

# DATA HARVEST — Dynamics System



## Introduction

The Data Harvest Dynamics System (*Product code 3800*) will grow with the physics departments 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 Sensor accessories***

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

**Rotary Motion Sensor** (*Product code 3280*).

**Rotary Motion Accessory Pack** (*Product code 3288*).

**Motion Sensor** (*Product code 3705*).

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

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

### **Accessories**

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

**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 7 and 8.

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

1. Dropping the cart from a height can potentially damage the wheels and axles.
2. 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.
3. Do not let the cart drop off the end of the track. A stop can be made using a small bracket (SB1) across the track, see page 8

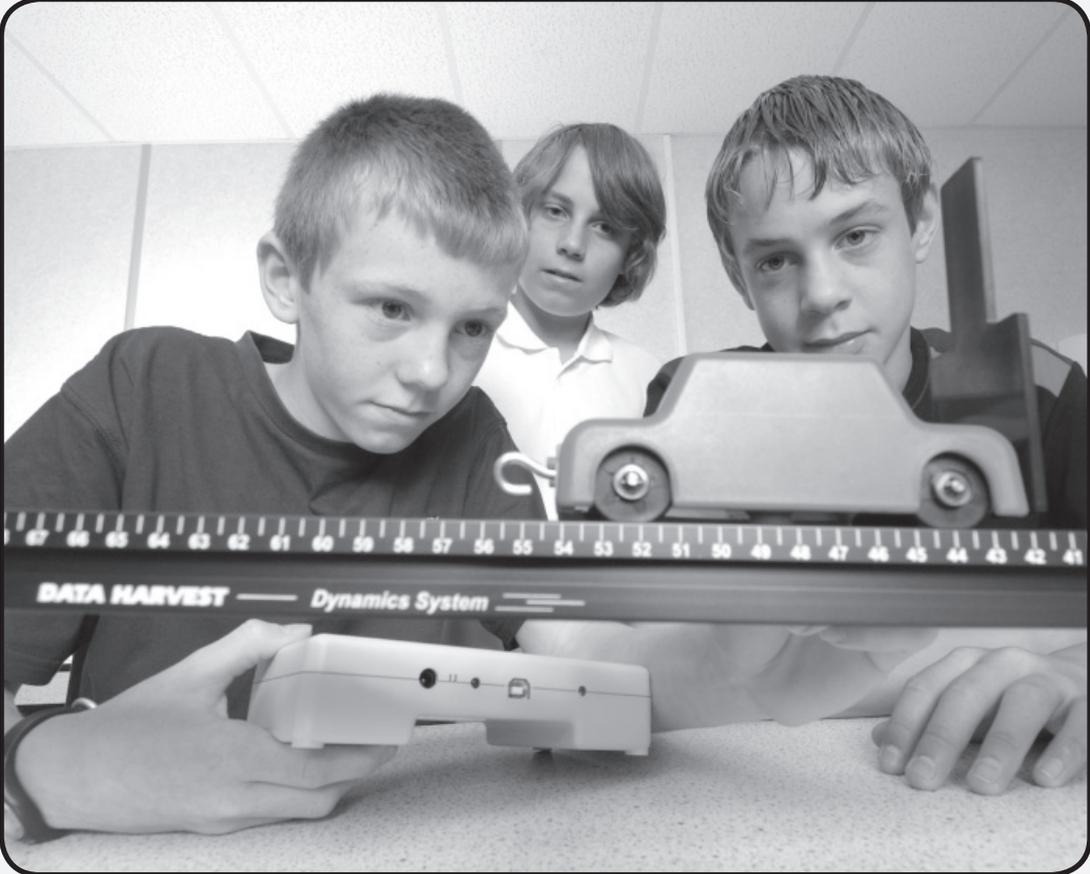
# Contents

	Page
<b>PART ONE .....</b>	<b>1</b>
<b>Component identification - No1 .....</b>	<b>2</b>
<b>Component identification - No2 .....</b>	<b>3</b>
<b>Assembling the pillar and track .....</b>	<b>4</b>
<b>Using the height scale to estimate the angle of the track .....</b>	<b>6</b>
<b>Crash box assembly.....</b>	<b>7</b>
<b>Crash barrier assembly.....</b>	<b>8</b>
<b>Attaching a Light Gate to the track.....</b>	<b>9</b>
<b>Attaching an interrupt card to the cart.....</b>	<b>10</b>
Motion: Using Light Gates on a slope to measure speed or acceleration .....	11
<b>Attaching a Motion Sensor to the bottom of the track .....</b>	<b>13</b>
<b>Attaching a Motion Sensor to the top of the track .....</b>	<b>14</b>
<b>Attaching the end reflector to a cart for use with a Motion Sensor .....</b>	<b>15</b>
Motion: Measuring motion up and down a slope using a Motion Sensor .....	16
<b>Attaching a Rotary Motion Sensor to the bottom of the track .....</b>	<b>17</b>
Motion: Measuring motion up and down a slope using a Rotary Motion Sensor .....	18
<b>Attaching a Light Gate with Spoked Pulley to the track .....</b>	<b>19</b>
Motion: Using a Light Gate and Spoked Pulley .....	20
<b>Attaching a Light Gate to the support pillar .....</b>	<b>21</b>
Gravity: Using a single Light Gate to measure g .....	22
Gravity: Using a single Light Gate to measure g, by logging the velocity after falling a known distance (d) .....	23
<b>Attaching 2 Light Gates to the support pillar .....</b>	<b>24</b>
Gravity: Using two Light Gates to measure g .....	25
<b>Attaching a Motion Sensor to the support pillar .....</b>	<b>26</b>
Gravity: Using a Motion Sensor to measure g by free fall .....	27
Gravity: Using a Light Gate and 'picket fence' to measure g.....	28
Gravity: Using a Motion Sensor with a rolling cart to measure diluted gravity .....	29

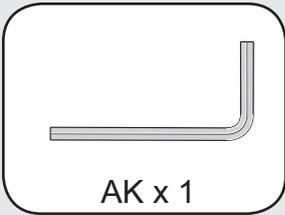
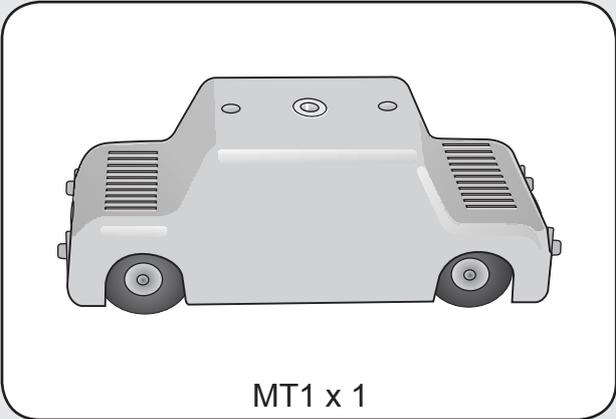
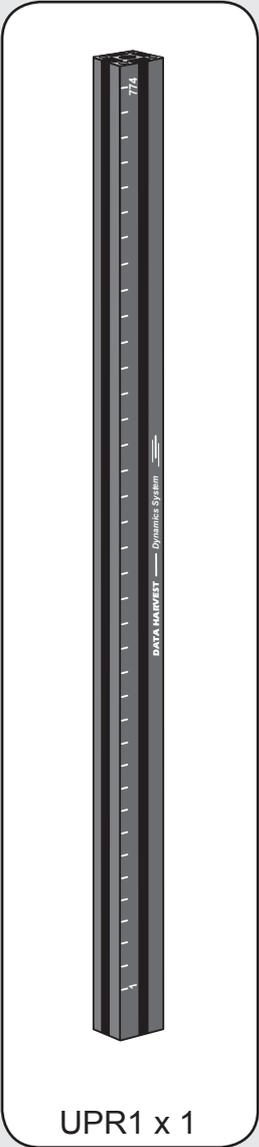
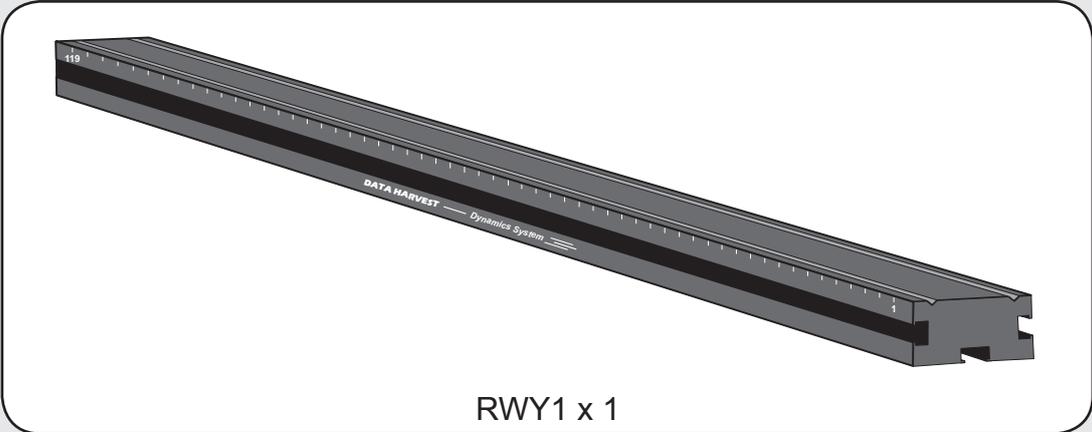
<b>Attaching a Light Gate to the track</b> .....	<b>30</b>
Forces: Motion with balanced forces .....	31
<b>Attaching a Spoked Pulley to the track</b> .....	<b>32</b>
Forces: Using two Light Gates to investigate forces e.g. Newton's 2 <sup>nd</sup> Law .....	33
Forces: Using a Motion Sensor to investigate forces e.g. Newton's 2 <sup>nd</sup> Law .....	34
Forces: Using a Rotary Motion Sensor to investigate forces .....	35
<b>Attaching a Light Gate and Spoked Pulley to the pillar</b> .....	<b>36</b>
Forces: Using a Light Gate and Spoked Pulley to investigate Newton's 2 <sup>nd</sup> Law (Atwood's Machine) .....	37
<b>Attaching a thin bracket to the cart</b> .....	<b>38</b>
Forces: Using a Force Sensor to investigate static and dynamic friction.....	40
<b>Attaching a Rotary Motion Sensor to the pillar</b> .....	<b>40</b>
Pendulum: Using a Rotary Motion Sensor for simple pendulum investigations.....	41
<b>PART TWO: Using Extension Kit 1</b> .....	<b>42</b>
<b>Component identification for Kit 1 - No1</b> .....	<b>43</b>
<b>Component identification for Kit 1 - No2</b> .....	<b>44</b>
Using the mass retainer (MR2) .....	45
Motion: Using the spring to roll a cart up a slope .....	46
Pendulum: Using a Light Gate and a simple pendulum .....	47
<b>Preparing carts for collision experiments</b> .....	<b>48</b>
Collisions: Using two Motion Sensors with magnets .....	49
Collisions: Using two Motion Sensors with springs .....	51
Collisions: Using two Light Gates with magnets.....	52
<b>Attaching end reflectors and a Force Sensor to a cart</b> .....	<b>53</b>
Collisions: Using two Motion Sensors and a Force Sensor.....	54
<b>Attaching a Force Sensor to the end of the track</b> .....	<b>55</b>
Collisions: Using a Force Sensor and a Light Gate.....	56
Collisions: Using a Force Sensor and a Light Gate to investigate crumple zones.....	57
<b>Attaching a Force Sensor to the pillar and the track</b> .....	<b>59</b>
Simple Harmonic Motion: Using a spring with a Force and Motion Sensor .....	60
Simple Harmonic Motion: Using elastic with two Force Sensors and a Motion Sensor and a cart oscillating horizontally .....	61
<b>Attaching a Light Sensor to a Rotary Motion Sensor and the Laser to a track</b> .....	<b>62</b>
Interference of light investigations (Young's slit) .....	64

PART ONE

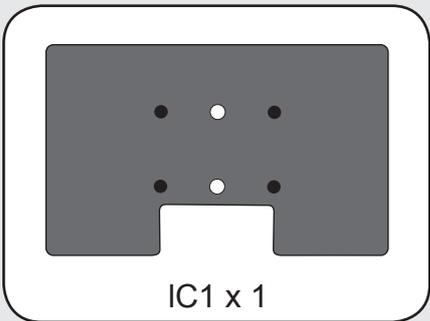
**DATA HARVEST** — *Dynamics System* —



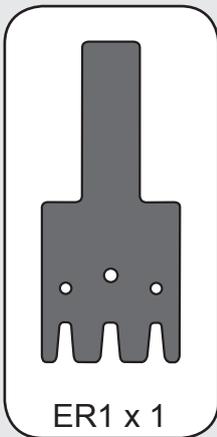
# Component identification - No1



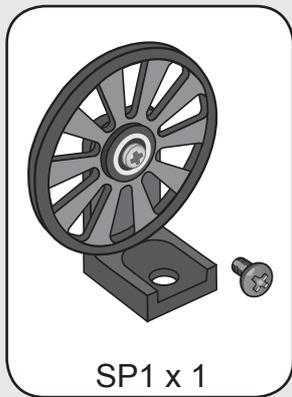
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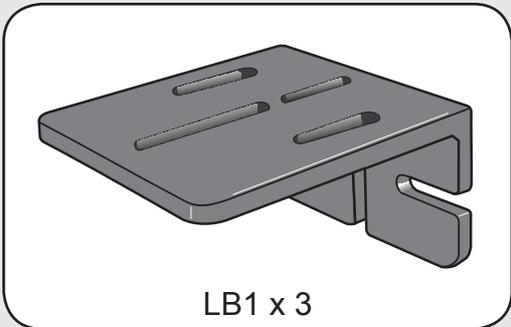
IC1 x 1



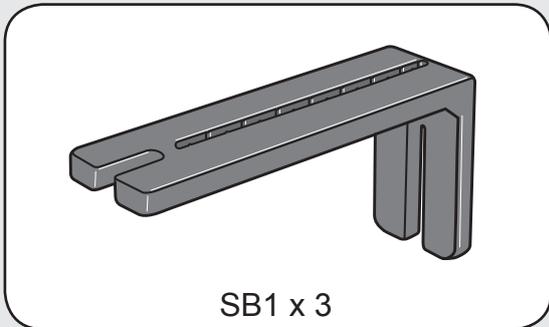
ER1 x 1



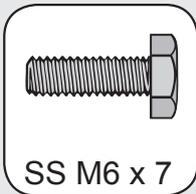
SP1 x 1



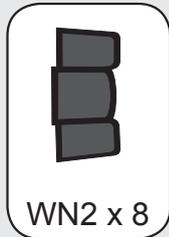
LB1 x 3



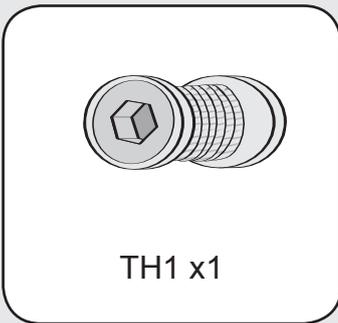
SB1 x 3



SS M6 x 7



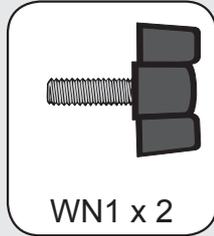
WN2 x 8



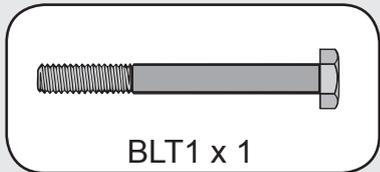
TH1 x 1



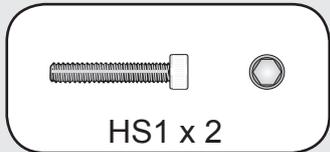
TS1 x 3  
(M4 thread)



WN1 x 2

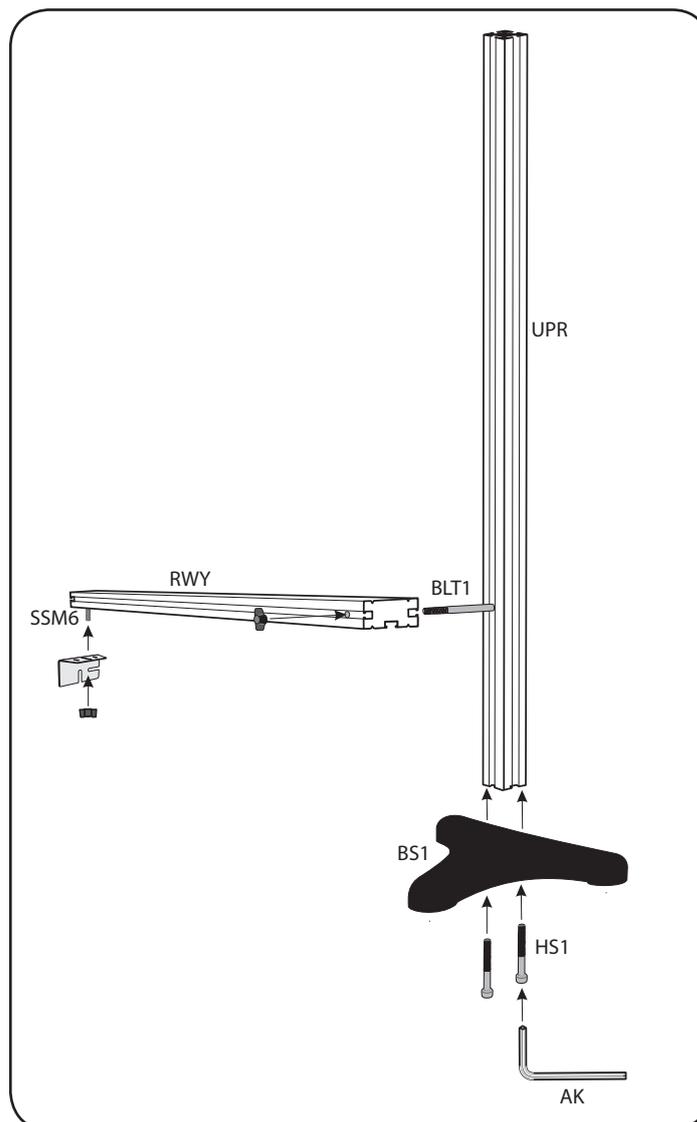
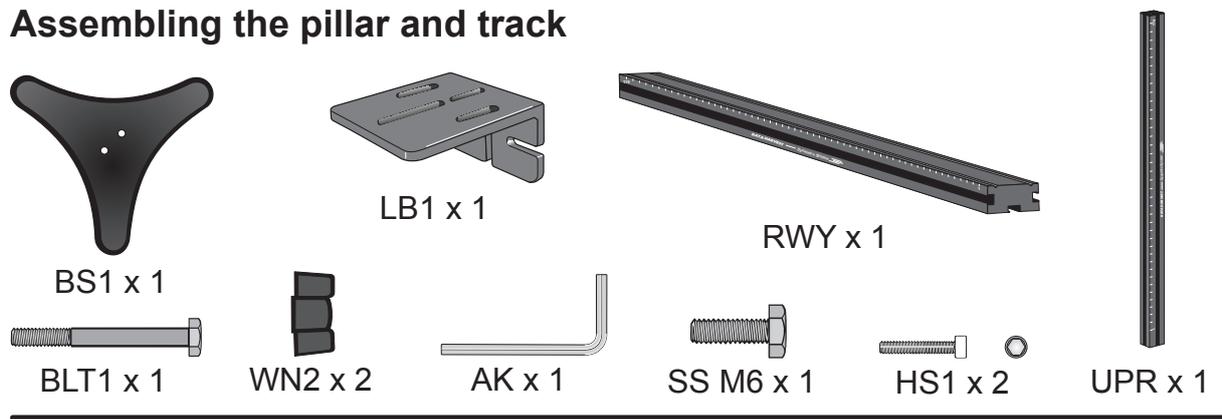


BLT1 x 1

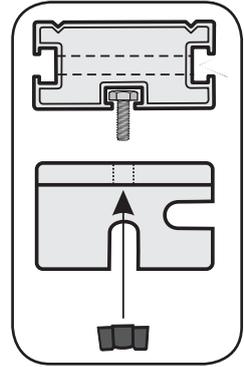
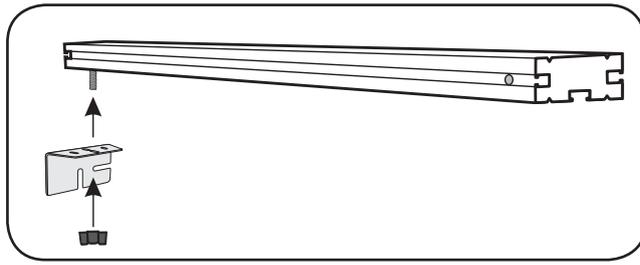


