat .	2,5 uur
17/02/23	Assembleren	- Grondplaat in kader steken, bakje van de motor en arduino hieraan monteren.	1 uur
17/02/23	GIP dossier	- Verder schrijven aan GIP dossier met behulp van mvr Vandenbulcke.	3,5 uur
23/02/23	GIP dossier	- Verder schrijven GIP dossier .	2 uur
27/02/23	Koppelstuk	- Koppel stuk was af, dit zijn we gaan ophalen en hebben er 2 extra gaten in geboord omdat deze vergeten waren. Begin assemblage van de sleepringen. Opnieuw plakken van de plaat waaruit de sleepringen gefreesd zullen worden (vorige keer is de plaat losgekomen).	2 uur
02/03/23	Frezen + assembleren	- De methode van het frezen uitgelegd gekregen. Ook verder assembleren en testen van koppelstuk en as.	1,5 uur
06/02/23	Assembleren + video analyse	- Testen van de video analyse in Capstone. Ook verder printen van stukken en koppelstuk bijwerken.	1 uur
09/03/23	GIP dossier	- Verder schrijven GIP dossier uitleg van de constructie.	1 uur
11/03/23	Power Point	- Maken van de gehele Power Point. Volledig nieuw ontwerp	6 uur

13/03/23	Voorstelling	- Voorbereiden van de presentatie voor de jury. Extra info over motor vragen aan Mnr Geeraert.	1,5 uur
17/03/23	Bespreken	- Bespreking van de presentatie (namen in alfabetische volgorde!).	
20/03/23	Frezen	- Frezen van de plexiplaat + sleepringen. De methode van mnr Geeraert uitgelegd gekregen + uitleg over programma van de frees.	2 uur
21/03/23	Pasco	- Bellen met Jeff van Pasco over de video analyse en hij beantwoorde onze vragen over de sensoren. Voorbereiding voor het assembleren van de sleepcontacten.	1,5 uur
23/03/23	Assembleren	- Montage van de plexiplaat en sleepcontacten op het profiel. Overige lijm van de sleepcontacten poetsen.	2 uur
28/03/23	Tekenen + assembleren	- Tekenen van de arduino en batterij houder. De definitieve sleepcontacten installeren op het koppelstuk. Ook de polyp getest, het werkte.	4 uur
29/03/23	GIP dossier	- Opzoekwerk over hypocycloïden en epicycloïden, hiervan de parametervergelijking bepalen.	2 uur
30/03/23	GIP dossier + montage	- Afwerking van de montage zoals arduino houder en arm testen. Ook verder opzoekwerk doen over epicycloïden en hypocycloïden.	3,5 uur
17/04/23	Tekenen + GIP dossier	- Herteken van de rotatiesensor houder (nadat deze niet klopte). Verder schrijven GIP dossier over batterij (chemie). Ook een Excel programma ontwerpen met Mnr Geeraert en Wout om epicycloïden en hypocycloïden te bepalen aan de hand van verschillende rotatiesnelheden.	1,5 uur

20/04/23	Uitleg + Capstone	- Feedback van de bewijzen krijgen en testmeting via Capstone uitvoeren.	1 uur
25/04/23	Uitleg	- Gehele uitleg van de cycloïden door meneer Vansteenlandt, nu kan wout hieruit een programma schrijven. Hertekenen van de arm en plaatjes om de cycloïden te bepalen.	2 uur
30/04/23	Tekenen	- Verder teken van de arm en plaatjes.	1 uur
04/05/23	Lazeren + assembleren	- Plaatjes en arm printen en lazeren. Nieuwe aansluitkabels zoeken om aan de sleepringen te hangen.	2 uur
07/05/23	Solderen en programmeren	- Programma voor servo maken om de video analyse te testen. Ook het solderen van de servo. GIP dossier schrijven.	3 uur
08/05/23	Capstone	- Snelheid van de servo bepalen bij verschillende PWM signalen, dit om het programma te kunnen schrijven. (Zal toch met de rotatiesensor moeten gebeuren.)	2 uur
10/05/23	Capstone	- Snelheid van de servo bepaald met de rotatiesensor. (woensdagnamiddag). Ook verwerkt in Excel.	3u
18/05/23	Logboek	- Schrijven van GIP dossier.	1u
19/05/23	Logboek	- Schrijven van GIP dossier.	2u
22/05/23	Krachtmetingen	- Krachtmetingen uitvoeren aan de hand van sensoren. Verder schrijven aan GIP dossier.	2u
24/05/23	Krachtmetingen	- Krachtmetingen verwerken via PASCO en Excel, ook nog enkele metingen uitvoeren omdat de grafiek die ik bekwam niet duidelijk en precies genoeg	4u

		was. Schrijven GIP dossier. (woensdagnamiddag in Newton)	
25/05/23	Cardioïde bekomen	- Het bekomen van een Cardioïde aan de hand van onze Polyp.	1u
27/05/23	GIP dossier	- Verwerking krachtmetingen en sensoren.	1,5u
28/05/23	GIP dossier	- Verwerking krachtmetingen + uploaden.	2u
29/05/23	GIP dossier	- Schrijven GIP-dossier	2u
30/05/23	GIP dossier	- Schrijven GIP-dossier	2u
31/05/23	GIP dossier	- Schrijven GIP-dossier	2u
01/06/23	GIP dossier	- Schrijven GIP-dossier	2u
02/06/23	GIP dossier	- Schrijven GIP-dossier	2u
03/06/23	GIP dossier	- Schrijven GIP-dossier	2u
04/06/23	GIP dossier	- Schrijven GIP-dossier	2u
05/06/23	GIP dossier	- Schrijven GIP-dossier	2u
06/06/23	GIP dossier	- Schrijven GIP-dossier	2u

