

# Fundamental MECHANICS

In association with



**Linear & Rotational Dynamics**



**MATRIX**

CP5099

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## Introduction

The Data Harvest Dynamics System (*Product code 3800*) will grow with the physics department's needs. It has the potential to become far more than a simple dynamics ramp. With the addition of a pair of Smart Q Light gates, it can be used to demonstrate basic speed, velocity and acceleration principles. The simple clamping system allows various sensors to be quickly connected and repositioned. Great care has been taken to ensure maximum compatibility with the Data Harvest range of sensors.

Simple experiment notes guide the student through the process of setting up the experiment and provide guidance to set up experiments and quickly start collecting accurate, repeatable and reliable results. Motivation and engagement in the experiments is enhanced by the simplicity and reliability of the system.

In order to make the most of your Dynamics System, add-on extension packs are available to extend the range and sophistication of the investigations that can be performed.

This manual consists of two parts:

### Part One

Describes the assembly of the system, how to attach sensors and investigations that will introduce the student to the basics of dynamics, motion, pendulums and forces. Investigations provided study speed, acceleration, friction, pendulums and gravity using a wide variety of sensors.

### Part Two

Describes how with the addition of the Extension Kit 1 (*Product code 3801*), the system can be extended, quickly and simply to accommodate advanced physics work. Investigations provided study collisions, dynamic forces and advanced pendulum work.

## Compatible sensors and accessories

**Extension Kit 1** (Product code 3801). Contains additional cart, mounting brackets and accessories to extend the Dynamics System. Essential for investigations with collisions.

**Light gate** (Product code 3250) - an essential for the system.

**Rotary Motion sensor** (Product code 3280) and **Rotary Motion Accessory Pack** (Product code 3288).

**Motion sensor** (Product code 3270).

**Force sensor** (Product code 3143).

**Laser Module** (Product code 3285).

**Additional Cart** (Product code 3821).

**Interrupt Card Set** (Product code 3803).



## Care of the Dynamics System carts

### Before use

The carts for the dynamics system have been tested for free running before packaging and dispatch. During transport and storage, the bearings and wheels may have become stiff. To bring the carts back to their free running state, place the carts on the track (with the wheels in the grooves) and push them up and down the track a few times. This will redistribute oil around the bearings.

### During use

The free running nature of the carts mean that steep angles are not required for good results. If the angle of the track becomes too steep, the carts will gather a lot of speed on their journey and any simple stop mechanism may cause the cart to leave the track and fall, with force, onto the table or floor.

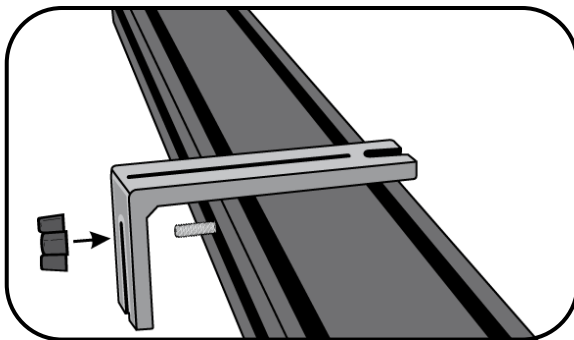
Methods of stopping the cart from high-speed runs, without it leaving the track, are described on page 10 and 11.

Occasional lubrication of the bearings may be necessary. Use good quality light machine oil, 1 drop per bearing will be sufficient. Oil should be applied to the inner face of the wheel bearing.

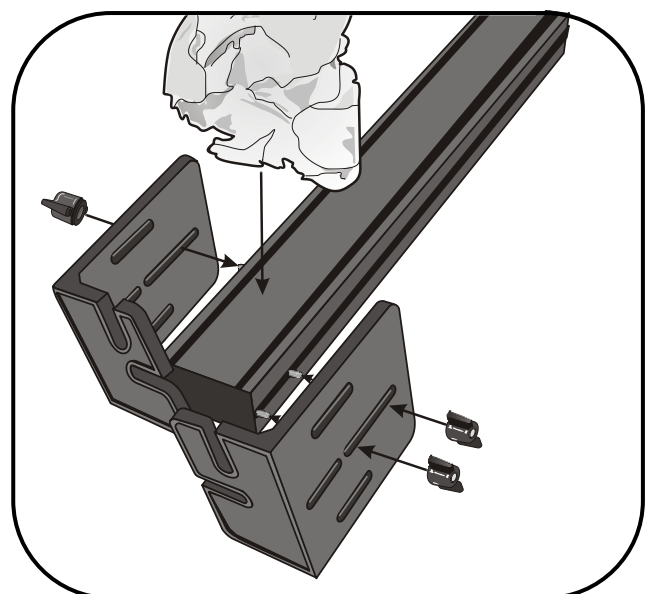
If a cart has been dropped or has fallen off the track the wheels may become misaligned on the bearings. To bring the wheels back to true running, place the cart on the track and with a light downward pressure on the cart push it back and forwards several times. Check for even running, if necessary repeat.

### Precautions

- Dropping the cart from a height can potentially damage the wheels and axles.
- The system has been designed to produce good results with low speeds. Unless absolutely demanded by an investigation, avoid high-speed runs and collisions. It is unlikely the results will be any better and you risk damaging the cart.
- Do not let the cart drop off the end of the track. A stop can be made using a thin bracket (SB1) across the track, see page 11. A crash barrier can be used to stop a cart at the end of the track, when using high track angles or carts traveling at high speed, see page 10.



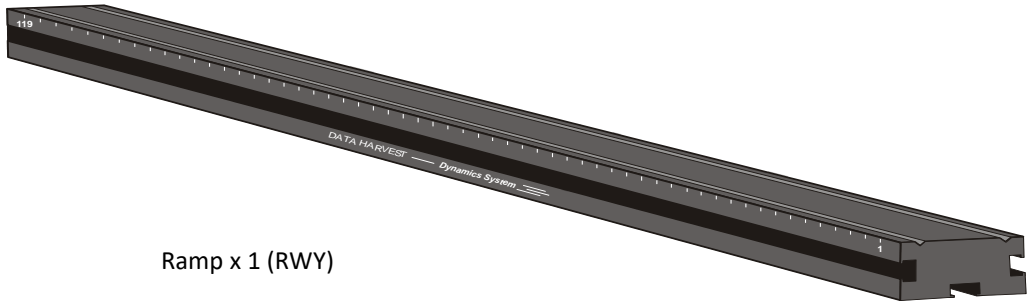
Stop bar



Crash barrier

# Component identification for the Dynamics System - Product No 3800

(Not to scale)



Ramp x 1 (RWY)



Pillar x 1 (UPR)



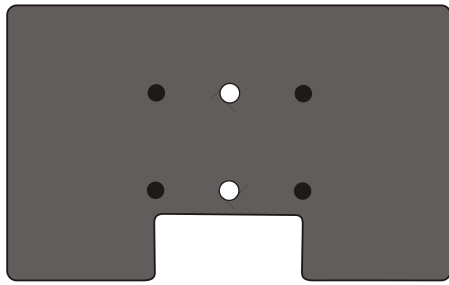
Cart x 1 (MT1)



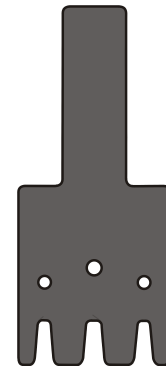
Allen key x 1 (AK)



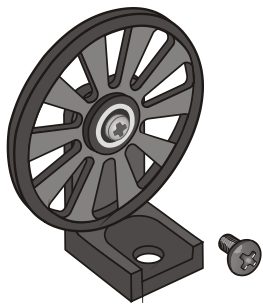
Base x 1 (BS)



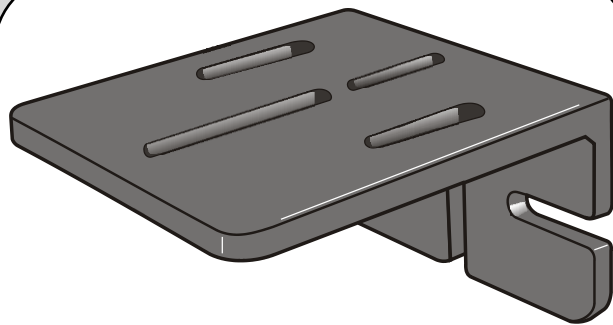
Interrupt card x 1 (IC1)



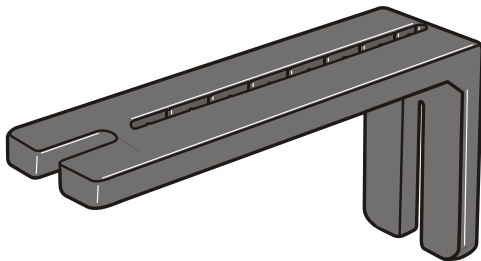
End reflector x 1 (ER1)



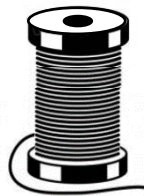
Spoked pulley x 1 (SP1)



Large bracket x 3 (LB1)



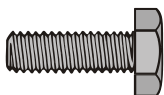
Thin bracket x 3 (SB1)



Thread x 1 (TH1)



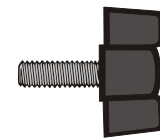
Wing nut x 8 (M6 - WN2)



Screw hex x 7 (SS M6 20 mm)



Thumbscrew x 3 (TS1 M4 x 15 mm)



Wing bolt x 2 (M6 - WN1)

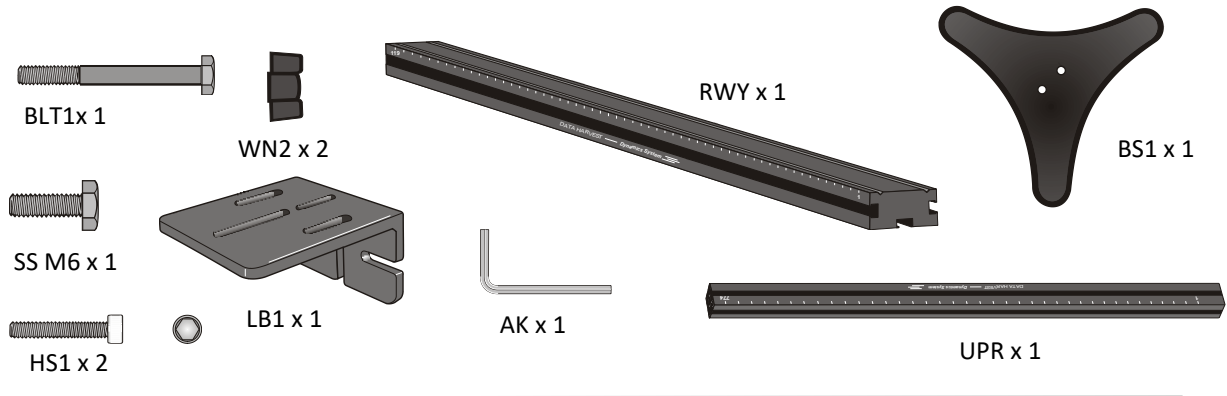


Bolt x 1 (Hex M6 x 65 mm x 1 - BLT1)

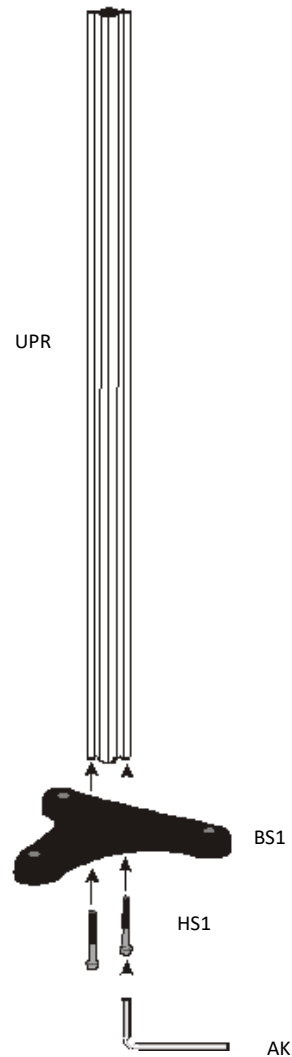


Socket head screw x 2 (HS1)

## Assembling the pillar and track

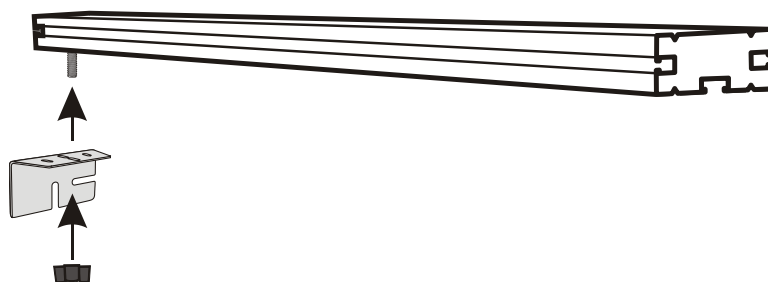
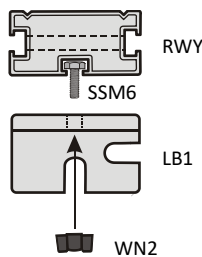


**Connect the pillar to the base:** Identify the threaded holes in the pillar (at 0 cm end) and screw the socket head screw (HS1) through the base into one of the threaded holes. Repeat for second screw. Use the Allen key supplied to tighten - DO NOT OVERTIGHTEN.



### Attach the large bracket to the end of the track:

- Align the short hex headed screw (SS M6) in the centre groove of the under surface of the track.
- Locate the screw to the centre slot in the larger surface of the bracket (LB1).
- Use a wing nut (WN2) to tighten the bracket to the track.



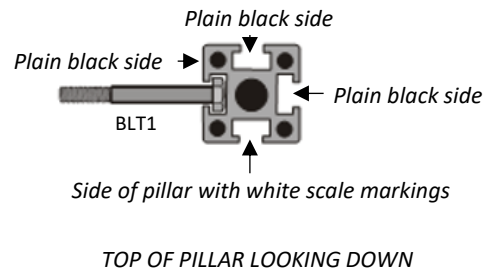




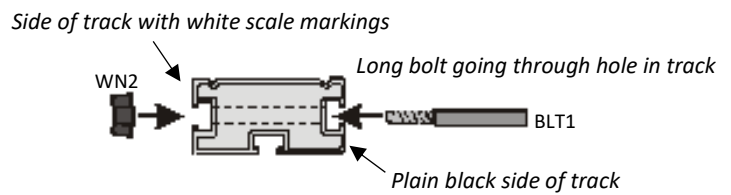
Setting up the pillar and track to avoid damage to the white scale markings

**Attach the track to the pillar:**

- a. Locate the head of the long bolt (BLT1) into the slot on the pillar and slide it down.



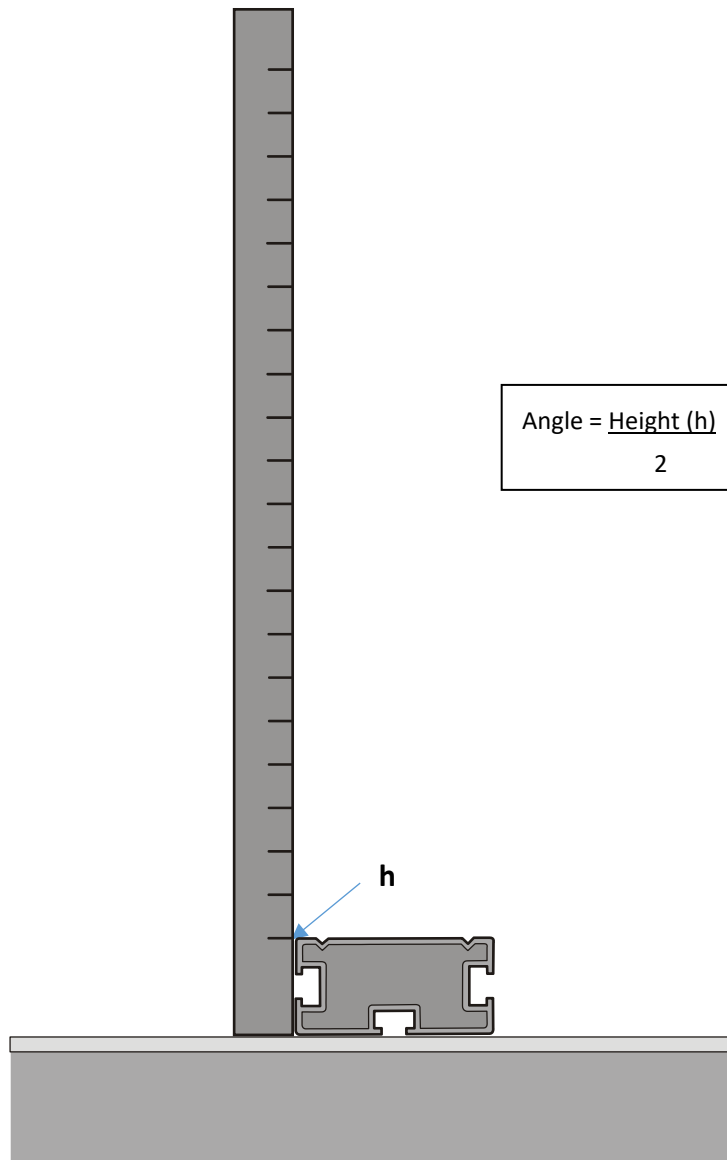
- b. Locate the hole in the track and fit over the bolt.



- c. Attach wing nut (WN2) to the bolt. Adjust track to the required height, secure in place by finger tightening the wing nut.

## Using the height scale to estimate the angle of the track

The height on the scale of the pillar divided by two equals the angle of the track, when the end of the track is supported by the large bracket

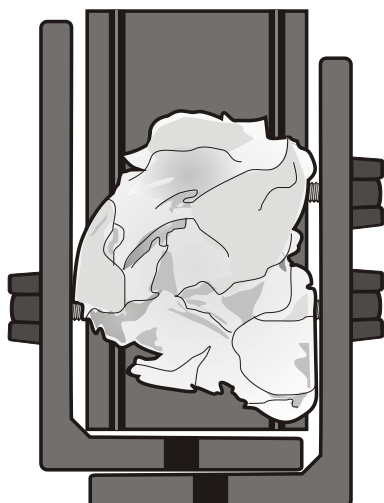
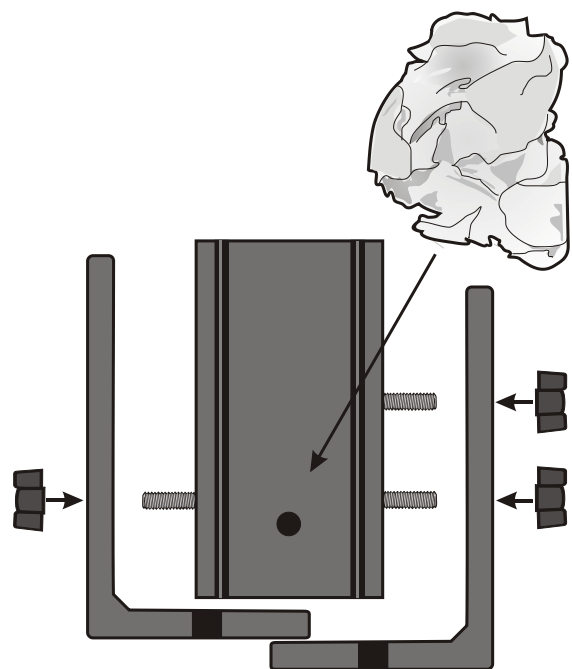
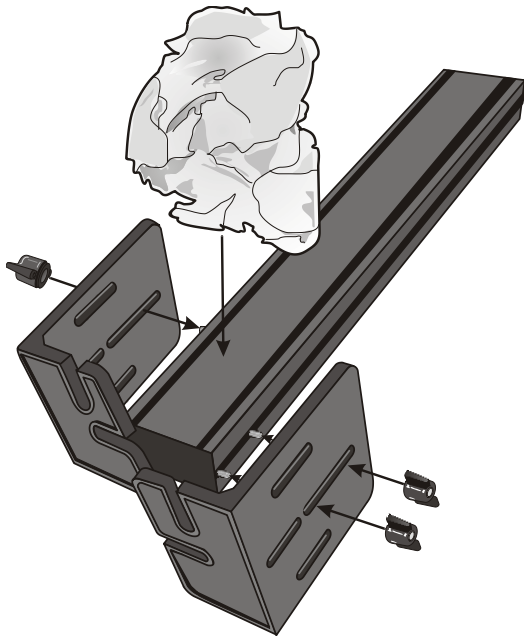
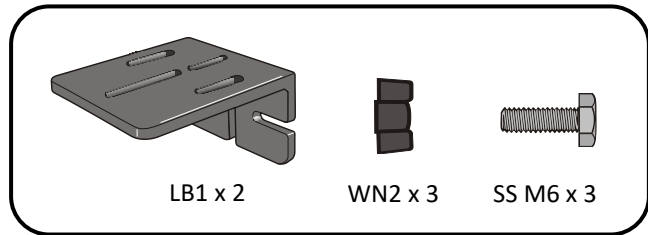


Height (h) cm	Angle (degrees)
0	0
10	5
20	10
30	15
40	20

## Crash box assembly

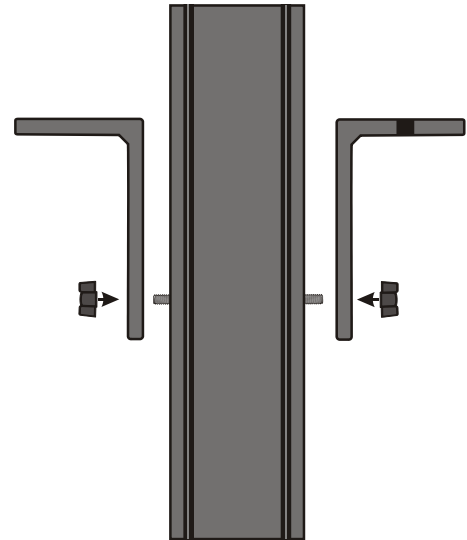
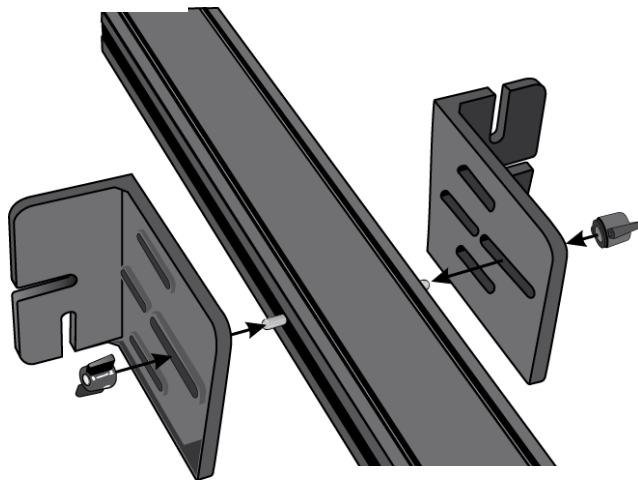
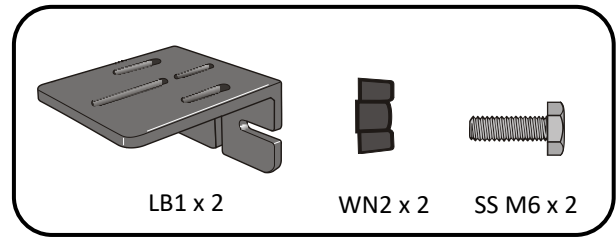
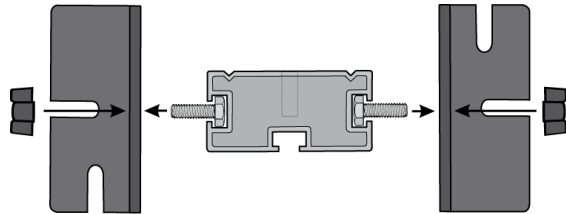
To stop a cart at the end of the track, when using high track angles or carts traveling at high speed.

Use crumpled paper to absorb the forward motion of the cart.



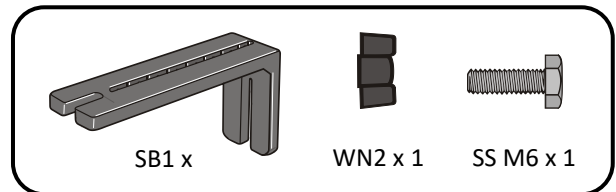
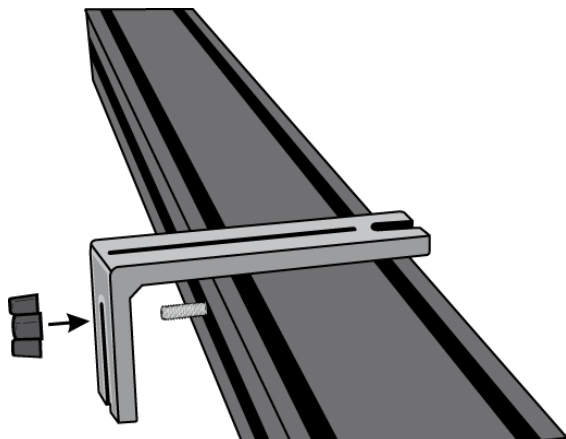
### Side barrier assembly

A side barrier can be positioned part way along on the track, to prevent a cart jumping tracks.

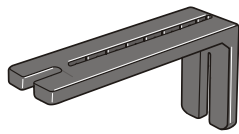


### Stop bar assembly

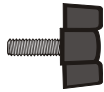
A thin bracket can be placed across the track to act as a stop bar.



## Attaching a Light gate to the track



SB1 x 1



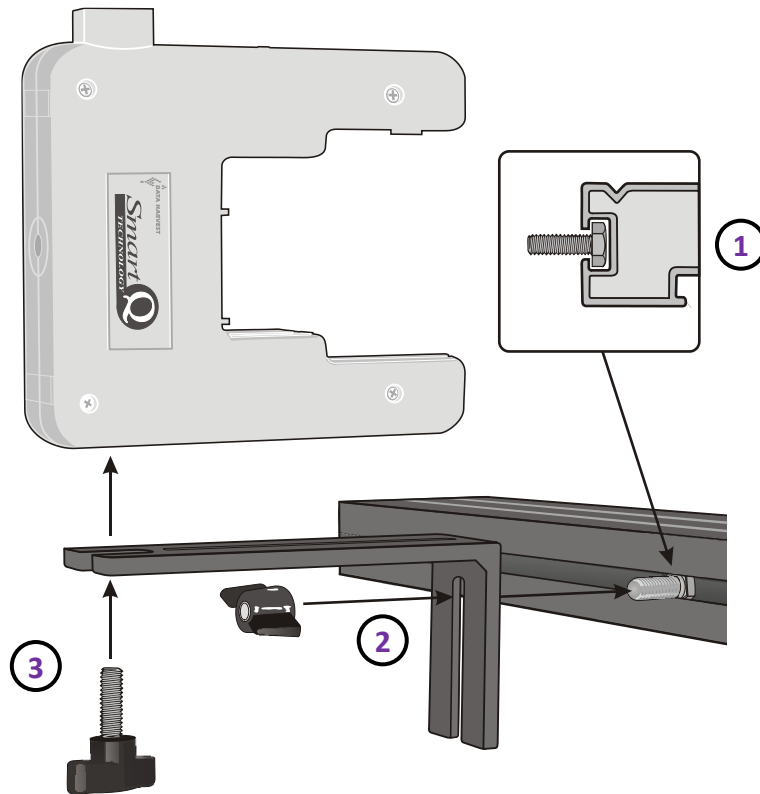
WN1 x 1



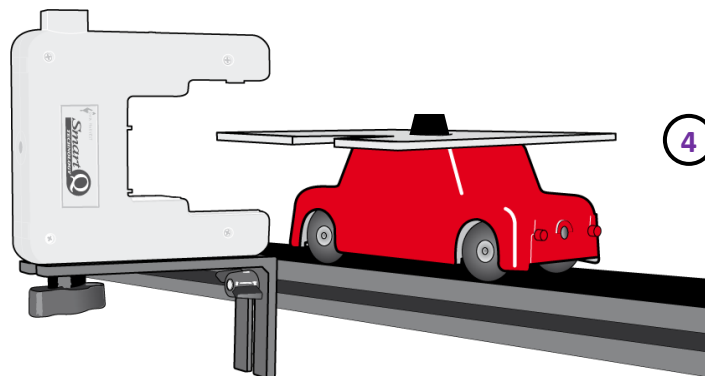
WN2 x 1



SS M6 x 1



1. Slide a short hex headed screw (SS M6) into the slot on the side of the track. Align the slot on the shorter end of the thin bracket over the screw thread.
2. Secure the bracket using a wing nut (WN2).
3. Attach the Light gate using wing bolt (WN1).



4. Attach an interrupt card to the cart (see page 13) and check the interrupt card passes through the Light gate.

## Attaching an interrupt card to the cart



MT1 x 1



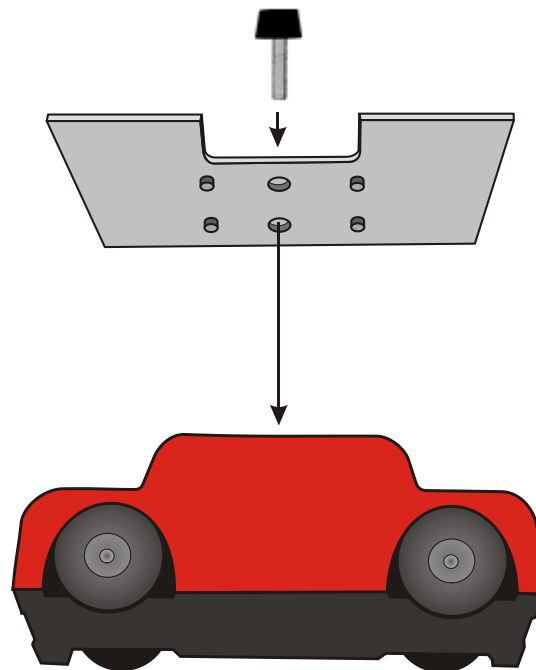
IC1 x 1



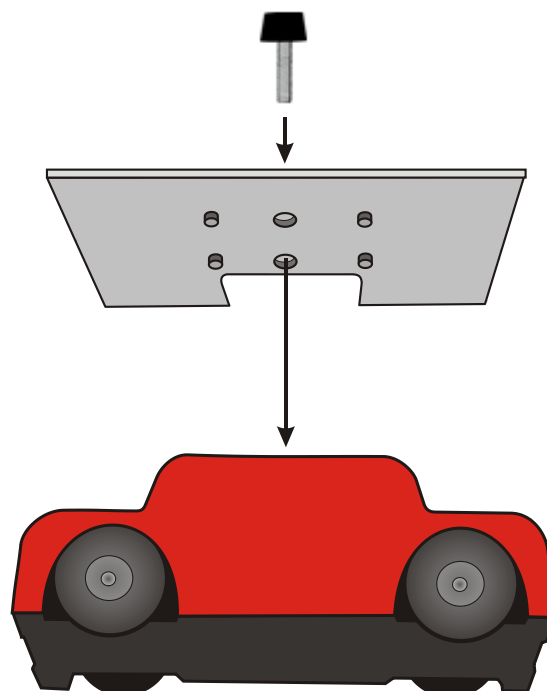
TS1 x 1

- Align the locating pegs on the card with the holes on the top of the cart.
- Locate the thumbscrew to the threaded hole in the top of the cart.
- Tighten the thumbscrew to secure the interrupt card to cart.