HS1 x 2

## Assembling the pillar and track

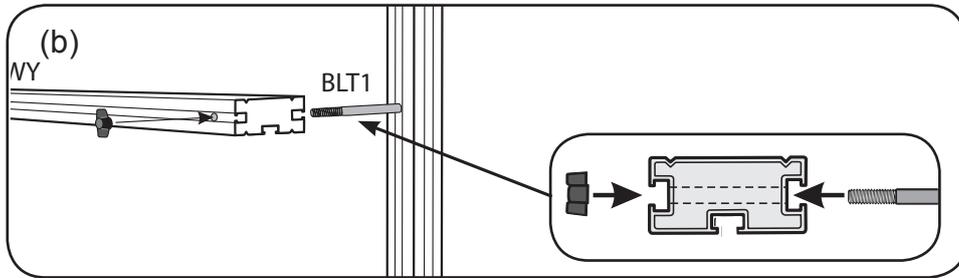
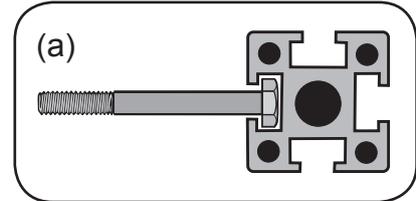


1. **Connect the pillar to the base:** Identify the threaded holes in the pillar (at 0 cm end) and screw the hex screw (HS1) through the base into one of the threaded holes. Repeat for second screw. Use the Allen key supplied to tighten - DO NOT OVERTIGHTEN.
2. **Attach the large bracket to the end of the track:**
  - a. Align the short hex headed screw (SS M6) in the centre groove of the under surface of the track.
  - b. Locate the screw to the center slot in the larger surface of the bracket (LB1).
  - c. Use a white wing nut (WN2) to tighten the bracket to the track



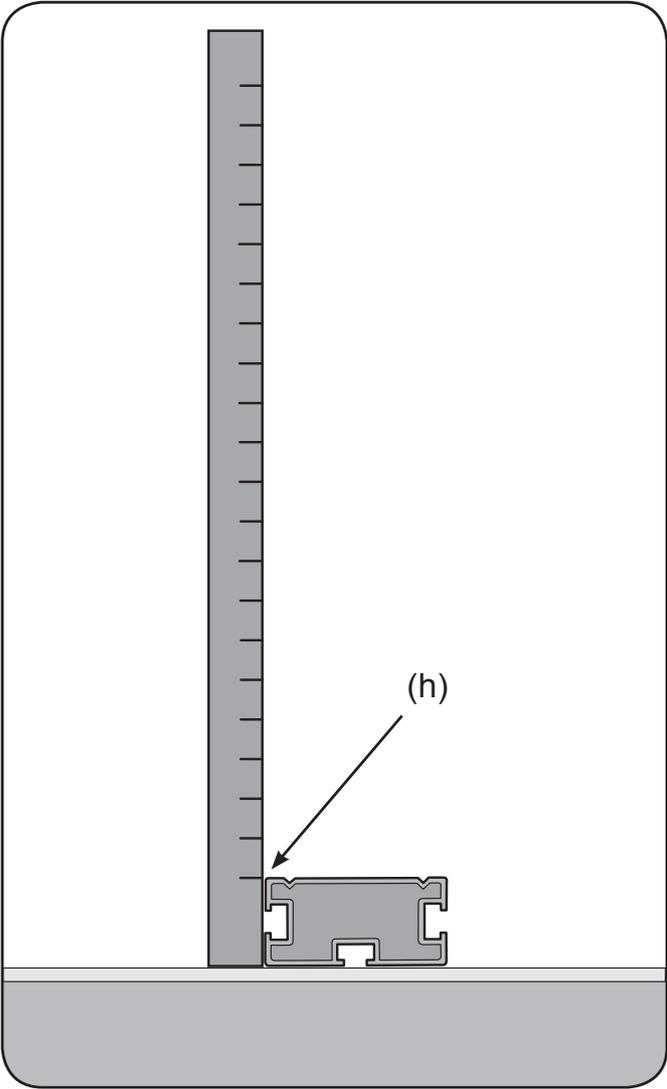
**3. Attach the track to the pillar:**

- 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 white 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 / 2 equals the angle of the track, when the end of the track is supported by the large bracket.

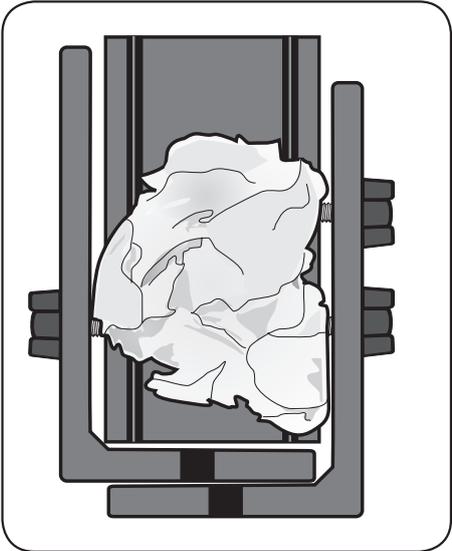
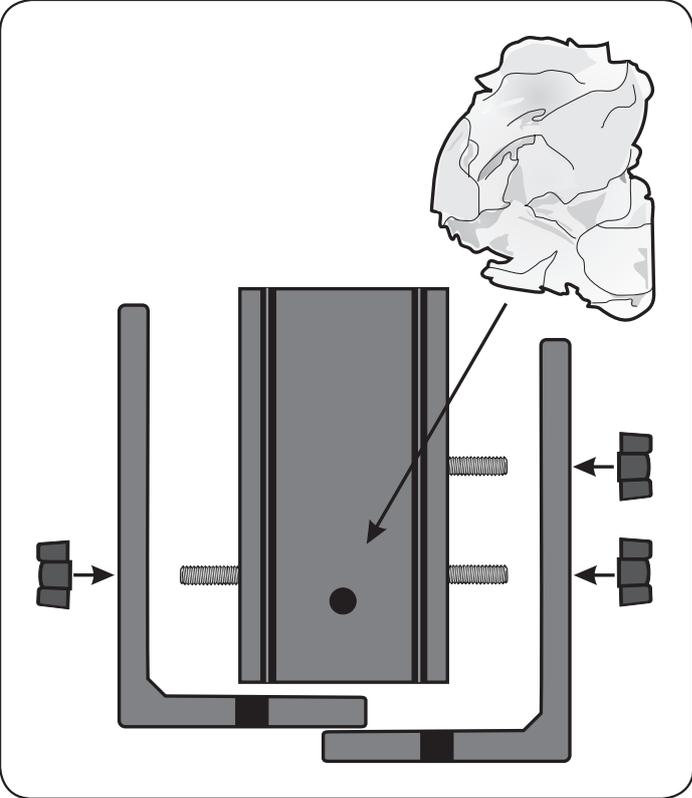
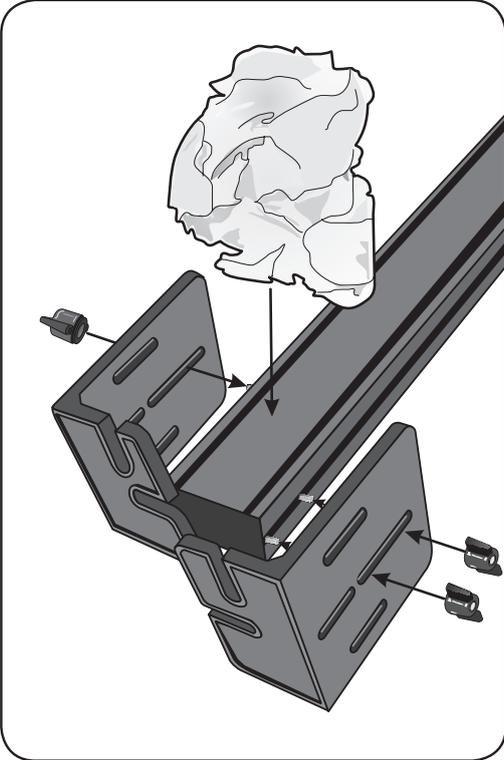


Height (h) cm	Angle Degrees
0	0
10	5
20	10
30	15
40	20

$$\left( \text{Angle} = \frac{\text{Height (h)}}{2} \right)$$

### Crash box assembly

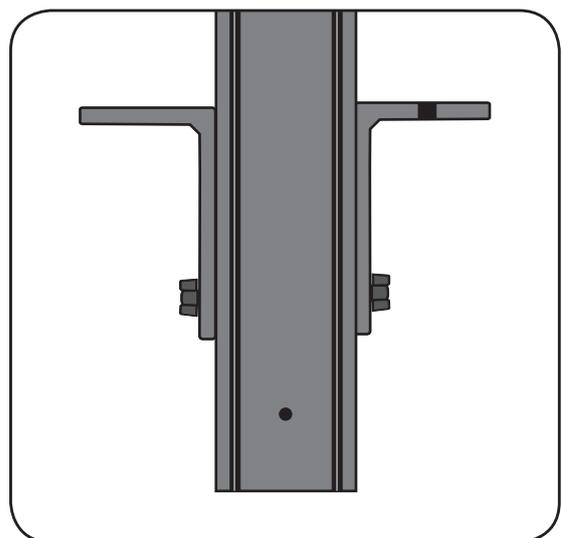
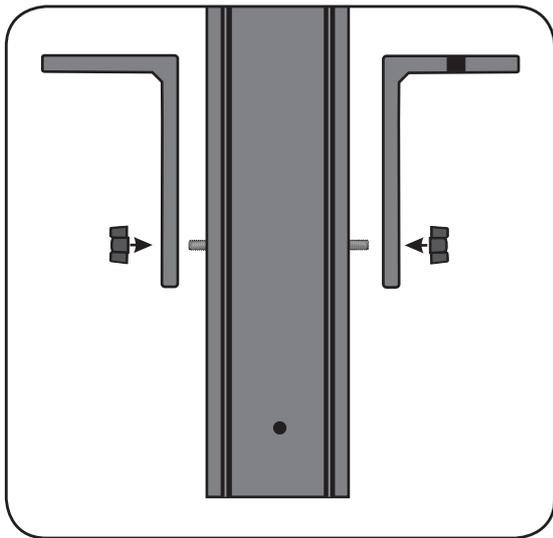
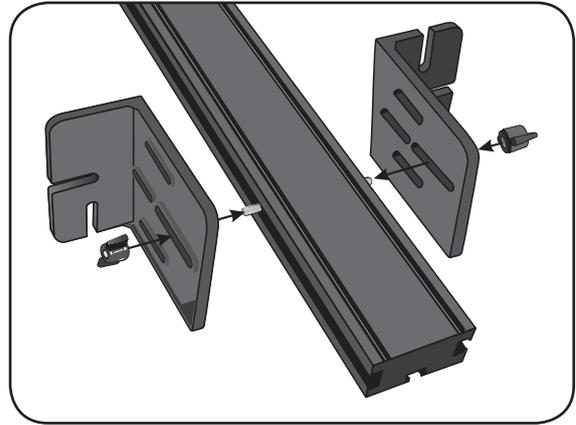
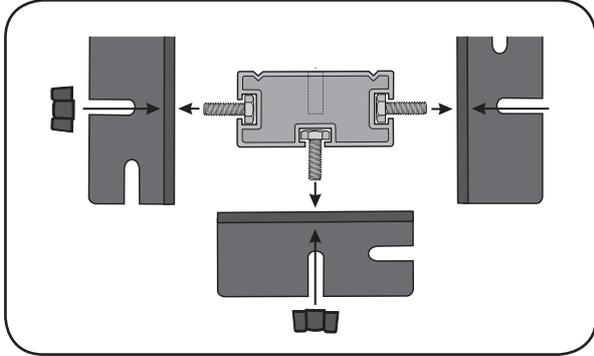
To stop a cart at the end of the track, when using high track angles or carts traveling with high speed.



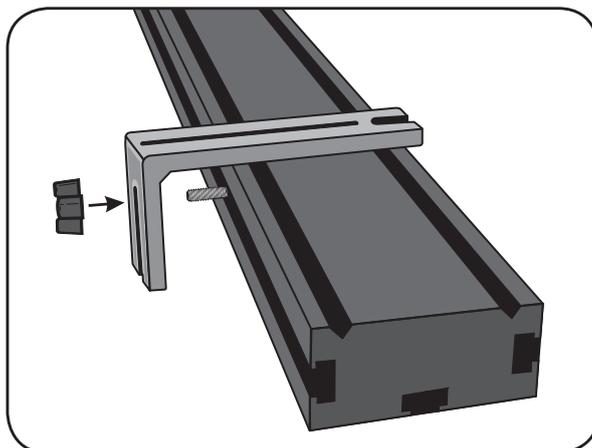
Crumpled paper absorbs the forward motion of the cart

## Crash barrier assembly

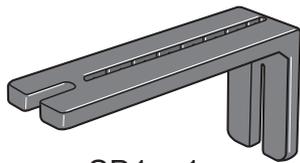
Placing a side barrier at any position on the track, to stop the cart jumping tracks with speed, or after a collision.



Place a small bracket across the track to act as a stop bar



## Attaching a Light Gate to the track



SB1 x 1



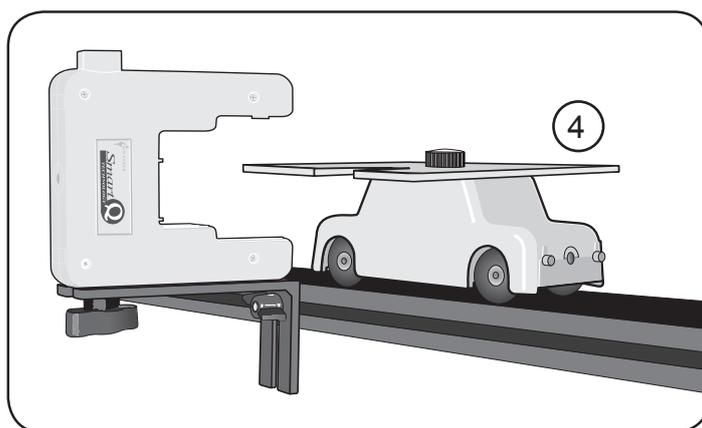
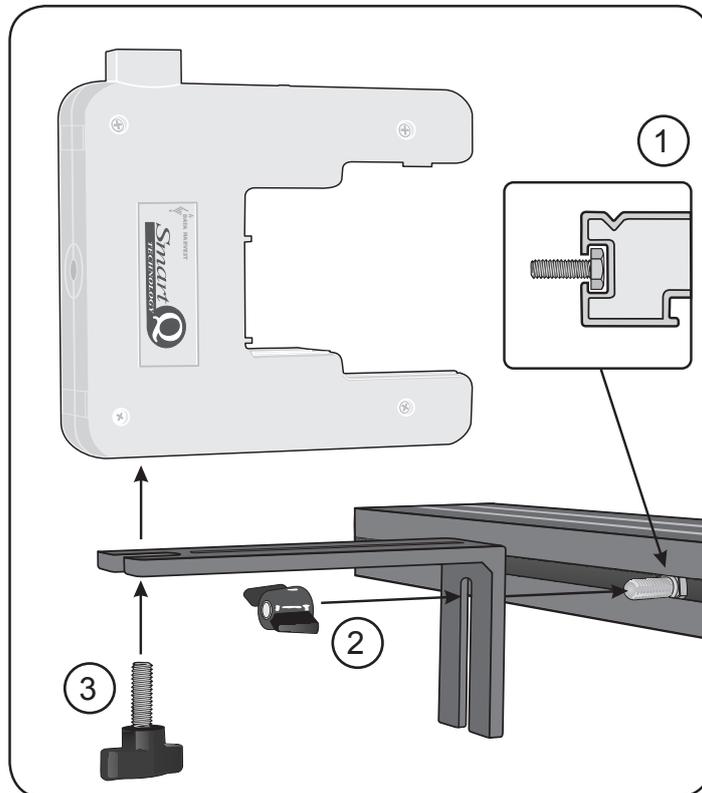
WN1 x 1



SS M6 x 1

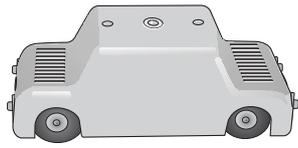


WN2 x 1

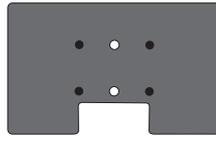


1. Slide a short hex headed screw (SS M6) into the slot on the side of the track. Align the slot on the shorter end of the thin bracket over the screw thread.
2. Secure the bracket using a wing nut (WN2).
3. Attach the Light Gate using wing bolt (WN1).
4. Attach an interrupt card to the cart (see page 10) and check the interrupt card passes through the Light Gate.

## Attaching an interrupt card to the cart



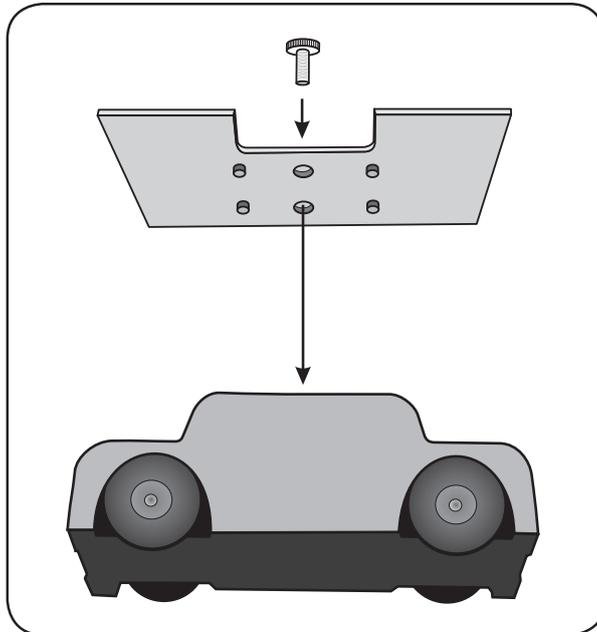
MT1 x 1



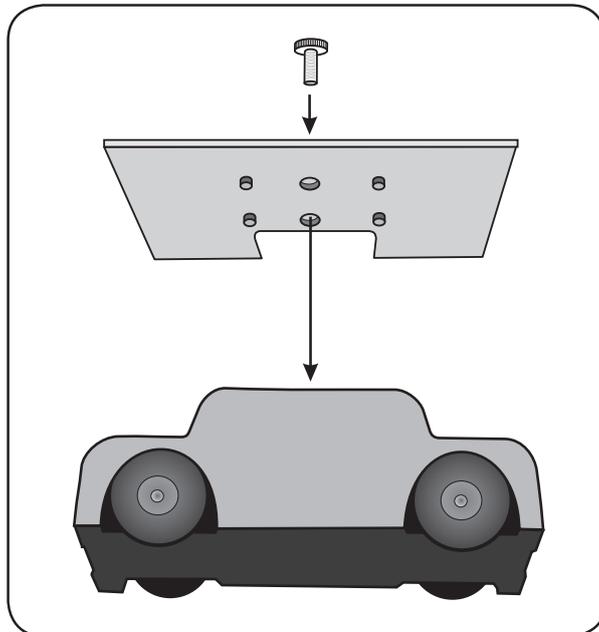
IC1 x 1



TS1 x 1



a) Attaching card for use as a double interrupt



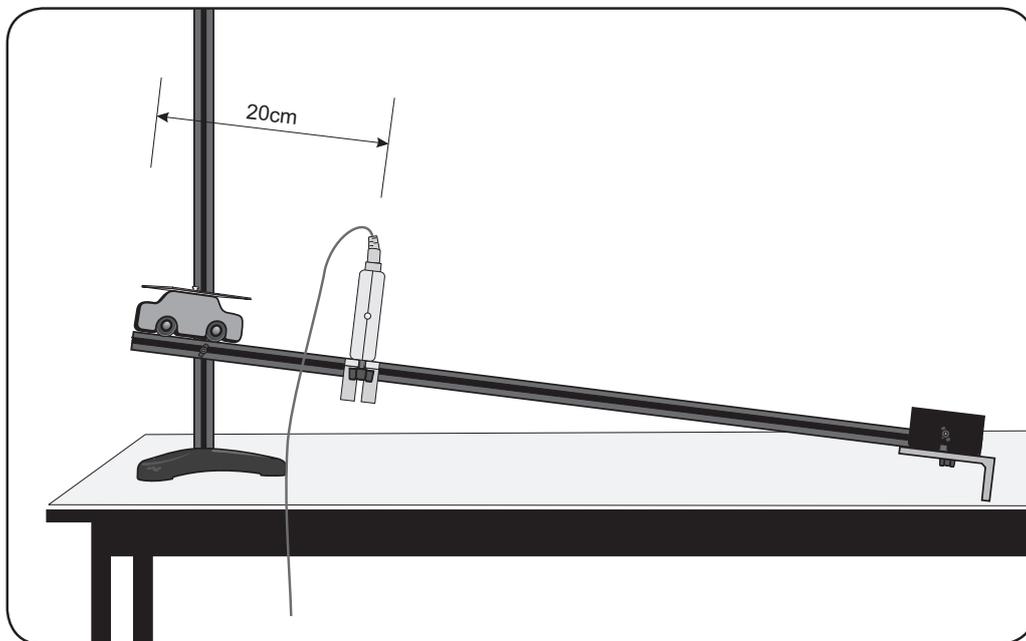
b) Attached card for use as a single interrupt

- 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.

