WIRELESS MOTION+ CART W54

USER GUIDE

cma-science.nl

Short description

CMA Wireless Motion+ Cart W54 is a low friction, durable aluminum cart designed for physics experiments. It can be used to study motion, forces, and energy. It has built-in sensors which measure the cart's position, velocity, acceleration, angular velocity, and applied force in real-time. The cart uses Bluetooth communication to transmit the measured data. To use it, you need the Coach 7 or Coach 7 Lite software.

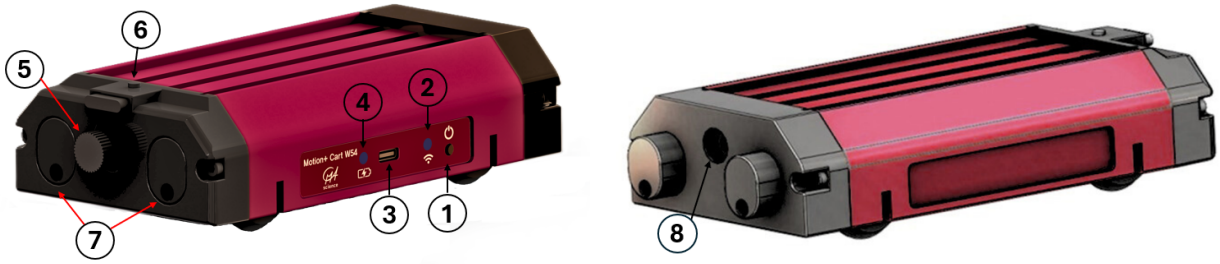
The Motion+ Cart comes with several accessories:

- A hook to use to measure pulling forces,
- A bumper for collision experiments or measuring pushing forces,
- Four magnets (2 x 10 mm and 2 x 3 mm) that can be placed inside the cart for elastic collisions,
- Adhesive Velcro rounds (15 mm),
- Mini wrench for unscrewing the plugs for magnets, and
- USB-A/C cable.

The cart can be used on its own or with CMA Motion+ Track & Accessories, which must be purchased separately (art. Nr W54TRACK).

Parts of the cart

The diagrams below show the different components of the sensor. Read on to learn about the function of each part.



① **Power Button**: Turns the device on and off.
② **Battery Status LED**: Lights red up when charging via the USB port.
③ **USB Port**: Used to connect the device to a computer for charging only.
④ **Status LED**: Indicates the Bluetooth mode - blinks blue when in Classic mode (compatible with Windows) and alternates blue and red when in BLE mode (compatible with Android, iOS, and macOS).
⑤ **Spring Plunger**: Spring-loaded plunger for collisions; press in and lift slightly to lock in one of two positions.
⑥ **Plunger Release Button**: Press to release the locked plunger.
⑦ **Attachment Port**: For attaching a hook or bumper accessory.
⑧ **Plugs for Magnets**: Place magnets in the plug compartments to create repulsion between two carts.