Attaching card for use as a **double** interrupt



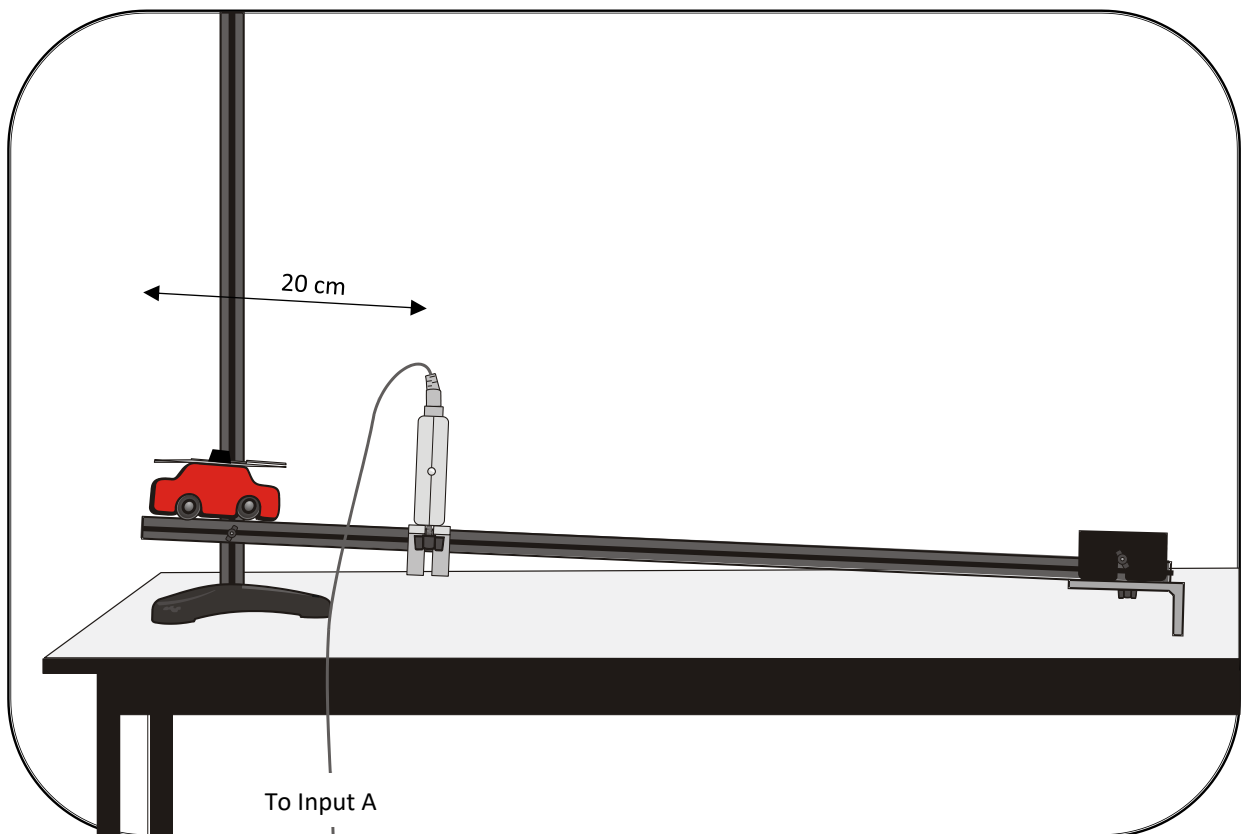
Attached card for use as a **single** interrupt



## Motion: Using Light gates on a slope to measure speed or acceleration

### Measuring speed with one Light gate

- Attach the track to the vertical pillar with the top edge of the track at the 5 cm mark (the vertical height on the support pillar divided by 2 gives the angle). Fit a crash box (page 10) at the bottom of the track.
- Position a Light gate approximately 20 cm from the top of the track and connect to input A on the EasySense data logger.
- Fit the interrupt card to the cart so the single interrupt edge will pass through the Light gate.
- Open the EasySense program and select **Timing**. Select to record **Speed at A** with a single interrupt card, and enter the length of the card as 120 mm.
- Select **Start** to begin. Position the cart in the start position at the top of the track and release the cart.
- Adjust the track to a new height / angle, and repeat using the same start position each time.

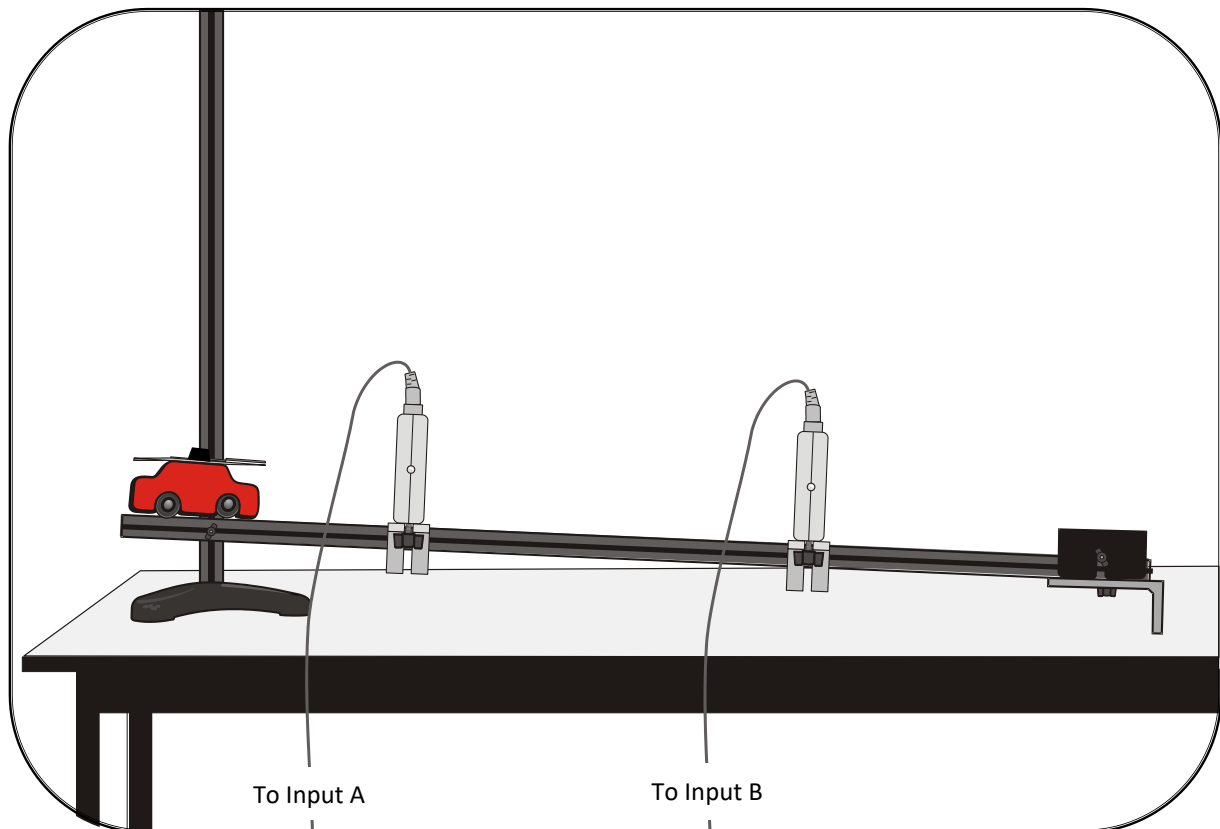


### Measuring acceleration with one Light gate

- Fit the interrupt card to the cart so the double interrupt edge will pass through the Light gate.
- Select to record **Acceleration at A** with a double interrupt card, and enter the length of the interrupt card segment as 40 mm.
- Proceed as before.

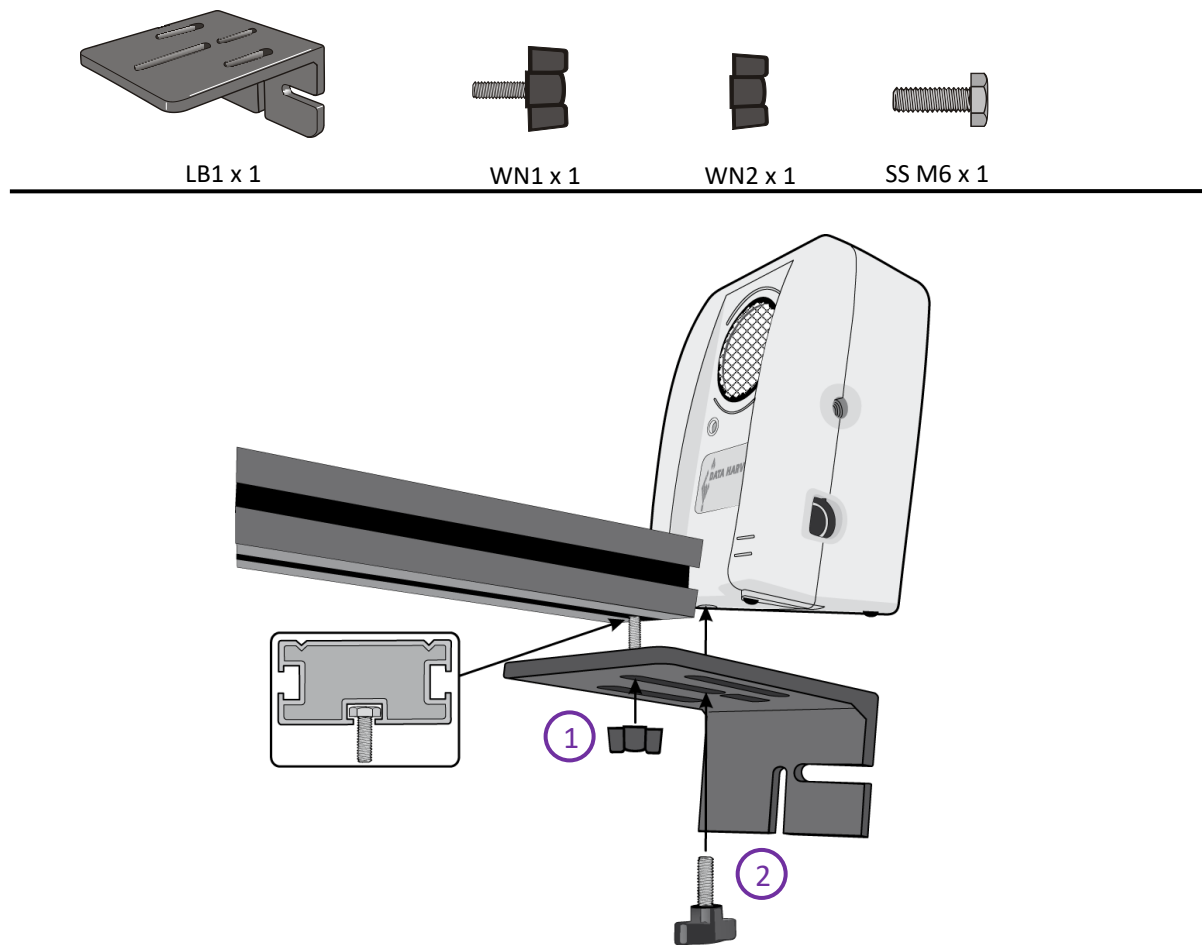
## Measuring speed with two Light gates

- Fit the interrupt card to the cart so the single interrupt edge will pass through the Light gates.
- Position a Light gate approximately 20 cm from the top of the track and connect to input A on the EasySense data logger. Position a second Light gate near the bottom of the track and connect to input B. Leave sufficient space for the cart to completely pass through the lower Light gate before either reaching the crash box, stop bar or the end of the track
- Select to record **Speed from A to B**, and enter the distance between the two Light gates.
- Proceed as before.

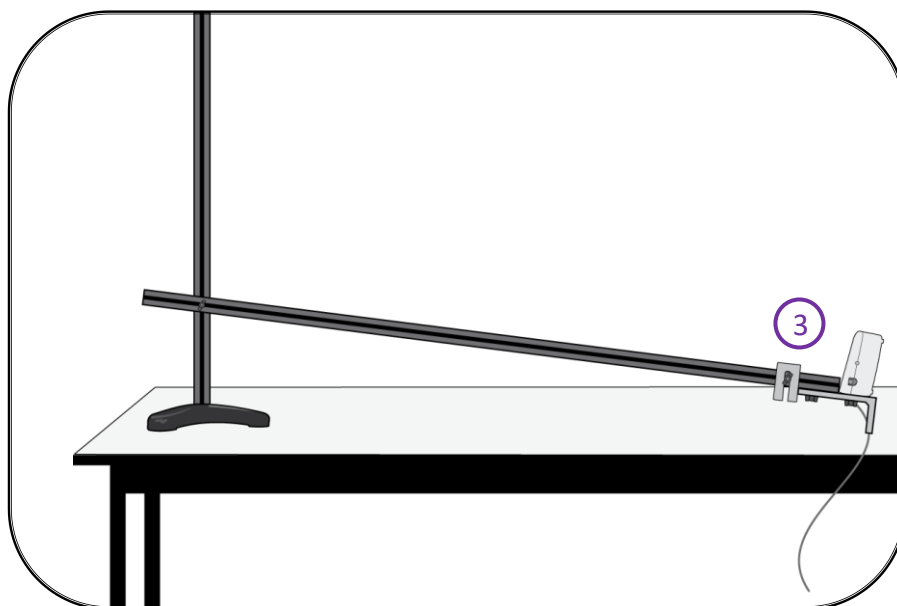




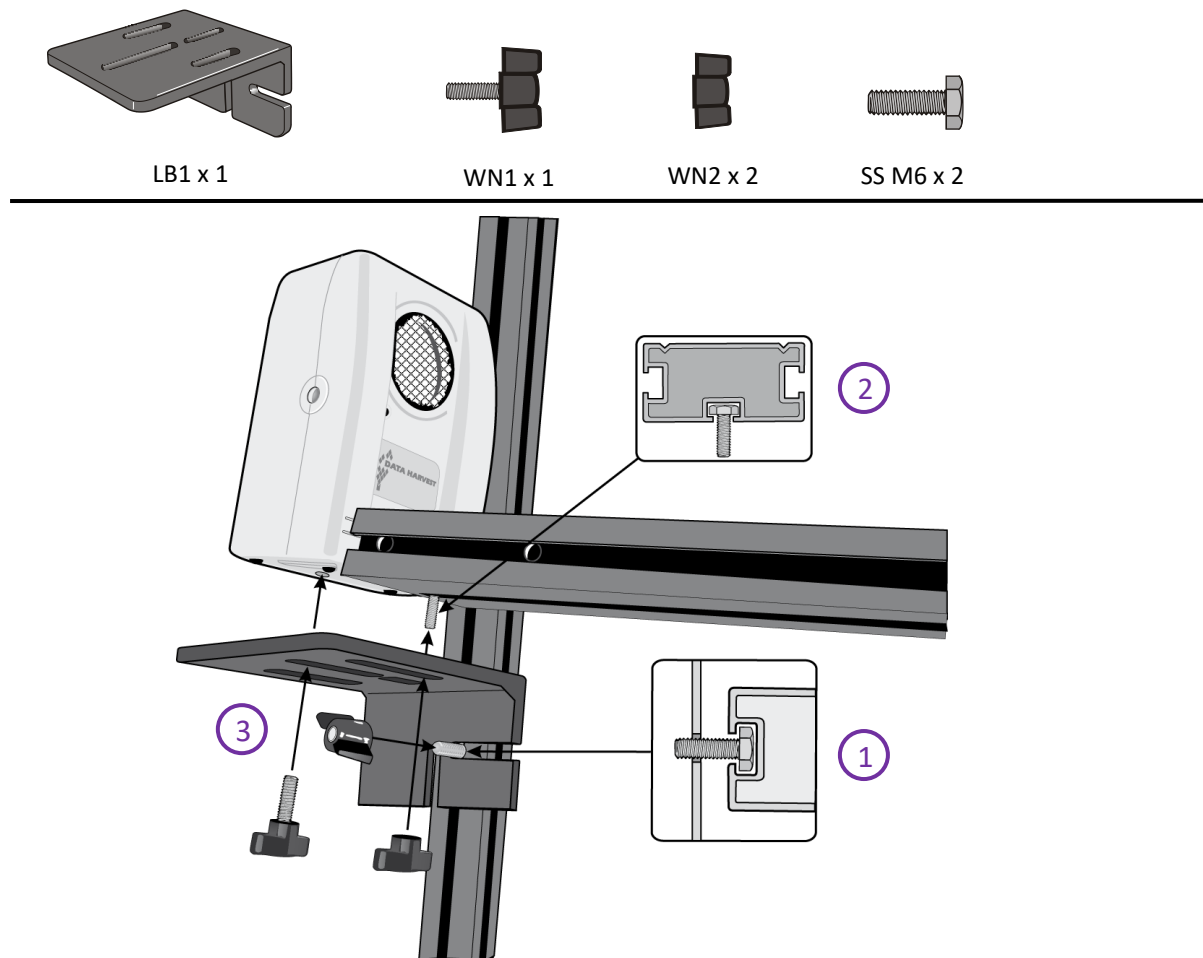
## Attaching a Motion sensor to the bottom of the track



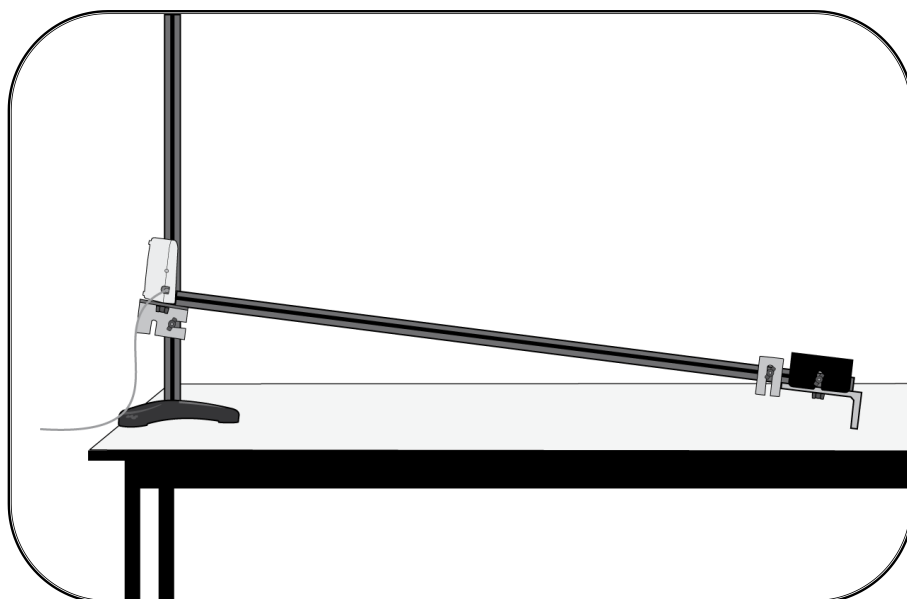
1. Use an SS M6 screw and WN2 wing to attach a large bracket to the end of the track to create a platform.
2. Position the Motion sensor on the platform. Insert a WN1 wing nut bolt through the long central slot in the bracket and screw into the threaded hole at the bottom of the Motion sensor.
3. Fix a small bracket across the end of the track to act as a stop for the cart (see page 11).



## Attaching a Motion sensor to the top of the track



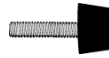
1. Use an SS M6 screw and WN2 wing nut to attach a large bracket to the pillar, the bracket will need to tilt to the angle of the track so do not over tighten.
2. Use an SS M6 screw and WN2 wing to attach the track to the bracket. Adjust the position to give enough space for the Motion sensor.
3. Insert a WN1 wing nut bolt through the long central slot in the bracket and screw into the threaded hole at the bottom of the Motion sensor.



## Attaching the end reflector to a cart for use with a Motion sensor



MT1 x 1

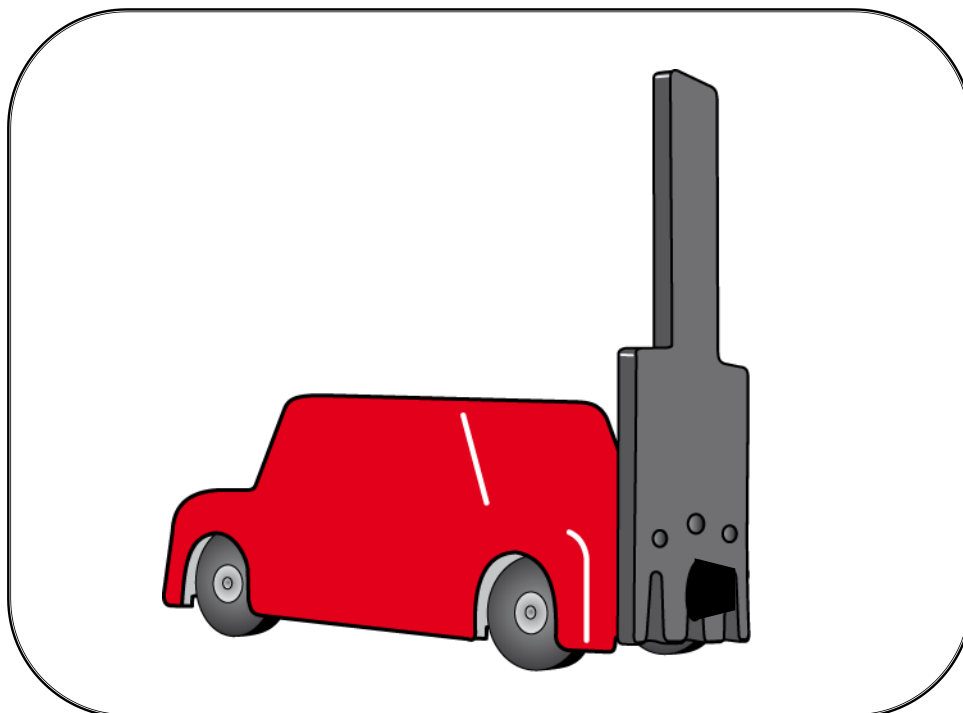
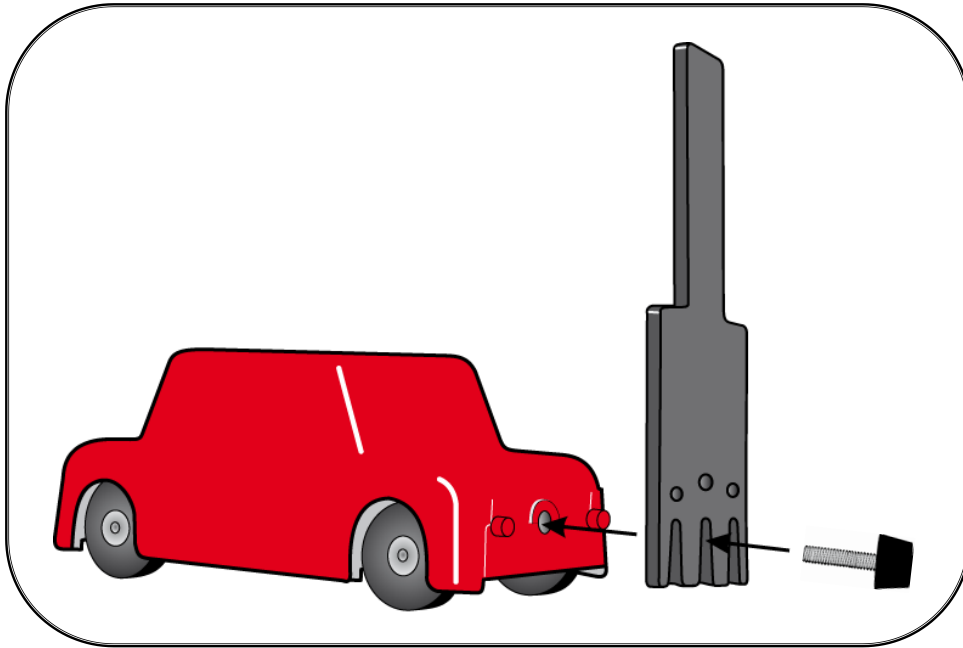


TS1 x 1

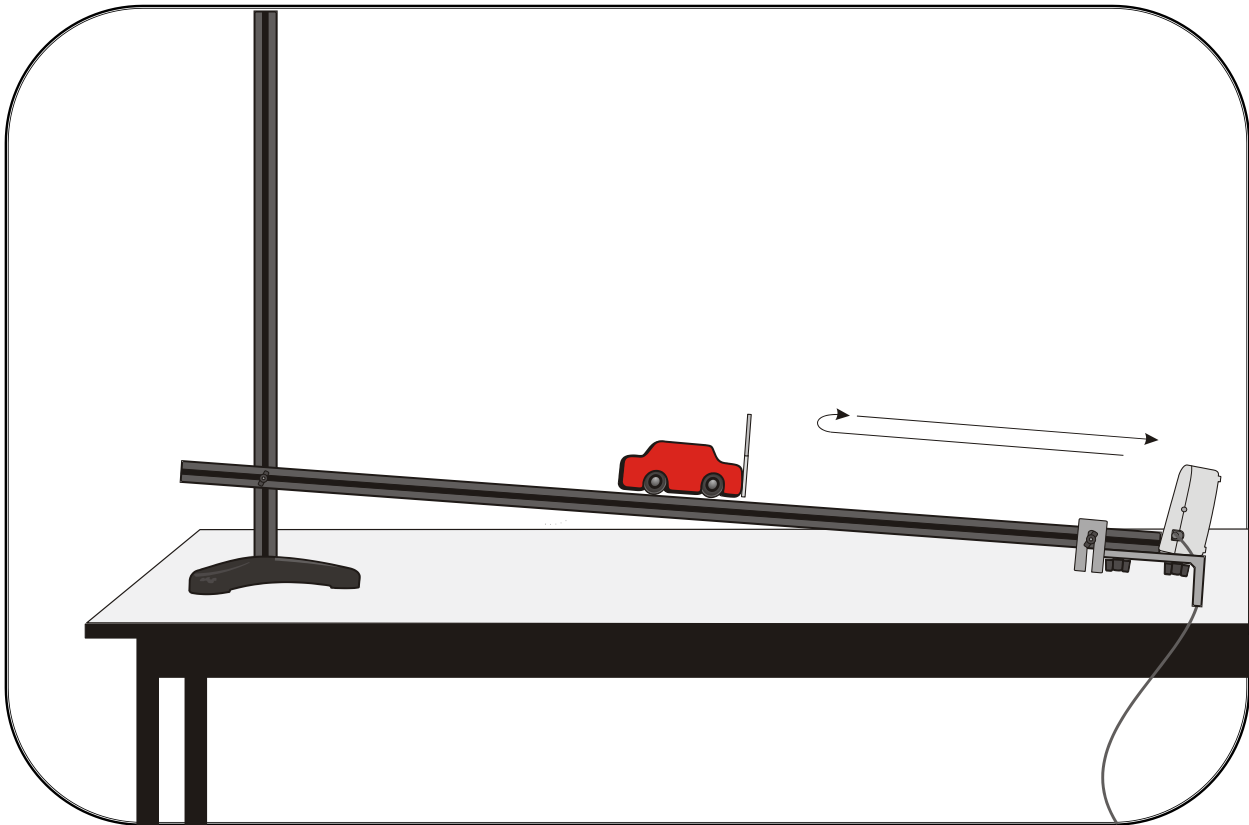


ER1 x 1

The reflector card should stick up into the ultrasound cone of the Motion sensor. Use the thumbscrew to attach the reflector card to the cart. The reflector card can be mounted at either end of the Cart; it should however be on the end that will face the Motion sensor.



## Motion: Measuring motion up and down a slope using a Motion sensor

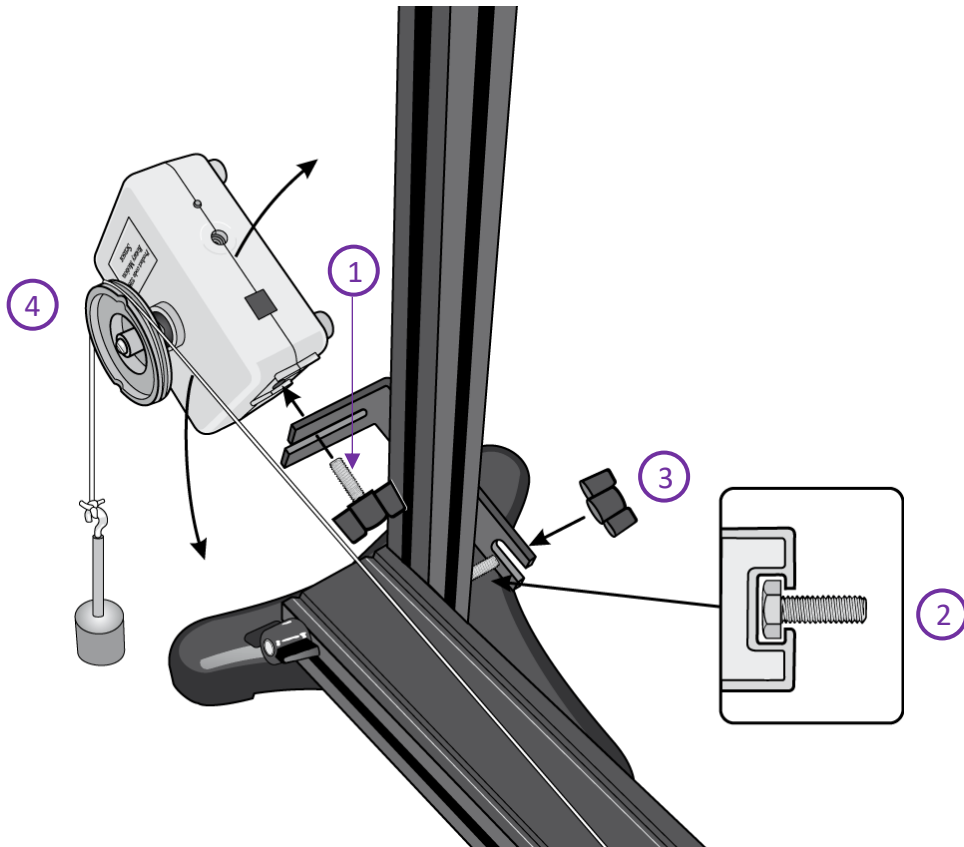
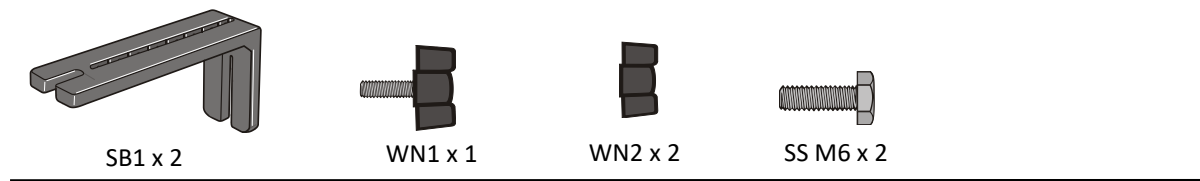


- Position a Motion sensor at the bottom of the track and connect to an EasySense data logger. The range of the Motion sensor should be set to Distance in metres.
- Position the top edge of the track at the 10 cm mark on the vertical pillar to give an angle of about  $5^\circ$ . A crash barrier is not suitable for this set up as it will interfere with the ultrasound pulses from the Motion sensor and create false distance readings. Place a thin bracket across the track in front of the Motion sensor and be prepared to catch the cart by hand when it reaches the end.
- Fit a reflector card to the end of the dynamics cart.
- Open the EasySense and select **Graph**. From the wizard select the following:

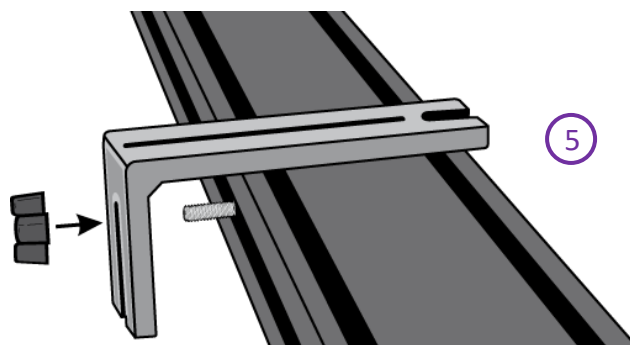
Time	Interval	Trigger
5 seconds	20 ms	When Distance is above 0.20 m

- Place the cart about 10 cm in front of the Motion sensor.
- Select **Start**.
- Give the cart a sharp, but gentle push up the track so it travels up about  $\frac{2}{3}$  rds of the way up. Let it run up the track and return – stop it just before it reaches the Motion sensor.
- Select **Overlay**. Adjust the track to a new height / angle, and repeat.