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

### ***Measuring speed with one Light Gate***

1. 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 7) at the bottom of the track.
2. Position a Light Gate approximately 20 cm from the top of the track and connect to input A on the **EASYSense** logger.
3. Fit the interrupt card to the cart so the single interrupt edge will pass through the Light Gate.
4. Open the **EASYSense** program and select **Timing** from the **Home page**. From the wizard select to record **Speed at A** with a single interrupt card, and enter the length of the card as 120 mm.
5. Click on the **Start** icon to begin. Position the cart in the start position at the top of the track and release the cart.

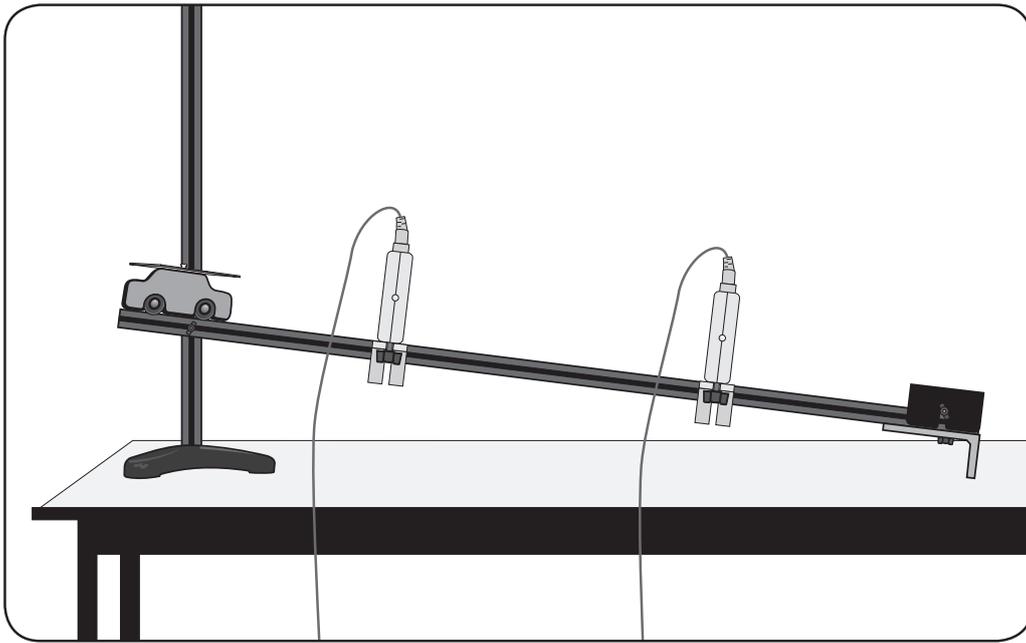


6. Adjust the track to a new height / angle, and repeat using the same start position each time.

### ***Measuring acceleration with one Light Gate***

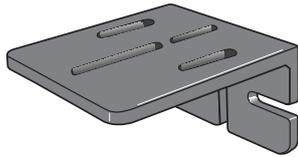
1. Fit the interrupt card to the cart so the double interrupt edge will pass through the Light Gate.
2. From the **Timing** wizard select to record **Acceleration at A** with a double interrupt card, and enter the length of the interrupt card segment as 40 mm.
3. Proceed as before.

## Measuring speed with two Light Gates



1. Fit the interrupt card to the cart so the single interrupt edge will pass through the Light Gates.
2. Position a Light Gate approximately 20 cm from the top of the track and connect to input A on the **EASYSense** 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 stop buffer or the end of the track
3. From the **Timing** wizard select to record **Speed from A to B**, and enter the distance between the two Light Gates.
4. Proceed as before.

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



LB1 x 1



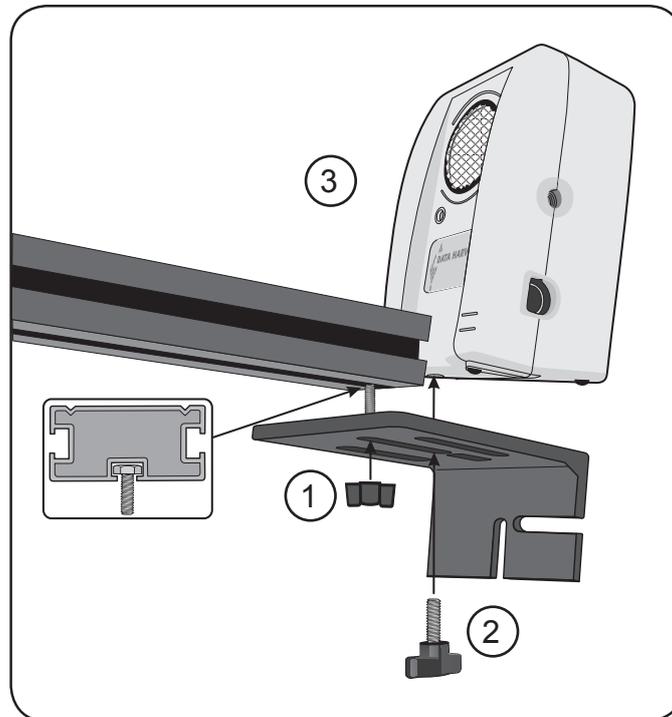
WN1 x 1



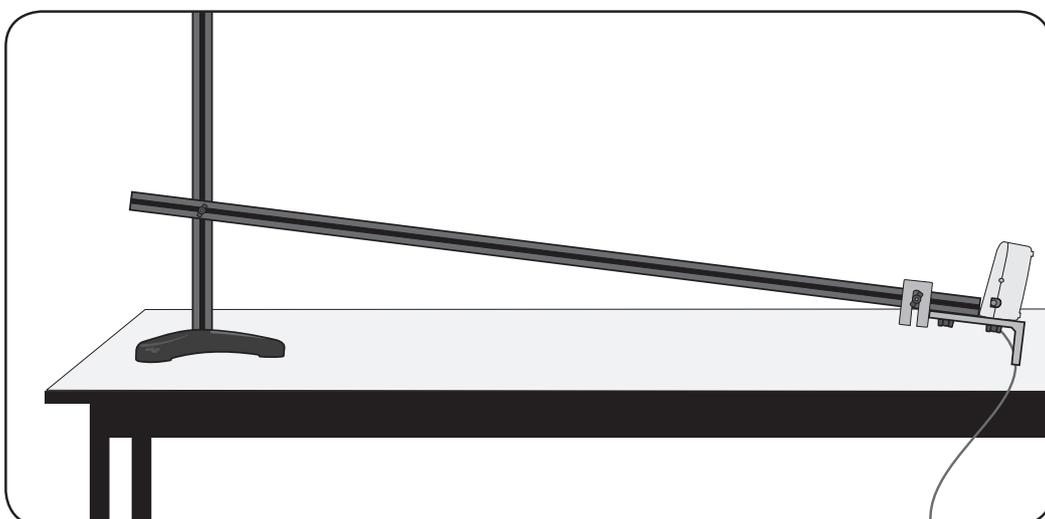
WN2 x 1



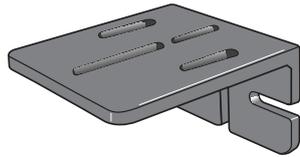
SS M6 x 1



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 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 8).



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



LB1 x 1



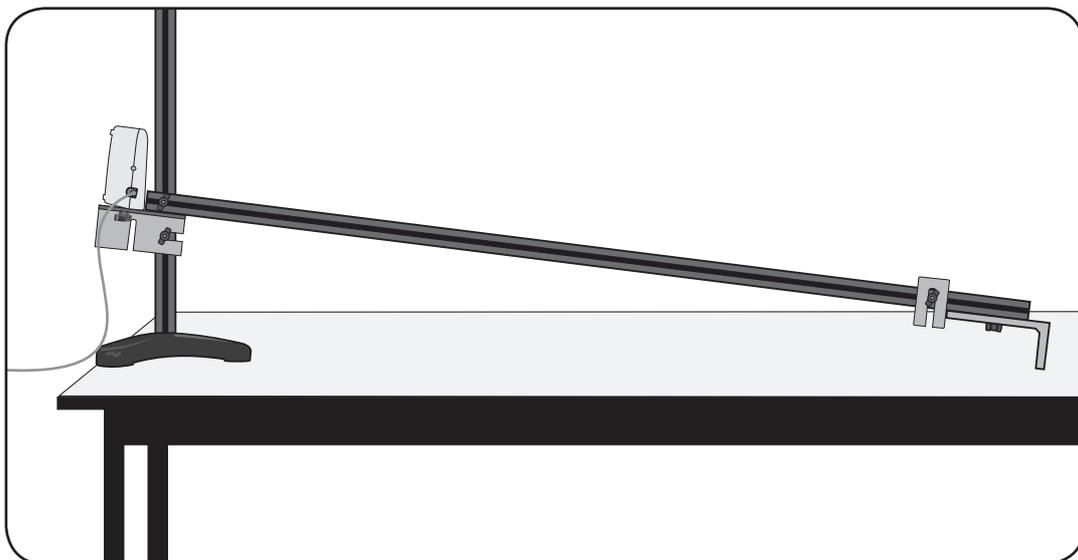
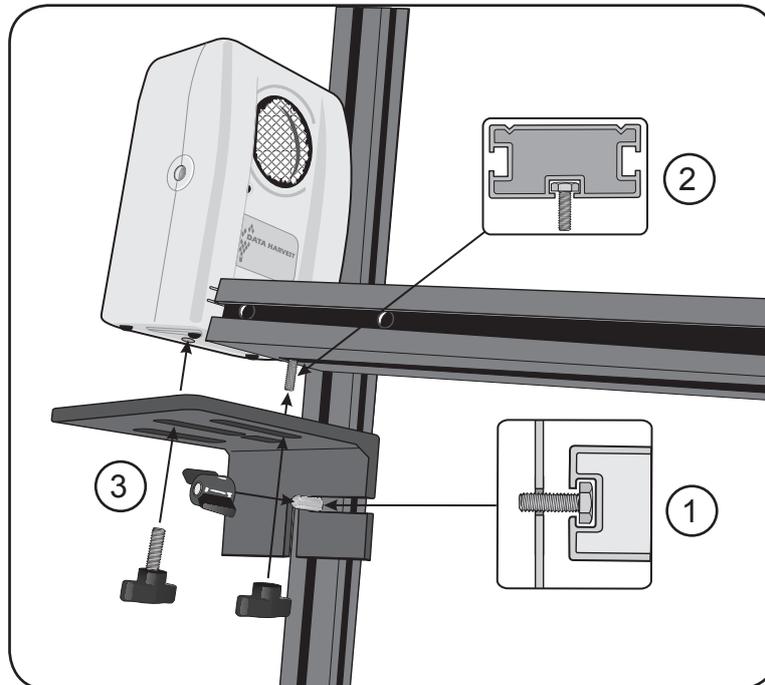
WN1 x 1



WN2 x 2

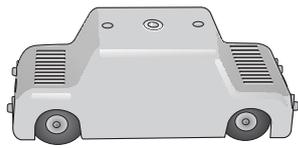


SS M6 x 2



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 nut to attach the track to the bracket. Adjust the position to give enough space for the Motion Sensor.
3. Insert a WN1 wing 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



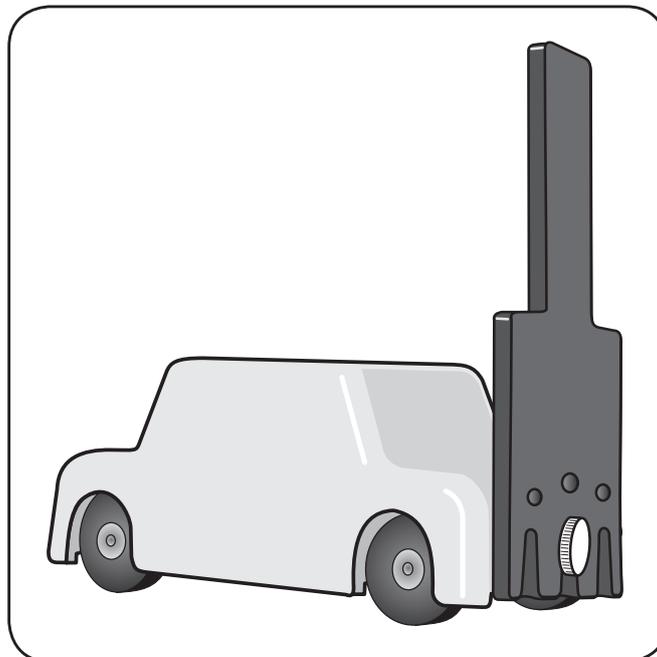
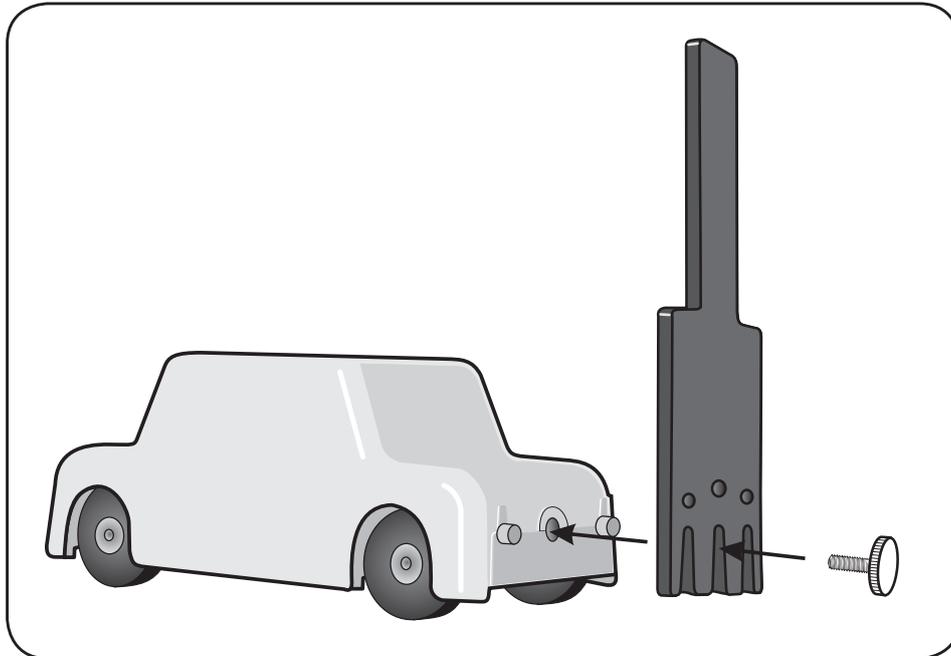
MT1 x 1



TS1 x 1

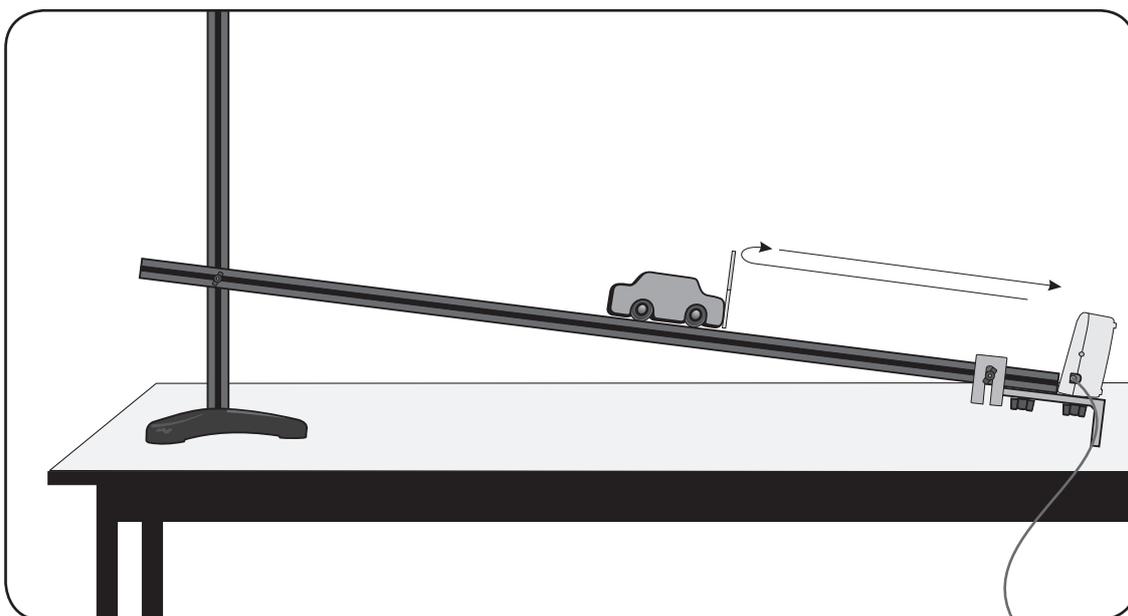


IC1 x 1



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

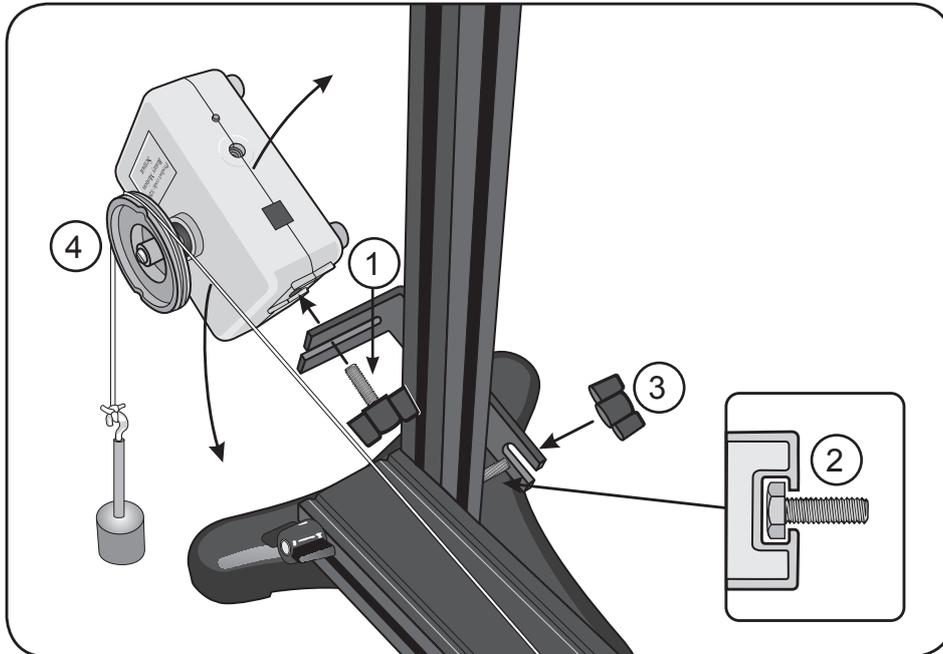
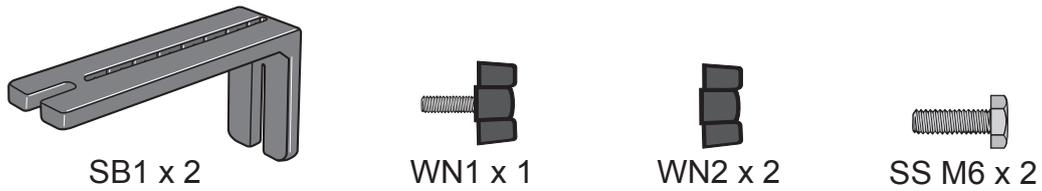


1. Position a Motion Sensor at the bottom of the track and connect to input 1 on an **EASYSense** logger. The range of the Motion Sensor should be set to Distance in metres.
2. Position the top edge of the track at the 10 cm mark on the vertical pillar to give an angle of about  $5^\circ$ . A crash barrier 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 small bracket across the track in front of the Motion Sensor and be prepared to catch the cart by hand when it reaches the end.
3. Fit the reflector card to the end of the dynamics cart.
4. Open the **EASYSense** program and select **Graph** from the Home page. From the wizard select the following:

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

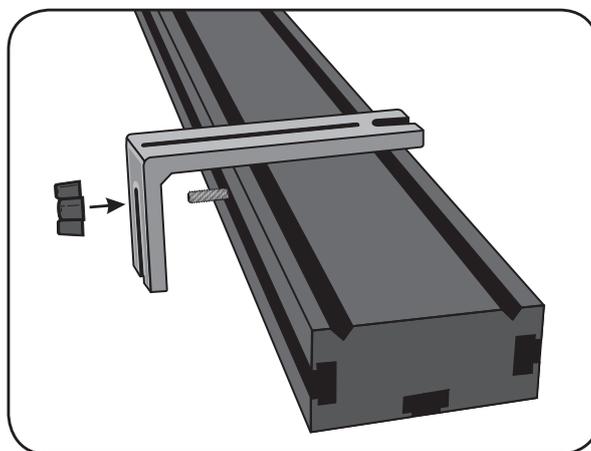
5. Place the cart about 10 cm in front of the Motion Sensor.
6. Click on the **Start** icon.
7. Give the cart a sharp, but gentle push up the track so it travels up about  $\frac{2}{3}$  rds of the way up. Let it run up the track and return – try to stop it just before it reaches the Motion Sensor.
8.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

## Attaching a Rotary Motion Sensor to the bottom of the track



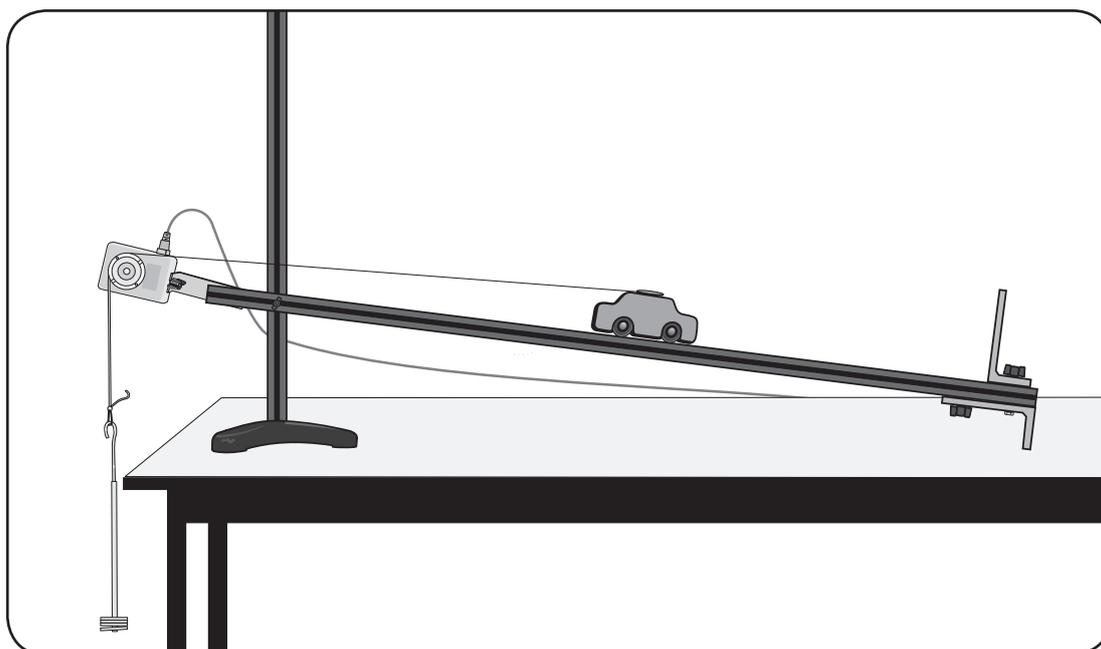
### Attaching a Rotary Motion Sensor

1. Attach a Rotary Motion Sensor to the short arm of a thin bracket using a WN1 wing bolt.
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 thread from the cart over the pulley wheel (loosen the WN1 wing bolt 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.