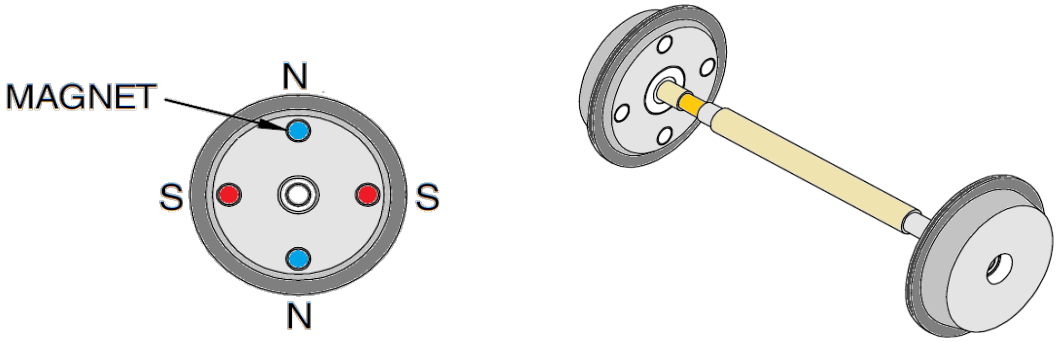
The Motion+ Cart sensors

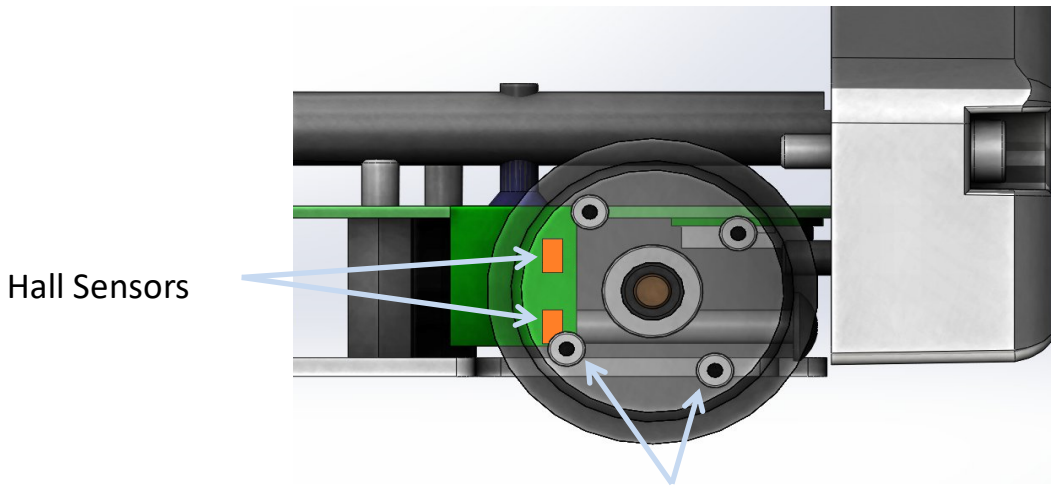
The sensor has four build-in sensors:

- Magnetic Rotary Encoder,
- Force sensor,
- 3-Axis Accelerometer, and
- 3-Axis Gyroscope.

Magnetic Rotary Encoder

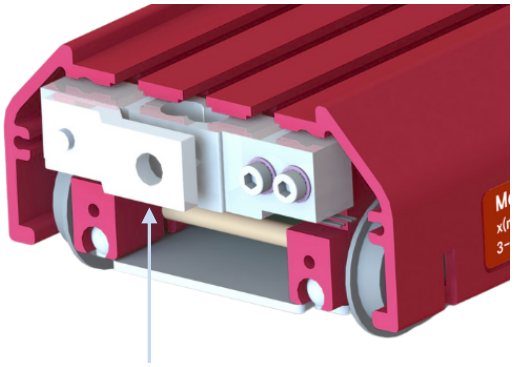
Each wheel of the cart is equipped with four small round magnets, placed at 90-degree intervals with alternating polarity. Hall sensors detect the magnetic field strength at each rotational position of the wheel, enabling the encoder to measure the wheel's angle of rotation. This process allows the system to track the cart's position with a resolution of 0.5 mm and a maximum velocity of 3 m/s. The encoder works by converting the magnetic field data into electrical signals, which are then decoded to determine the cart's exact position and velocity.



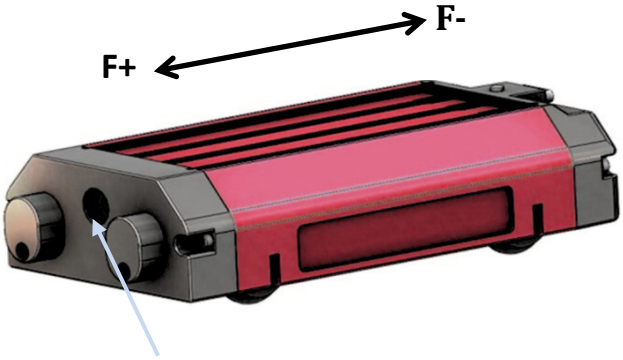


Force sensor

The force sensor uses strain gauge technology to measure force. Strain gauges are attached to both sides of a flexible beam. When the beam bends due to force, the resistance in the gauges changes. These changes create voltage variations, which a digital processor uses to calculate the force accurately. The sensor measures in the range -100 .. 100 N. It measures both push and pull forces along the direction the cart is moving. Use the hook for pulling and the bumper for pushing. Avoid exposing the sensor to strong shocks or forces above 100 N, as this could permanently damage the sensor.