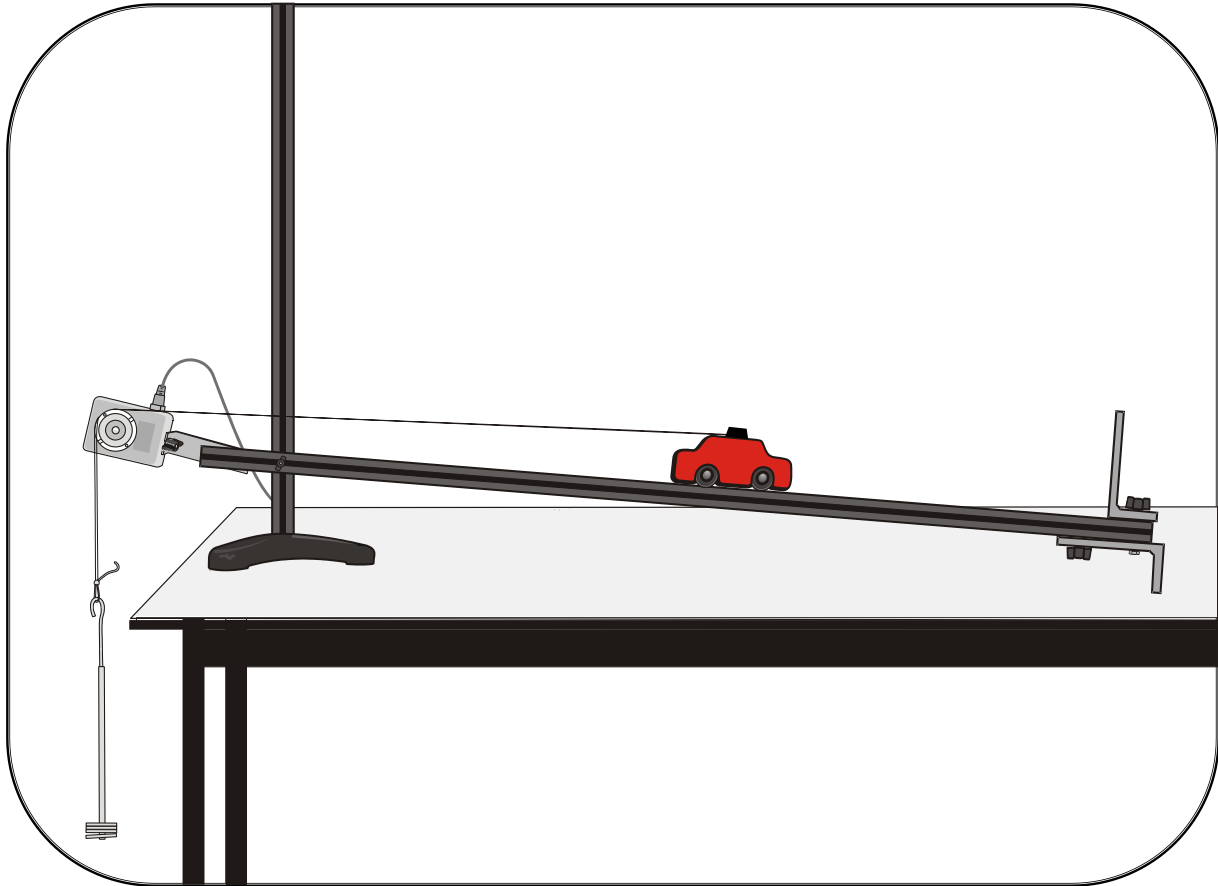
## Attaching a Rotary Motion sensor to the track



1. Attach a Rotary Motion sensor to the short arm of a thin bracket using a WN1 wing nut.
2. Slide a SS M6 hex screw into the slot in the pillar.
3. Attach the long arm of the thin bracket to the hex screw and secure with wing nut.
4. Run the string from the cart over the pulley wheel (loosen the WN1 wing nut and slide the Rotary Motion back and forward to line up the correct pulley). Tilt the sensor by loosening wing nut that secures the thin bracket to the pillar.
5. Attach a thin bracket as a stop



## Motion: Measuring motion up and down a slope using a Rotary Motion sensor

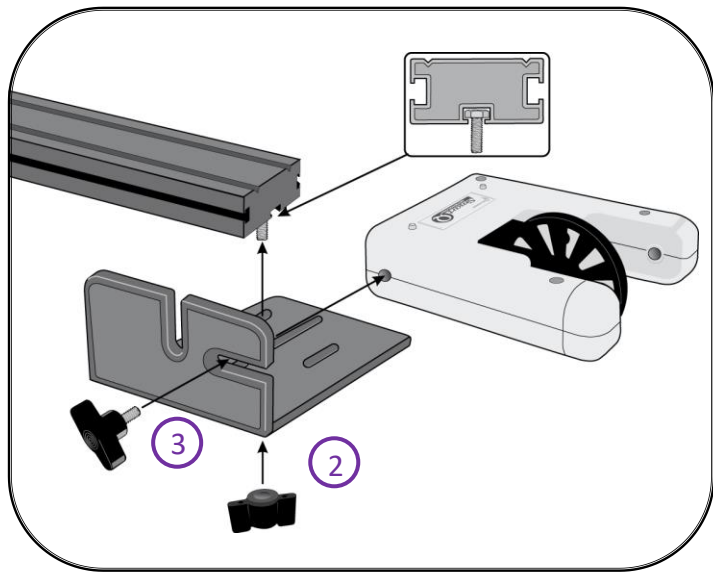
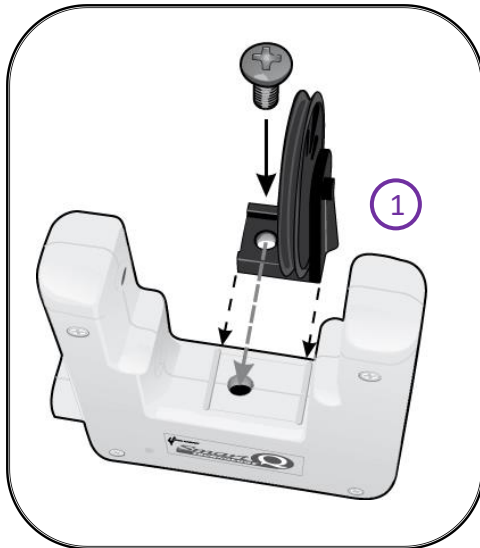
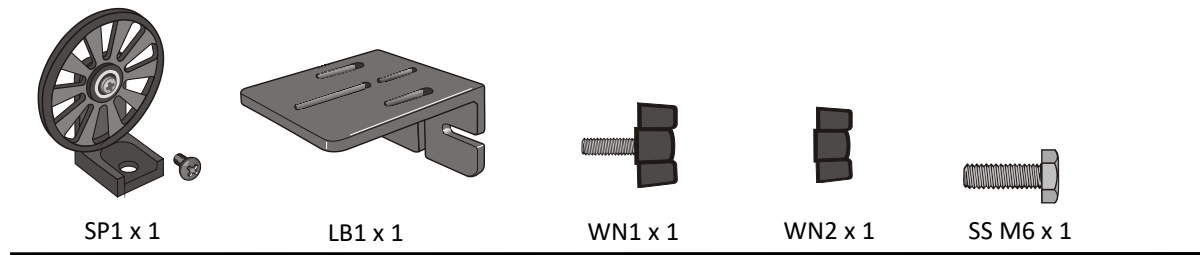


- Position a Rotary Motion sensor at the top of the track and connect to an input on an EasySense data logger. The range of the sensor should be set to Pulley 49 mm.
- Position the track at the 10 cm mark on the vertical pillar to give an angle of about  $5^\circ$ .
- Fix the TS1 thumbscrew to the top of the cart. Cut a piece of string slightly shorter than the length from the Rotary Motion sensor to the floor and attach to the thumbscrew. Attach a 20 g mass to the other end of the thread (the weight is to tension the thread, not pull the cart). Run the thread over the largest pulley. A thin bracket can be fitted to the track to mark the start position.
- Open the EasySense and select **Graph**. From the wizard select the following:

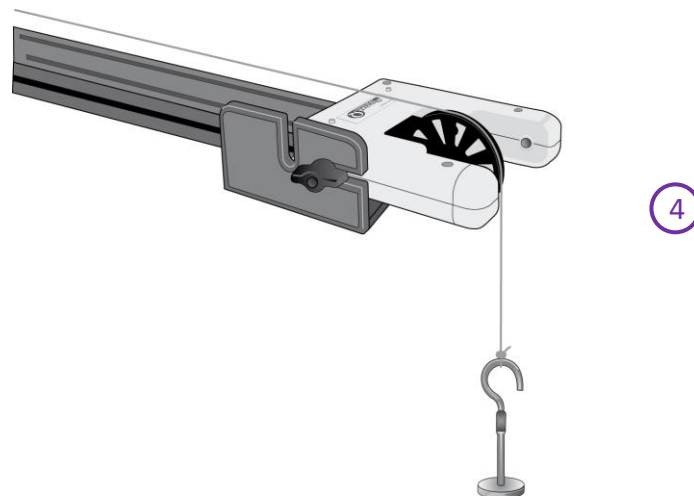
Time	Interval
10 seconds	20 ms

- Pull the cart back to its start position. Press the **zero** reset button on the Rotary Motion sensor. Select **Start** to begin logging.
- Give the cart a sharp, but gentle push up the track - let it run up the track and return.
- Select **Overlay**, adjust the track to a new height / angle, and repeat.

## Attaching a Light gate with Spoked Pulley to the track

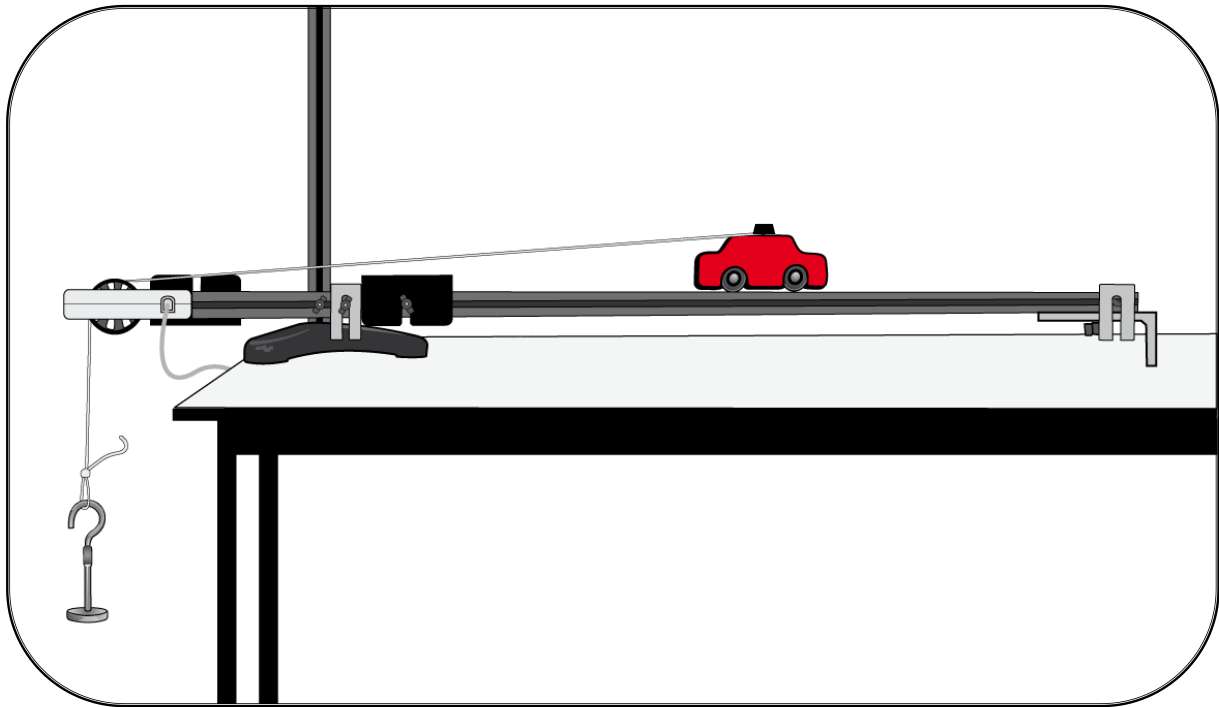


1. Connect a spoked Pulley to a Light gate.
2. Fix a large bracket to the underside of the track. I.e. Slide a hex screw (SS M6) into the slot in the underside of the track, attach the left slot of the longer arm of the large bracket to the hex screw and secure with a wing nut (WN2).
3. Attach a Light gate to the large bracket using a wing nut screw (WN1).



4. Adjust the Light gate and Pulley for clearance. Connect a length of thread (with a mass carrier attached) to the cart and run the thread over the top of the Pulley.

## Motion: Using a Light gate and Spoked Pulley



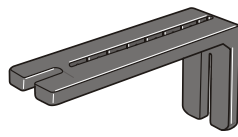
- Position a Light gate with a pulley (SP1) attached to the end of the track and connect to input A on the EasySense data logger.
- Set up the apparatus as shown. The mass is used to tension the thread (not to pull the cart along or make the cart increase in speed). Run the thread over the pulley.
- Open the EasySense program and select **Timing**. From the wizard select what you want to measure and the necessary parameters.
- Select **Start** to begin logging.
- When the data collection is complete Show Data As (from the Settings menu) can be used to recalculate the data in another form.

Use this set up to study:

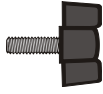
- Effect of mass on motion: alter the mass on the hanger, as the mass falls it will pull the cart along the track.
- Effect of slope on motion: alter the angle of the track and either use mass to pull the cart up the track or keep the tensioning mass constant and study the effect of increasing the angle on the motion of the cart down the track.
- Change in velocity and acceleration: use the software to show the collected data in different forms and study changes as the cart moves along the track.



## Attaching a Light gate to the support pillar



SB1 x 1



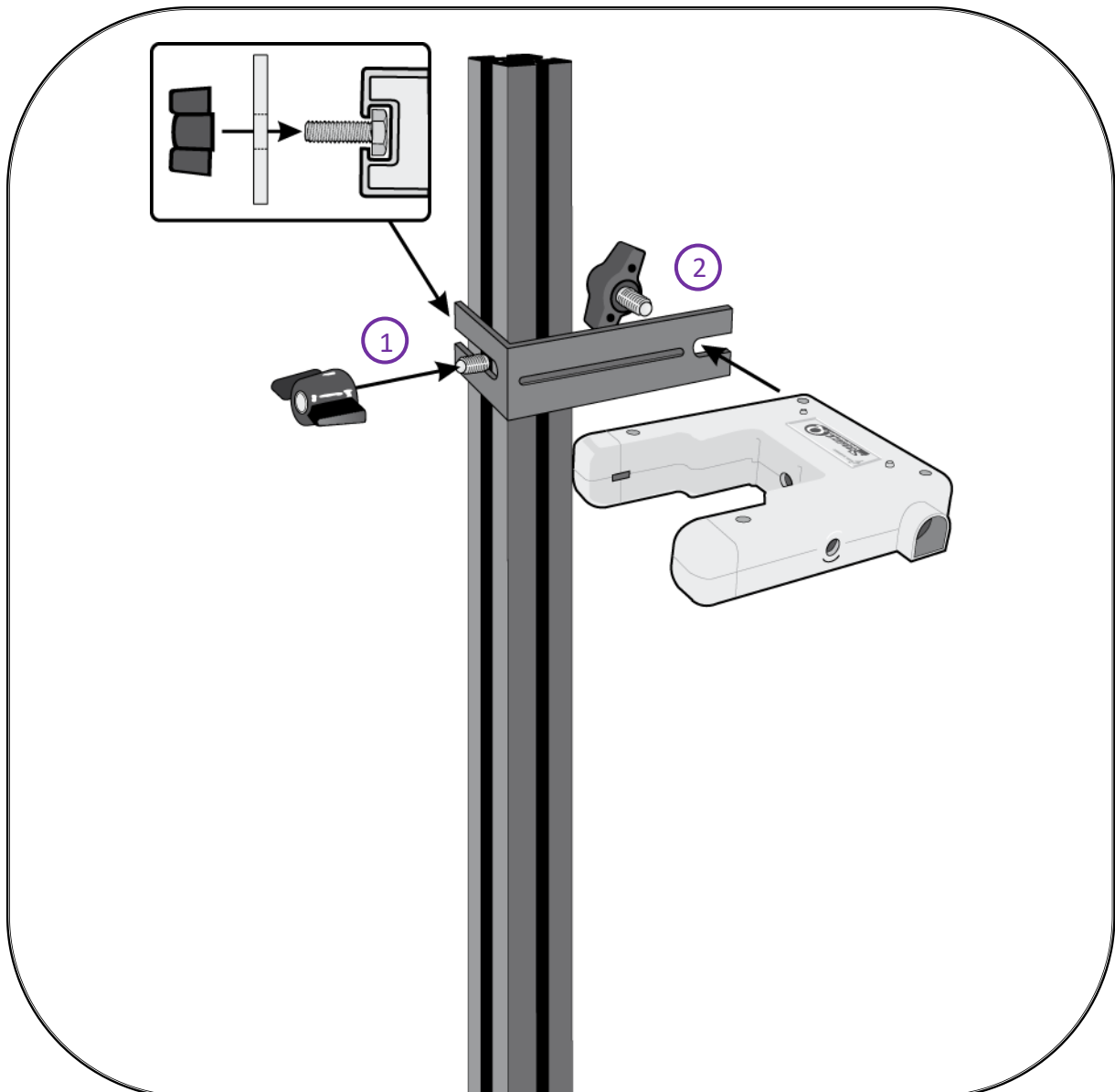
WN1 x 1



WN2 x 1

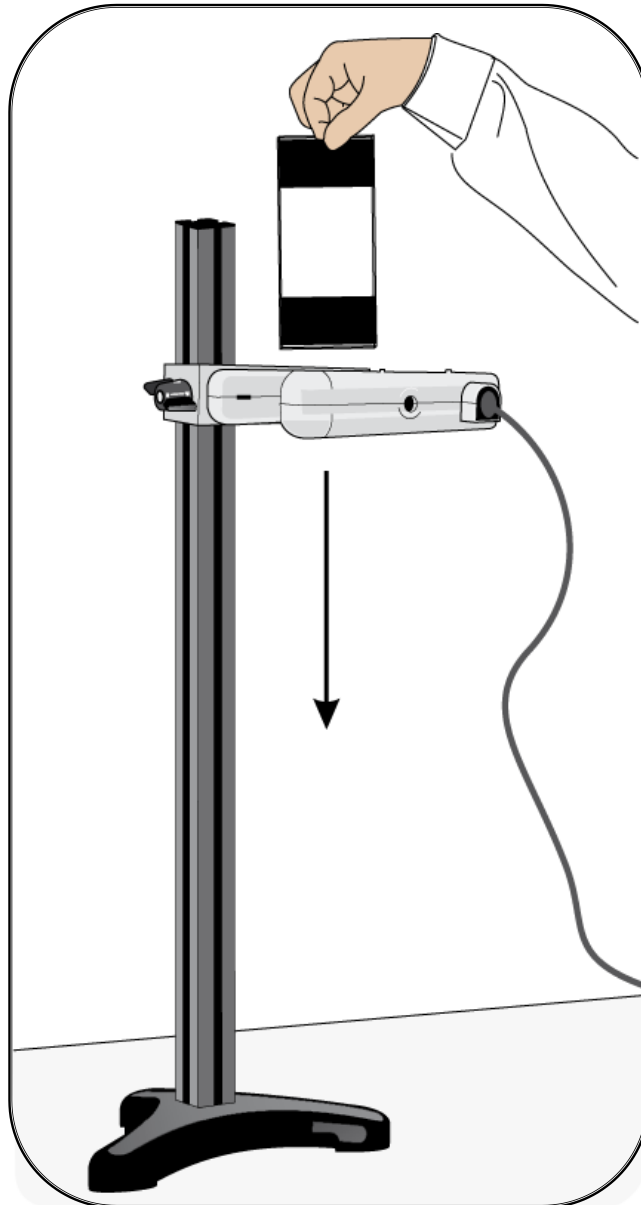


SS M6 x 1



1. Use an SS M6 hex headed screw and wing nut to secure a thin bracket to the pillar.
2. Attach the Light gate to the bracket with a wing bolt (WN1). Tighten the wing nut to secure in position.

## Gravity: Using a single Light gate to measure g

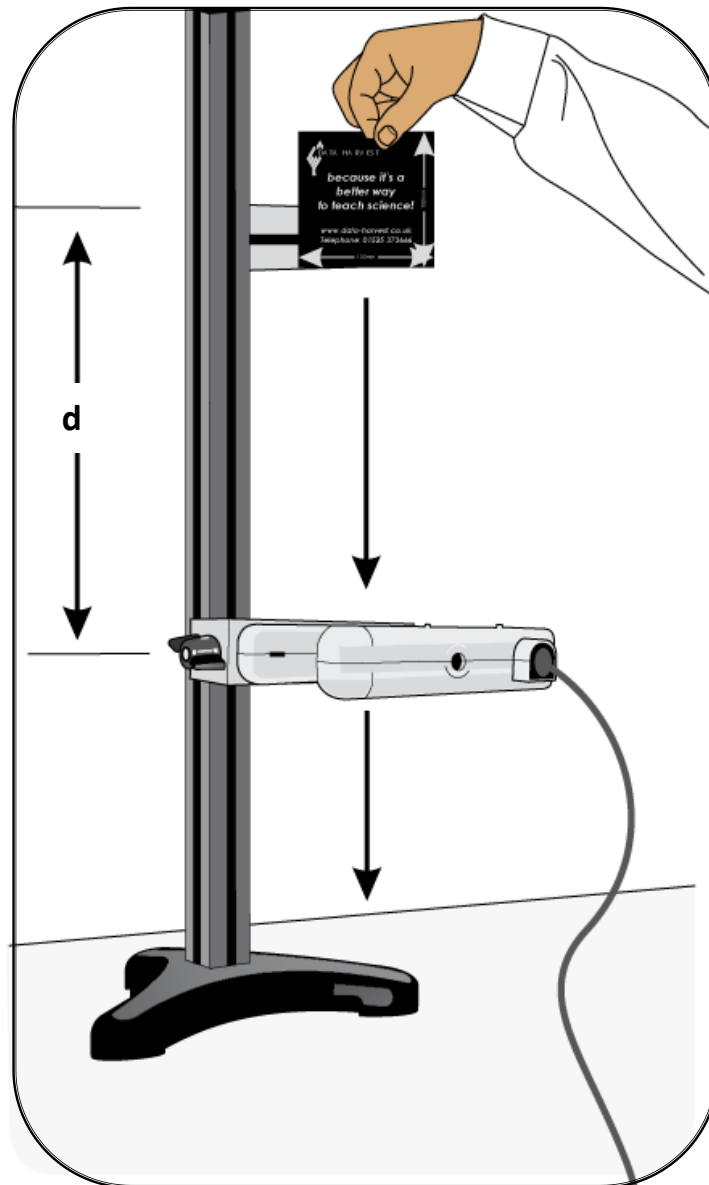


Acceleration can be measured with a single Light gate and a double interrupt card. The two segments of the double interrupt card must be equal in width.

*Note: A suitable double interrupt card is available as part of the Dynamics Extension Kit 1 (Product No 3801) or the Interrupt card set (Product No. 3803)*

- Position a Light gate near the top of the vertical pillar and connect to input A on the EasySense data logger.
- Open the EasySense program and select **Timing**. Select to record **Acceleration at A** with a double interrupt card, and enter the length of the interrupts (mm).
- Select **Start** and drop the interrupt card through the Light gate. Ensure the card drops vertically, if not select the measurement and Delete.

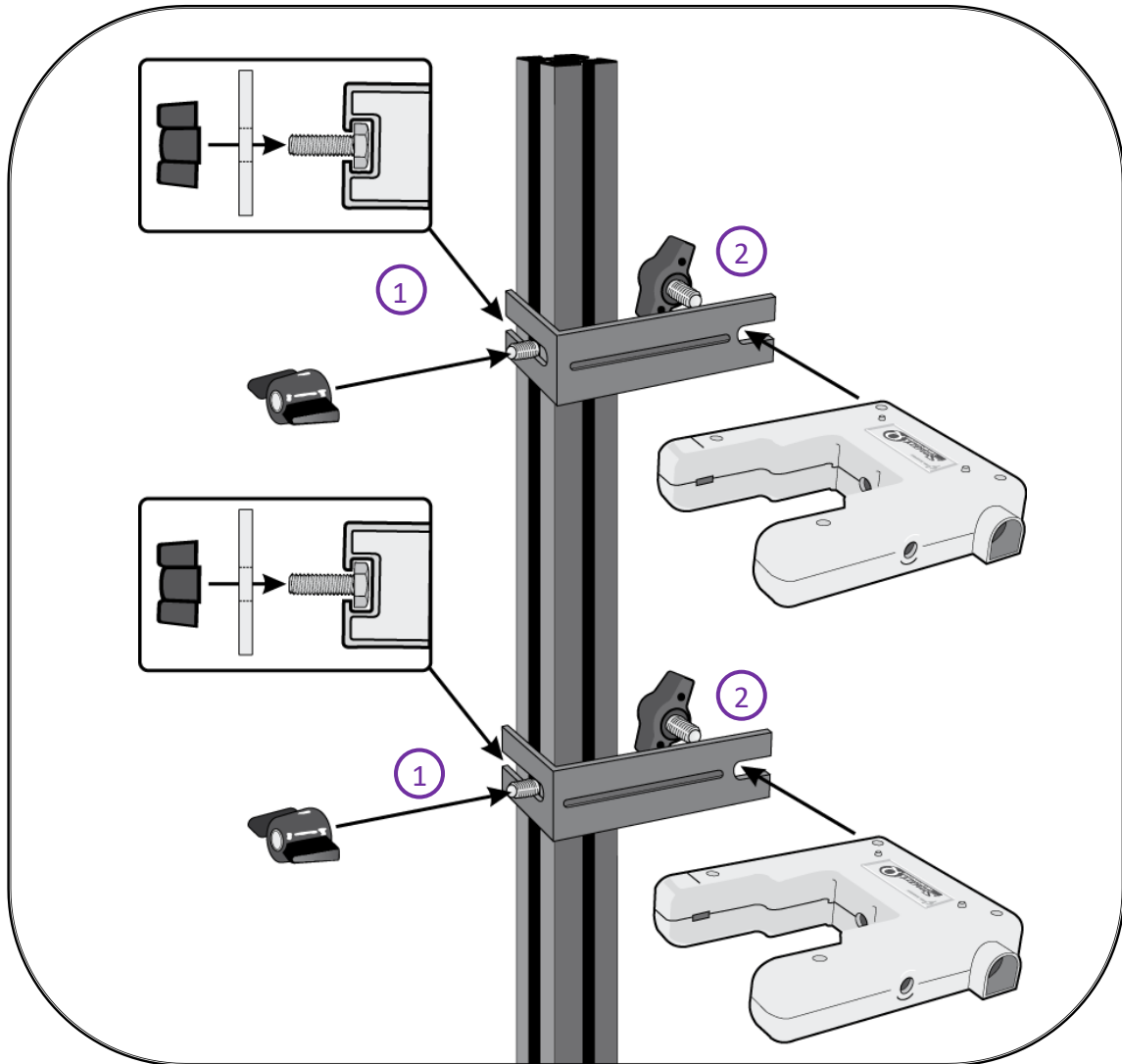
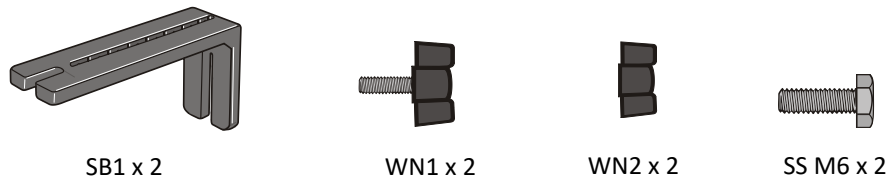
## Gravity: Using a single Light gate to measure $g$ , by logging the velocity after falling a known distance ( $d$ )



*Note: A suitable single interrupt card is available as part of the Dynamics Extension Kit 1 (Product No 3801) or the Interrupt card set (Product No. 3803)*

- Use a single interrupt card. The position marks specified are for use with a card 100 mm in length.
- Position a Light gate at the 20 cm mark on the vertical pillar and connect to input A on the EasySense data logger.
- Use a thin small bracket to indicate the drop point. Measure the distance from centre of interrupt card to the centre line on the Light gate ( $d$ ).
- Open the EasySense program and select **Timing**. Select to record **Velocity at A** with a single interrupt card, and enter the length of the interrupt card e.g. 100 mm.
- Select **Start** and drop the interrupt card through the Light gate. Ensure the card drops vertically, if not select the measurement and Delete.