### Attaching the small bracket as a stop

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



1. Position a Rotary Motion Sensor at the top of the track and connect to input 1 on an **EASYSense** logger. The range of the Sensor should be set to Pulley 49 mm.
2. Position the track at the 10 cm mark on the vertical pillar to give an angle of about  $5^\circ$ .
3. Fix the TS1 thumbscrew to the top of the cart. Cut a piece of thread 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.
4. Open the **EASYSense** program and select **Graph** from the Home page. From the wizard select the following:

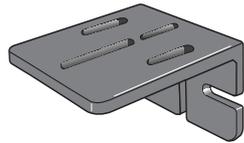
Time	Interval
10 seconds	20 ms

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

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



SP1 x 1



LB1 x 1



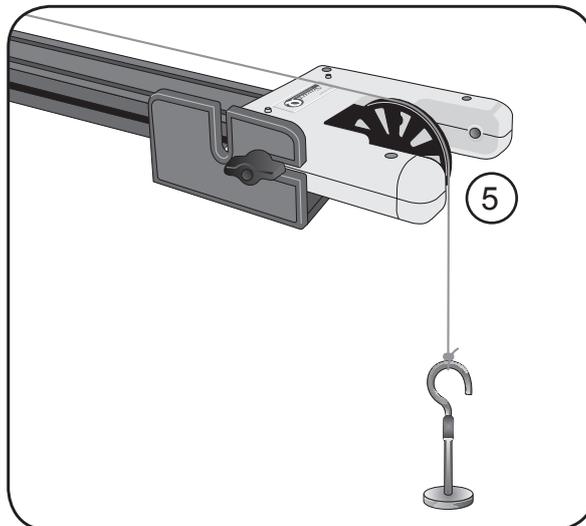
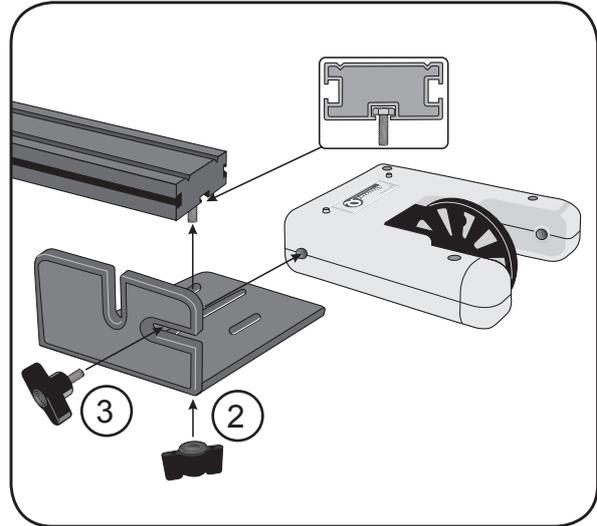
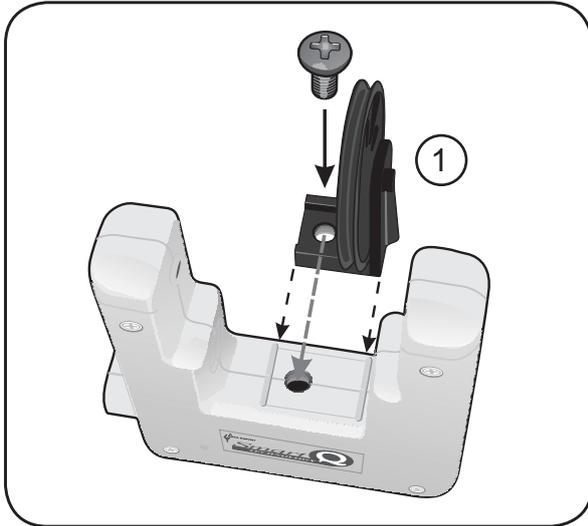
WN1 x 1



WN2 x 1

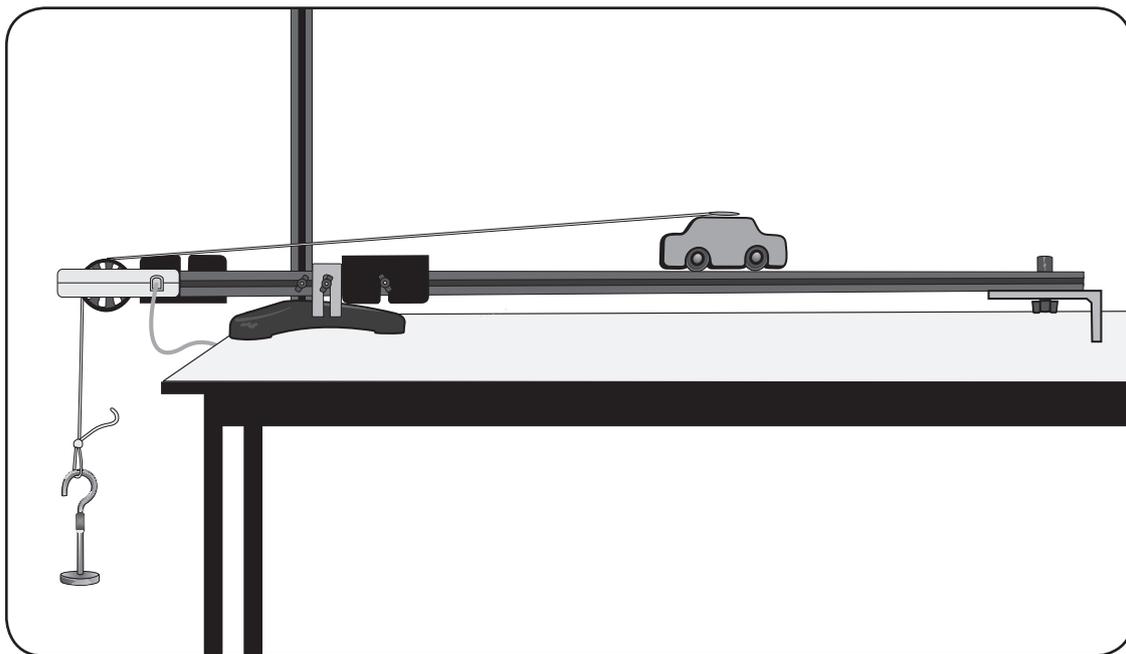


SS M6 x 1



1. Connect a spoked Pulley to a Light Gate.
2. Fix a large bracket to the underside of the track.
3. Attach a Light Gate to the large bracket using a wing bolt (WN1).
4. Adjust the Light Gate and Pulley for clearance.
5. 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***

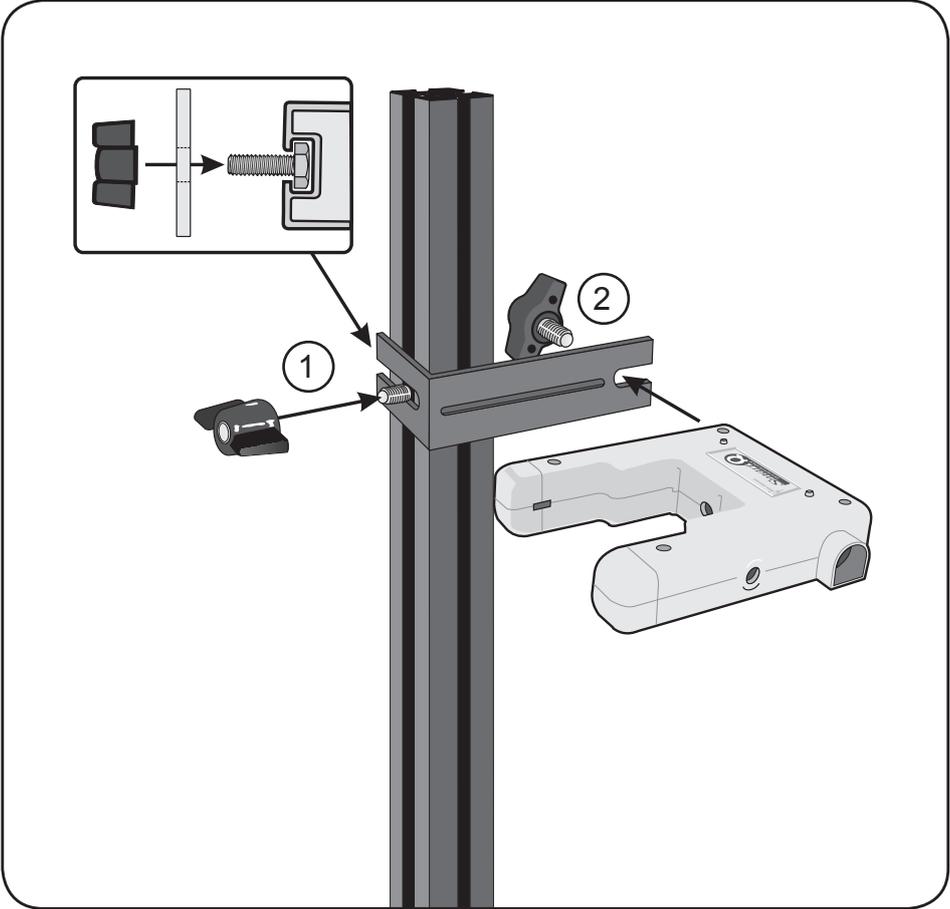
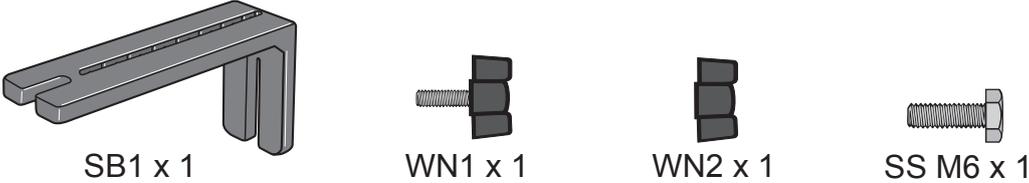


1. Position a Light Gate with a pulley (SP1) attached to the end of the track and connect to input A on the **EASYSense** logger.
2. Set up the apparatus as shown. The mass is used to tension the thread (not to pull the cart along or make the cart increase in speed). Run the thread over the pulley.
3. Open the **EASYSense** program and select **Timing** from the Home page. From the wizard select what you want to measure and the necessary parameters.
4. Click on the **Start** icon to begin logging.
5. 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:**

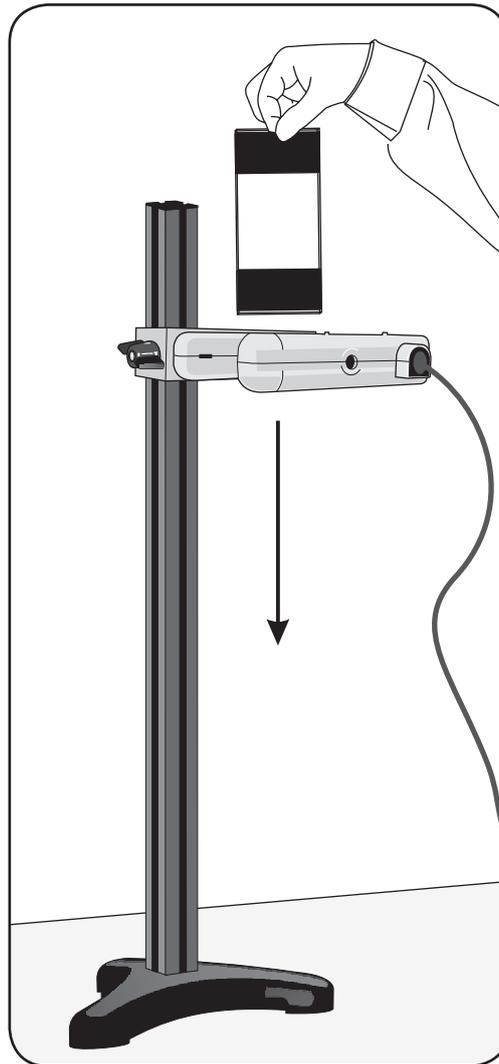
1. Effect of mass on motion: alter the mass on the hanger, as the mass falls it will pull the cart along the track.
2. Effect of slope on motion: alter the angle of the track and either use mass to pull the cart up the track or keep the tensioning mass constant and study the effect of increasing the angle on the motion of the cart down the track.
3. 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



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 $g$

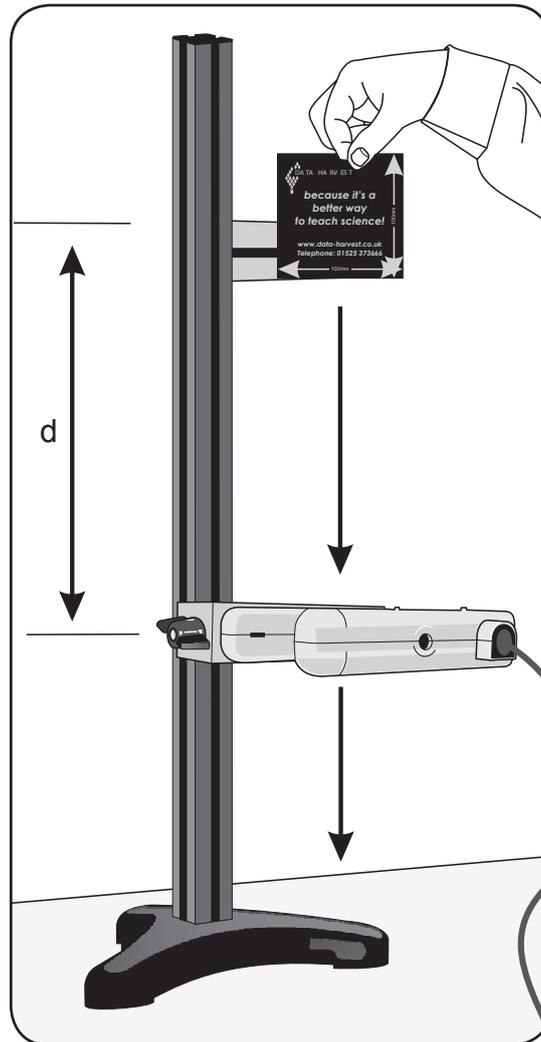


Acceleration can be measured with a single Light Gate and a double interrupt card. The two segments of the double interrupt card must be equal in width.

**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).

1. Position a Light Gate near the top of the vertical pillar and connect to input A on the **EASYSense** logger.
2. Open the **EASYSense** program and select **Timing** from the Home page. From the wizard select to record **Acceleration at A** with a double interrupt card, and enter the length of the interrupts (mm).
3. Click on the **Start** icon and drop the interrupt card through the Light Gate. Ensure the card drops vertically, if it not select the measurement and click on the **Delete** icon.

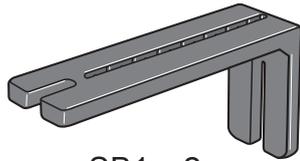
**Gravity: Using a single Light Gate to measure  $g$ , by logging the velocity after falling a known distance ( $d$ )**



**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).

1. Use a single, weighted, interrupt card. The position marks specified are for use with a card 100 mm in length.
2. Position a Light Gate at the 20 cm mark on the vertical pillar and connect to input A on the **EASYSense** logger.
3. 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 ( $d$ ).
4. Open the **EASYSense** program and select **Timing** from the Home page. From the wizard select to record **Velocity at A** with a single interrupt card, and enter the length of the interrupt e.g. 100 mm.
5. Click on the **Start** icon and drop the interrupt card through the Light Gate. Ensure the card drops vertically, if not select the measurement and click on the **Delete** icon.

## Attaching 2 Light Gates to the support pillar



SB1 x 2



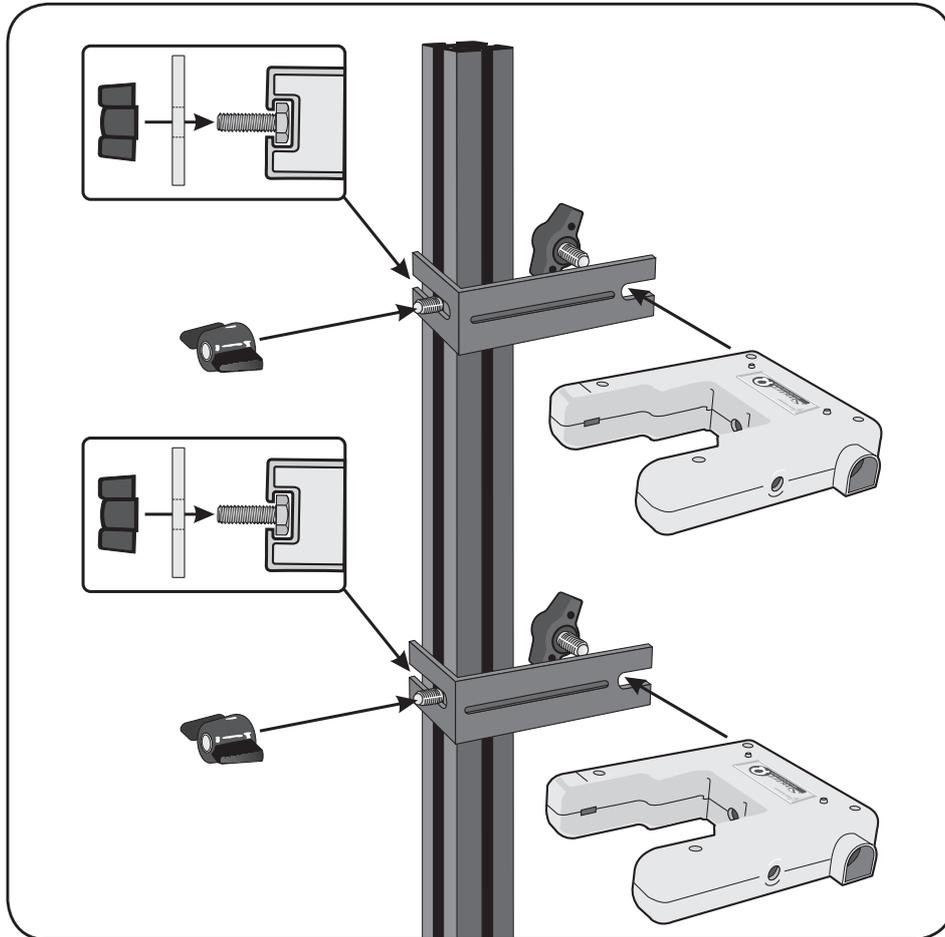
WN1 x 2



WN2 x 2



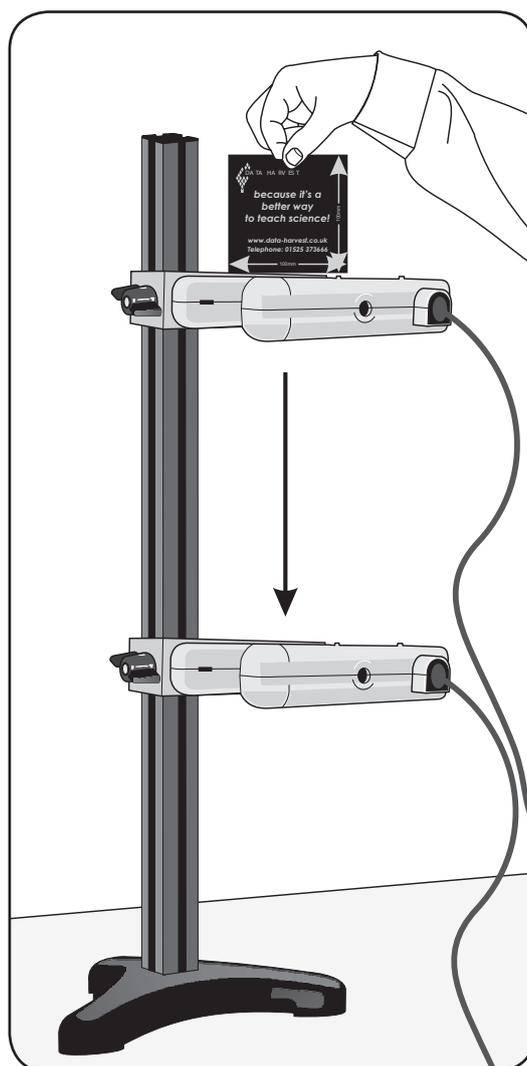
SS M6 x 2



**Note:** The two brackets keep the Light Gates correctly aligned.

- Use an SS M6 hex headed screw and wing nut to secure two thin brackets to the pillar.
- Attach a Light Gate to each bracket with a wing bolt (WN1).
- Position the Light Gates to their correct position and secure.
- Test the interrupt card passes through both Light Gates.