Load Cell with Strain Gauge

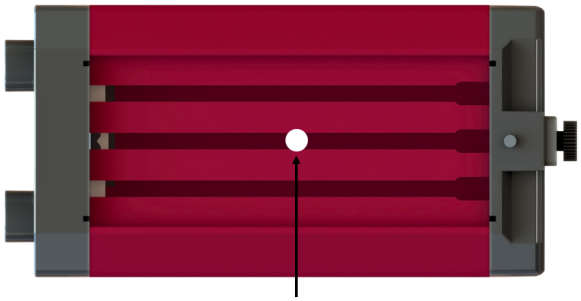


Port to attach Hook or Bumper

To connect the bumper or hook attachment, screw the attachment into the threaded hole on the front end of the Motion+ Cart, as shown above.

3-Axis accelerometer

The Motion+ Cart features a built-in 3-axis accelerometer that measures acceleration along the X, Y, and Z axes. The sensor's location within the cart and the directions of the axes are shown in the images below. The accelerometer operates within a range of -16 to 16 g (-156.96 to 156.96 m/s²) where "g" represents the acceleration due to gravity (9.81 m/s²).



Location of the accelerometer

The three axes are aligned as follows:

- The X-axis runs along the long axis of the Motion+ Cart.
- The Y-axis is perpendicular to the top of the cart.
- The Z-axis is perpendicular to the long axis of the cart and parallel to the top surface.

In the given orientation, the accelerometer measures:

- X-component = 0 g
- Y-component = 0 g
- Z-component = -1 g

The net acceleration is calculated as the square root of the sum of the squares of the component accelerations.

3-Axis Gyroscope

The sensor measures the angular velocity of the Motion+ Cart's rotation in three directions: around the X, Y, and Z axis. Angular velocity refers to how quickly the cart is rotating in each direction and is measured in degrees per second (°/s). The sensor can detect angular velocities within the range of -500 to 500 °/s, which corresponds to ± 83.3 RPM (revolutions per minute).

This is achieved using a 3-axis gyroscope, which detects changes in angular position by measuring the rate at which the cart's orientation changes over time. As the cart rotates, the gyroscope senses the angular motion and translates it into electrical signals, which are then processed to give accurate readings of the angular velocity in each direction. This allows precise monitoring of rotational movements and helps in studying rotational dynamics and angular motion in physics experiments.

Calibration

All sensors in the Motion+ Cart come with factory calibrations, so no additional calibration is required.

At the start of an experiment, the measurements from the built-in force sensor, accelerometer or Gyroscope may not read zero, even when there is no force, acceleration, or angular velocity. This is normal and can be corrected by zeroing the sensors. You can do this using the **Set to Zero** option in the Coach software (right click a sensor display and select **Set to > Zero**). Alternatively, you can adjust the sensor calibration using the **Set to Value** option, (right click a sensor display and select **Set to > Value…**), which allows you to shift the predefined calibration to a specific value.

Software

You can use the Motion+ Cart W54 with Coach 7 or Coach 7 Lite (free) program on computers (Windows and Mac) or Coach 7 and Coach 7 Lite (free) app on mobile devices (Android and iOS). For Chromebooks, we offer a special Android app. The support for wireless sensors is added starting from Coach version 7.12.
Check the CMA website for the latest installations.

https://cma-science.nl/downloads_en

Selecting Bluetooth mode

For mobile devices (Android, iOS), Chromebooks, and Macs, the Motion+ cart uses Bluetooth Low Energy (BLE). These devices do **not** require pairing — just use the cart directly in Coach. For Windows computers, Bluetooth Classic is used, and the cart must be **paired** before use in Coach.

The Bluetooth status LED indicates the current mode:

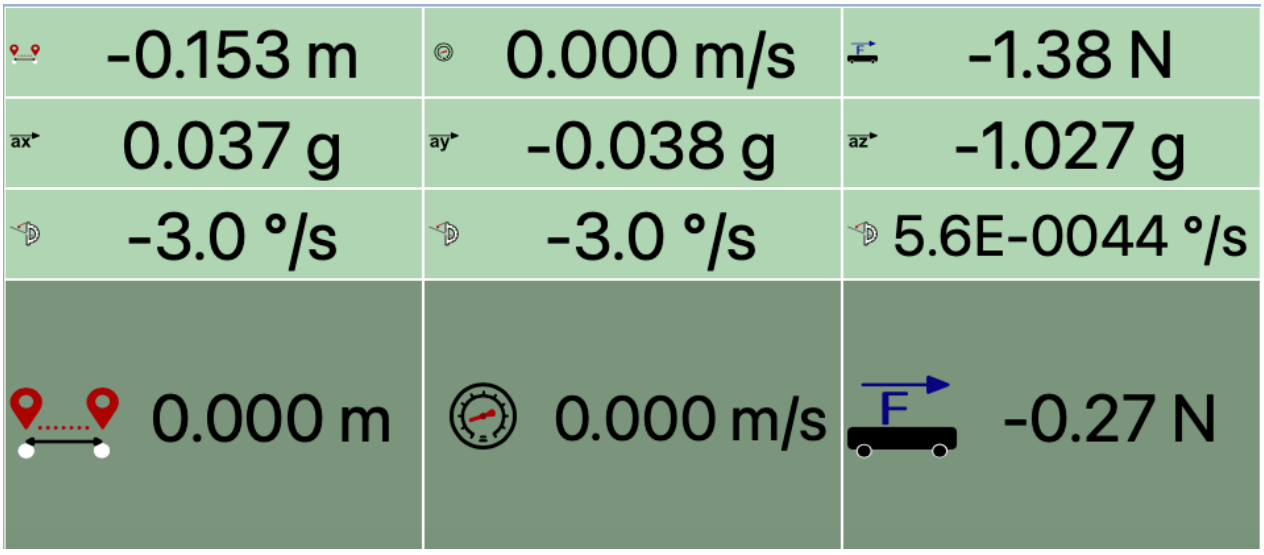
- **Blinking blue:** Bluetooth Classic - for use with Windows,
- **Alternating blue and red:** BLE mode - for use with mobile devices, Chromebooks, and Macs.

If your cart is not in the mode compatible with your device, switch modes by pressing and holding the power button until the LED blinks in the desired mode and a short melody sounds.

Collecting data with Motion+ Carts

1. Turn on the Motion+ Cart by pressing its power button; a short melody plays.
2. Check whether your cart is in the correct Bluetooth mode by looking at the status LED. If it is not, switch the mode (see the section above).
3. The Bluetooth identification code is printed on a sticker located on the side of the cart. You will need this code to identify the cart when connecting it.
4. **For Windows computers only:**
   skip this step if you are using Apple computers, mobile devices, or Chromebooks.
   You must pair your cart before using it in the Coach software on Windows:
   - Go to **Windows Settings** > **Bluetooth & other devices** and select **Add Bluetooth or other device**, then choose **Bluetooth**.
   - Windows will search for available Bluetooth devices and, after a short wait, display a list of discovered devices. The carts will be listed with their Bluetooth IDs.
   - Select the cart you want to connect to. If needed, verify the cart's Bluetooth ID.
   - Once the connection is successfully established, Windows will indicate that the cart is paired and ready to use.
5. Start the Coach 7 or Coach 7 Lite program/app.
6. Select a measurement activity for Wireless Motion+ Cart(s), for example Dashboard > Measurement > Measurement with Wireless Motion+ Cart(s) .

7. Coach starts scanning and displays a list of detected Motion+ Carts.
8. Select the Motion+ Cart you want to connect to. If needed, verify the cart's Bluetooth ID. Note: If the Motion+ Cart has not yet been paired with the Windows computer, Coach will prompt you to pair the sensor first via Windows Settings.
9. You can connect up to two carts simultaneously. The first connected cart is assigned index A, and the second cart index B.
10. Once the connection is established, the values measured by the sensors built into the carts are displayed in the panel.
11. By default, all cart sensors are displayed in the panel; showing nine icons with their measured values: x(m), v(m/s), F(N), a_x(g), a_y(g), a_z(g), ω_x(°/s), ω_y(°/s) and ω_z(°/s).
12. To limit the number of displayed sensor values in the panel, right-click the display and select the **Sensors Selection** option. In the dialog that appears, each sensor has a switch next to its name that allows you to show or hide it in the panel. You can adjust this setting for each connected Motion+ Cart. You can use the **+** sign next to the sensor switch to apply an inverse sign, selecting the opposite to the default direction.
13. When using the second cart, the sensor selection for this cart must be made separately in **Tab B**.



The panel displaying all sensors selected for Cart A and three sensors selected for Cart B.

Working with two Motion+ Carts

Two Motion+ Carts can be used in various experiments to explore concepts like collisions, momentum, and force interactions.

To study collisions between two carts, you can use the provided magnets. For elastic collisions these magnets must be positioned so that both carts have the same polarity on both sides. This ensures the carts repel each other and never make contact, resulting in a nearly elastic collision—unlike collisions involving springs or direct contact.
To insert the magnets, first, remove the screws from the oval-shaped ends of the cart and take out the plugs. Place a magnet inside each plug compartment, ensuring they are oriented to repel the magnets in the other cart. Reinsert the plugs with the magnets back into the cart, then tighten the screws. Once assembled, test whether the magnets repel each other.