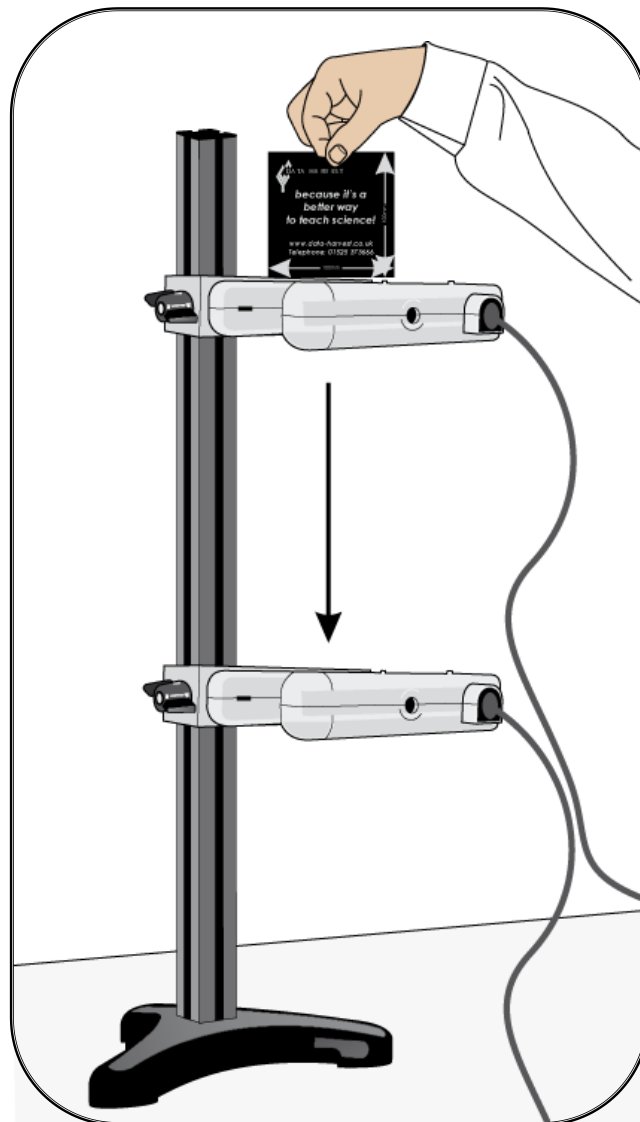
## Attaching 2 Light gates to the support pillar



*(Note how the brackets keep the Light gates correctly aligned)*

1. Slide two hex headed screws (SS M6) into the slot of the pillar. Use the wing nuts (WN2) to secure the two thin brackets to the pillar.
2. Attach a Light gate to each bracket using a wing nut screw (WN1).
3. Move the Light gates to their correct position and secure.
4. Test the interrupt card will pass through both Light gates.

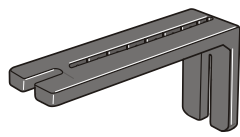
## Gravity: Using two Light gates to measure g



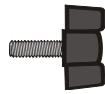
*Note: A suitable single interrupt card is available as part of the Dynamics Extension Kit 1 (Product No 3801) or the Interrupt card set (Product No. 3803)*

- Position a Light gate near the top of the vertical pillar and connect to input A on the EasySense data logger. Position a second Light gate lower down the pillar and connect to input B.
- Open the EasySense program and select **Timing**. Select to record **Acceleration from A to B** with a single interrupt card, and enter the length of the interrupt card (e.g. 100 mm).
- Select **Start** and drop the interrupt card through the Light gates. Ensure the card drops vertically through both gates, if not select the measurement and Delete.

## Attaching a Motion sensor to the support pillar



SB1 x 1



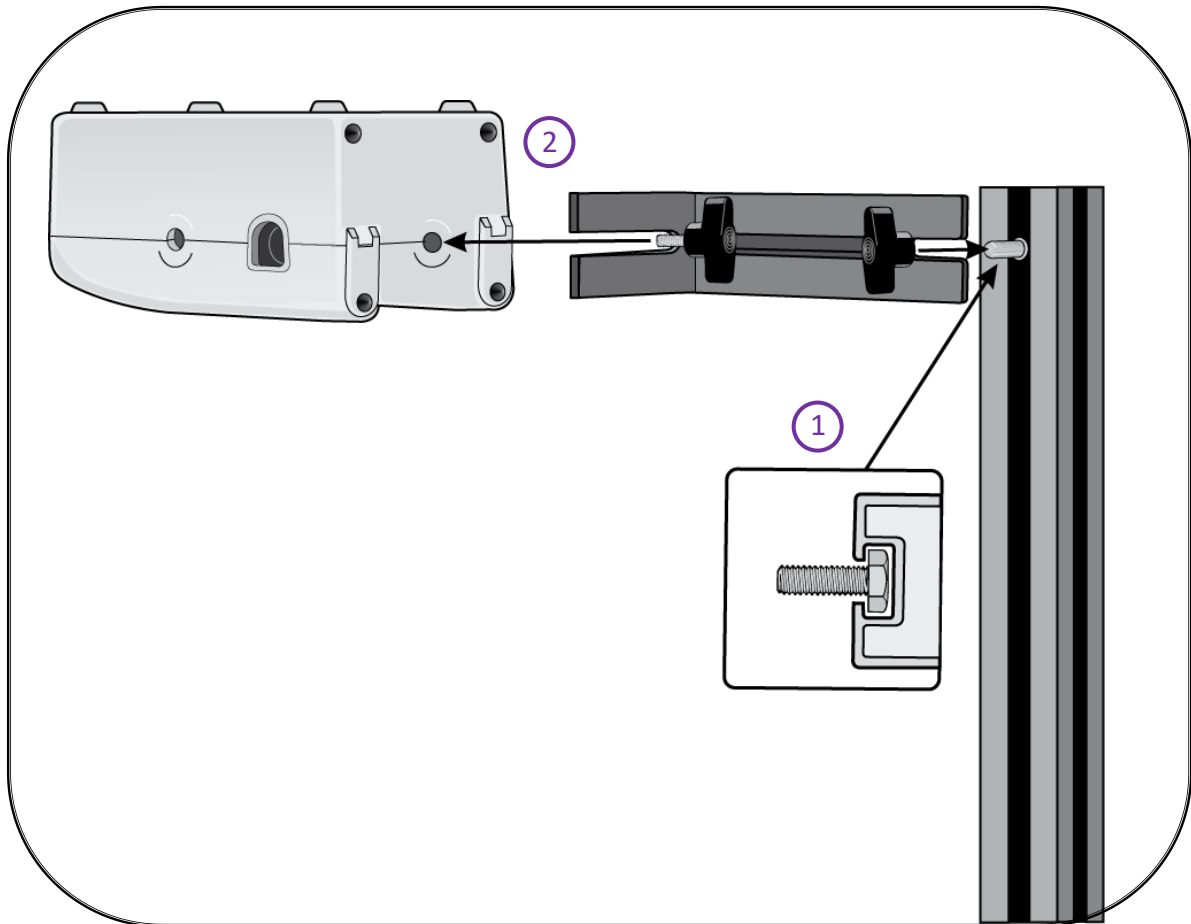
WN1 x 1



WN2 x 1

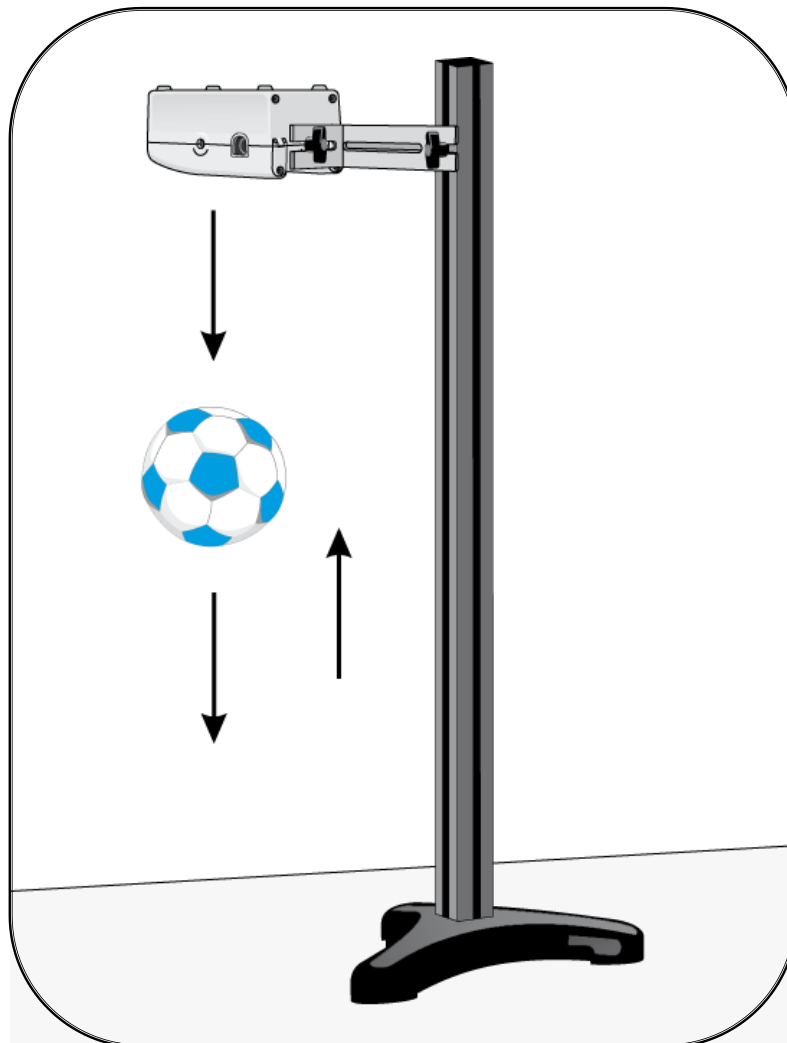


SS M6 x 1



1. Attach a thin bracket to the pillar with a SS M6 hex screw and wing nut.
2. Attach the Motion sensor to the thin bracket using a WN1 wing bolt.
3. Adjust as needed. Drop the object within the ultrasound cone of the Motion sensor

## Gravity: Using a Motion sensor to measure $g$ by free fall

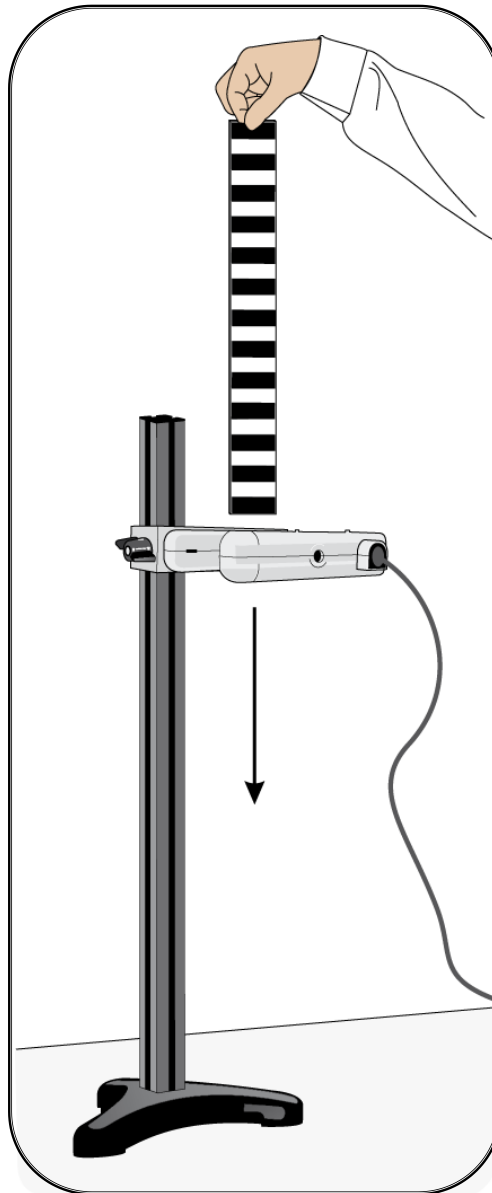


- Position the Motion sensor at the top of the vertical pillar and connect to an EasySense data logger. The range of the Motion sensor should be set to Distance. The ball needs to bounce onto a hard surface.
- Open the EasySense program and select **Graph**. From the wizard select the following:

Time	Interval	Trigger
5 seconds	20 ms	Distance rises above 0.30 m

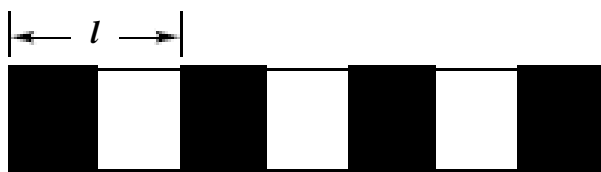
- Select **Start**. Hold the ball about 10 cm below the Motion sensor. Release the ball (move the hands away quickly).

## Gravity: Using a Light gate and 'picket fence' to measure g



*Note: A suitable multi-segmented card (picket fence) is available as part of the Dynamics Extension Kit 1 (Product No 3801) or the Interrupt card set (Product No. 3803)*

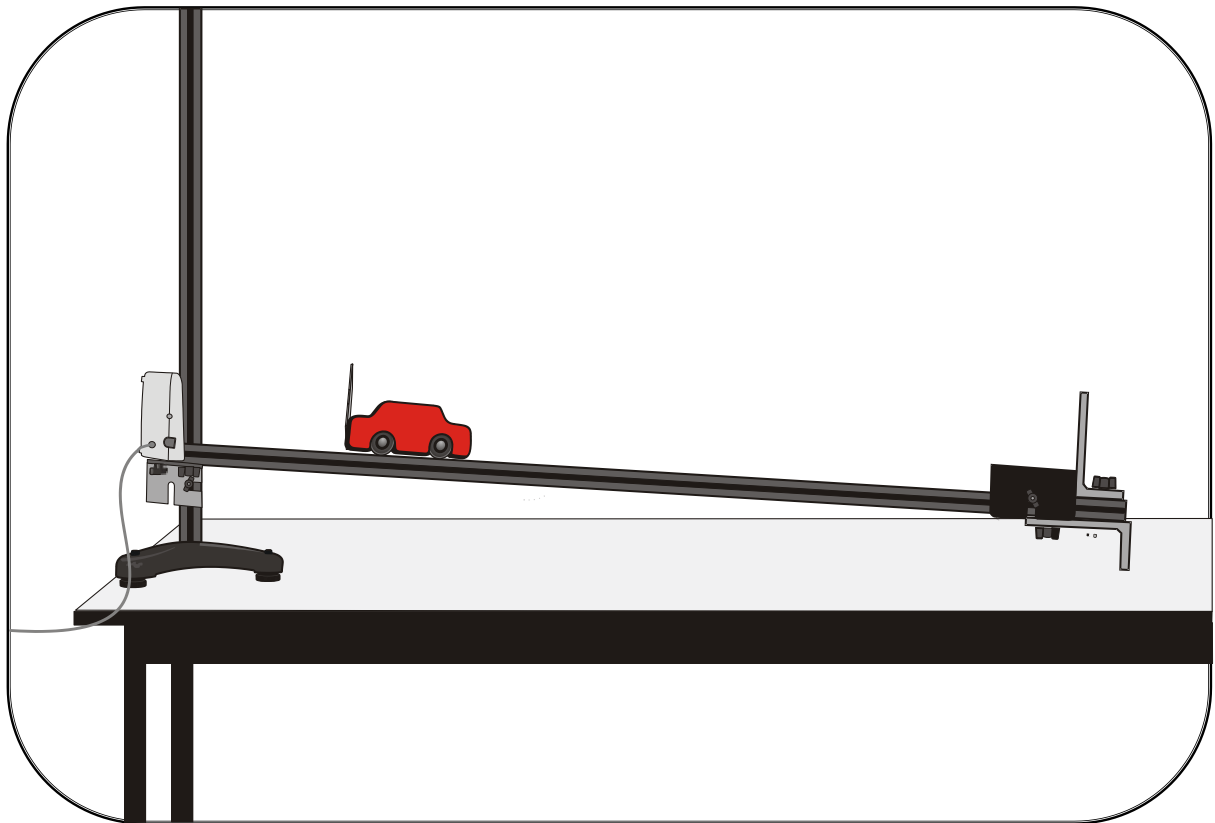
- Position a Light gate at the top of the vertical pillar and connect to input A on the EasySense logger.
- Open the EasySense program and select **Timing**. Select to record **Acceleration at A** with a picket fence. Enter the pitch length e.g. 40 mm and the calculation increment e.g. 2.



- Select **Start**. Hold the picket fence just above the Light gate and release.



## Gravity: Using a Motion sensor with a rolling cart to measure diluted gravity

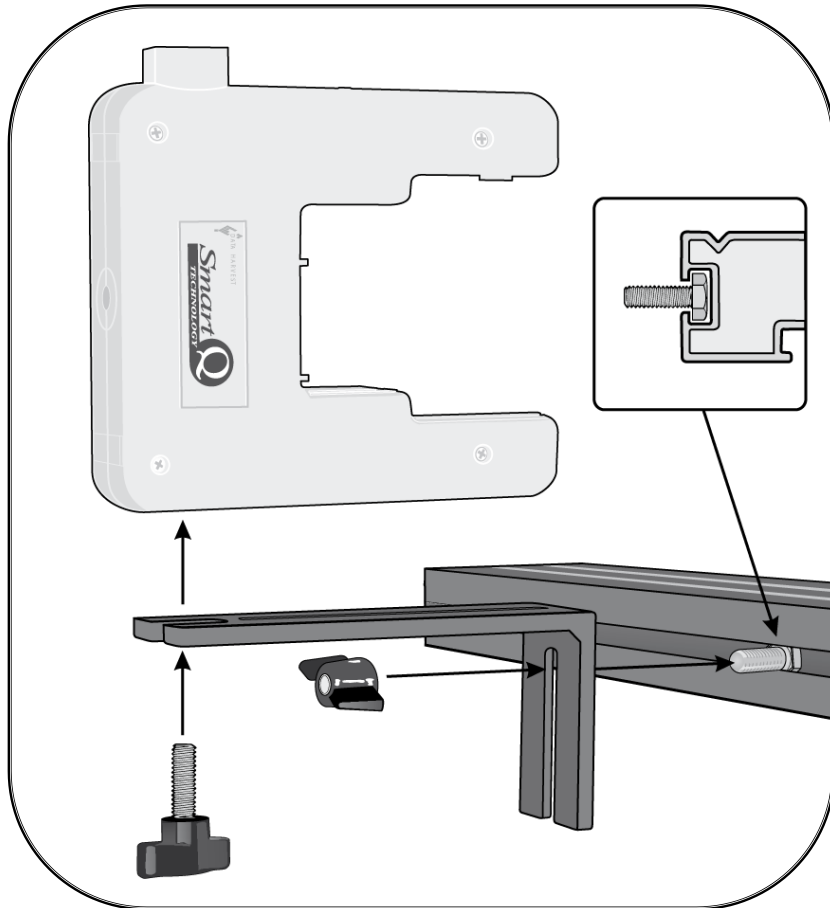
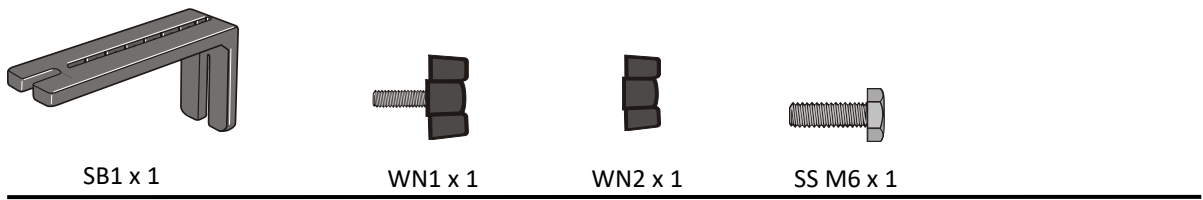


- Position a Motion sensor at the top of the track and connect to an EasySense data logger. The range of the Motion sensor should be set to Distance in metres.
- Position the track at the 10 cm mark on the vertical pillar to give an angle of about 5°.
- Fit a crash box to the end of the track (see page 10) with crumbled paper. Fit a reflector card to one end of the cart (see page 18).
- Open the EasySense program and select **Graph**. From the wizard select the following:

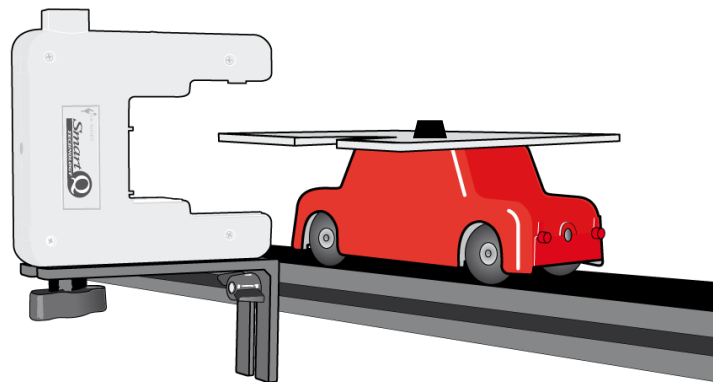
Time	Interval	Trigger
5 seconds	20 ms	When Distance is above 0.30 m

- Place the cart about 20 cm in front of the Motion sensor. Select **Start**.
- Let the cart roll down the track. The cart will squash the crumbled paper on impact so re-fluff the paper each time.
- Select **Overlay**. Adjust the track to a new height / angle, and repeat increasing the angle of the slope by 2 to 3 degrees each time.

## Attaching a Light gate to the track

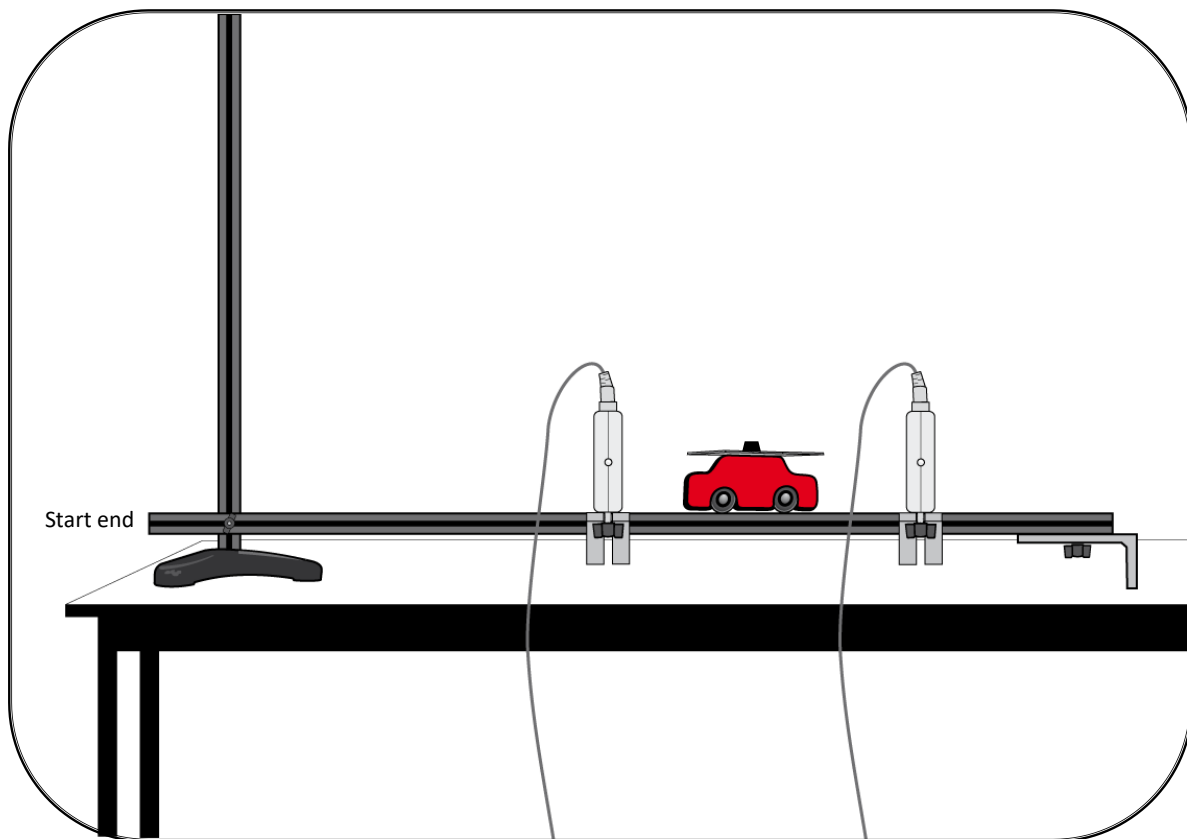


Attaching a Light gate to the track



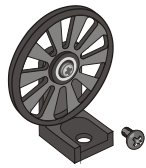
Check the interrupt card passes through the Light gate

## Forces: Motion with balanced forces

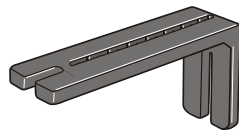


- Place the track in its lowest position, supported at the end by a large bracket. Adjust the track to be horizontal.
- Fit the interrupt card to the cart so the single interrupt edge will pass through the Light gates.
- Position a Light gate near mid-way along the track and connect to input A on the EasySense data logger. Position a second Light gate nearer the end of the track and connect to input B.
- Open the EasySense program and select **Timing**. Select to record **Speed at A or B**, and enter the length of the card as 120 mm.
- Select the **Start** icon. Push the cart gently from the start end to run freely along the track through the two Light gates. When the values for speed are the same at both A and B, the forces acting on the cart will be balanced. Make sight adjustments to the height of the track until both values are the same (if the value for B is larger than A lower the track, if A is larger than B raise the track).

## Attaching a Spoked Pulley to the track



SP1 x 1



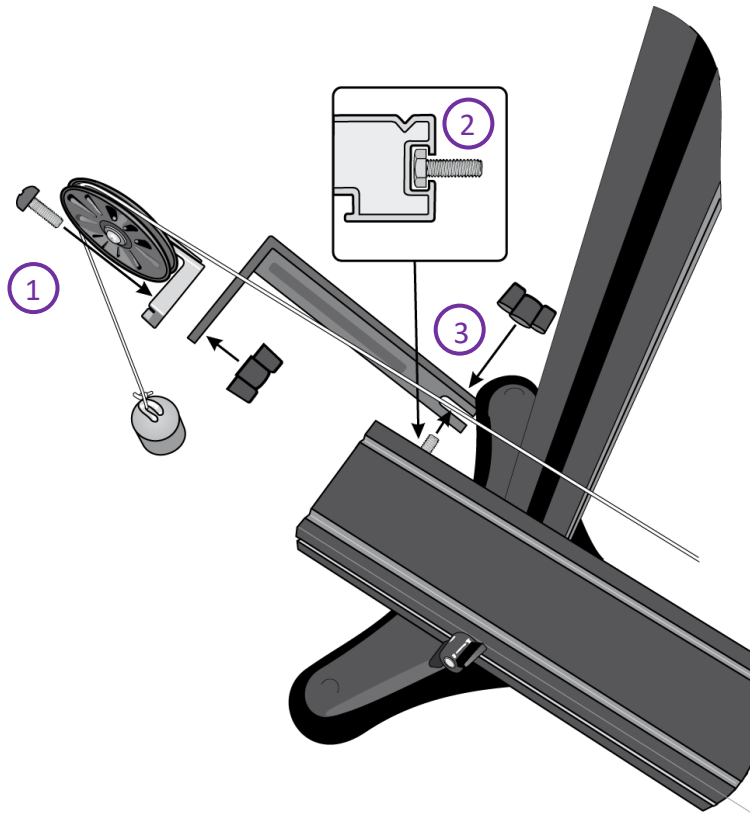
SB1 x 1



WN2 x 3



SS M6 x 3

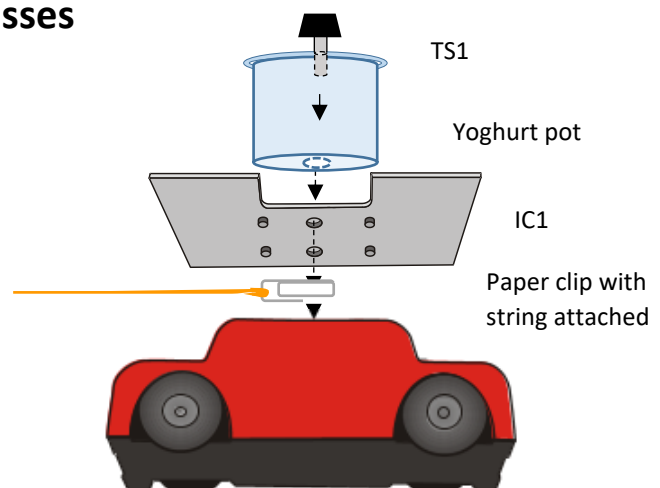


1. Attach the Spoked Pulley to the short arm of a thin bracket using the screw supplied with the pulley and a wing nut.
2. Slide an SS M6 hex screw into the slot on the track.
3. Attach the long arm of a thin bracket to the screw and secure with a wing nut.
4. Connect a length of thread (with a mass carrier attached) to the Cart. Run the thread over the top of the pulley.