## Gravity: Using two Light Gates to measure $g$

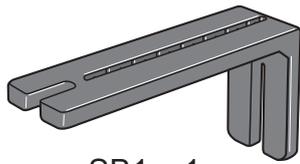


Acceleration can be measured using two Light Gates with a single, weighted, interrupt card.

**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).

1. Position a Light Gate near the top of the vertical pillar and connect to input A on the **EASYSense** logger. Position a second Light Gate lower down the pillar and connect to input B.
2. Open the **EASYSense** program and select **Timing** from the Home page. From the wizard select to record **Acceleration from A to B** with a single interrupt card, and enter the length of the interrupt (e.g. 100 mm).
3. Click on the **Start** icon and drop the interrupt card through the Light Gates. Ensure the card drops vertically through both gates. If not select the measurement and click on the **Delete** icon.

## Attaching a Motion Sensor to the support pillar



SB1 x 1



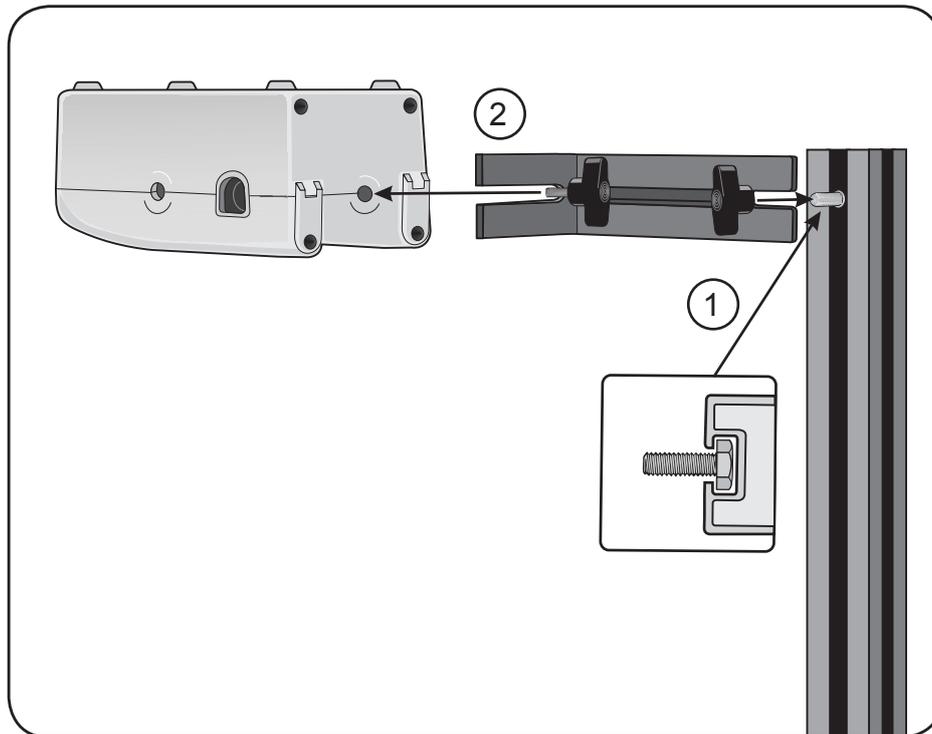
WN1 x1



WN2 x 1

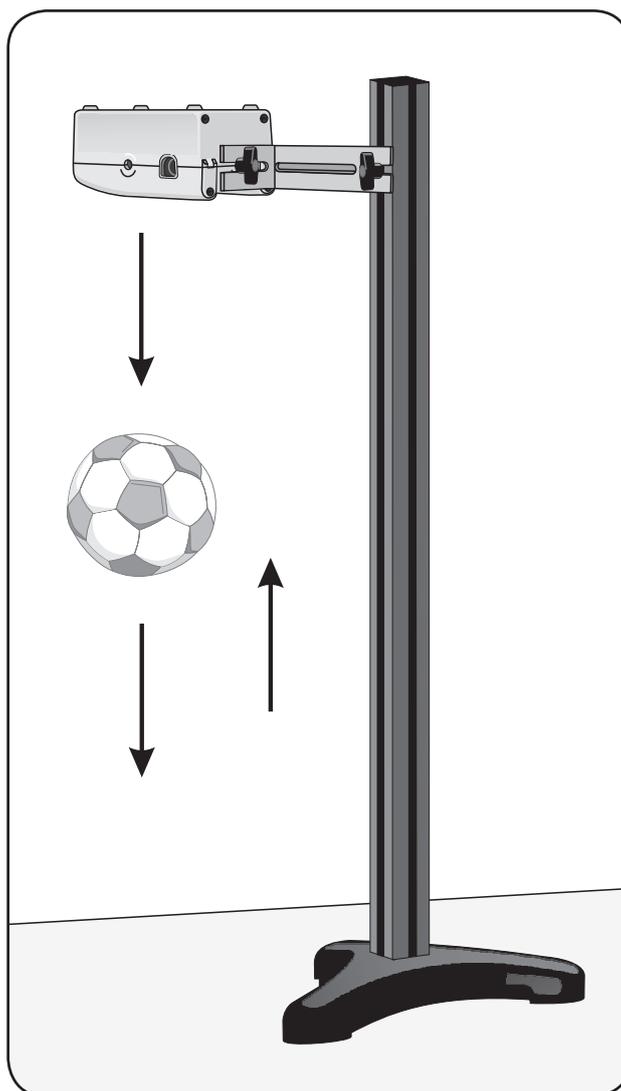


SS M6 x 1



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

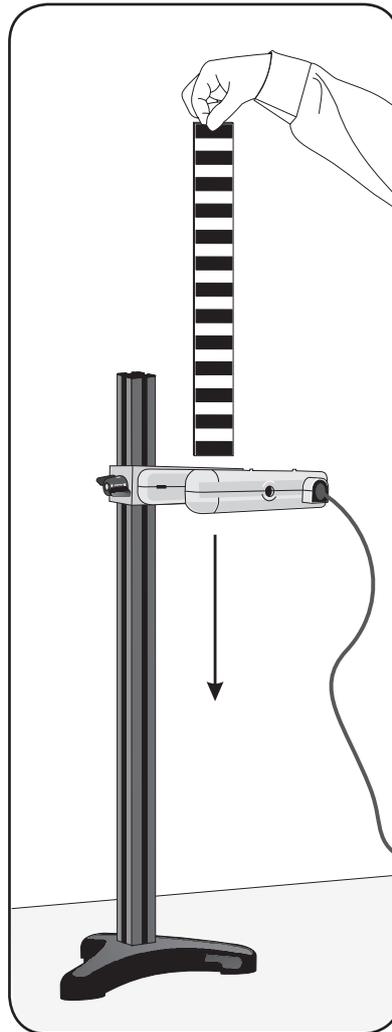


1. Position the Motion Sensor at the top of the vertical pillar and connect to input 1 on an **EASYSense** logger. The range of the Motion Sensor should be set to Distance. The ball needs to bounce onto a hard surface.
2. Open the **EASYSense** program and select **Graph** from the Home page. From the wizard select the following:

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

3. Click on the **Start** icon. 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 $g$



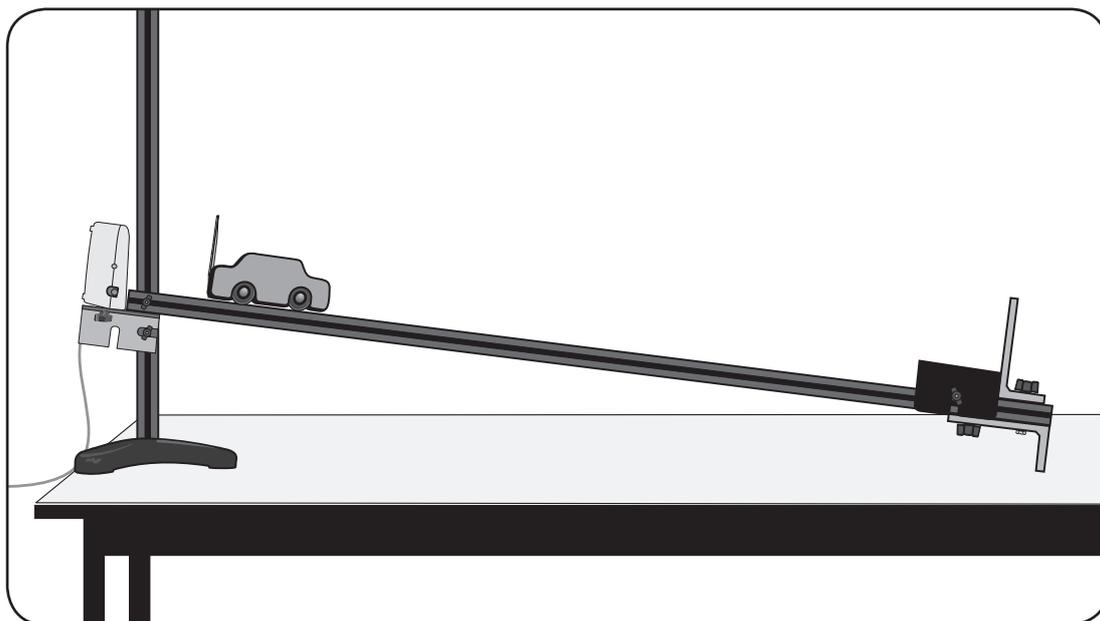
**Note:** A suitable multi-segmented card (picket fence) is available as part of the Dynamics Extension Kit 1 (Product No 3801) or the Interrupt card set (Product No. 3803)

1. Position a Light Gate at the top of the vertical pillar and connect to input A on the **EASYSense** logger.
2. Open the **EASYSense** program and select **Timing** from the Home page. From the wizard 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.



3. Click on the **Start** icon. Hold the picket fence just above the Light Gate and release.

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

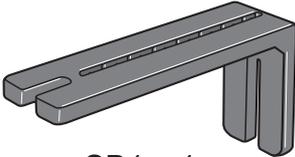


1. Position a Motion Sensor at the top of the track and connect to input 1 on an **EASYSense** logger. The range of the Motion Sensor should be set to Distance in metres.
2. Position the track at the 10 cm mark on the vertical pillar to give an angle of about  $5^\circ$ .
3. Fit a crash box to the end of the track (see page 7 - 8). Fit a reflector card to one end of the cart.
4. Open the **EASYSense** program and select **Graph** from the Home page. From the wizard select the following:

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

5. Place the cart about 20 cm in front of the Motion Sensor. Click on the **Start** icon.
6. Let the cart roll down the track. The cart will squash the crumbled paper on impact so re-fluff the paper each time.
7. 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



SB1 x 1



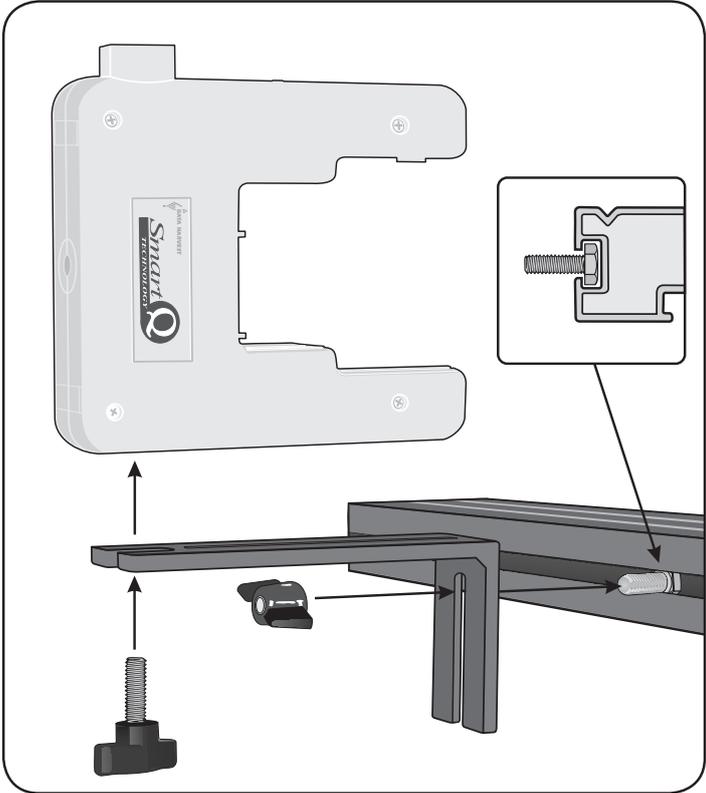
WN1 x 1



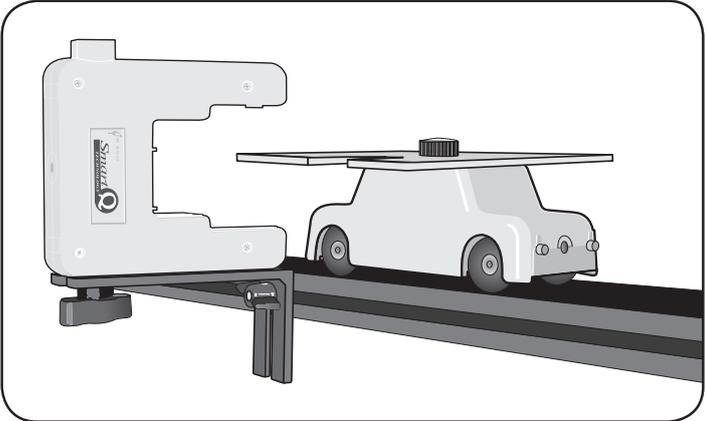
SS M6 x 1



WN2 x 1



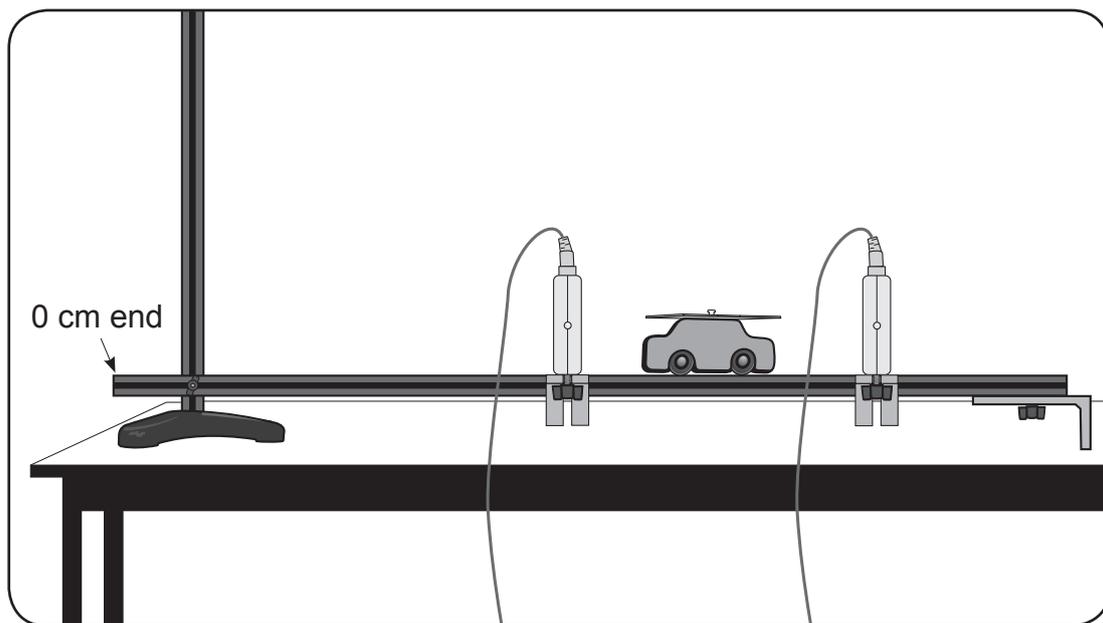
## Attaching a Light Gate to the track



Check the interrupt card passes through the Light Gate

### ***Forces: Motion with balanced forces***

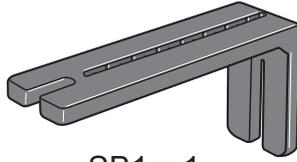
1. Place the track in its lowest position, supported at the end by a large bracket. Adjust the track so it is horizontal.
2. Fit the interrupt card to the cart so the single interrupt edge will pass through the Light Gates.
3. Position a Light Gate near midway along the track and connect to input A on the **EASYSense** logger. Position a second Light Gate nearer the end of the track and connect to input B.
4. Open the **EASYSense** program and select **Timing** from the Home page. From the wizard select to record **Speed at A or B**, and enter the length of the card as 120 mm.
5. Click on the **Start** icon. Push the cart gently from the 0 cm 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