If you reverse the polarity of the magnets, the carts will attract instead of repel. When two carts with opposite magnet orientations collide, they will stick together upon impact. This setup allows you to study inelastic collisions, where the carts remain attached after the collision rather than bouncing apart. To achieve this, simply insert the magnets in the plugs so that opposite poles face each other.

An alternative method for studying inelastic collisions, instead of using magnets, is to attach Velcro pads to the top of the oval-shaped plugs. Place the rough hook pad on the left plug and the soft loop pad on the right plug, making sure they are centered. This allows any cart with Velcro pads to stick to another. When two Velcro-equipped carts collide, they will remain attached, creating a fully inelastic collision.

Charging a battery

An internal rechargeable battery (Li-Poly 3.7 V, 1000 mAh) powers the sensor. Use the provided cable to connect the sensor to a USB port for charging. The battery LED lights up red when the device is charging. A fully discharged battery requires up to 4 hours of charge time to become fully charged again. To prolong battery life, automatic power down turns the sensor off after 10 minutes of inactivity.
To replace the battery, use **only** the approved rechargeable batteries provided by CMA.

Practical information

- Keep the track clean; if it is dirty the carts will not roll smoothly.
- Use lower speeds and lower inclines than you might initially choose; the physics is the same and students will have more time to observe what is happening.
- The magnets are designed for relatively gentle collisions. If the cart is moving too quickly, the magnetic forces may cause it to veer off the track. In such cases, try using a lower initial velocity for the cart.

- To prevent interference, store the magnets away from computers.
- For safety reasons, Motion+ Carts are designed to be secured to the suspension and not move when excessive loads are applied.

Suggested experiments

One Motion+ Cart

1. Study motion by measuring position, velocity, and acceleration.
2. Measure acceleration on inclined planes to explore gravitational force and friction.
3. Match the Motion Graphs: Analyze different types of motion.
4. Newton's Second Law: Investigate the relationship between force, mass, and acceleration.
5. Measure impulse and compare it to changes in momentum.
6. Hooke's Law: Use a spring to measure displacement and find the spring constant.
7. Study static and kinetic friction on different surfaces.
8. Explore potential and kinetic energy by rolling the cart down an incline.
9. Perform experiments with spring plunger-triggered kinetic and potential energy transformations.
10. Investigate the buoyant force.
11. Study circular motion by attaching the cart to a rotating platform.

Two Motion+ Carts

1. Newton's Third Law: Study action and reaction forces in collisions.
2. Perform collision experiments to observe and calculate momentum conservation in elastic and inelastic collisions.
3. Study how kinetic energy is conserved or transformed in different types of collisions.

Technical Specifications

Sensors included	Magnetic Rotary Encoder Force sensor 3-Axis Accelerometer 3-Axis Gyroscope
Measuring ranges	Velocity: - 3 .. 3 m/s Force: -100 .. 100 N 3-axis acceleration: - 16 .. 16 g 3-axis gyroscope: - 500 .. 500 °/s
Resolutions	Position: 0.5 mm Force: 0.01N / 0.1N Acceleration: 0.001 g Gyroscope: 0.1 °/s
Maximal sampling rate	100 Hz
Mass	500 g
Condition	-20 ~ 60℃, 85%RH
Battery	Li-Poly Rechargeable Battery (3,7 V 1000 mAh)
Battery life after full charge	Approximately 4 hours, battery life varies by use, configuration, temperature, and many other factors; actual results will vary.
Wireless communication	Bluetooth 5, (Mac, Android, iOS) Bluetooth 2.1, Classic (Windows)
USB port	USB-C, only for charging not for communication
Bluetooth ID	W54-xxx

Warranty

The Motion+ Cart W54 is warranted to be free from defects in materials and workmanship for a period of 3 years from the date of purchase provided that it has been used under normal laboratory conditions. This warranty does not apply if the sensor has been damaged by accident or misuse. The sensor battery is a consumable and is warranted to be free from defects in materials and workmanship for a period of 12 months from the date of purchase.

Discard batteries according to local regulations.

Note: *This product is to be used for educational purposes only. It is not intended for industrial, medical, research, or commercial applications.*

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