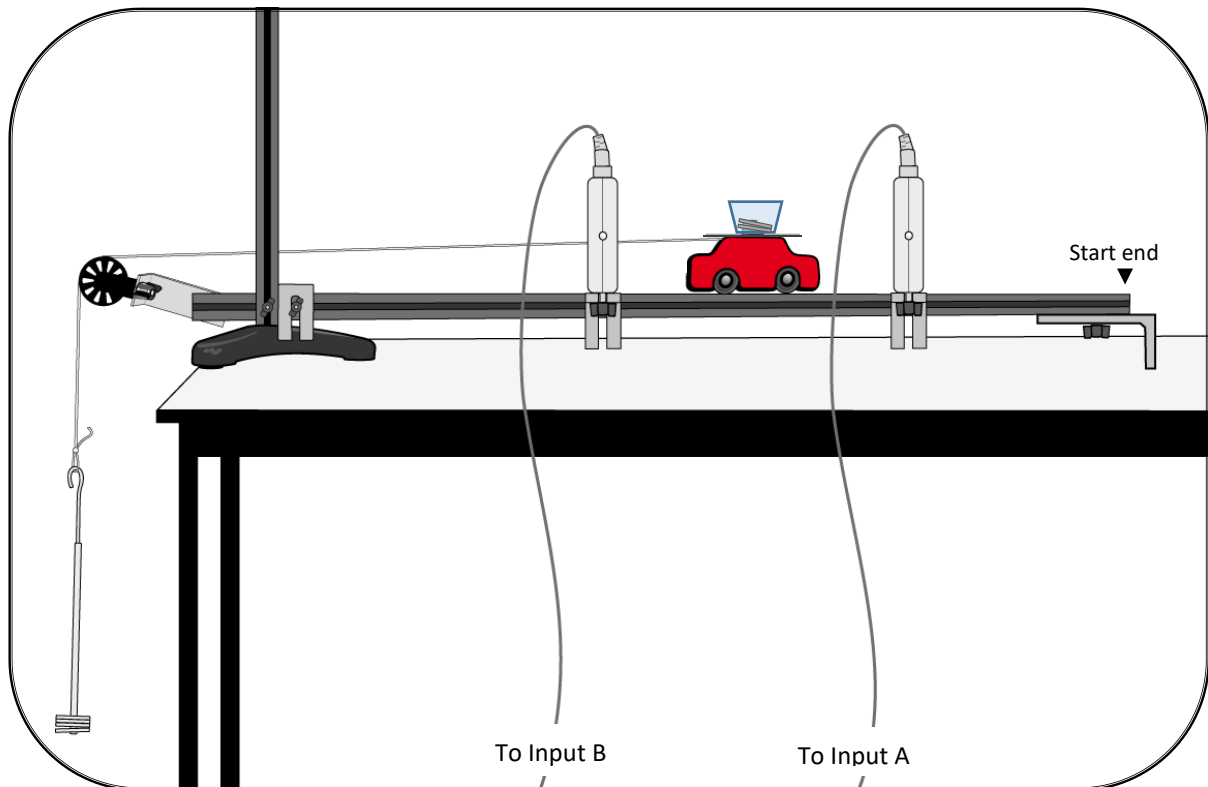
## Using a DIY container to hold masses

Make a hole in the base of a yoghurt pot or similar.

Use thumbscrew (TS1) to attach the yoghurt pot to the top of the cart.

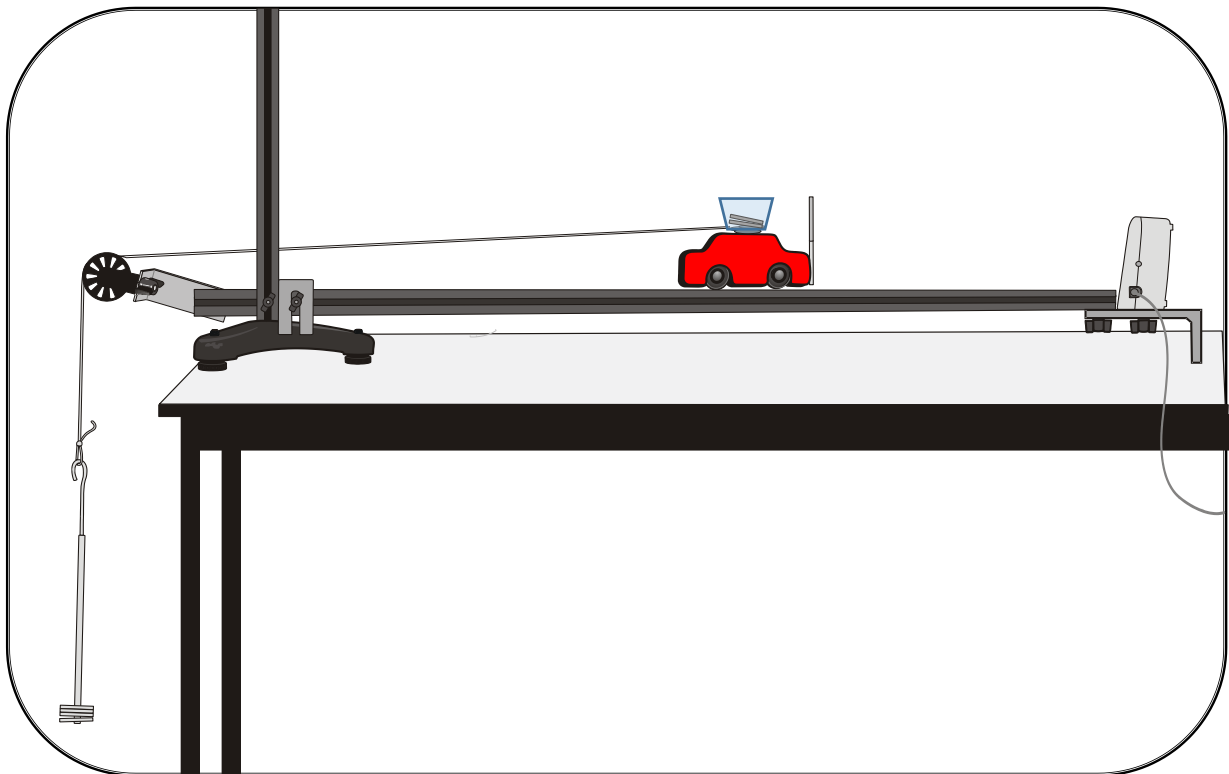


## Forces: Using two Light gates to investigate forces e.g. Newton's 2<sup>nd</sup> Law



- Place the track in its lowest position, supported at the end by a large bracket. Adjust the track to be accurately horizontal (see page 34).
- Place a thin bracket on the track as close to the vertical pillar as possible to act as a stop. Fit the interrupt card to the cart so the single interrupt edge will pass through the Light gates. Connect a length of thread (with a mass carrier attached) to the cart. Run the thread over the top of the pulley.
- Position a Light gate mid-way along the track and connect to input B on the EasySense data logger. Position a second Light gate nearer the start end of the track and connect to input A.
- Place 50 g of masses on top of the cart and 10 g on the mass hanger.
- Open the EasySense program and select **Timing**. From the wizard select to record **Acceleration from A to B**, and enter the length of the card as 120 mm.
- Select **Start**. Allow the cart gently to run freely along the track through the two Light gates.
- Transfer 10 g from the cart to the hanger and repeat. Repeat until all the weights have been transferred from the cart to the hanger. The total moving mass of the cart and hanger must be the same each time.

## Forces: Using a Motion sensor to investigate forces e.g. Newton's 2<sup>nd</sup> Law

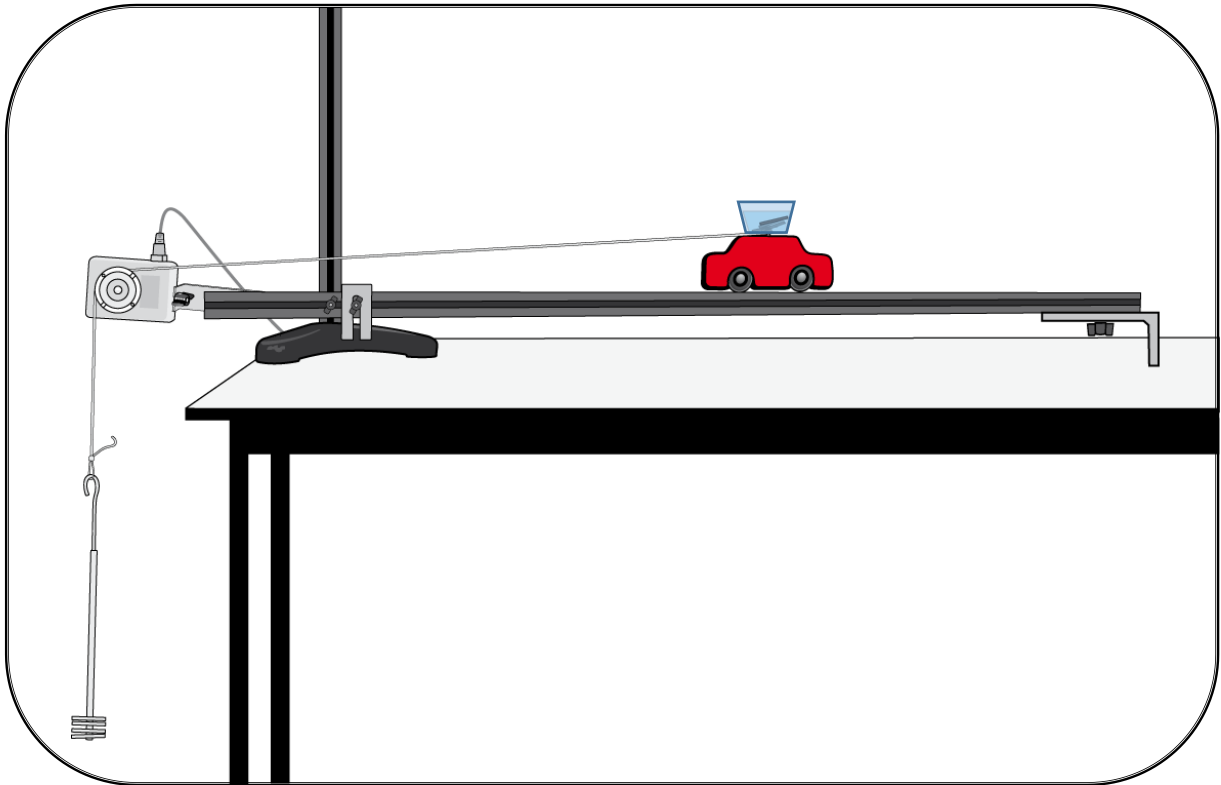


- Place the track in its lowest position, supported at the end by a large bracket. Adjust the track to be accurately horizontal (see page 34).
- Position a Motion sensor at the end of the track and connect to an EasySense data logger. The range of the Motion sensor should be set to Distance.
- Place a thin bracket on the track as close to the vertical pillar as possible to act as a stop.
- Fix a reflector to one end of the cart. Cut a piece of thread slightly shorter than the length from the pulley to the floor and attach to the cart. Attach a hanger to the other end of the thread (the weight is to tension the thread, not pull the cart). Run the thread over the Spoked pulley.
- Place 50 g of slotted masses on the top of the cart.
- Open the EasySense program and select **Graph**. From the wizard select the following:

Time	Interval	Trigger
5 seconds	20 ms	Distance rises above 0.20 m

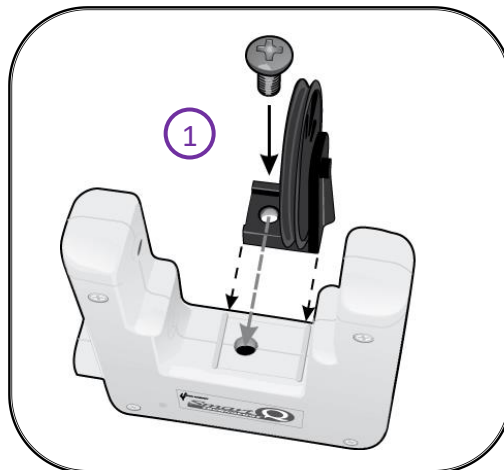
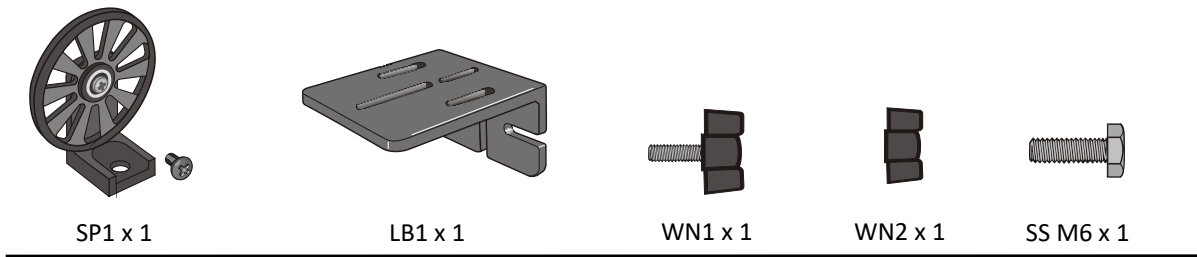
- Hold the cart at least 15 cm away from the Motion sensor - you want the cart to produce data for about 80 cm before it reaches the pulley. Select **Start** and release the cart to run freely along the track.
- Select **Overlay**. Transfer 10 g from the cart to the hanger and repeat. Repeat until all the weights have been transferred from the cart to the hanger. The total moving mass of the cart and hanger must be the same each time.

## Forces: Using a Rotary Motion sensor to investigate forces

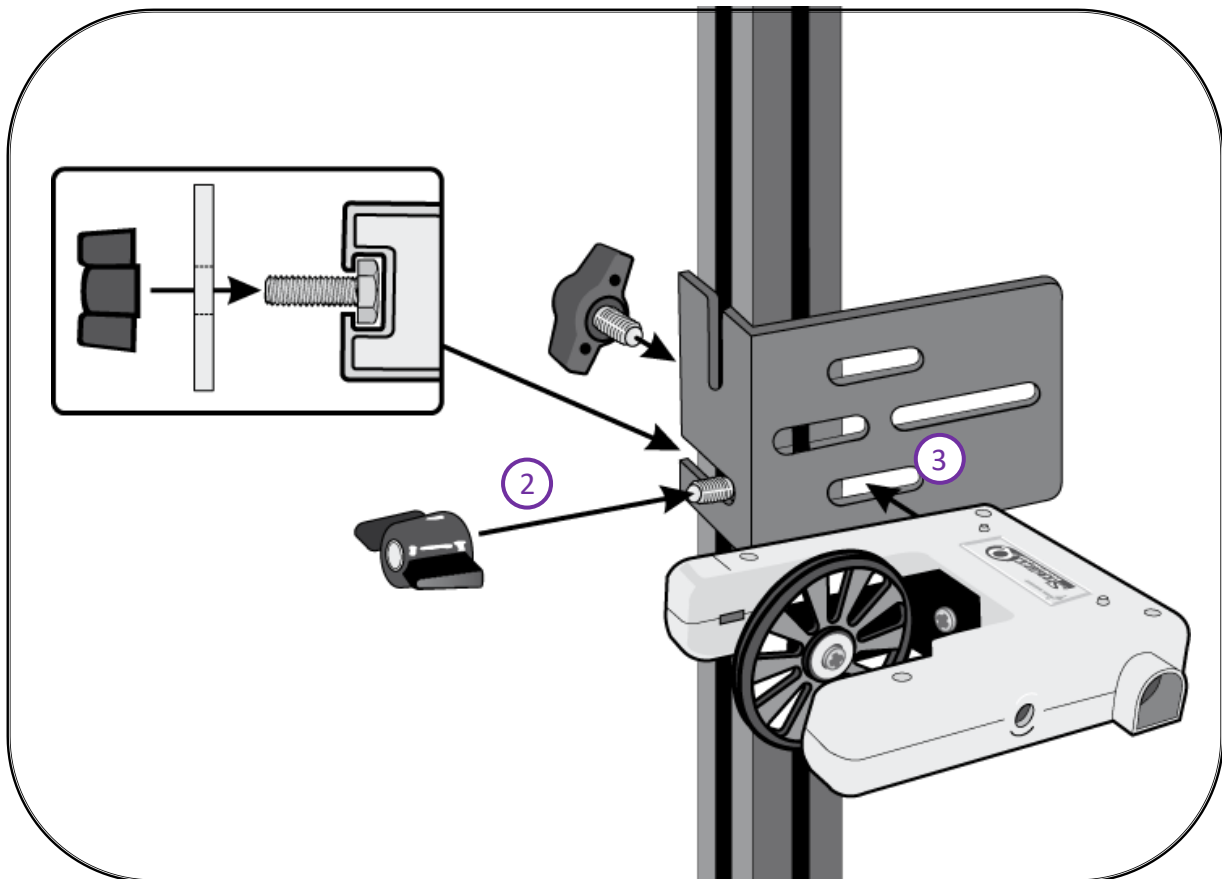


- The procedure is the same as using the Motion sensor, except in the way the Rotary Motion sensor is set up to take measurements. See page 20 for how to attach the Rotary Motion sensor to the track.
- Set the range of the sensor to the size of pulley you are using e.g. Pulley 49 mm for the largest pulley.

## Attaching a Light gate and Spoked Pulley to the pillar

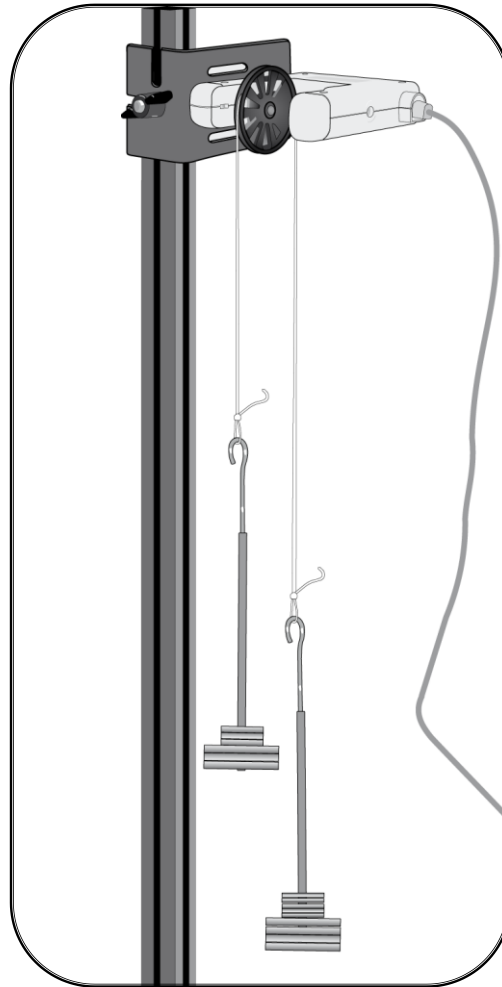


1. Attach a spoked pulley to the Light gate.
2. Attach a large bracket to the pillar using a SS M6 hex screw and WN2 wing nut.
3. Attach the Light gate to the bracket using a wing nut screw (WN1).



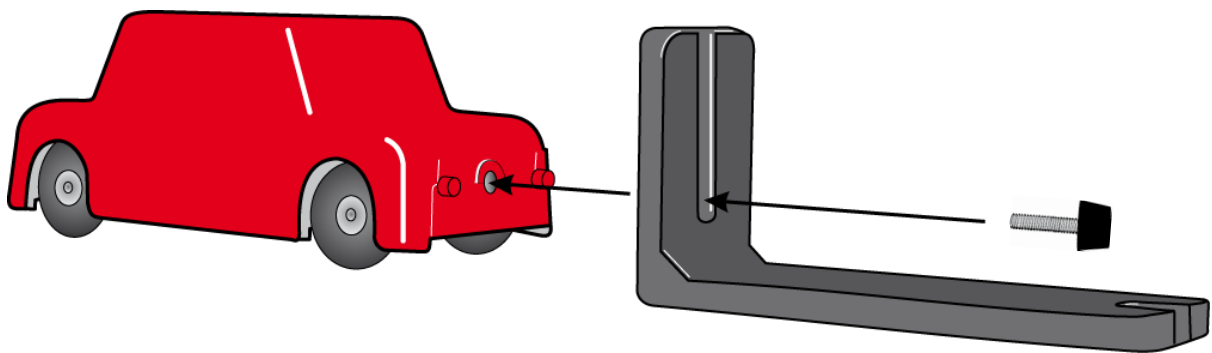
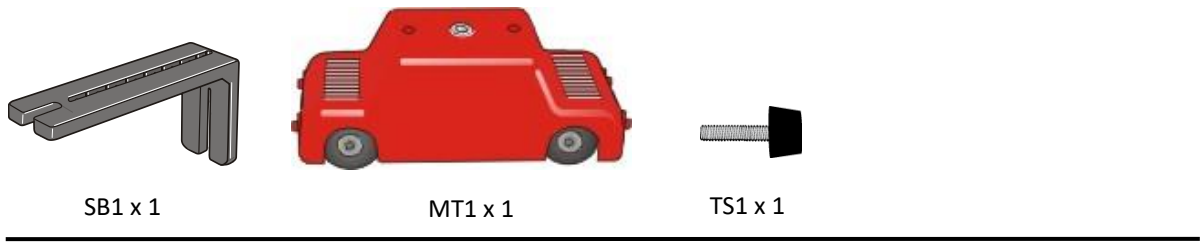


## Forces: Using a Light gate and Spoked Pulley to investigate Newton's 2<sup>nd</sup> Law (Atwood's machine)

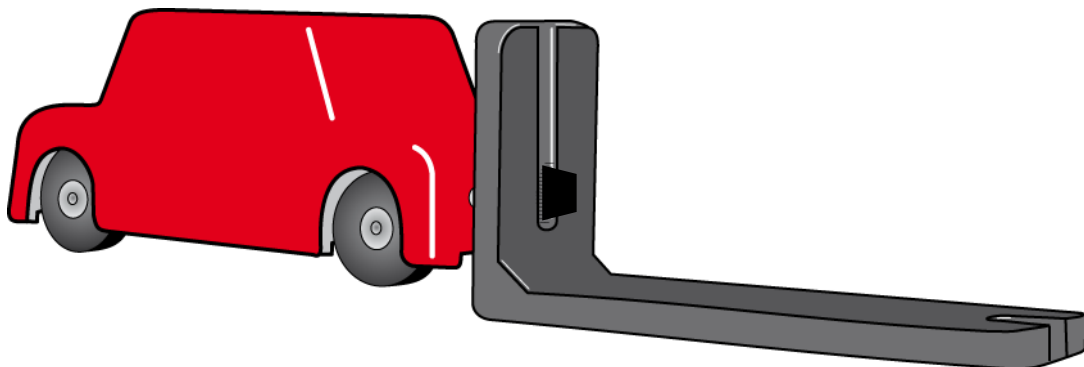


- Connect the Light gate to input A on the EasySense data logger.
- Check the exact weight of the masses on a good balance. The suggested masses to be used are 6 x 100 g and 10 x 10 g.
  - a. Start with 3 x 100 g on both sides and all 10 of the 10 g masses on one side only. This will give a force of 0.1 x g N.
  - b. The force is equal to the difference in mass between the two sets of masses expressed as kg.
- Arrange the set up so the heavier mass hangs below the lighter mass - this will stop the masses clashing as they move. The lighter mass should be able to move at least 400 mm, the heavier mass should reach a 'floor' before the lighter mass has reached the pulley.
- Open the EasySense program and select **Timing**. Select to record **Acceleration at A** using a Pulley.
- Hold the masses in position, release and immediately select **Start**. Select Stop when the lighter mass reaches the pulley.
- Select the suitable data, and use **Show Statistics** to find the average acceleration. Keep a record of this value.
- Transfer 10 g from the heavier mass to the 300 g mass and repeat (force = 0.08 x g N). The force is equal to the difference in mass between the two sets of masses expressed as kg.
- Continue to repeat, transferring 10 g between each reading until the masses are equal.

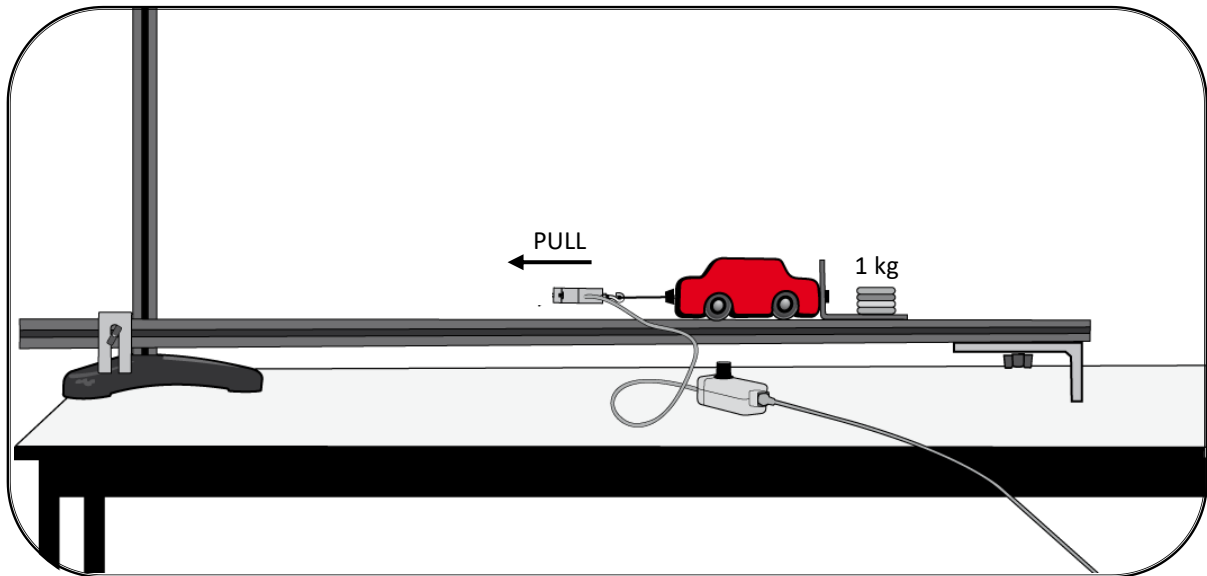
## Attaching a thin bracket to the cart



Use a thumbscrew to attach the short arm of the thin bracket to the cart



## Forces: Using a Force sensor to investigate static and dynamic friction

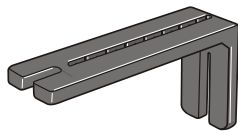


- Place the track in its lowest position, supported at the end by a large bracket. Adjust the track to be accurately horizontal (see page 34).
- Attach the thin bracket to the front of the cart; keep the TS1 bolt loose so the bracket is in contact with the track surface. Place a 1 kg weight on the bracket.
- Attach the hook supplied with the Force sensor to its centre hole.
- Attach another TS1 bolt to the other end of the cart and use a short length of thread to attach it to the hook on the Force sensor. Connect the Force sensor to an EasySense data logger.
- Open the EasySense program and select **Graph**. From the wizard select the following:

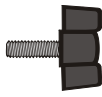
Time	Interval	Trigger
5 seconds	5 ms	Force rises above 1 N with a 25% pre-trigger

- **Zero** the Force sensor.
- Select **Start**. Hold onto the Force sensor and pull the cart along steadily until it begins to move, continue along the track at a steady speed.
- Repeat for other values of load e.g. 2 kg, 3 kg, etc.

## Attaching a Rotary Motion sensor to the pillar



SB1 x 1



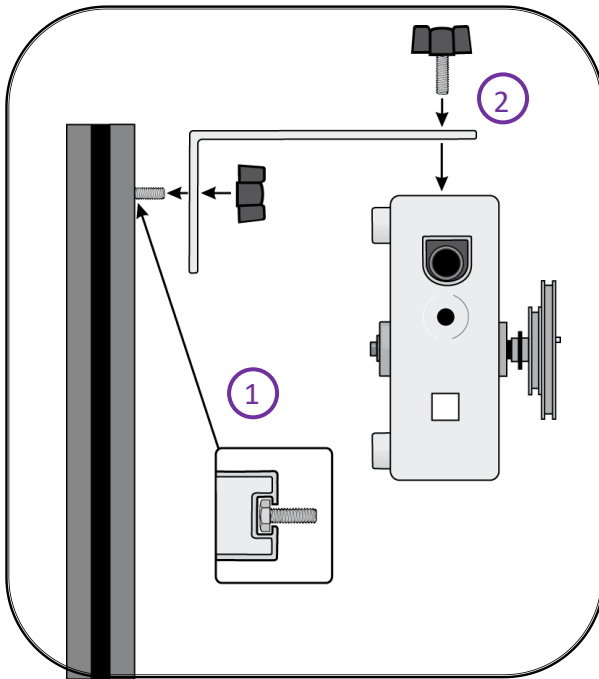
WN1 x 1



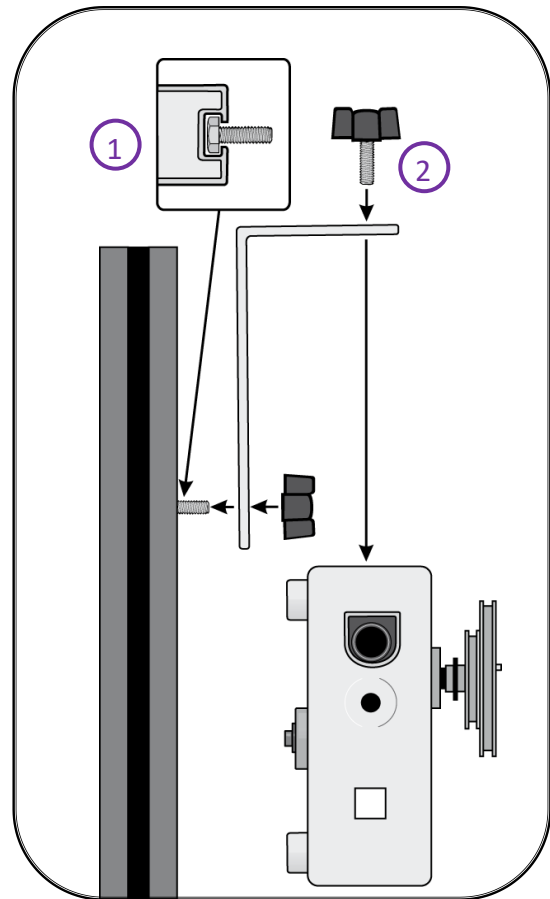
WN2 x 1



SS M6 x 1



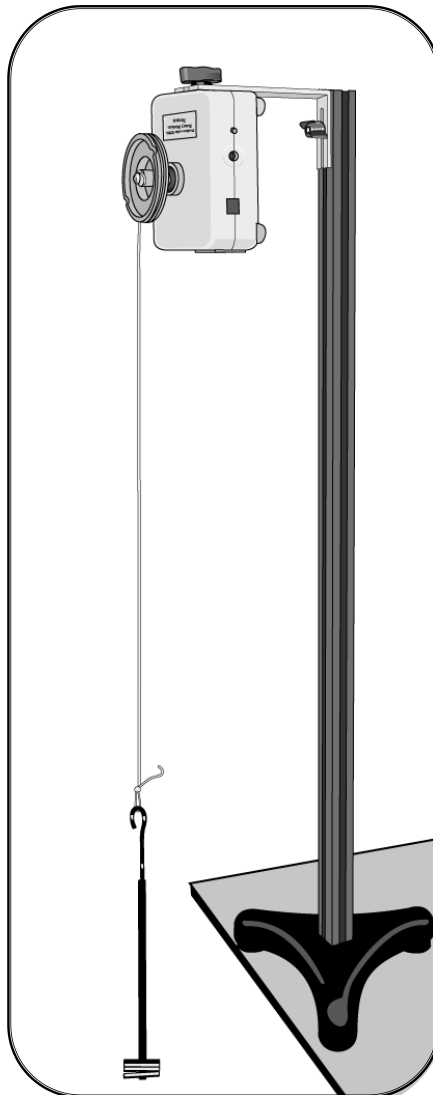
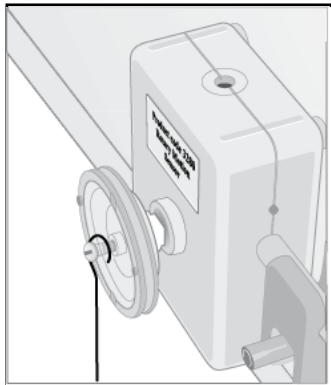
Alternative a