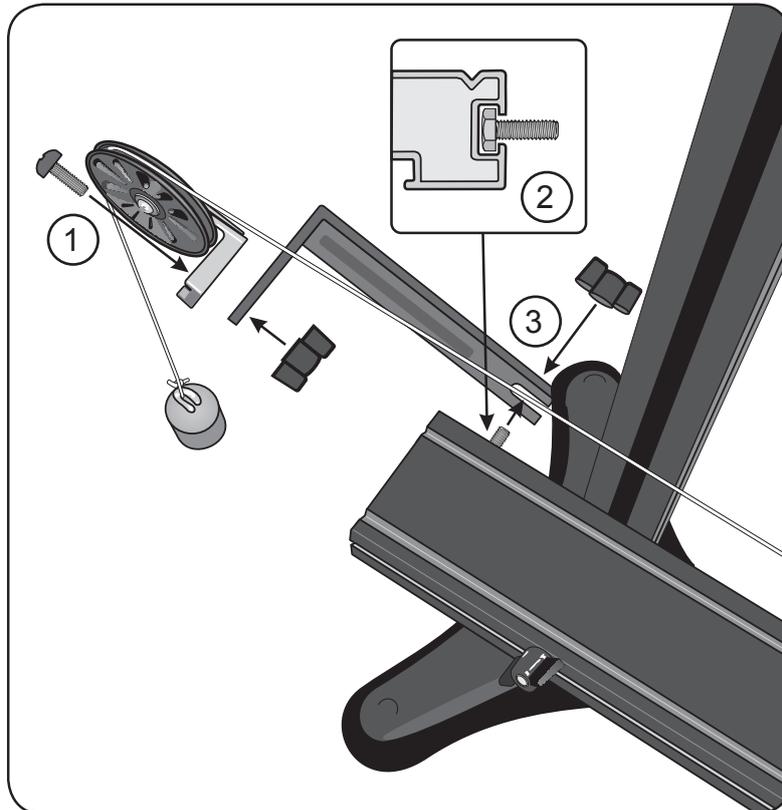
SB1 x 1



WN2 x 3

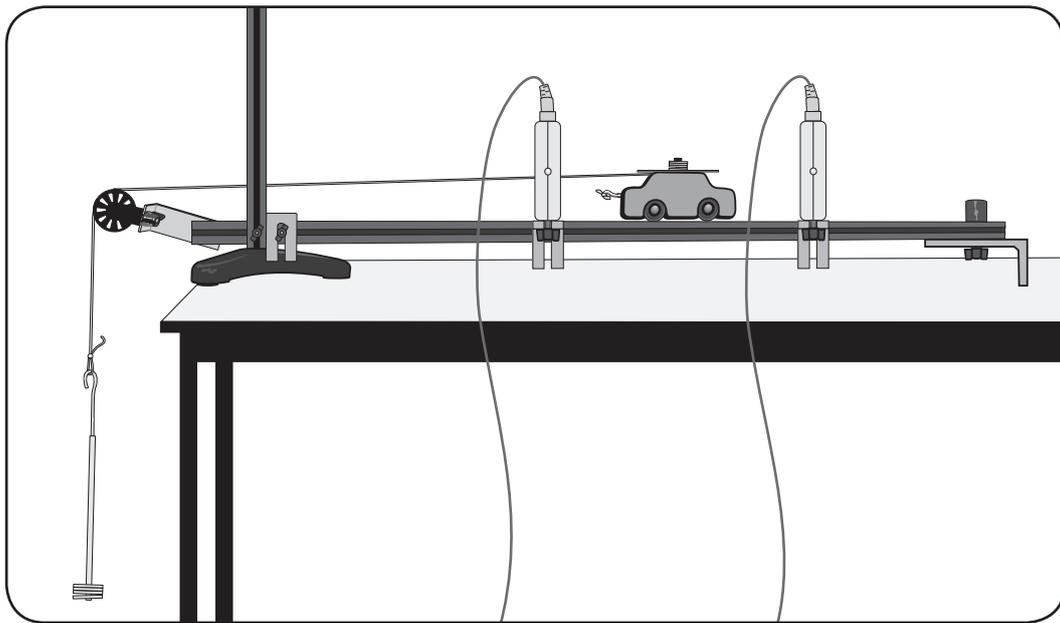


SS M6 x 3



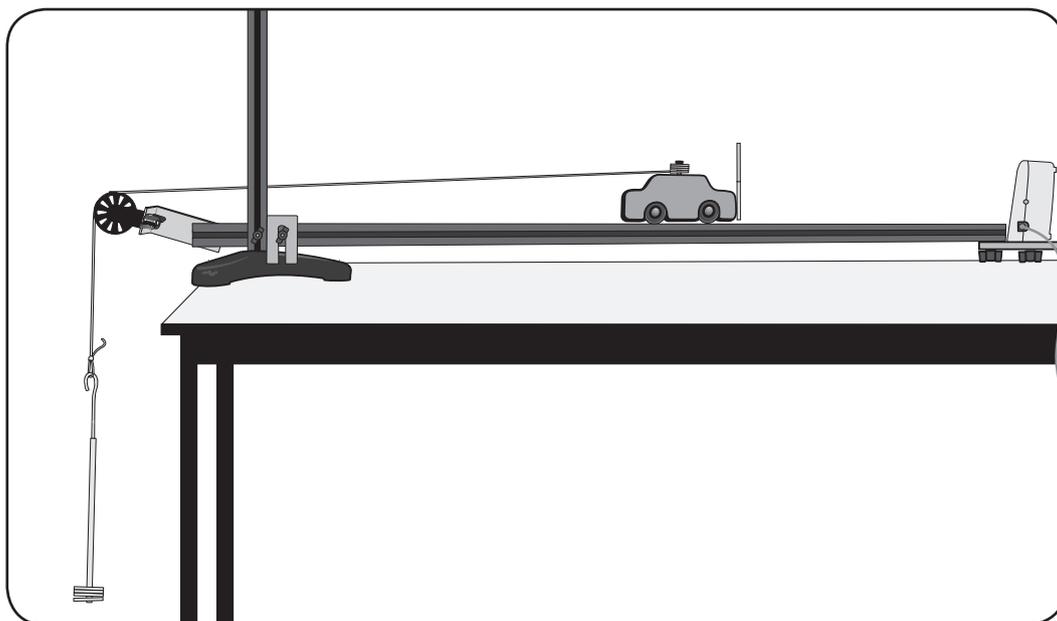
1. Attach the Spoked Pulley to the short arm of a thin bracket.
2. Slide an SS M6 hex screw into the slot on the track.
3. Attach the long arm of a thin bracket to the screw and secure with a wing nut.
4. Connect a length of thread (with a mass carrier attached) to the Cart. Run the thread over the top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

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



1. Place the track in its lowest position, supported at the end by a large bracket. Adjust the track to be horizontal (see page 31).
2. 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.
3. Position a Light Gate midway along the track and connect to input A on the **EASYSense** logger. Position a second Light Gate nearer the end of the track and connect to input B.
4. Place 50 g on top of the cart and secure in position and 10 g on the hanger.
5. Open the **EASYSense** program and select **Timing** from the Home page. From the wizard select to record **Acceleration from A to B**, and enter the length of the card as 120 mm.
6. Click on the **Start** icon. Push the cart gently from the 0 cm end to run freely along the track through the two Light Gates.
7. 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



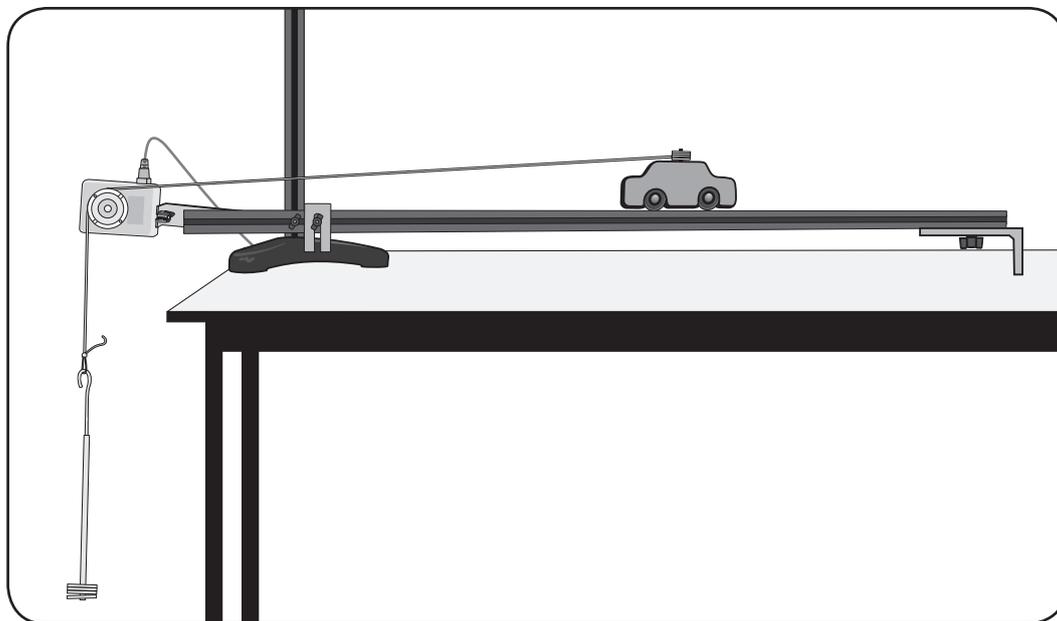
1. Place the track in its lowest position, supported at the end by a large bracket. Adjust the track to be horizontal.
2. Position a Motion Sensor at the bottom of the track and connect to input 1 on an **EASYSense** logger. The range of the Motion Sensor should be set to Distance.
3. Place a thin bracket on the track as close to the vertical pillar as possible to act as a stop.
4. 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 hook. 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.
5. Place 50 g of slotted masses on the top of the cart and secure in position.
6. Open the **EASYSense** program and select **Graph** from the Home page. From the wizard select the following:

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

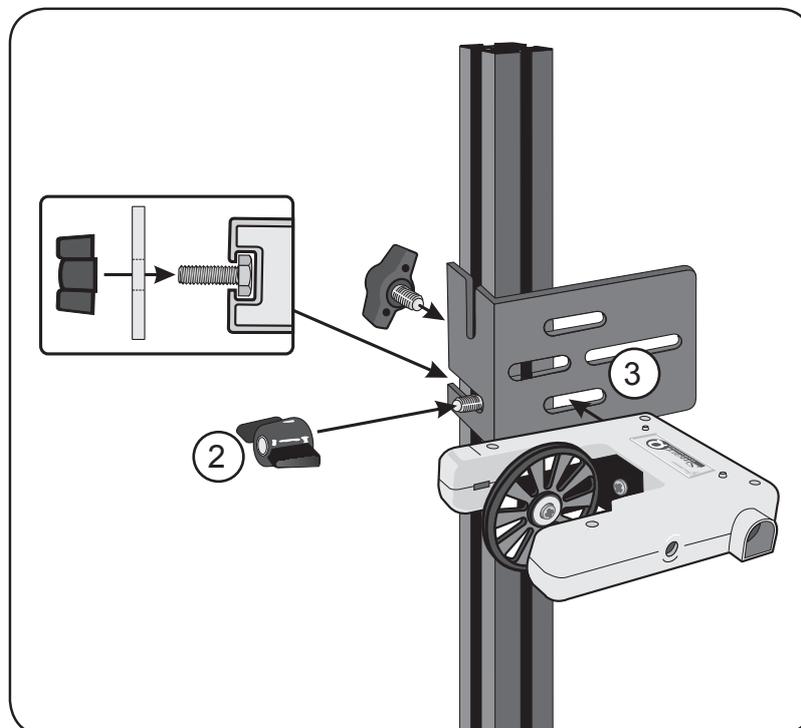
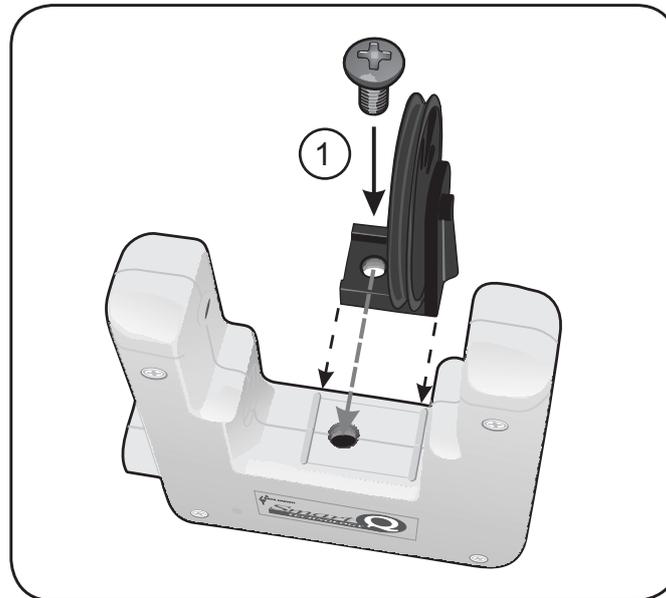
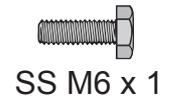
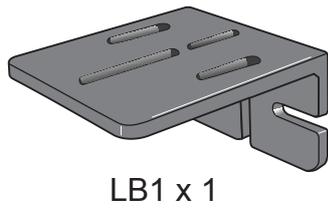
7. Hold the cart at least 15 cm from the Motion Sensor - you want the cart to produce data for about 80 cm before it reaches the pulley. Click on the **Start** icon and release the cart to run freely along the track.
8. Click on **Overlay**. Transfer 10 g from the cart to the hanger and repeat. Repeat 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***

1. The procedure is the same as using the Motion Sensor, except in the way the Rotary Motion Sensor is set up to take measurements.
2. Set the range of the Sensor to the size of pulley you are using e.g. Pulley 49 mm for the largest pulley.

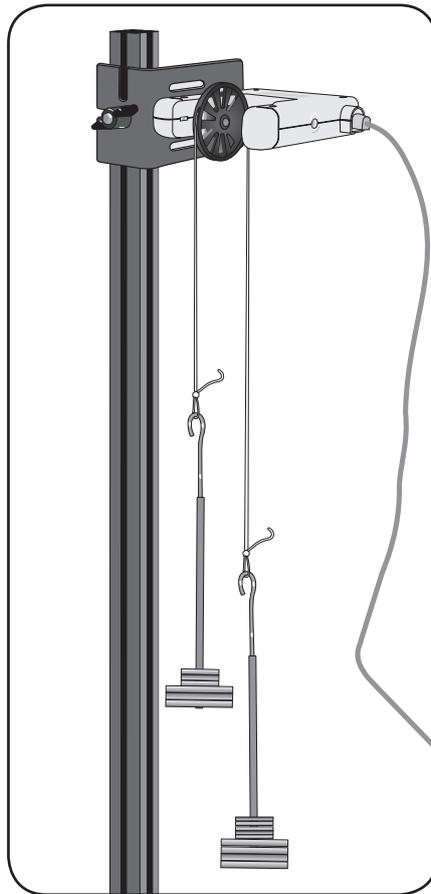


## Attaching a Light Gate and Spoked Pulley to the pillar



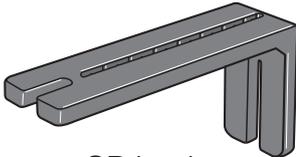
1. Attach a spoked pulley to the Light Gate.
2. Attach a large bracket to the pillar using a SS M6 hex screw and WN2 wing nut.
3. Attach the Light Gate to the thin bracket with a wing nut screw.

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



1. Connect the Light Gate to input A on the **EASYSense** logger.
2. 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.
3. 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.
4. Open the **EASYSense** program and select **Timing** from the Home page. From the wizard select to record **Acceleration at A** using a Pulley.
5. Hold the masses in position, release and immediately click on the **Start** icon. Click on Stop when the lighter mass reaches the pulley.
6. Select the suitable data, and use **Show Statistics** (analysis menu) to find the average acceleration. Keep a record of this value.
7. Transfer 10 g from the heavier mass to the 300 g mass. The force is now 0.08 x g N. Repeat steps 5 and 6. The force is equal to the difference in mass between the two sets of masses expressed as kg.
8. Continue to repeat, transferring 10 g between each reading until the masses are equal.

# Attaching a thin bracket to the cart



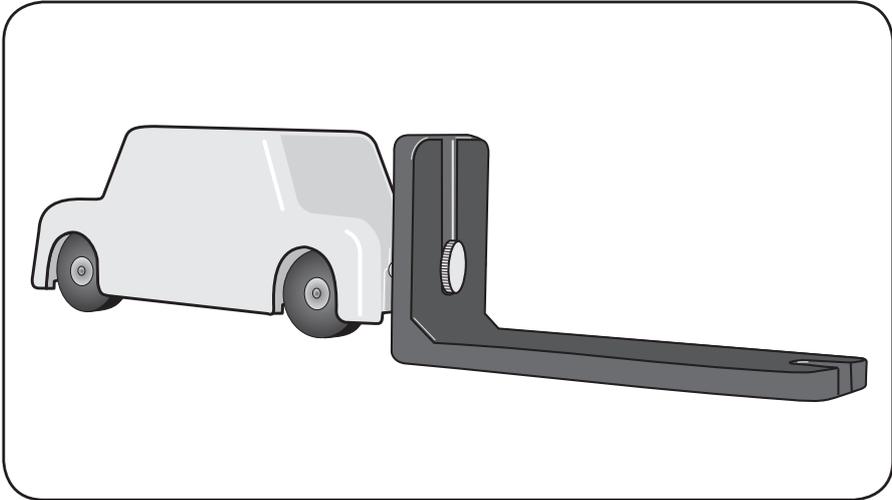
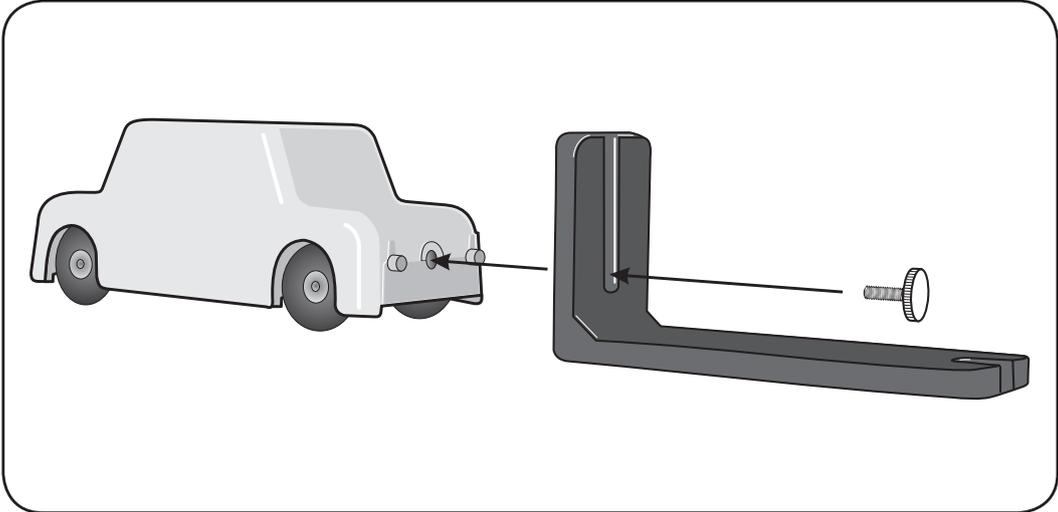
SB1 x 1



MT1 x 1

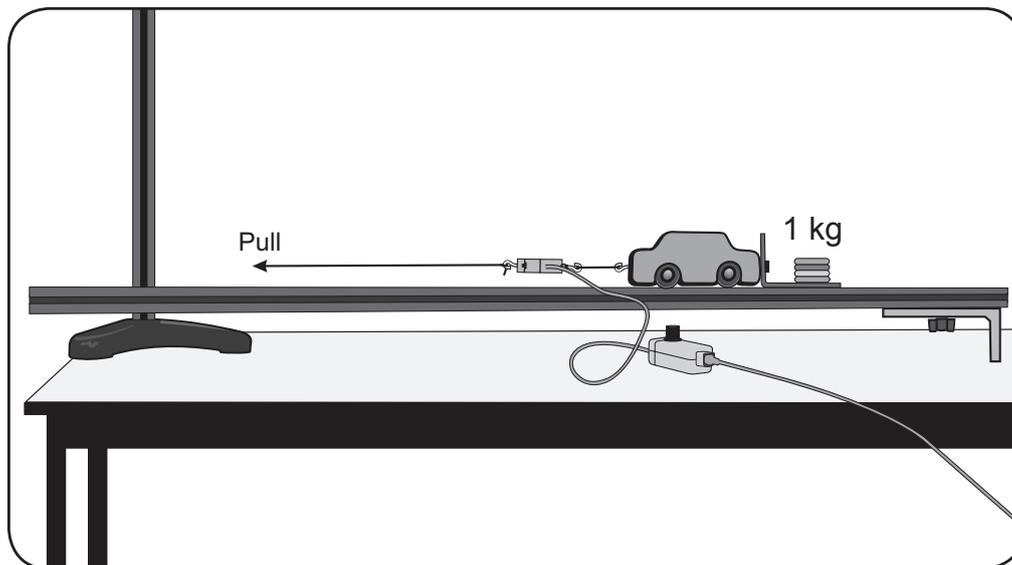


TS1 x 1



- 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

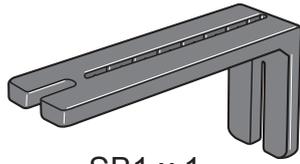


1. Place the track in its lowest position, supported at the end by a large bracket. Adjust the track so it is horizontal.
2. Attach the thin bracket to the front of the cart; keep the TS1 bolt loose so the bracket is in contact with the track surface. Place a 1 kg weight on the bracket.
3. Attach a short length of thread to the cart and tie it to the the Force Sensor. Use the hook that comes with the Force sensor to attach a pulling thread to the Force Sensor.
4. Connect the Force Sensor to input 1 on an **EASYSense** logger.
5. Open the **EASYSense** program and select **Graph** from the Home page. From the wizard select the following:

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

6. **Zero** the Force Sensor.
7. Click on the **Start** icon. Hold the Force Sensor and pull the cart along steadily until it begins to move, continue along the track at a steady speed.
8. Repeat for other values of load e.g. 2 kg, 3 kg, etc.