5. Bronvermelding

https://soda.crouzet.com/pn/?i=80149510 --> Site motor

https://www.linak.nl/segmenten/techline/actuator-academyindustri%C3%ABle-actuatoren/hoe-een-dc-motor-werkt-in-een-industri%C3%ABle-actuator/#:~:text=Een%20DC%2Dmotor%20(Direct%20Current,beurt%20een%20roterende%20beweging%20cre%C3%ABert. --> info DC-motor met borstels

https://www.cset.oit.edu/~lynnd/cst120/ho/Lec11%20Slides.pdf --> info overflow interrupt servo

https://kiwi-aerialshots.nl/hoe-werkt-een-drone/ --> info ESC https://glowing-travesseiro-100bb2.netlify.app/ --> info NRF24

https://hobbyking.com/nl_nl/blog/brushed-brushless-electronic-speed-controllers-work/?___store=nl_nl --> info motoren

https://vtk.ugent.be/w/images/2/27/Theoretische_mechanica_I_-_TheoretischeMechanica_AlleOef.pdf -->info cycloiden

https://discoveryoftech.com/what-is-esc-drone/ --> info ESC

https://nl.wikipedia.org/wiki/Servomotor#:~:text=De%20servo%20vergelijkt%20voortdurend%20het,nul%20is%2C%20stopt%20de%20servomotor. --> info servomotor

https://ww1.microchip.com/downloads/en/DeviceDoc/2N7000-N-Channel-Enhancement-Mode-Vertical-DMOS-FET-Data-Sheet-20005695A.pdf --> foto datesheet ESC

Datum	Link/Boek/Tijdschrift	Onderwerp
02/11/22	https://www.geogebra.org/m/vScpzrcu	Hypocycloïde
02/11/22	https://www.geogebra.org/m/R47JJDPs	epicycloïde
02/11/22	https://en.wikipedia.org/wiki/Hypocycloid	Hypocycloïde
02/11/22	https://en.wikipedia.org/wiki/Epicycloid	epicycloïde
14/02/23	https://nl.wikipedia.org/wiki/Middelpuntvliedende_kracht	Middelpuntvliedende kracht
14/02/23	https://www.natuurkunde.nl/artikelen/3417/middelpuntzoekende-en--vliedendekracht	Middelpuntvliedende kracht
17/02/23	https://sciencewithmat.com.au/products/pasco-force-sensor-50n	Kracht sensor
17/02/23	https://www.vosinstrumenten.nl/onderwijs/computermeten/bluetooth-sensoren/draadloze-kracht-sensor-pasco.html	Kracht sensor
17/02/23	https://www.pasco.com/products/sensors/wireless/me-1240	smartcart
25/04/23	Boek mechanica	Berekening Fk en Fn

25/05/23	https://cdn.pasco.com/product_document/PASPORT-High-Resolution-Force-Sensor-Manual-PS-2189.pdf	Kracht sensor
25/05/23	https://cdn.pasco.com/product_document/013-15949A_PS-3220_WI_RMS_REF_GUIDE_11-28-18.pdf	Rotatie sensor
25/05/23	https://cdn.pasco.com/product_document/Smart-Cart-Manual-ME-1240-1241.pdf	Smart cart
30/05/23	https://www.tinytronics.nl/shop/nl/power/bms-en-laders/li-ion-en-li-po/met-protectiecircuit/lilygo-ttgo-t-bat-met-18650-batterijhouder-cn3065	Shield batterij
30/05/23	https://nl.wikipedia.org/wiki/3D-printer#:~:text=Het%20driedimensionale%20printproces%20is%20ontstaan,met%20een%20metaal%20als%20productiestof.	3D-Printen
30/05/23	https://nl.wikipedia.org/wiki/Medium-density_fibreboard	MDF
30/05/23	https://www.opmaatzagen.nl/klustips/alles-over-mdf-je-leest-het-hier	MDF
01/06/23	https://nl.wikipedia.org/wiki/Plexiglas	Plexiglas
01/06/23	https://www.plexiglas.nl/blog/voor-en-nadelen-van-plexiglas#:~:text=Plexiglas%20laat%20meer%20licht%20door,gewoon%20glas%20van%20gelijke%20dikte.	Plexiglas
01/06/23	https://nl.wikipedia.org/wiki/Filament_(3D-printer)	Filament
01/06/23	https://www.reichelt.com/magazin/nl/advies/3d-printen-nieuwe-filamenten-nieuwe-ideen/#:~:text=Zowel%20PLA-%20als%20ABS-filamenten,dikkere%20filament%20echt%20drie%20millimeter.	Filament

01/06/23	https://nl.wikipedia.org/wiki/Polymelkzuur	Filament
02/06/23	https://nl.wikipedia.org/wiki/Bosch_Rexroth	Rexroth
02/06/23	https://www.boschrexroth.com/nl/be/producten/productgroepen/assemblagetechniek/onderwerpen/aluminium-profielen-oplossingen-en-componenten/#:~:text=met%20%27s%20werelds%20grootste%20selectie,dan%20veertig%20jaar%20continu%20uitgebreid.	Rexroth
04/06/23	https://nl.wikipedia.org/wiki/Lithium-ion-accu	batterij
04/06/23	https://www.stibat.nl/kennisbank/lithiumbatterijen/#:~:text=Lithium%20batterijen%20zijn%20veel%20krachtiger,wel%20zeven%20keer%20langer%20mee.	batterij
04/06/23	https://opencircuit.be/product/18650-battery-shield-v3	Battery shield
05/06/23	https://www.geogebra.org/classic?lang=nl	Tekening booglengte
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