Alternative b

1. Attach a thin bracket to the pillar using a SS M6 hex screw and WN2 wing nut.
2. Attach the Rotary Motion sensor to the bracket with a wing nut screw

## Pendulum: Using a Rotary Motion sensor for simple pendulum investigations

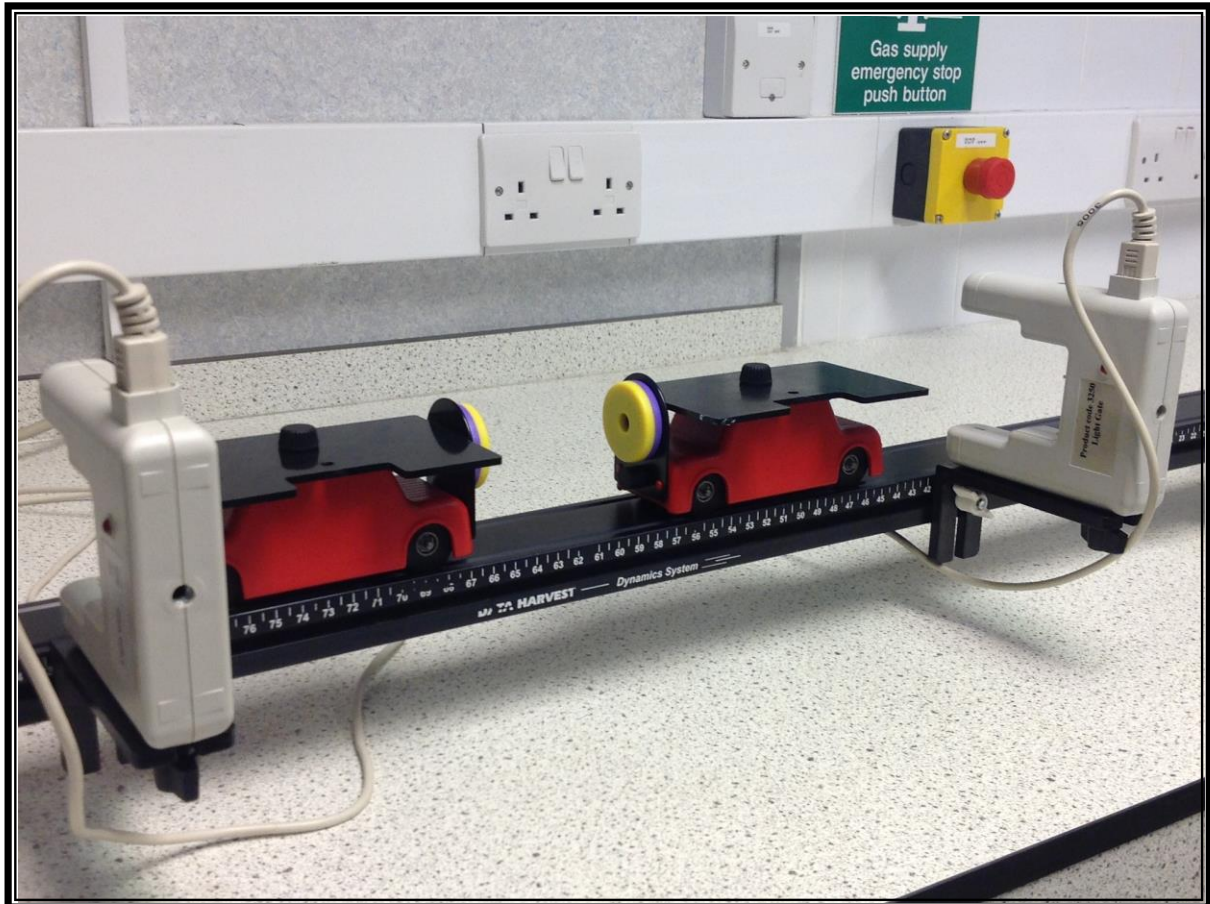
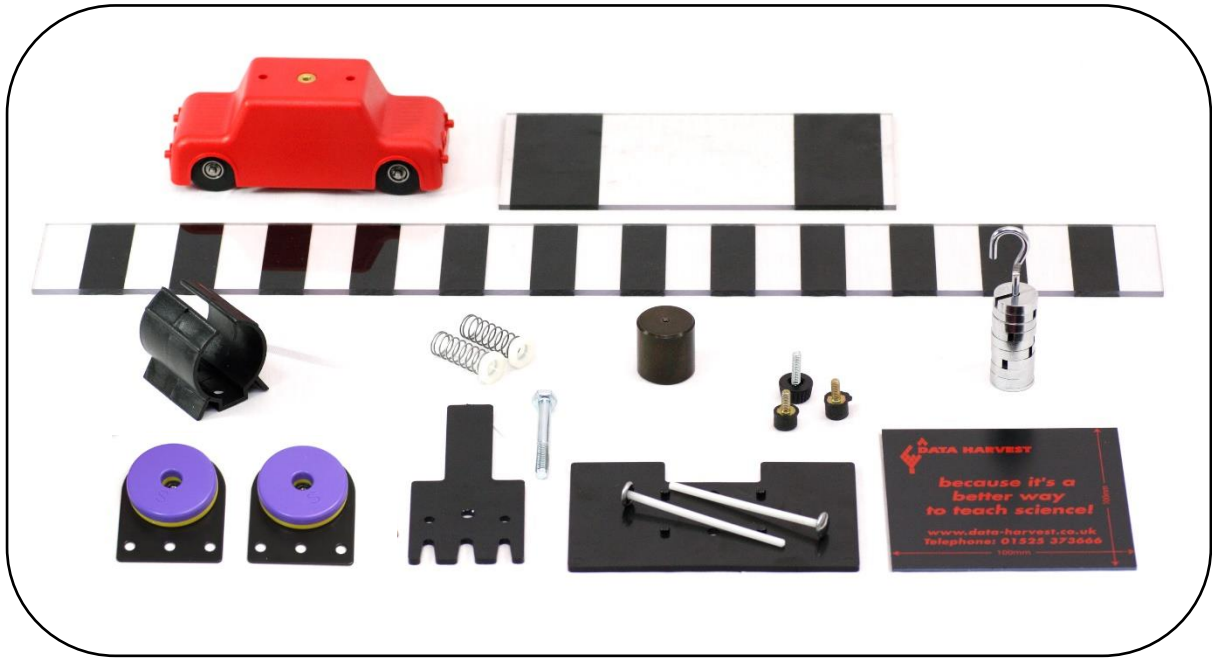


- Use either strong cord or thin wire for the pendulum. Start with a pendulum 0.7 m long. Attach as shown.
- Connect the Rotary Motion sensor to an EasySense data logger. The range of the Rotary Motion sensor should be set to Pendulum.
- With the pendulum hanging freely, press the reset **zero** button on the sensor.
- Open the EasySense program and select **Graph**. From the wizard select a suitable duration with an interval of 20 ms e.g.

Time	Interval	Trigger
10 seconds	20 ms	Falls below 5 deg

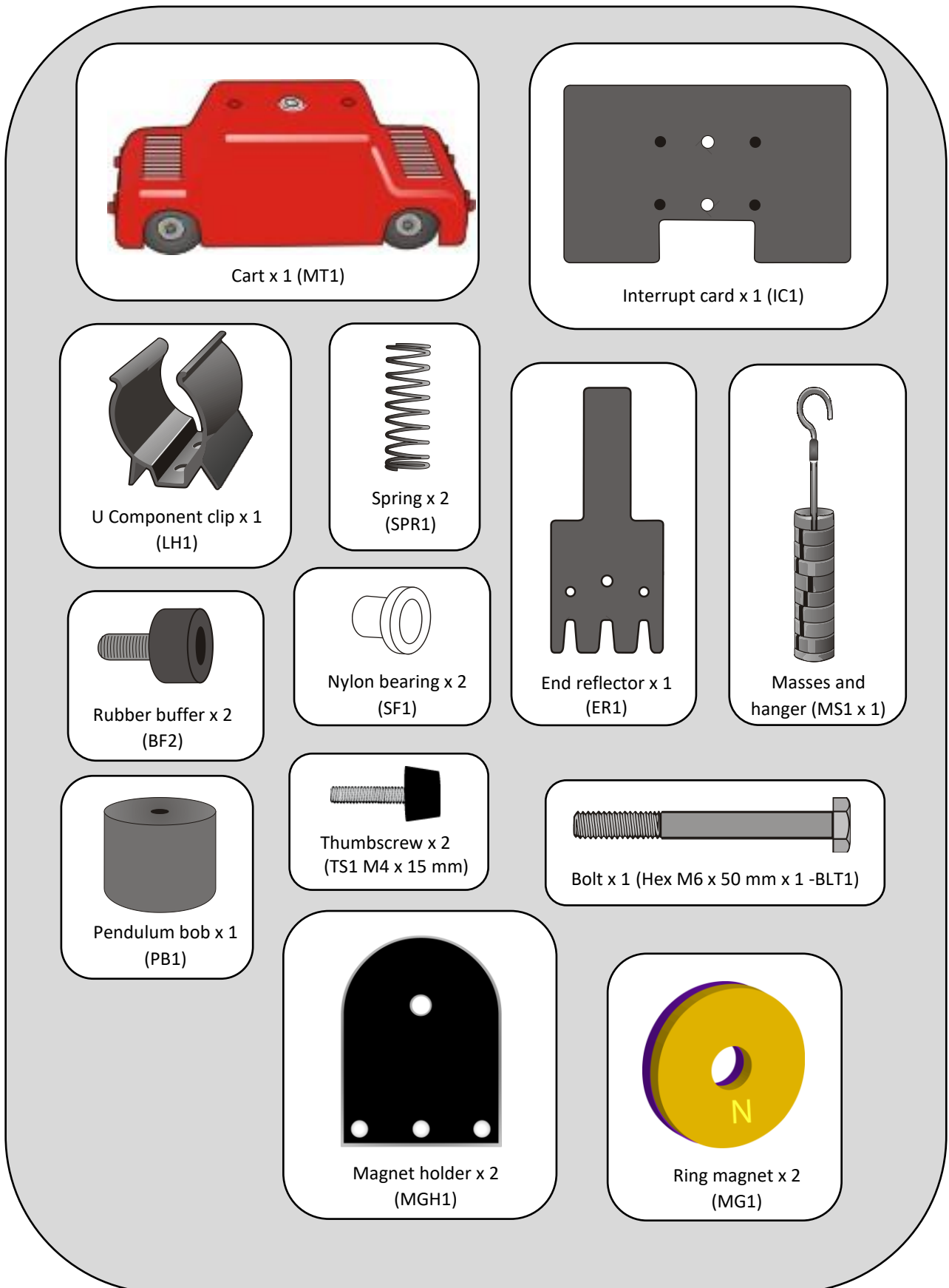
- Set the pendulum swinging through an angle of less than 10 degrees either side of vertical.
- Select **Start** to begin logging.
- Reduce the length of the pendulum by 0.1 m. Select **Overlay** and repeat.
- Continue until the length of the pendulum is reduced to 0.2 m.

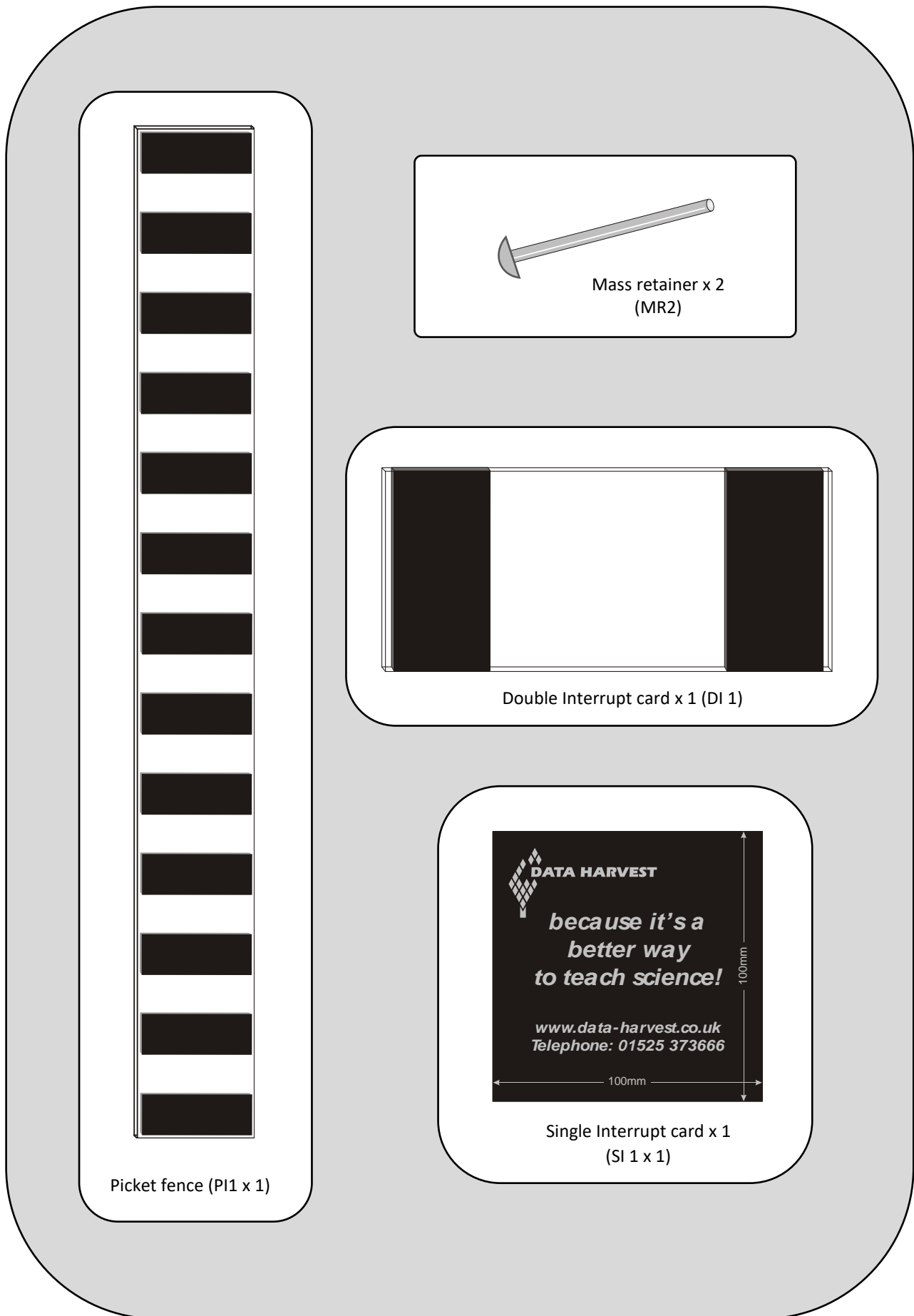
## PART TWO: Using Extension Kit 1



## Component identification for the Dynamics Extension kit

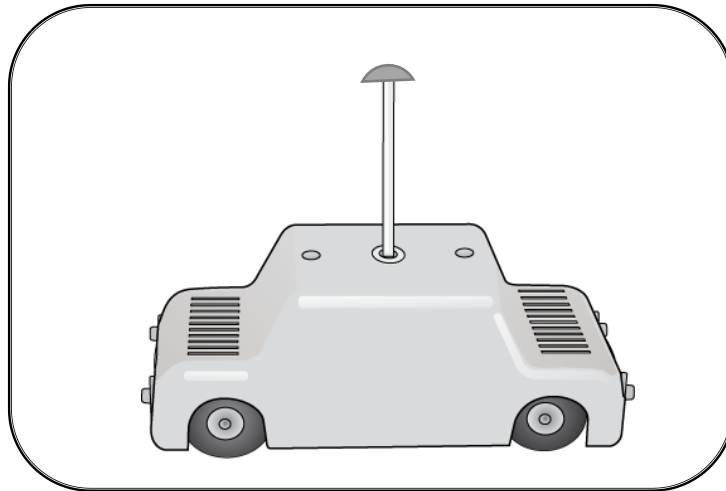
Product No 3801 (Not to scale)



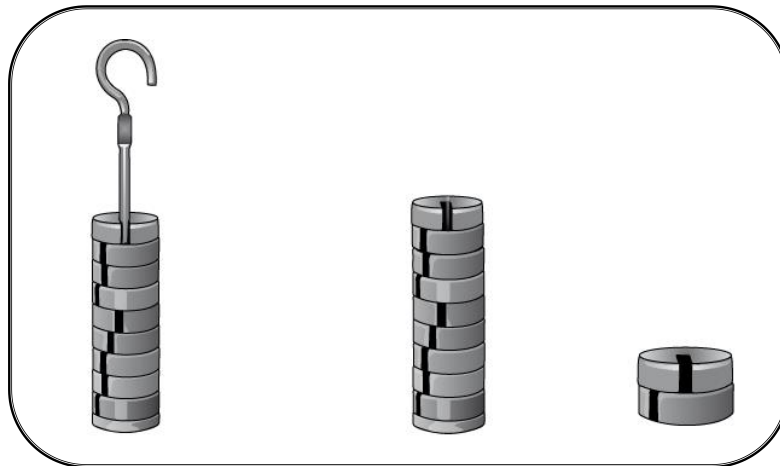




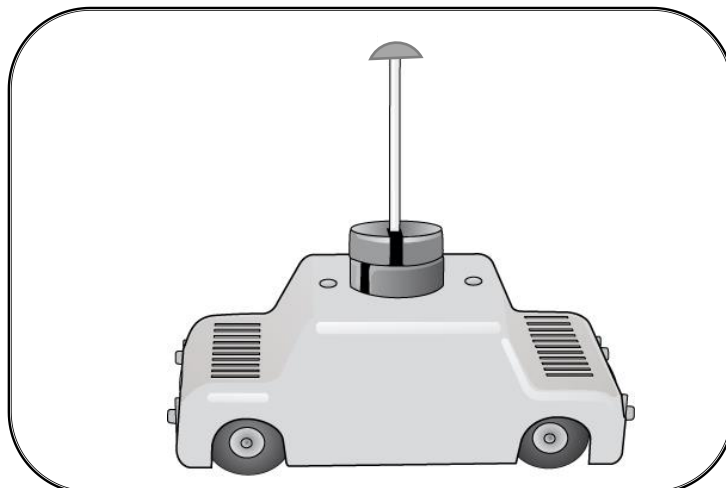
## Using the Mass retainer to hold masses on top of the cart



The mass retainer pushes into the threaded brass hole on top of the cart.

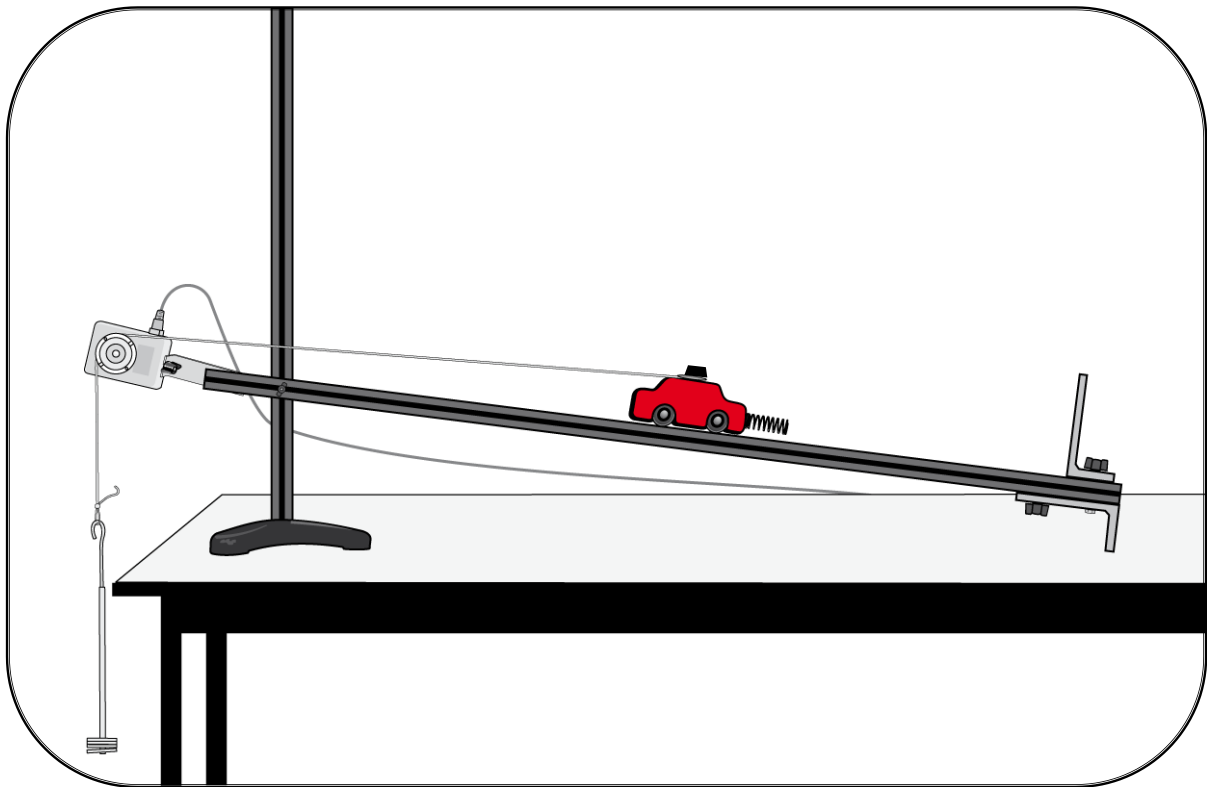


Remove the masses from the mass hanger, the mass retainer will fit through the centre hole in the supplied masses.

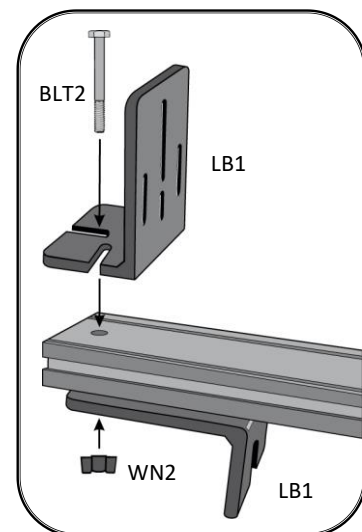
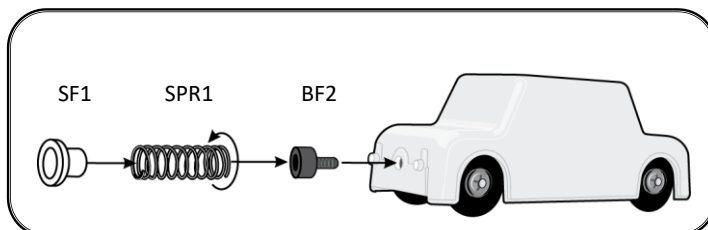


Place the masses on the top of the cart, align the centre hole of the masses with the hole in the cart. Push the mass retainer through the masses into the hole. To add or remove masses, remove the retainer, alter the number of masses and refit the retainer.

## Motion: Using the spring to roll a cart up a slope



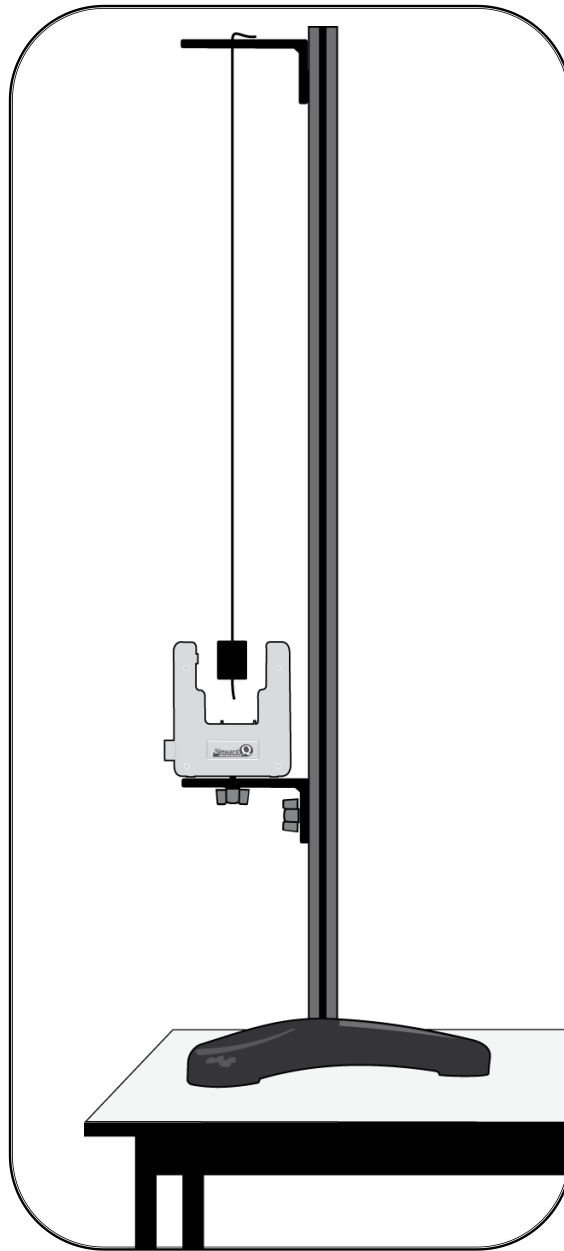
- Fit two large brackets (LB1) at the end of the track, one under the track and one upright using the 50 mm bolt (BLT2) and a wing nut (WN2).
- Position the track at the 10 cm mark on the vertical pillar to give an angle of about 5°.
- Attach a spring to the cart.



- Place the cart at the bottom of the track. **Start** logging and push the cart to compress the spring against bracket.
- Release the cart and let the spring push the cart up the track. Let the cart run up the track and catch it as it returns.

Note: The suspended mass is only to tension the thread running over the pulley of the Rotary Motion sensor, it should only have a very minimal effect on the motion of the cart.

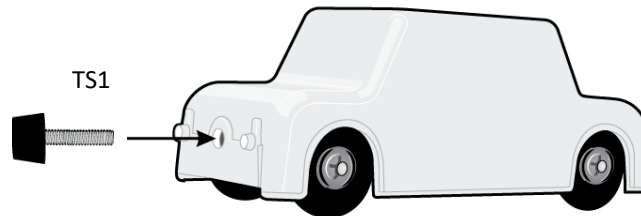
## Pendulum: Using a Light gate and a simple pendulum



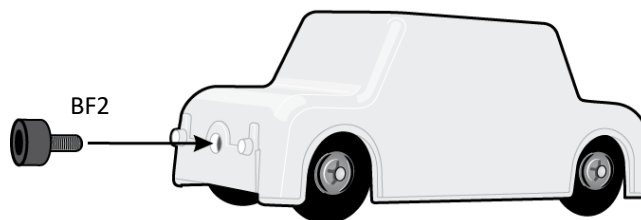
- Attach the short arm of a thin bracket to the pillar. Thread the end of a piece of thread (at least 0.8 m long) through the hole in the long arm of the bracket and secure in place e.g. clamp with a crocodile clip.
- Guide the other end of the thread through the pendulum bob (PB1) and tie a knot in the end of the thread.
- Use a large bracket to attach a Light gate to the pillar. Adjust the length of the thread to 0.7 m and make sure the pendulum bob lines up correctly with the Light gate.
- Open the EasySense program and select **Timing**. Select **Time, Period at A**.
- Pull the pendulum bob back, release to set it swinging and select **Start**. Stop after it has recorded at least 10 cycles.