## Attaching a Rotary Motion Sensor to the pillar



SB1 x 1



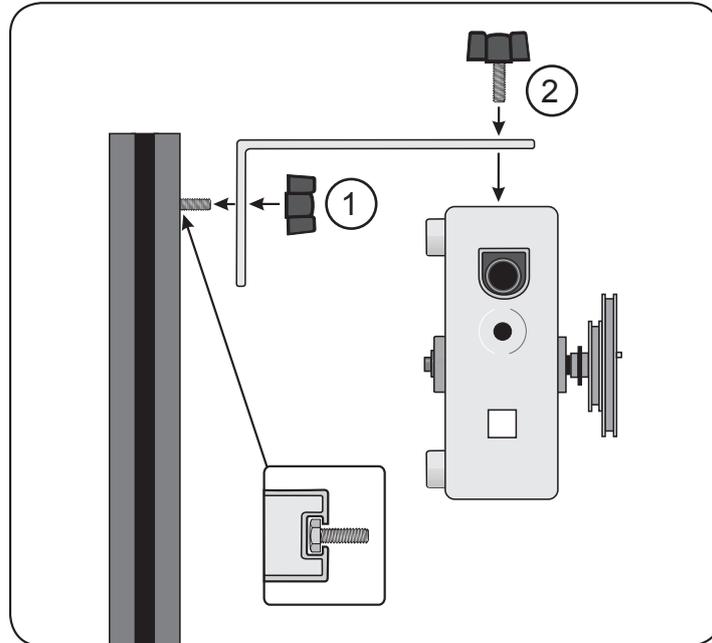
WN1 x 1



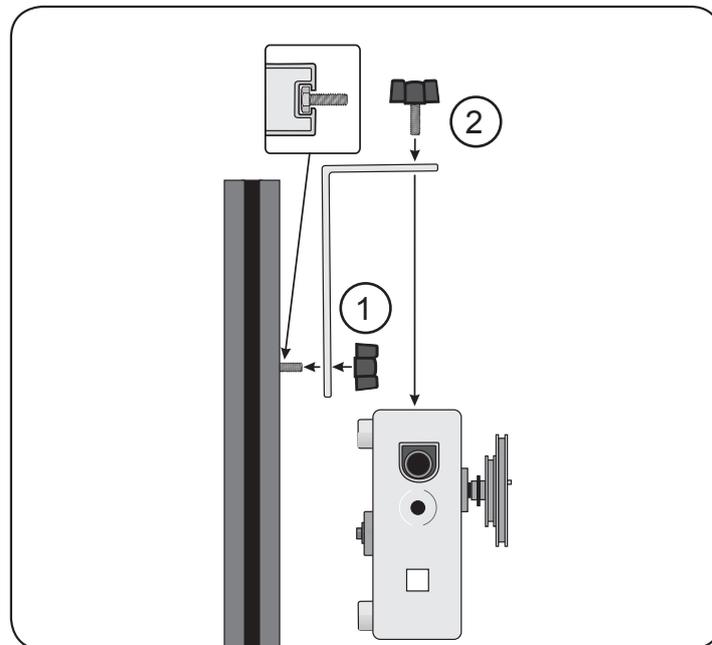
WN2 x 1



SS M6 x 1



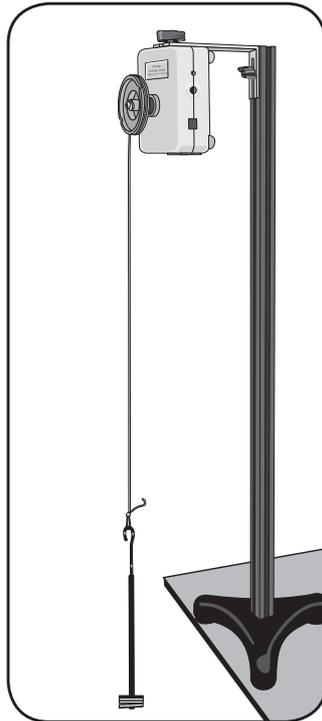
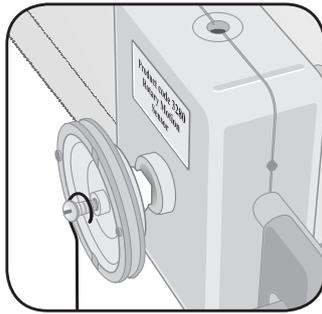
Alternative - a



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 screw.

## ***Pendulum: Using a Rotary Motion Sensor for simple pendulum investigations***

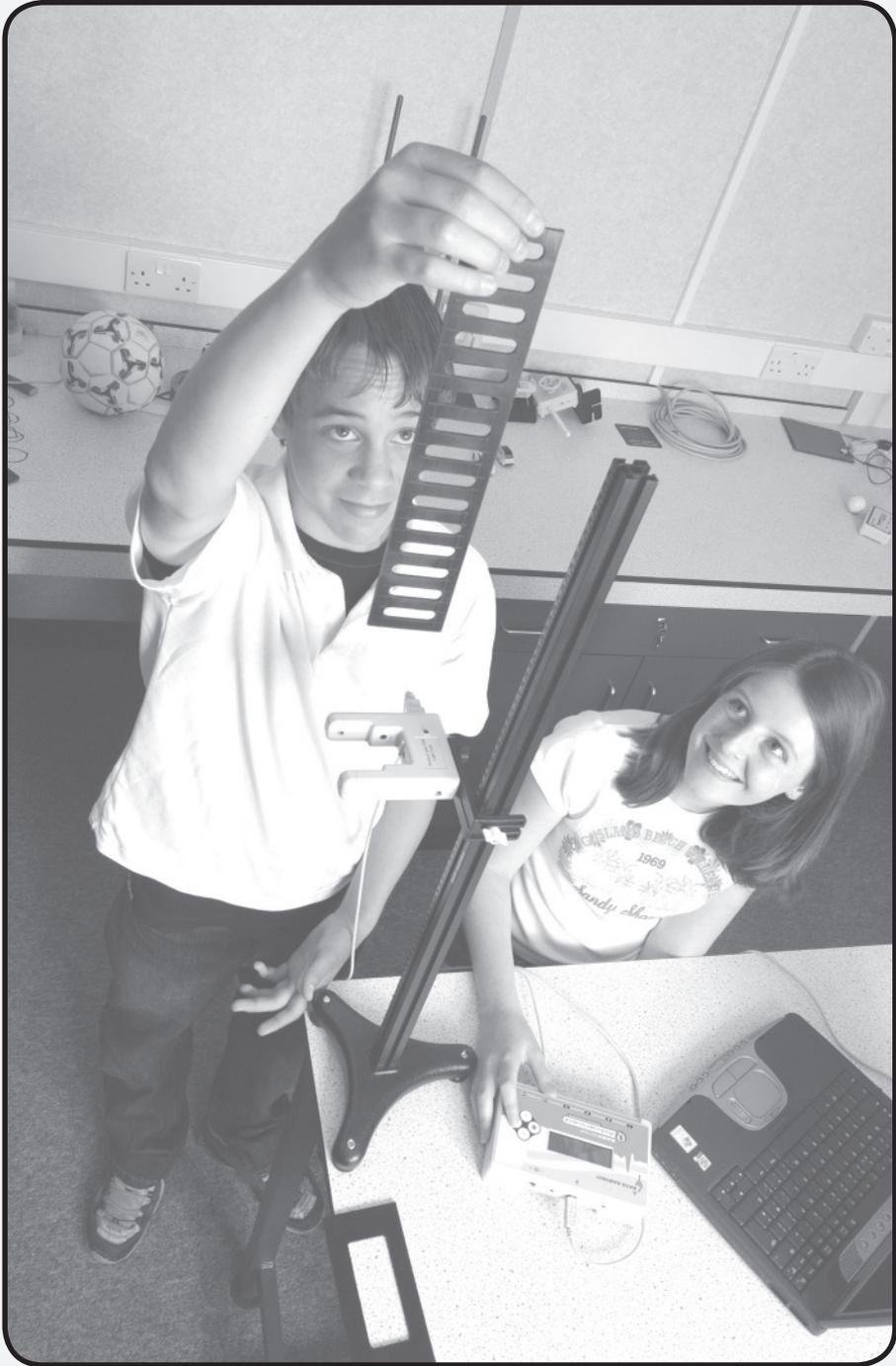


1. Use either strong cord or thin wire for the pendulum. Start with a pendulum 0.7 m long. Attach as shown.
2. Connect a Rotary Motion Sensor to input 1 on an **EASYSense** logger. The range of the Rotary Motion Sensor should be set to Pendulum.
3. With the pendulum hanging freely, press the reset **zero** button on the Sensor.
4. Open the **EASYSense** program and select **Graph** from the Home page. From the wizard select a suitable duration with an interval of 20 ms e.g.

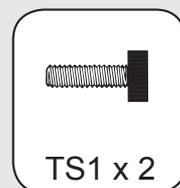
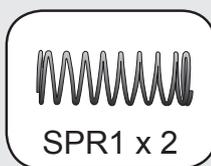
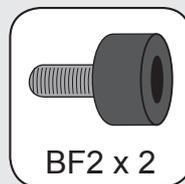
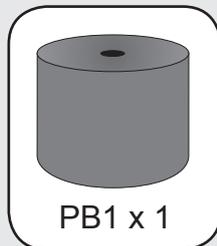
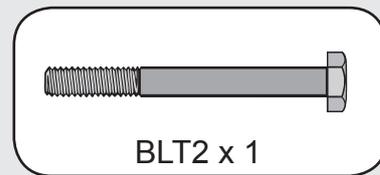
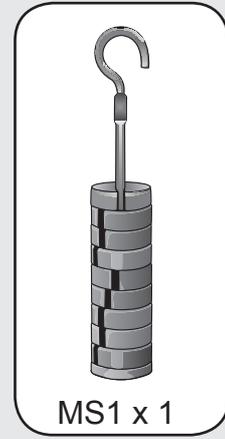
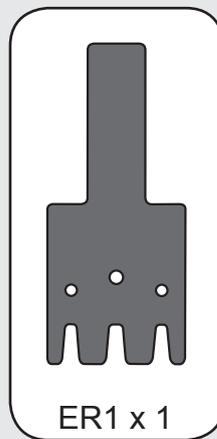
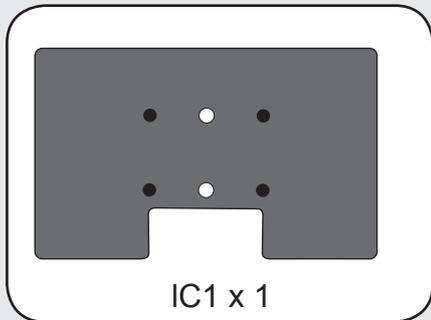
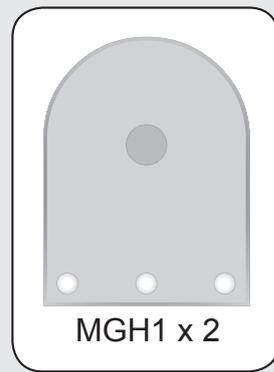
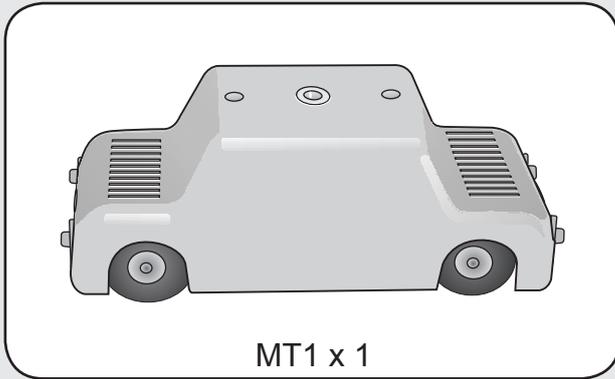
<b>Time</b>	<b>Interval</b>	<b>Trigger</b>
10 seconds	20 ms	Falls below 5 deg

5. Set the pendulum swinging through an angle of less than 10 degrees either side of vertical.
6. Click on the **Start** icon to begin logging.
7. Reduce the length of the pendulum by 0.1 m. Select **Overlay** and repeat.
8. Continue until the length of the pendulum is reduced to 0.20 m.

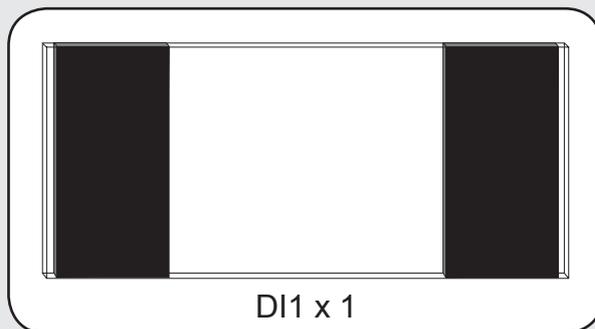
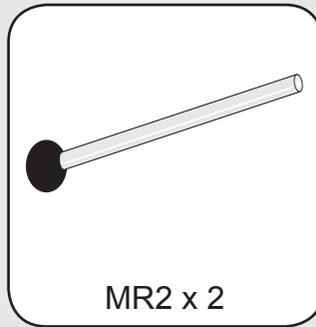
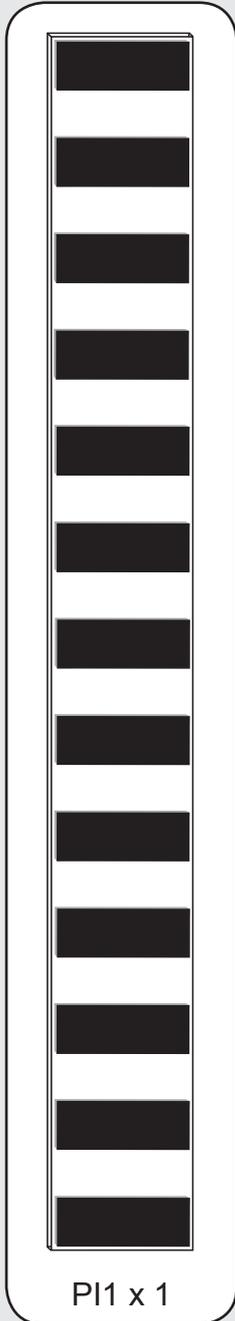
**DATA HARVEST** ——— *Dynamics System* 



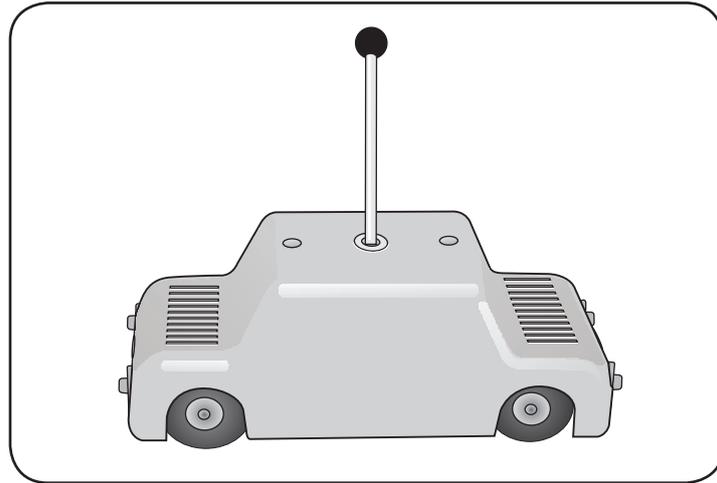
## Component identification for Kit 1 - No1



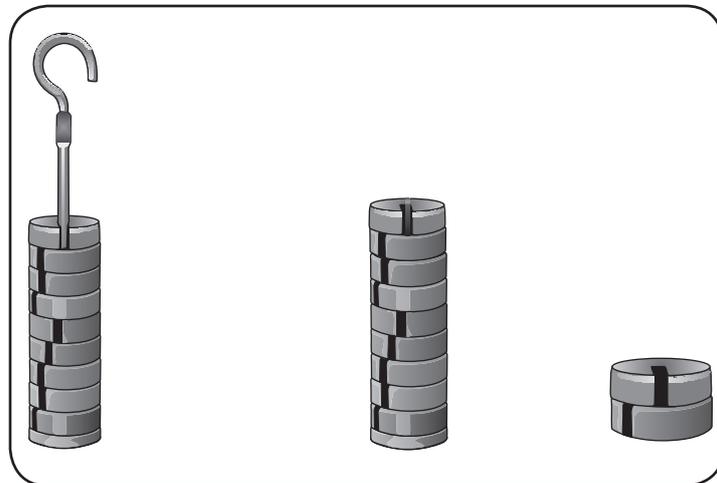
## Component identification for Kit 1 - No2



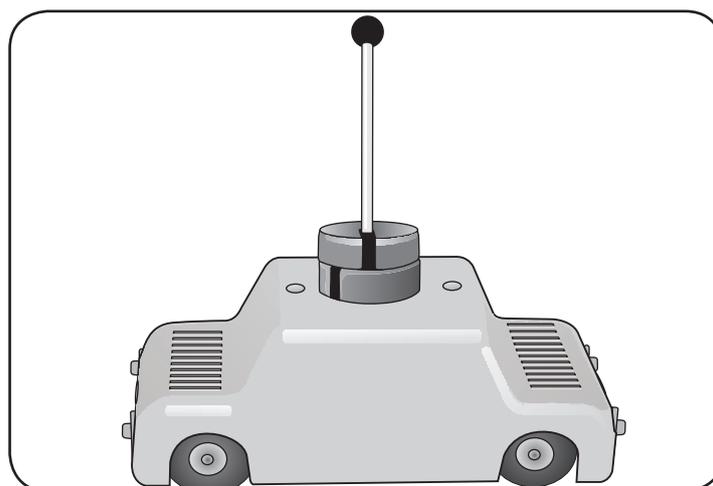
## Using the Mass Retainer MR” to hold masses on top of the cart



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

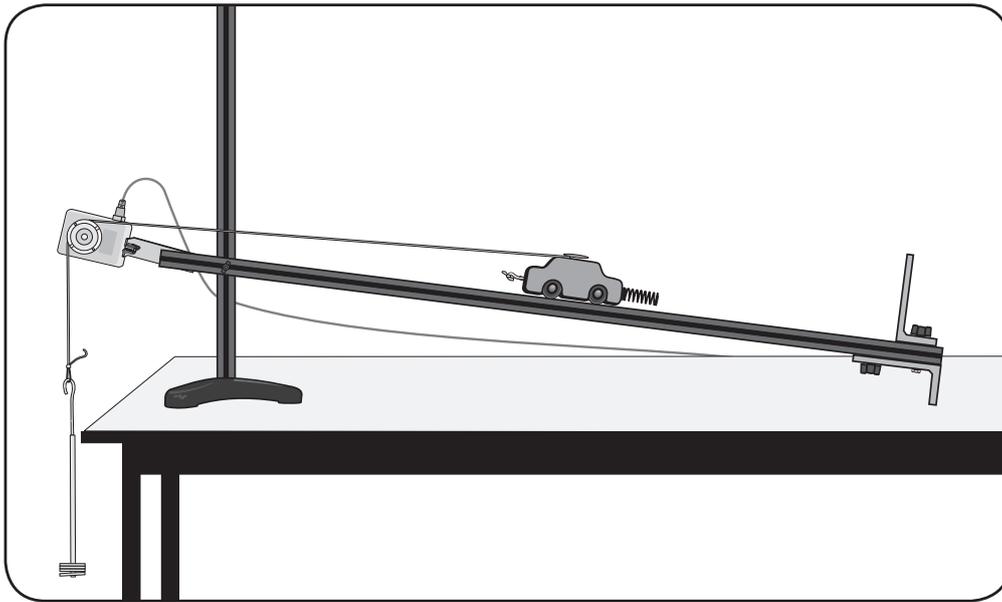


Remove the masses from the mass hanger, the mass retainer will fit through the centre hole in the supplied masses.

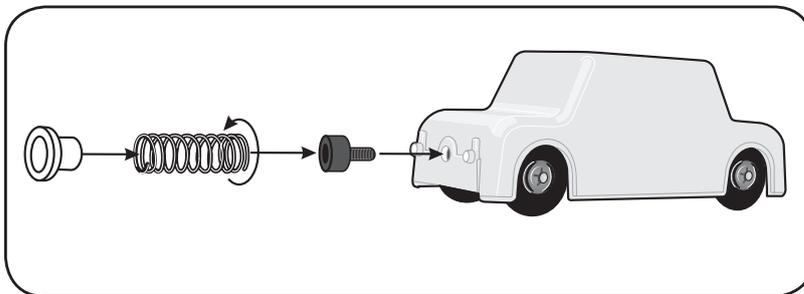


Place the masses on the top of the cart, align the centre hole of the masses with the hole in the cart. Push the mass retainer through the masses into the hole. To add or remove masses remove the retainer, alter the number of masses and refit the retainer

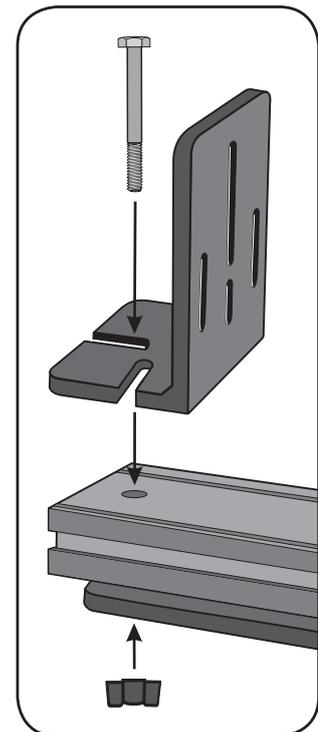
## Motion: Using the spring to roll a cart up a slope



1. Position the track at the 10 cm mark on the vertical pillar to give an angle of about  $5^\circ$ .
2. Fit the large bracket (LB1) to the end of the track using a medium bolt (BT2) and wing nut (WN2).
3. Attach a spring to the cart using a BF2, SPR1 and a SF1.

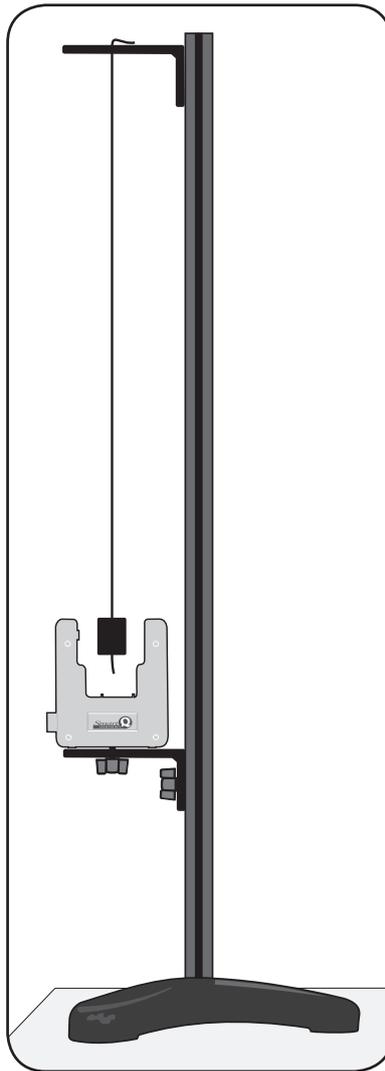


4. Place the cart at the bottom of the track. **Start** logging and push the cart back to compress spring against bracket.
5. Release the cart and let the spring push the cart up the track. Let the cart run up the track and return. Catch it as it returns.