## Preparing carts for collision experiments

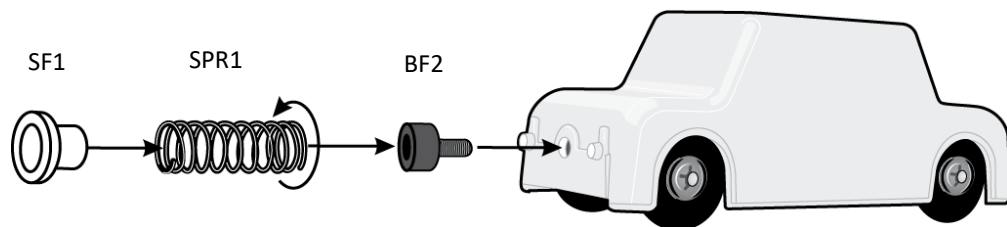
- a) Attaching a solid buffer to the cart



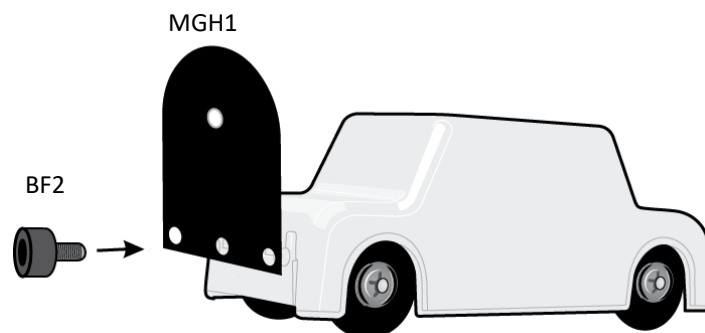
- b) Attaching a rubber buffer to the cart



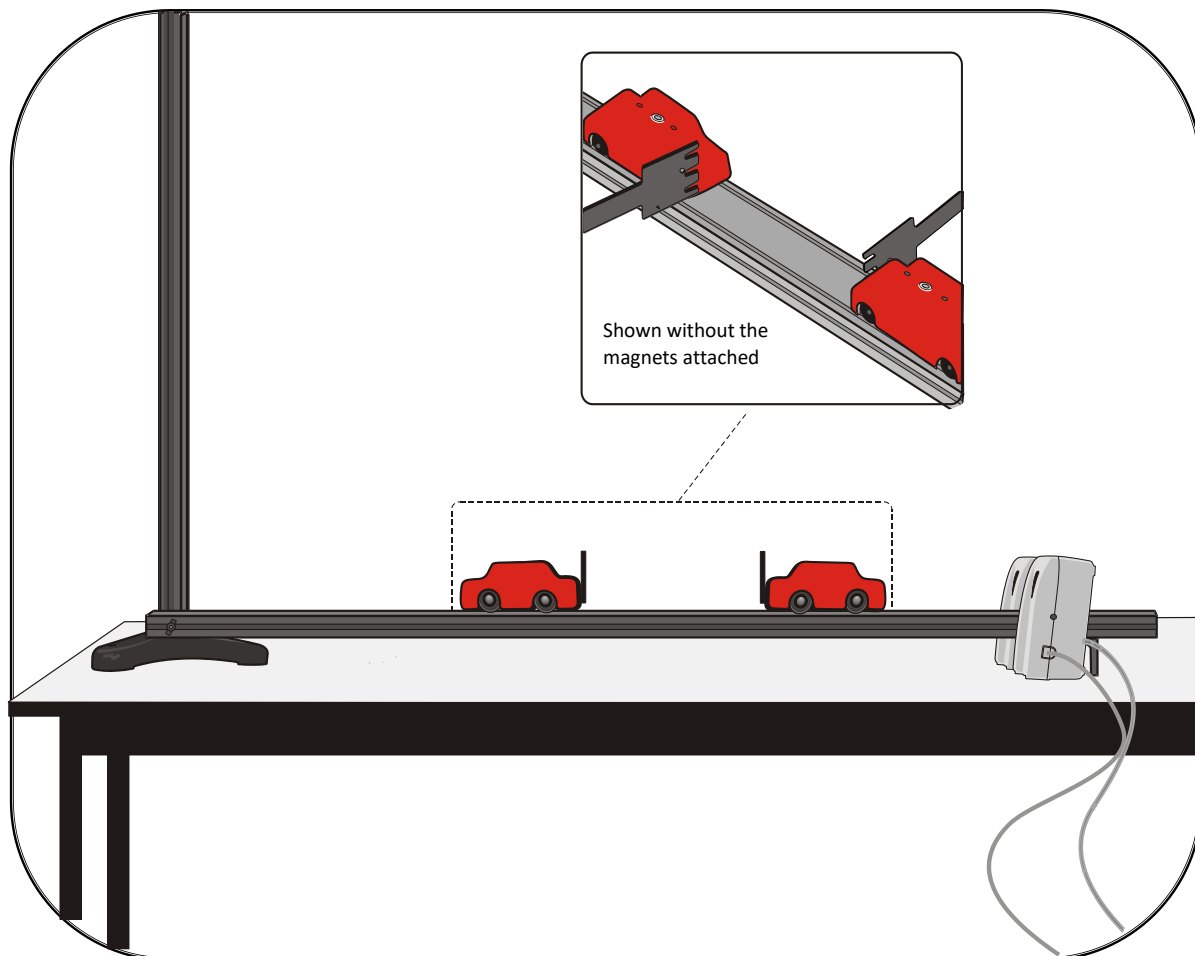
- c) Attaching a spring to the cart



- d) Attaching a magnet holder to the cart



## Collisions: Using two Motion sensors with magnets

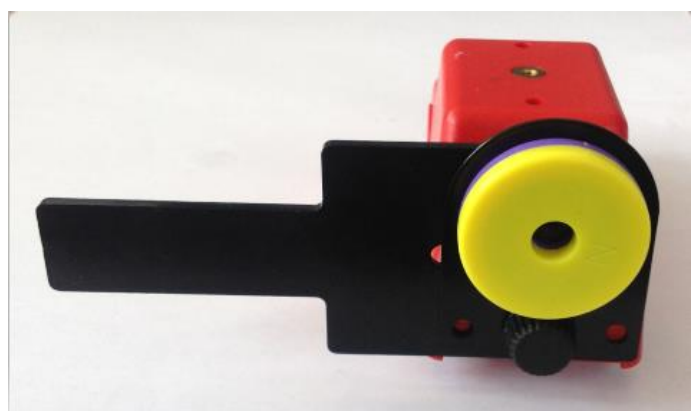


This investigation works best over small distances.

- Attach an end reflector and magnet holder with magnets to the contact end of each cart.  
To test for an **elastic collision** use magnets with same poles facing (so they repel each other).  
For **inelastic collisions** use either opposite poles facing or attach a thumbtack to one cart with modelling clay and on the other cart use a thumbscrew (TS1) and a cone of modeling clay (so after the collision the carts stick together and move off together).

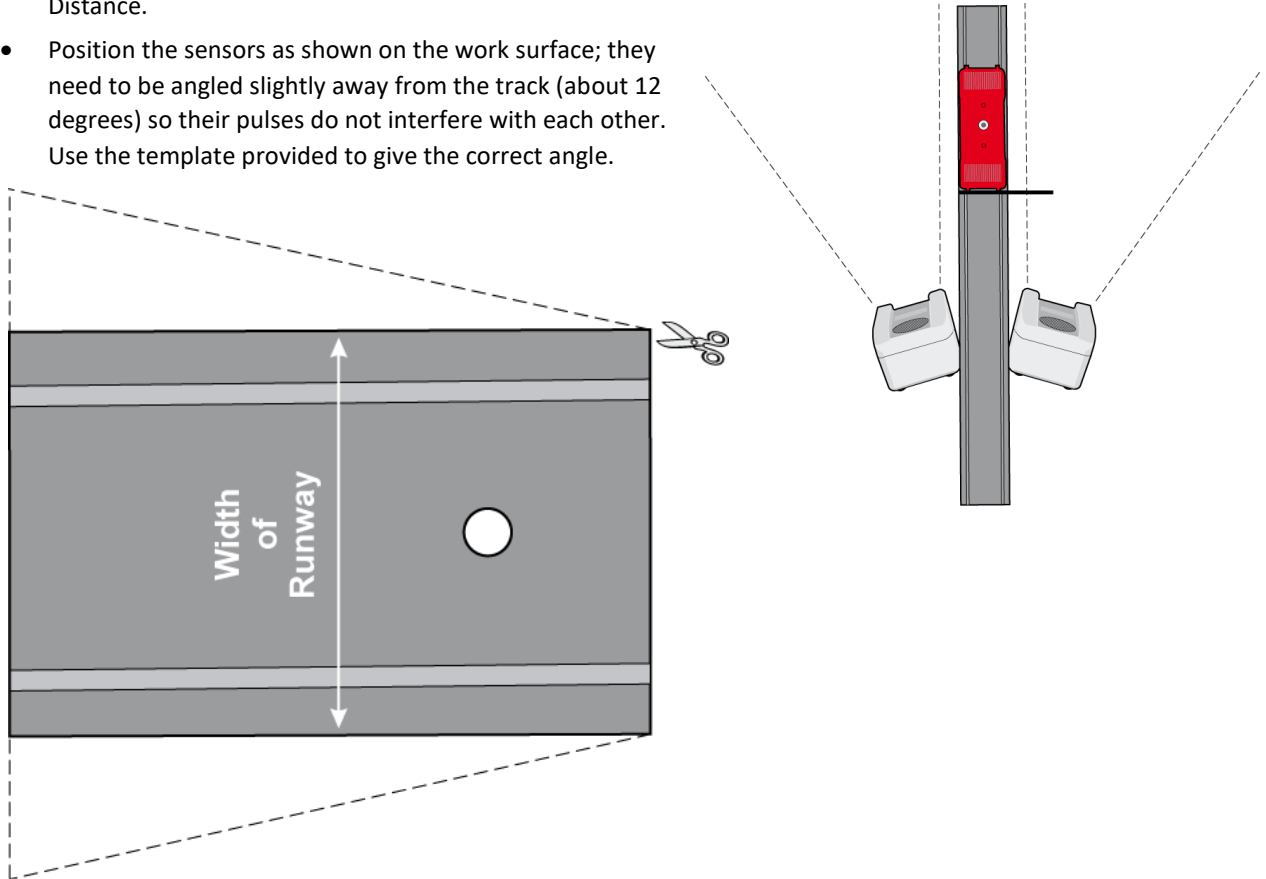


Position the end reflector as shown



Then fit the magnetic holder over the top and screw both into place using a thumbscrew (TS1)

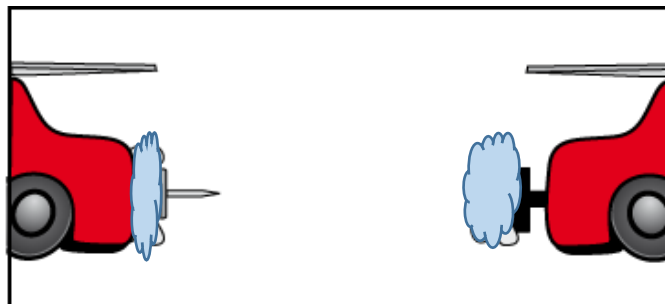
- Measure the mass of each cart and attachments (reflector, magnets, etc.) to make sure they are both equal. Use modeling clay to adjust until they are.
- Place the track in its lowest position, supported at the end by a large bracket. Adjust the track to be accurately horizontal (see page 34).
- Connect the two Motion sensors to the EasySense data logger. The range of the sensors should be set to Distance.
- Position the sensors as shown on the work surface; they need to be angled slightly away from the track (about 12 degrees) so their pulses do not interfere with each other. Use the template provided to give the correct angle.



- Open the EasySense program and select **Graph**. From the wizard select the following:

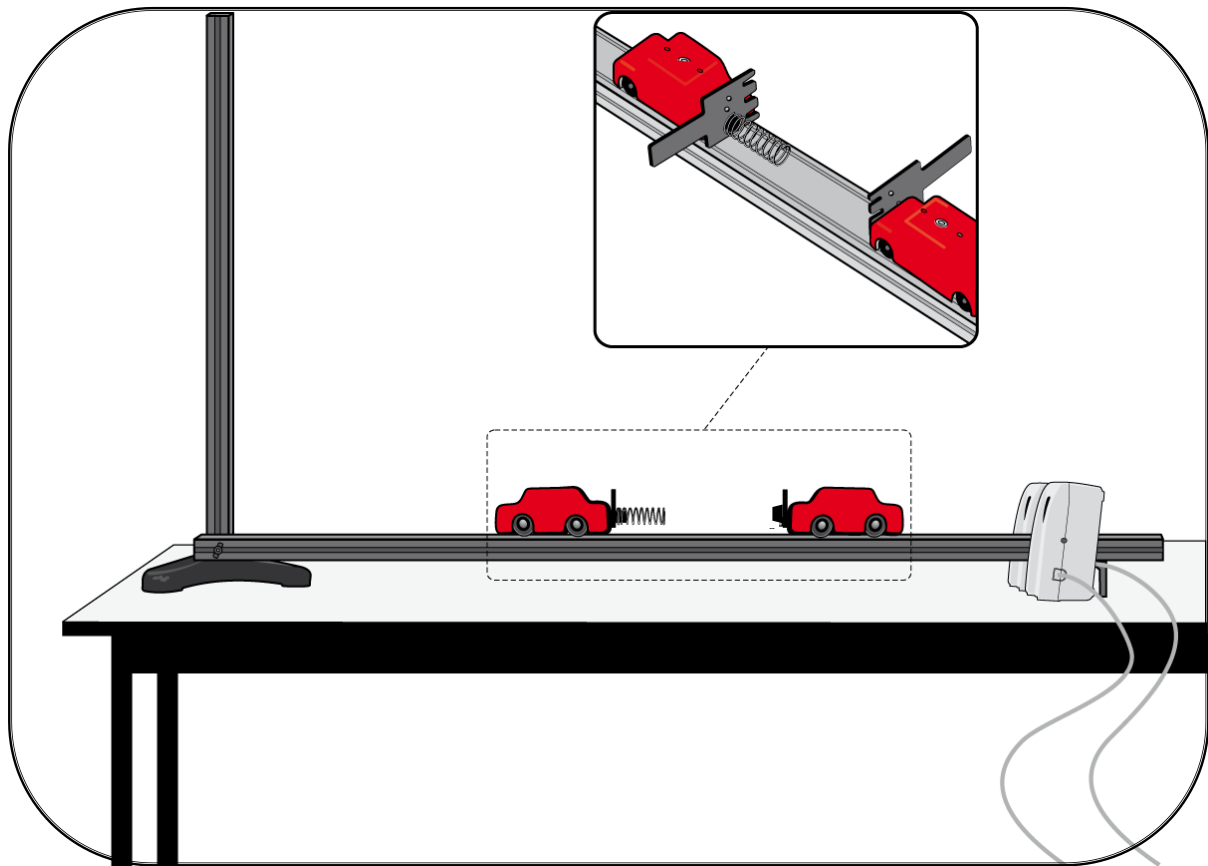
Time	Interval	Trigger
2 seconds	20 ms	When Distance (1) falls below 0.5 m

- Position the target car (No 1) at least 17 cm away from the Motion sensor (at the 50 cm mark). Start with this cart stationary.
- Select the **Start** icon and push cart 2 gently towards cart 1.

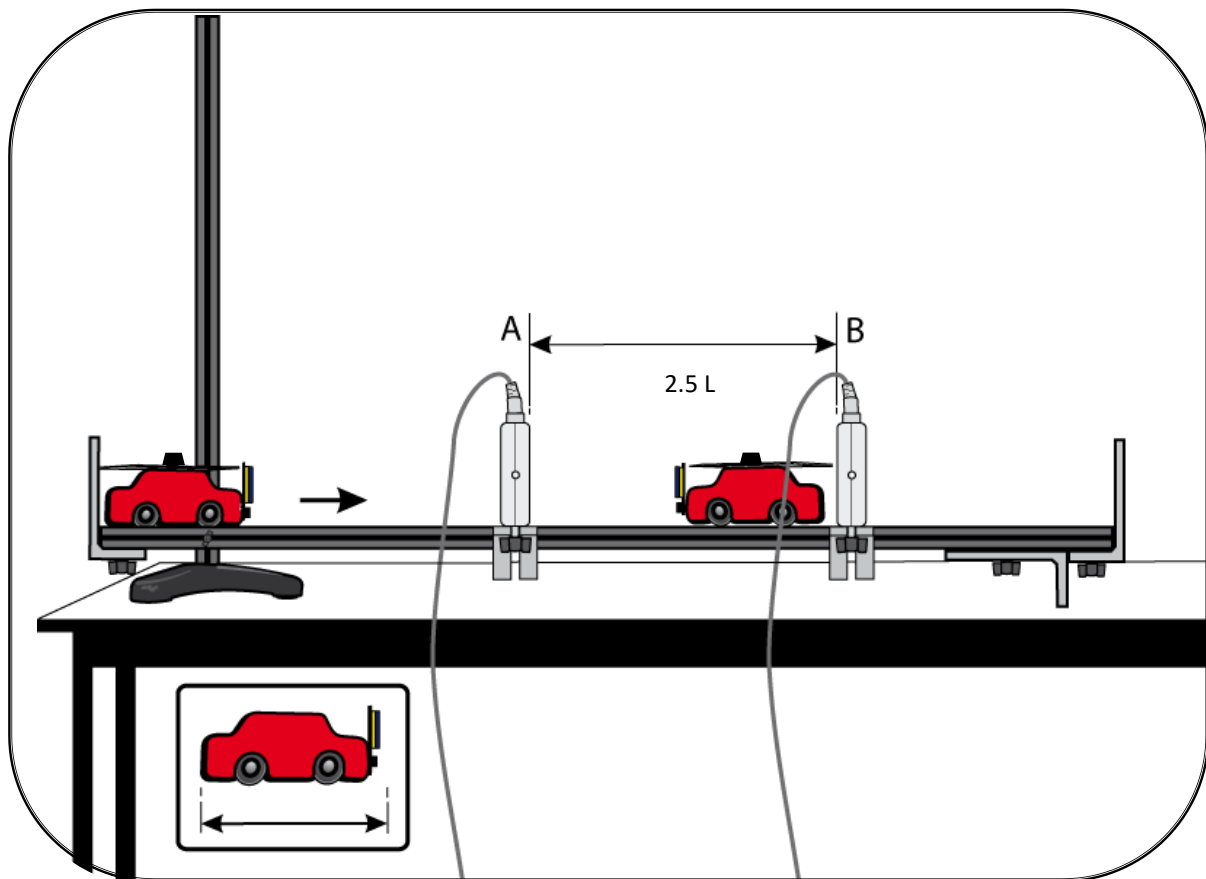


Alternative for inelastic collisions, attach a thumbtack to one cart with modelling clay and on the other cart use a thumbscrew (TS1) and a cone of modeling clay.

### Collisions: Using two Motion sensors with springs



## Collisions: Using two Light gates with magnets

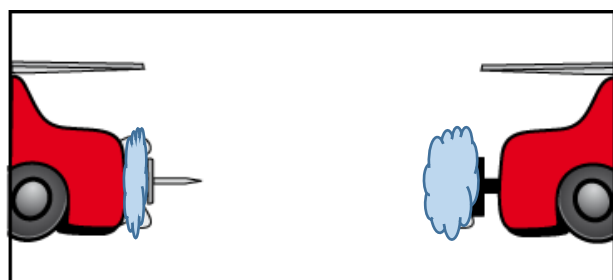


### Elastic collisions

- Place the track in its lowest position, supported at the end by a large bracket. Adjust the track to be accurately horizontal (see page 34). The distance between the Light gates should be at least 2.5 times the length of the cart and attachments.
- Fit an interrupt card to each cart so the single interrupt edge will pass through the Light gates. Attach a magnet holder and magnet to the end of each cart (use same poles facing).
- Measure the mass of each cart and attachments (interrupt card, magnets, etc.) to make sure they are both equal. Use modeling clay to adjust until they are.
- Connect the Light gates to input A and B on the EasySense data logger. Position the 'target' cart between the two Light gates (nearer B than A). Position the other cart before Light gate A.
- Open the EasySense program and select **Timing**. From the wizard select **Speed at A or B** with a single interrupt card, and enter the length as 120 mm.
- Select **Start** and push the first cart towards the other target car.

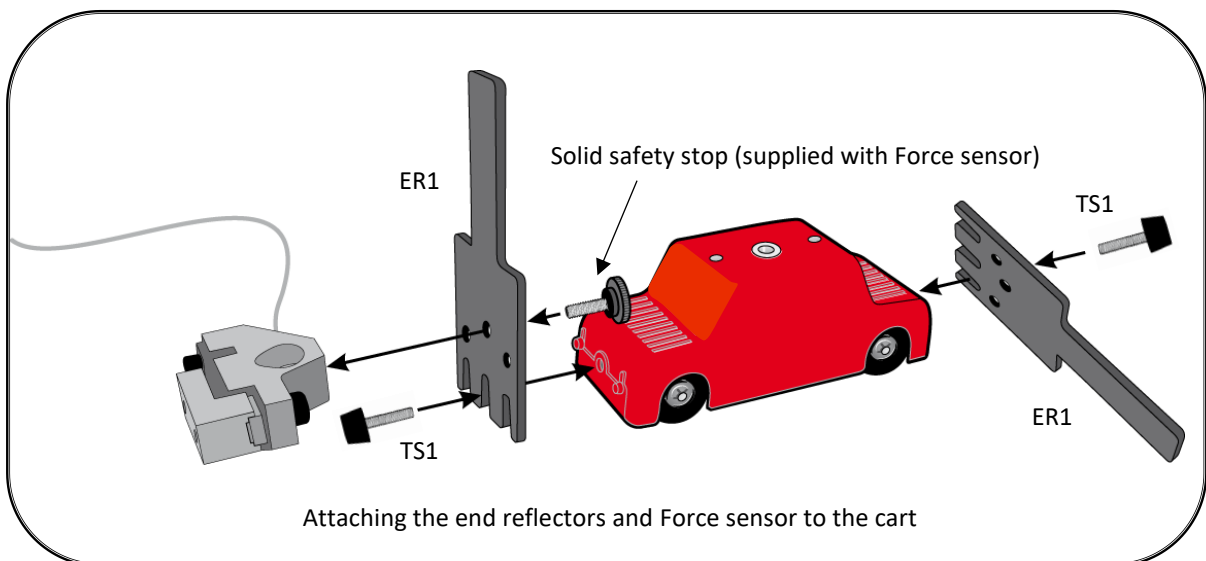
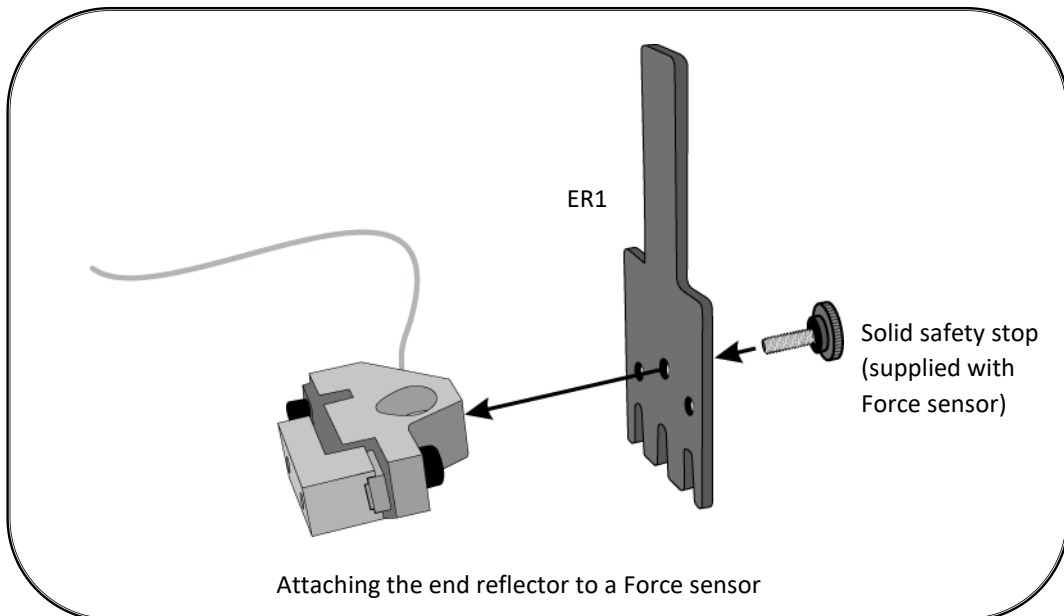
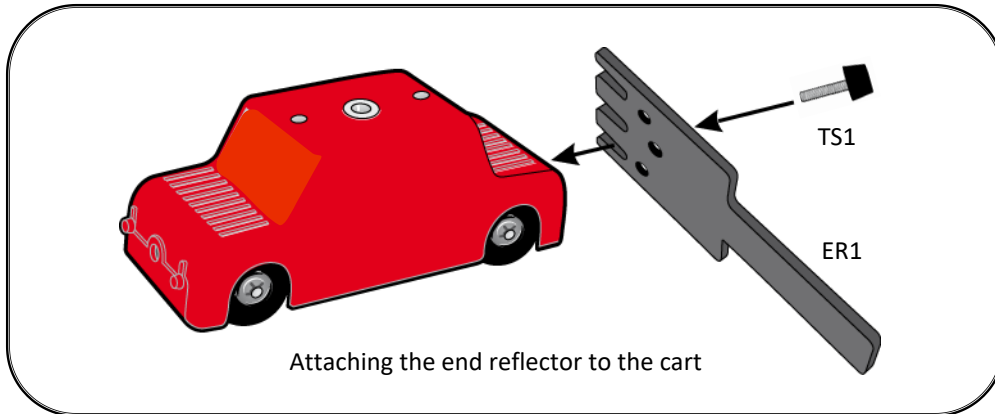
### Inelastic collisions

The same investigation is used for inelastic collisions but on one cart attach a thumbtack. On the other cart use a thumbscrew (TS1) and a cone of modeling clay or use the magnets with opposite poles facing.

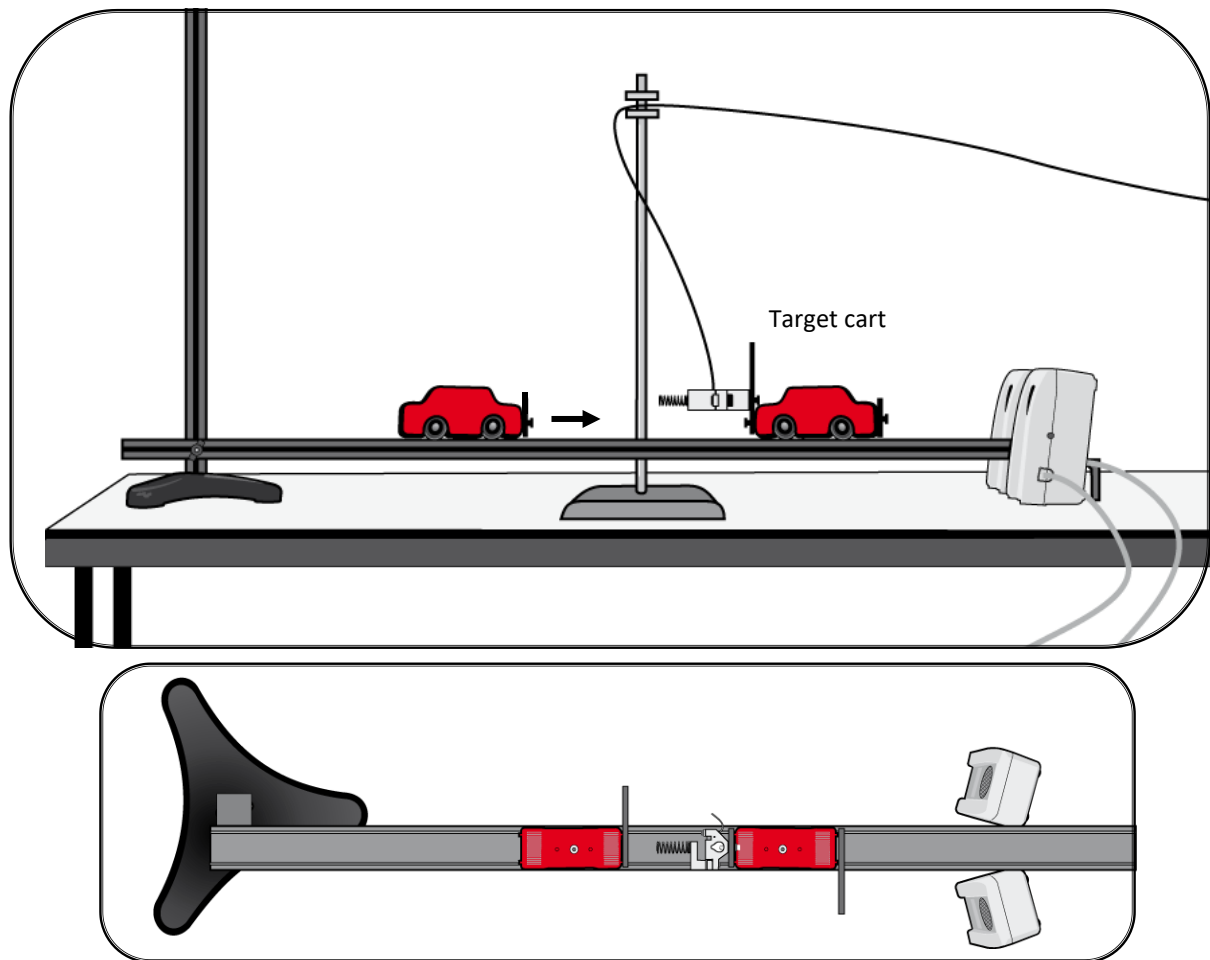




### Attaching end reflectors and a Force sensor to a cart



## Collisions: Using two Motion sensors and a Force sensor

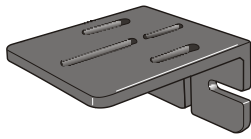


- On one end of the target cart, attach a reflector in the horizontal position. At the other end of this cart, attach an upright reflector. Then attach the Force sensor to this reflector and a spring to the Force sensor (see page 51).
- On the other cart, attach a reflector in the horizontal position.
- Measure the mass of each cart and attachments (reflector, spring, etc.) to make sure they are both equal. Use modeling clay to adjust until they are.
- Place the track in its lowest position, supported at the end by a large bracket. Adjust the track to be accurately horizontal (see page 34).
- Connect both Motion sensors and the Force sensor to the EasySense data logger, the range of the Motion sensors should be set to Distance.
- Position the Motion sensors as shown on the work surface; they need to be angled slightly away from the track (about 12 degrees) so their pulses do not interfere with each other. Use the template provided on page 53 to give the correct angle.
- Support the Force sensor cable vertically above the carts. **Zero** the Force sensor.
- Open the EasySense program and select **Graph**. From the wizard select the following:

Time	Interval	Trigger
2 seconds	20 ms	When Distance (in 1) falls below 0.5 m

- Position the target cart at least 17 cm away from the Motion sensor. Start with this cart stationary.
- Select **Start** and push the other cart towards the target cart.

## Attaching a Force sensor to the end of the track



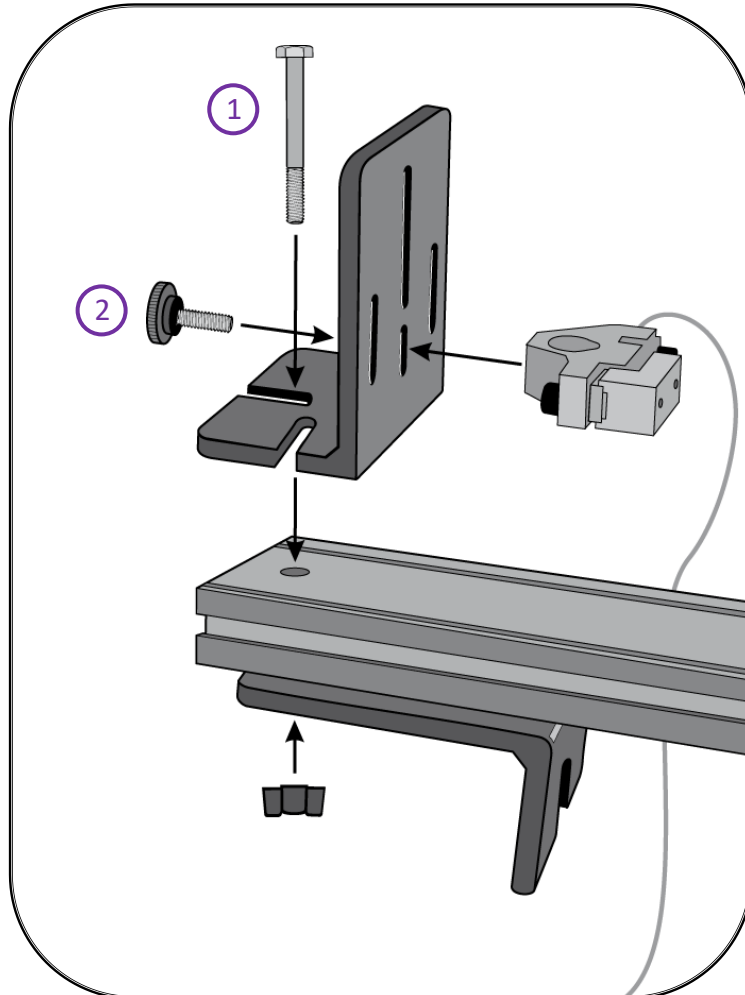
LB1 x 1



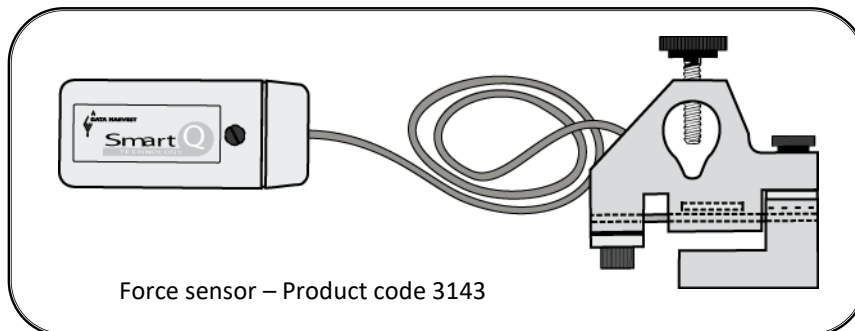
WN2 x 1



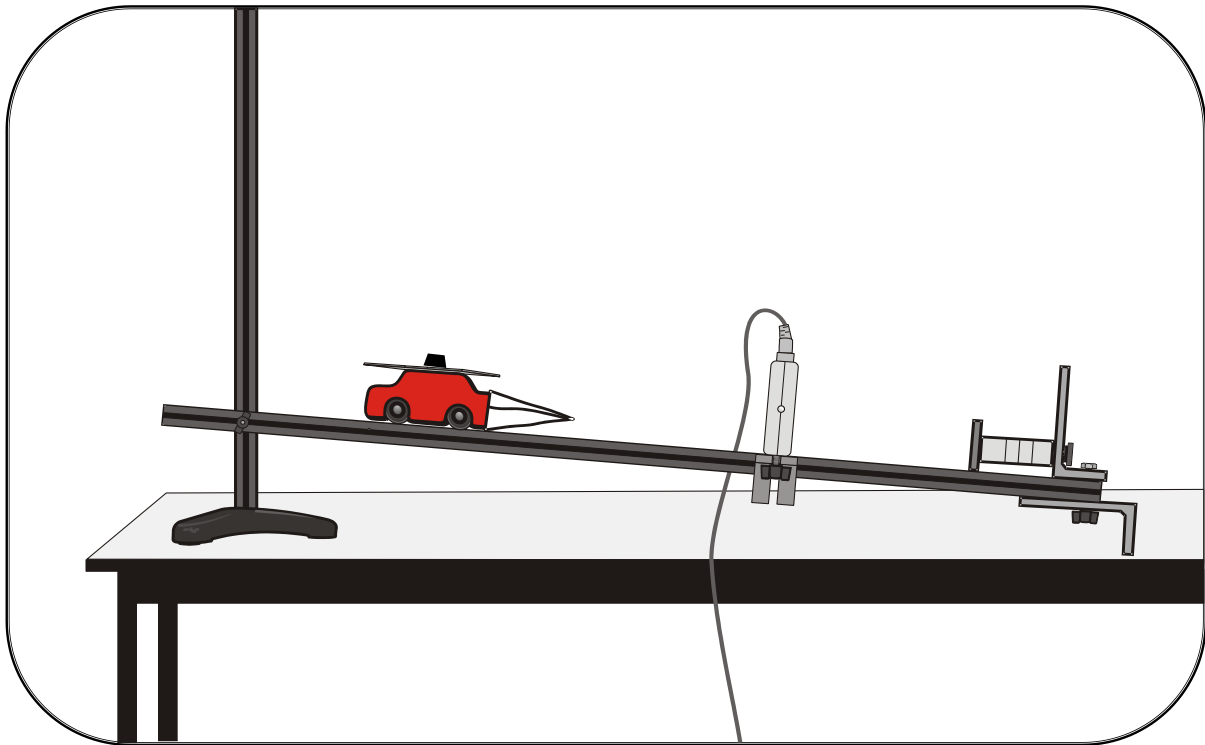
BLT2 x 1



1. Attach a large bracket to the track using a BLT2 bolt and wing nut.
2. Attach the Force sensor to the large bracket using the thumbscrew that is supplied with the Force sensor.



## Collisions: Using a Force sensor and a Light gate to investigate crumple zones

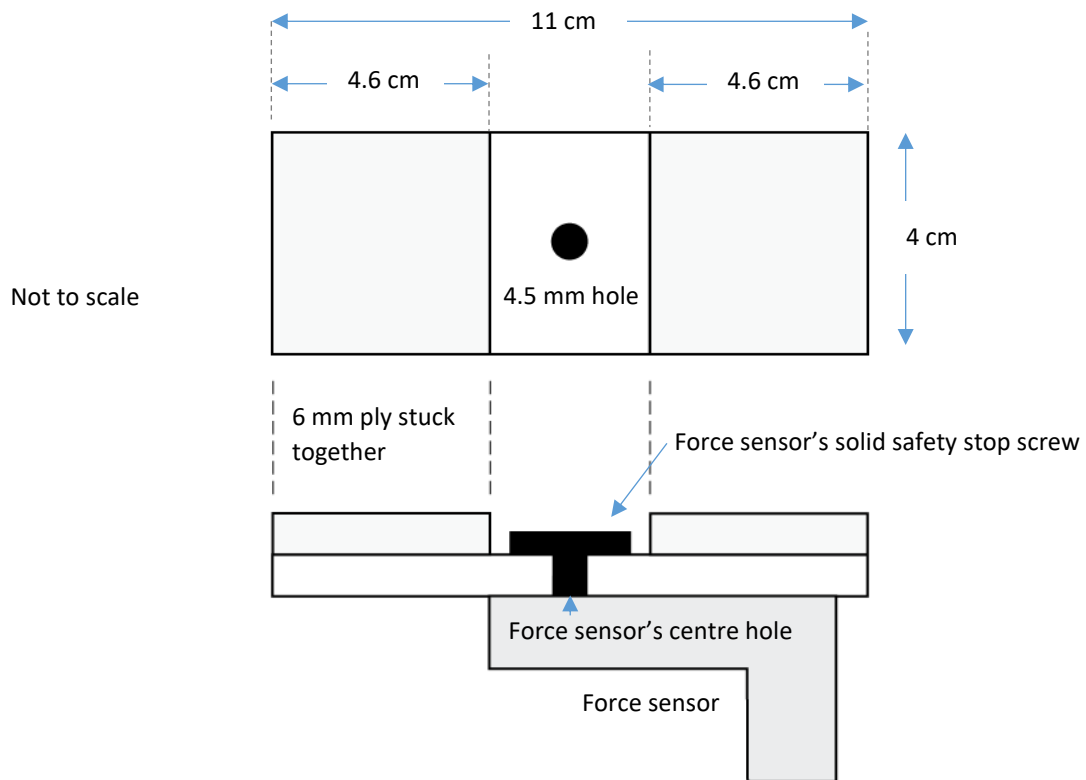


- Make and attach a model crumple zone to the front of the cart. It must be clear of the track when the cart is moving
- Fit the interrupt card to the cart so the single interrupt edge will pass through the Light gate. Measure the mass of the cart and attachments (interrupt card, crumple zone, etc.).
- Attach an extension target to the front of the Force sensor to increase its frontal surface area. See page 61 for a possible design. Attach the Force sensor to a large bracket at the end of the track.
- Connect the Force sensor and Light gate to the EasySense data logger (the Light gate is to be used in analogue mode to measure how long it takes the interrupt card to pass through).
- Arrange the position of the Light gate so that the cart has just passed through the Light gate and is moving at its maximum speed as the impact begins.
- Find by trial and error the best start position and angle of slope (start with the track at the 10 cm mark).
- You must start each experiment from the same position on the track and with the same slope.
- Open the EasySense program and select **Graph**. The suitability of a recording set up will depend on the angle of the slope e.g. with the top edge of the track at the 10 cm mark on the pillar (angle 5°) a suitable set up was:

Time	Interval	Trigger
500 ms	200 $\mu$ s	Light gate rises above 40% with 25% pre-trigger

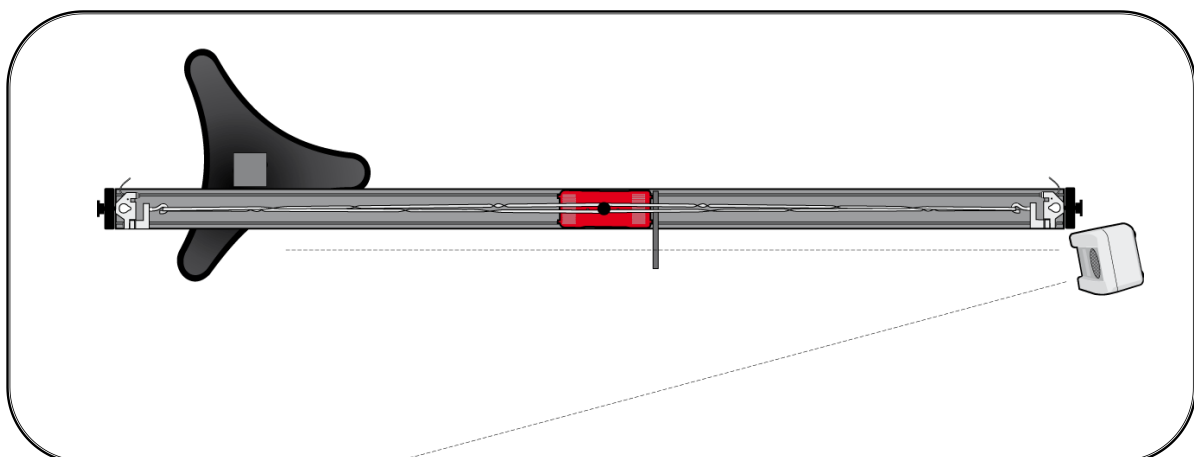
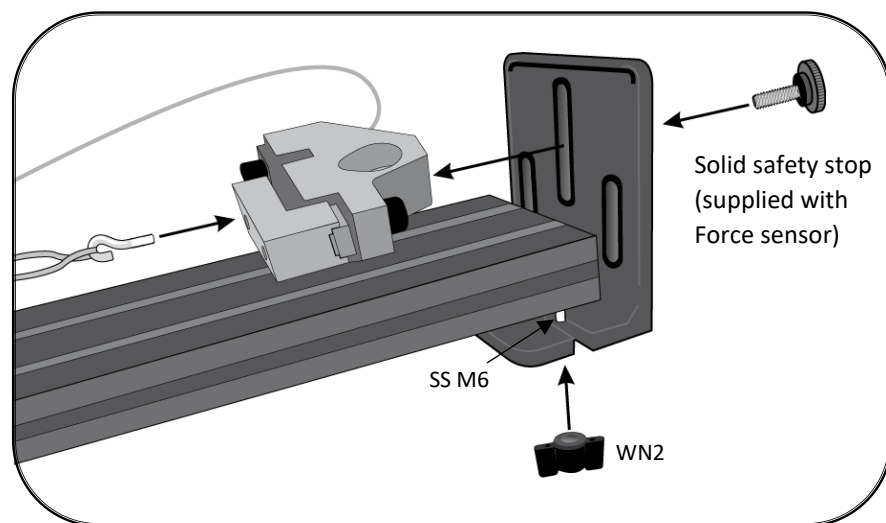
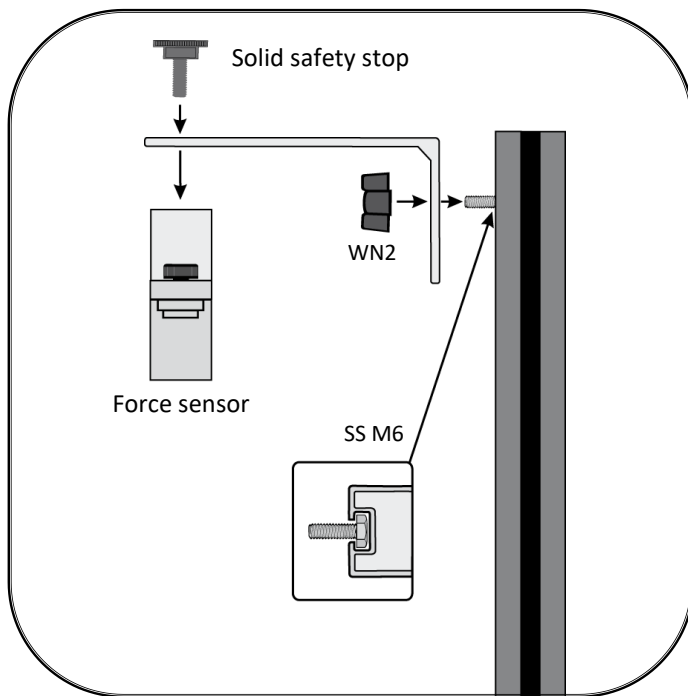
- **Zero** the Force sensor. Select **Start** and release the cart cleanly to run down the track towards the Force sensor.
- Repeat with a variety of different crumple zones.

### Extension target for the Force sensor

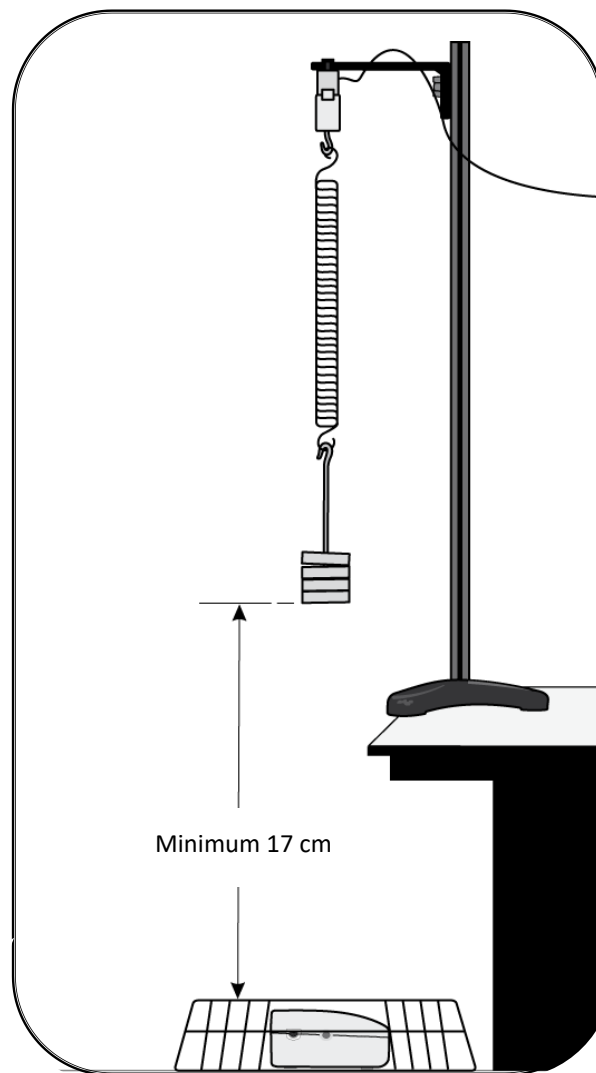


Use Force sensor's safety stop to attach the target to the centre hole in the base of the Force sensor.

## Attaching a Force sensor to the pillar and the track



## Simple Harmonic Motion: Using a spring with a Force and Motion sensor

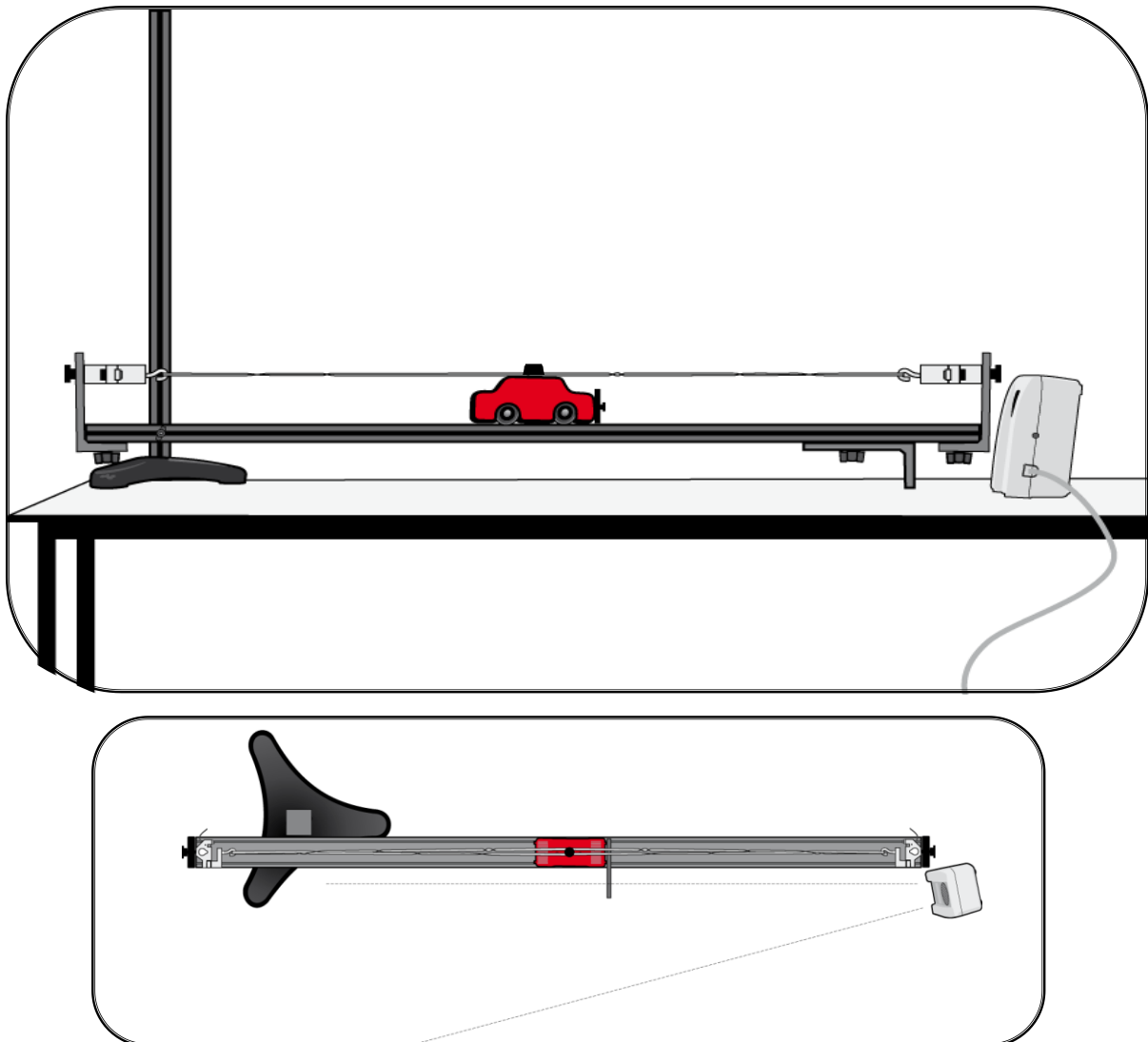


- Weigh both the spring and the suspended mass (added together they are the oscillating mass).
- Make sure that the apparatus is as rigid as possible, if necessary use clamps to secure the base.
- When the mass is stationary it should be about 50 cm from the Motion sensor.
- Connect the Motion and Force sensor to the EasySense data logger. The range of the Motion sensor should be set to Distance.
- Open the EasySense program and select **Graph**. From the wizard select the following:

Time	Interval
5 seconds	20 ms

- Select **Test Mode** and ensure that the Motion sensor will detect the mass throughout its travel.
- With the mass hanging stationary on the spring, **zero** the Force sensor.
- Using amplitude of about 15 – 25 cm, pull the spring downwards and set it oscillating. Check that it is oscillating vertically.
- Select the **Start** icon to begin logging.

## Simple Harmonic Motion: Using elastic with two Force sensors and a Motion sensor and a cart oscillating horizontally



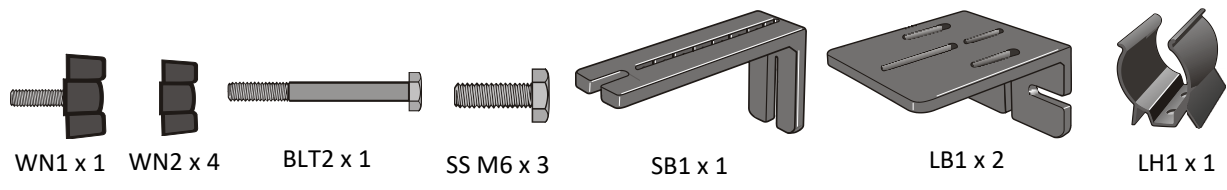
- Assemble the apparatus as shown with the reflector card facing the Motion sensor. Adjust the track to be accurately horizontal. When the cart is stationary, it should be in the middle of the track. Do not use fabric-covered elastic.
- Connect the two Force sensors and the Motion sensor to the EasySense data logger. The range of the Motion sensor should be set to Distance. Angle the Motion sensor about  $12^\circ$  away from the track to prevent interference from the track.
- Open the EasySense program and select **Graph**. From the wizard select the following:

Time	Interval
5 seconds	20 ms

- Select **Test Mode** and without the elastic attached **zero** the Force sensors. Attach the elastic and adjust the tension to give a reading of about 5 N with a period of oscillation of about a second.
- **Zero** the Force sensors while they are under tension.
- Pull the cart to about 80 cm on the scale. Select the **Start** icon to begin logging and set the cart oscillating (it must not get closer than 17 cm to the Motion sensor).



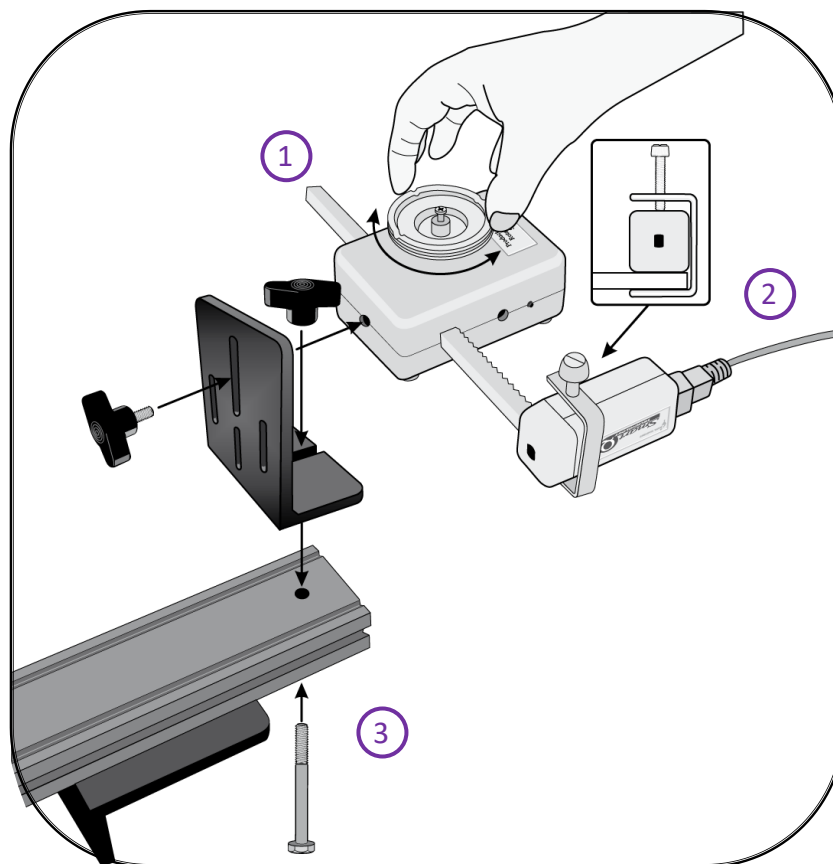
## Attaching a Light sensor to a Rotary Motion sensor and the Laser to a track



### Additional apparatus

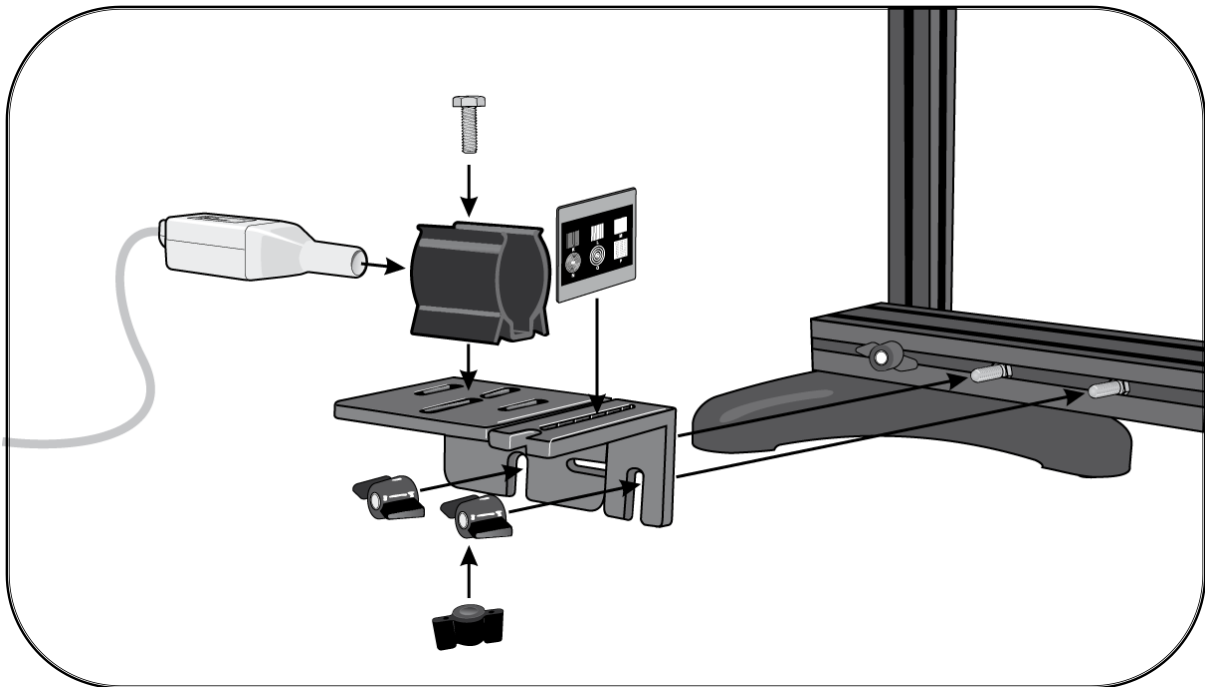
- Rotary Motion sensor set to Linear rack range (*Product code 3280*).
- Rack attachment and miniature c clamp for Rotary Motion sensor (*Product code 3288*).
- Laser and set of slits (*Product 3285*).
- 1000 lx Fast Light sensor (*Product code 3124 or 3288*)

### Attaching a Rotary Motion sensor, Light sensor and Rack attachment



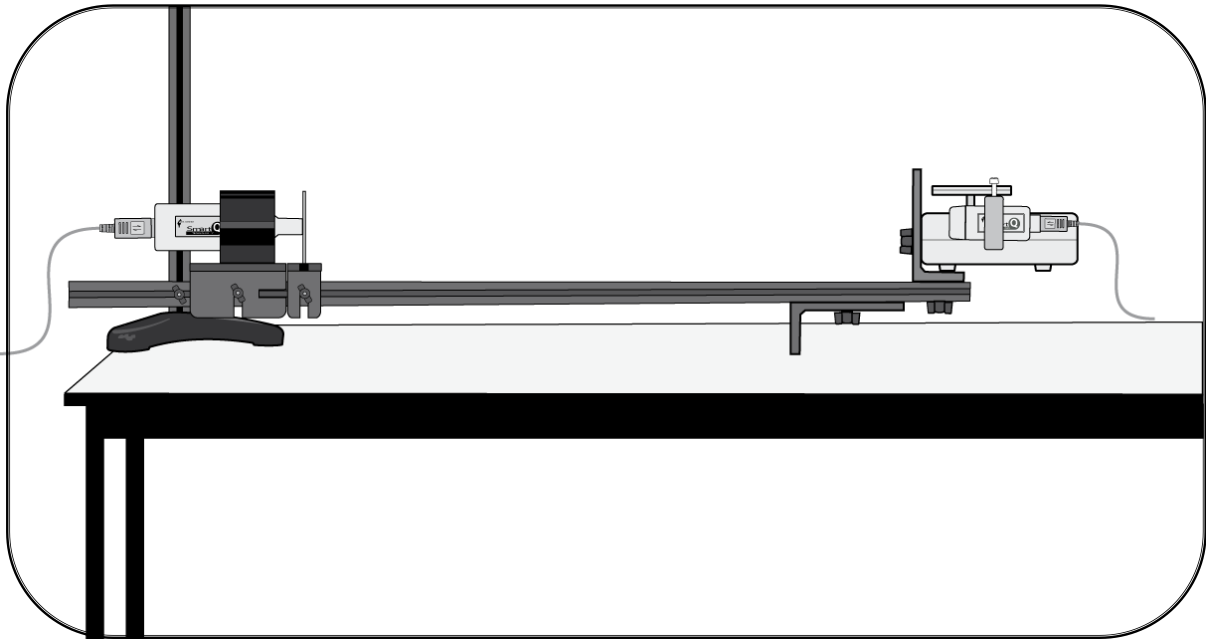
1. Push the linear rack through the Rotary Motion sensor.
2. Place the Light sensor (on its side) on top of the rack. Use the small C clamp to secure the sensor in place
3. Use a long bolt (BLT1) to secure a large bracket to the end of the track.
4. Attach the Rotary Motion sensor to the large bracket using a wing nut screw (WN1).

## Attaching a Laser and slits



1. Slide 2 SS M6 Hex screws into the side groove of the track.
2. Attach a large and thin bracket (thin bracket to the front).
3. Attach a laser module holder to the large bracket; fit a diffraction slide into the slot on top of thin bracket.
4. Align the laser beam to strike the Light sensor's sensing element (adjustments can be made at laser end and at the Rotary Motion sensor end of apparatus).

## Interference of light investigations (Young's slit)



**When using laser light all safety precautions must be followed. If there is any doubt check with your instructor.**

- Assemble the apparatus as shown. Mount the Light sensor so the sensing window is at right angles to the rack attachment.
- Turn the laser on. Look from behind the laser and make sure the laser light lines up with the Light sensor as it is moved along by the rack. Adjust as needed – remember not to look directly at the laser beam.
- Connect the Rotary Motion sensor, the Light level sensor and the Laser to the EasySense data logger. The range of the Rotary Motion sensor should be set to Linear rack.
- Open the EasySense program and select **Graph**. From the wizard select the following:

Time	Interval
10 seconds	5 ms

- Move the Light sensor so it is next to the Rotary Motion sensor. Press the **zero** button on the Rotary Motion sensor.
- Select the **Start** icon and move the Light sensor across the diffraction pattern and back. If necessary, hold the Light sensor in the lasers light path.

Tip: Use the pulley wheel of the RMS to move the rack smoothly.

- Select Options, X-Axis and select **Channel** as the X-Axis. Plot the results with Light on the X-axis and Distance on the Y-axis. The data collected can be used to find the wavelength of the laser, the slit width or the distance from the slit to the sensor. Refer to documentation that came with the laser for extra information.