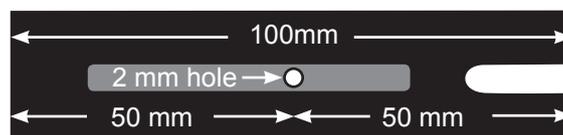
**Note:** The suspended mass is only to tension the thread running over the pulley of the Rotary Motion Sensor, it should only have a very minimal effect on the motion of the cart.

## ***Pendulum: Using a Light Gate and a simple pendulum***



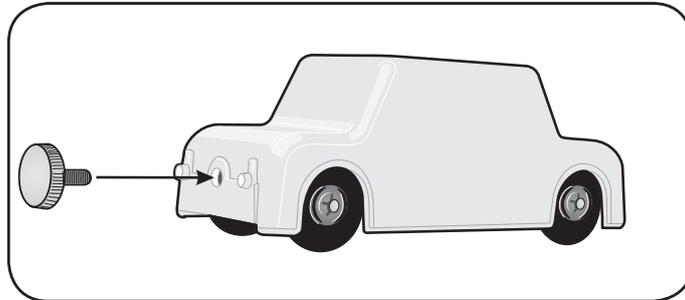
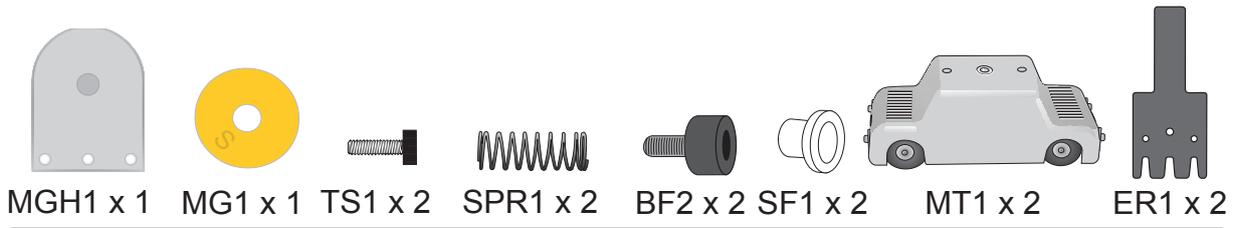
1. Attach the short arm of the thin bracket to the pillar. Thread the end of a piece of thread (at least 0.8 m long) through the hole in the long arm of the bracket and secure in place e.g. clamp with a crocodile clip.

**Note:** Early versions of the thin brackets were not supplied with a hole – drill a 2 mm hole in the centre of the long arm of the bracket.

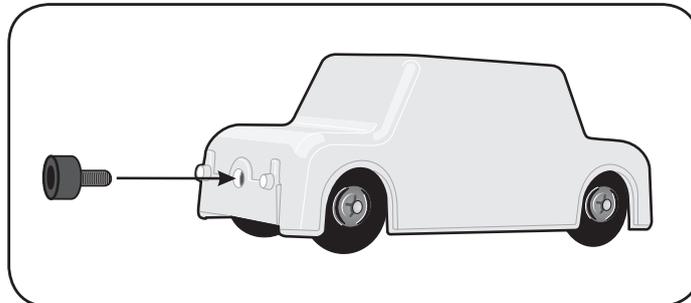


2. Thread the other end of the thread through the pendulum bob (PB1) and tie a knot in the end of the thread.
3. Use a large bracket to attach a Light Gate to the pillar. Make sure the bob lines up correctly with the Light Gate. Adjust the length of the thread to 0.7 m.
4. Open the **EASYSense** program and select **Timing** from the **Home** page. From the wizard select **Time, Period at A**.
5. Pull the pendulum bob back and release to set it swinging. Click on the **Start** icon, stop after it has recorded at least 10 cycles.

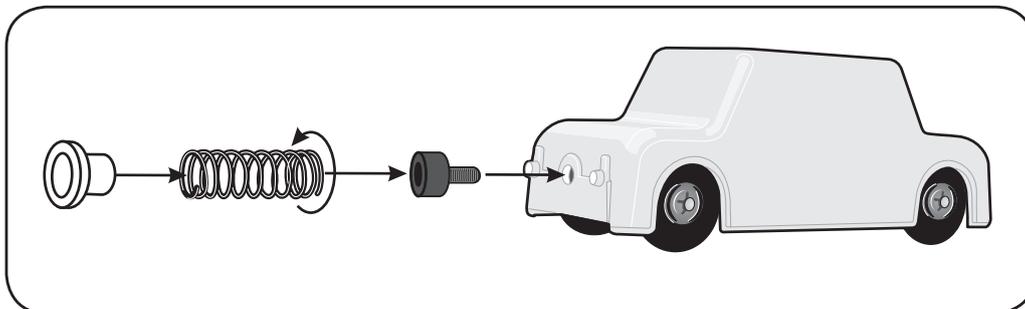
## Preparing carts for collision experiments



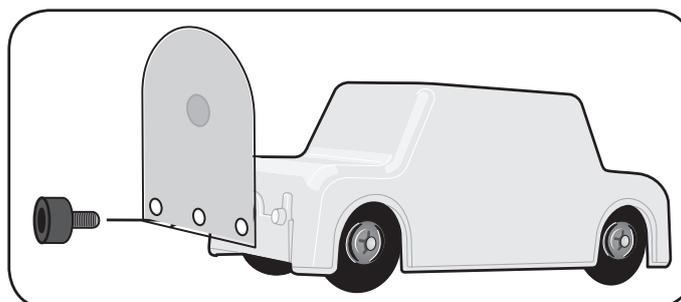
**a) Attaching solid buffer to the cart**



**b) Attaching rubber buffer to the cart**



**c) Attaching spring to the cart**

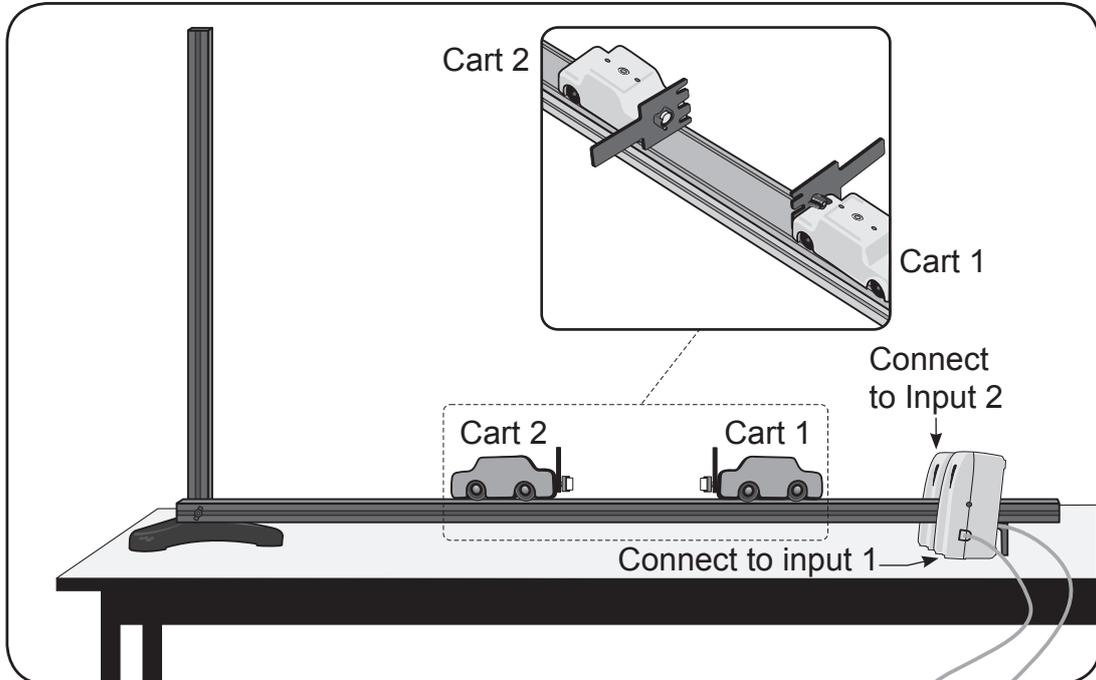


**d) Attaching magnet holder to the cart**

## Collisions: Using two Motion Sensors with magnets

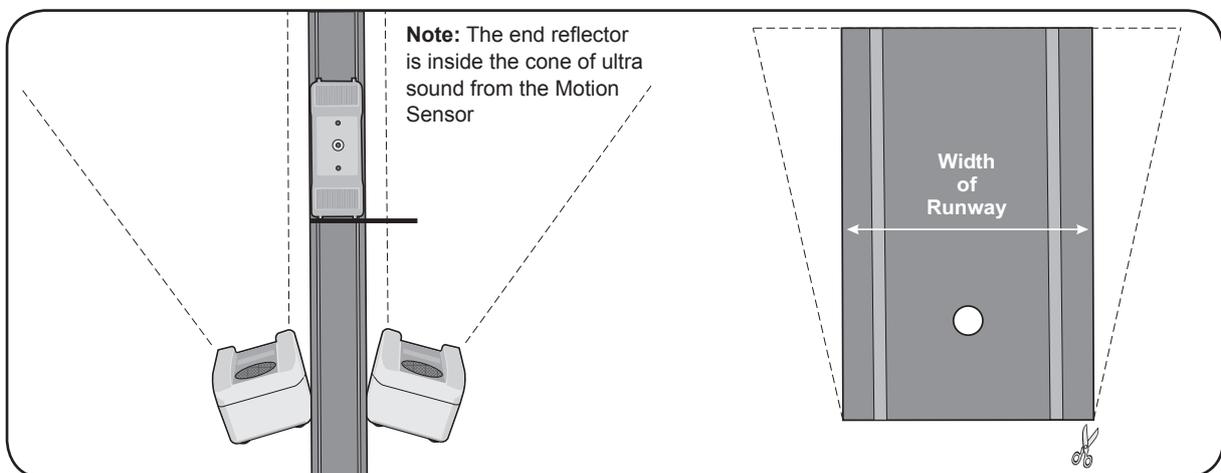
### Inelastic collisions

1. Attach an end reflector and magnet holder with magnets (to test for an elastic collision use same poles facing).



**This investigation works best over small distances**

2. 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.
3. Place the track in its lowest position, supported at the end by a large bracket. Adjust the track to be horizontal.
4. Connect the Motion Sensors to input 1 and 2 on the **EASYSense** logger. The range of the Sensors should be set to Distance.
5. 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.



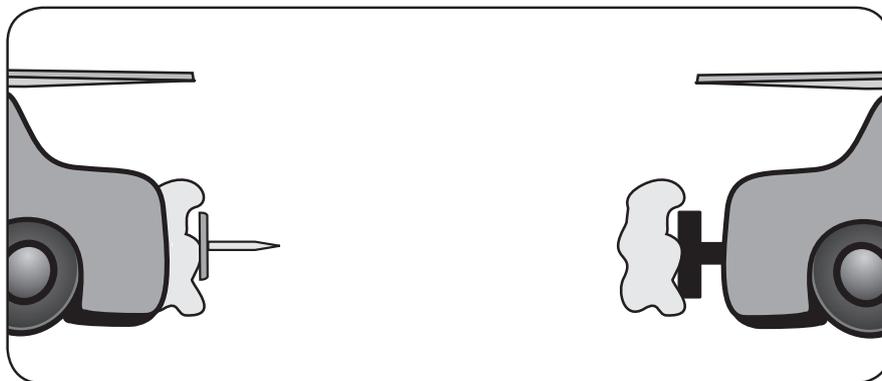
6. Open the **EASYSense** program and select **Graph** from the **Home** page. From the wizard select the following:

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

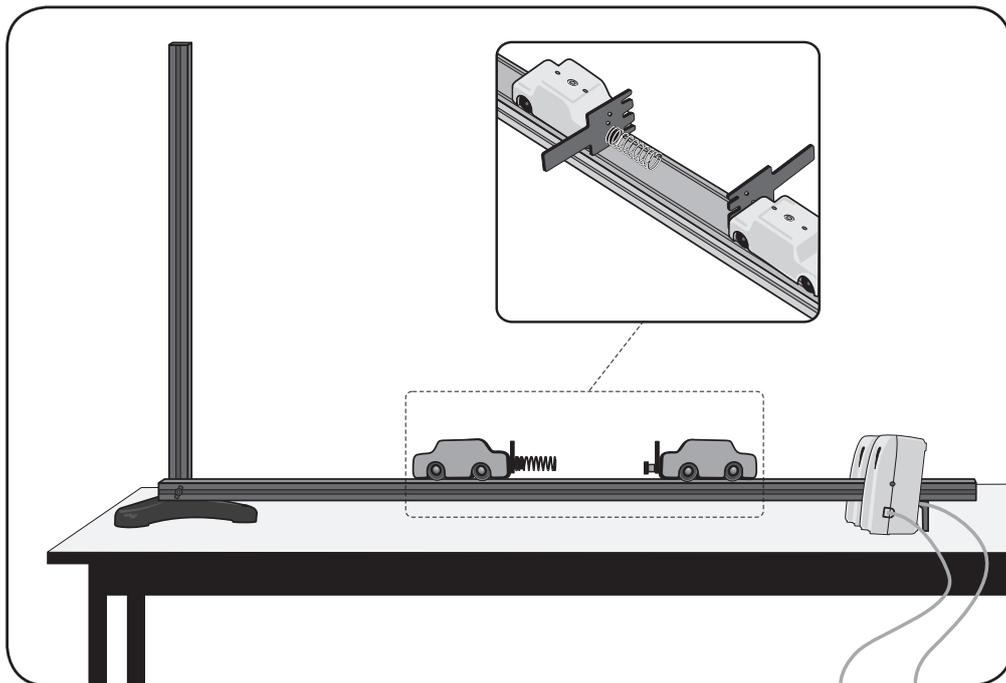
7. Position the target car (No 1) at least 17 cm away from the Motion Sensor (at the 50 cm mark). Start with this cart stationary.
8. Click on the **Start** icon and push cart 2 gently towards cart 1.

### ***Elastic collisions***

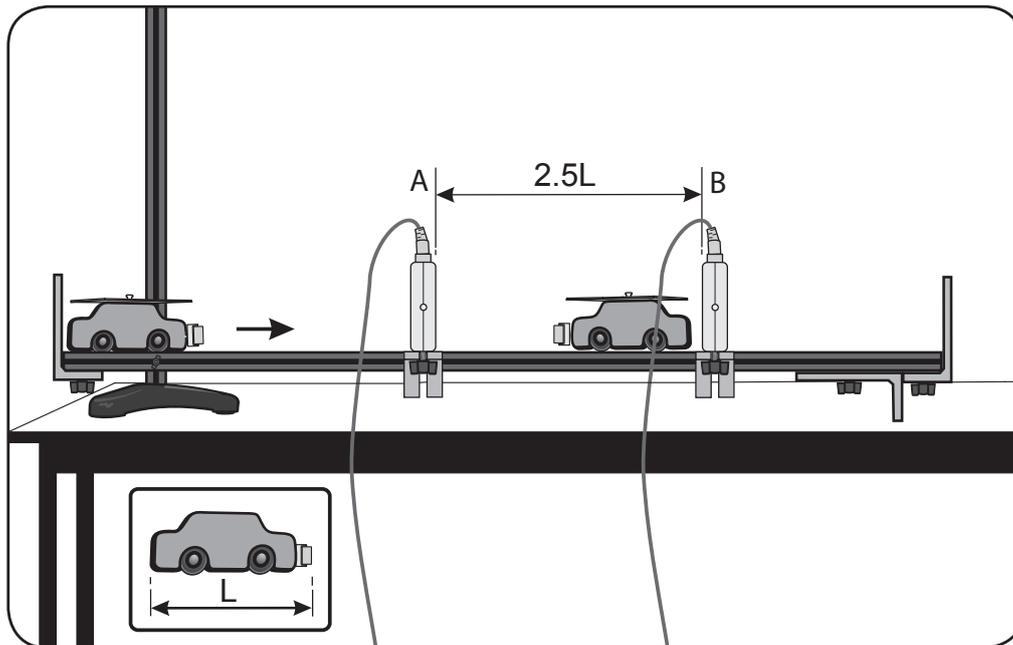
The same investigation is used for inelastic collisions. Attach a thumbtack to one cart with modelling clay and on the other cart use a thumbscrew (TS1) and a cone of modeling clay.



***Collisions: Using two Motion Sensors with springs***



## Collisions: Using two Light Gates with magnets

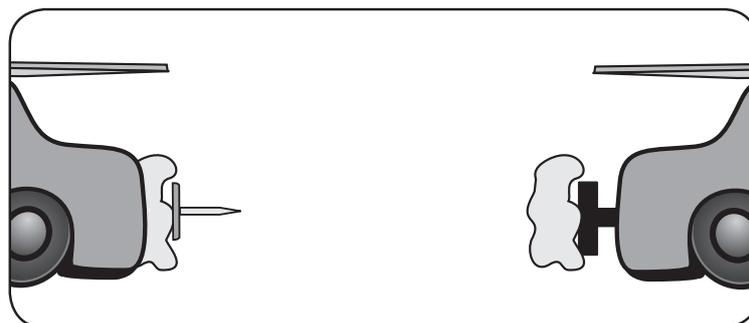


### Elastic collisions

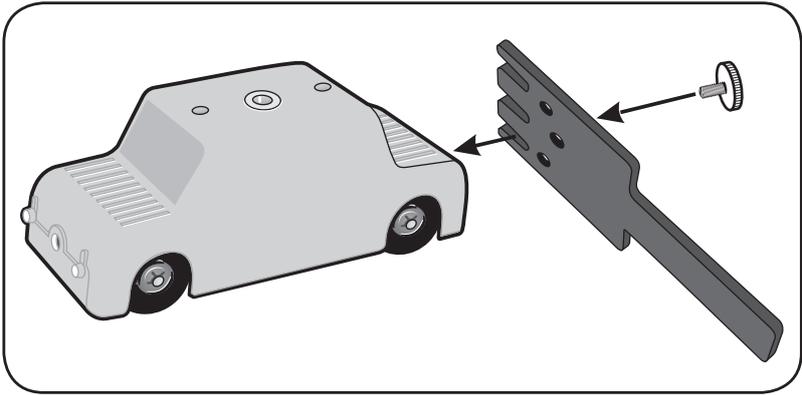
1. Place the track in its lowest position, supported at the end by a large bracket. Adjust the track to be accurately horizontal. The distance between the Light Gates should be at least 2.5 times the length of the cart and attachments.
2. Fit an interrupt card to each cart so the single interrupt edge will pass through the Light Gates. Attach a magnet holder and magnet to the end of each cart (to test for an elastic collision use same poles facing).
3. 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.
4. Connect the Light Gates to input A and B on the **EASYSense** logger. Position the 'target' cart between the two Light Gates (nearer B than A). Position the other cart before Light Gate A.
5. Open the **EASYSense** program and select **Timing** from the Home page. From the wizard select **Speed, at A or B** with a single interrupt card, and enter the length as 120 mm.
6. Click on the **Start** icon and push the first cart towards the other target car.

### Inelastic collisions

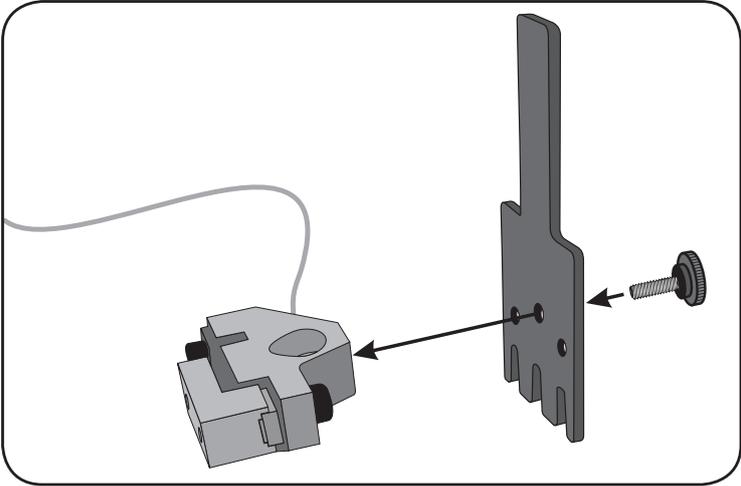
The same investigation is used for inelastic collisions but on one cart add a thumbtack to the magnet. On the other cart remove the magnet and holder and replace with a thumbscrew (TS1) and a cone of modeling clay, or use the magnets with opposite poles facing.



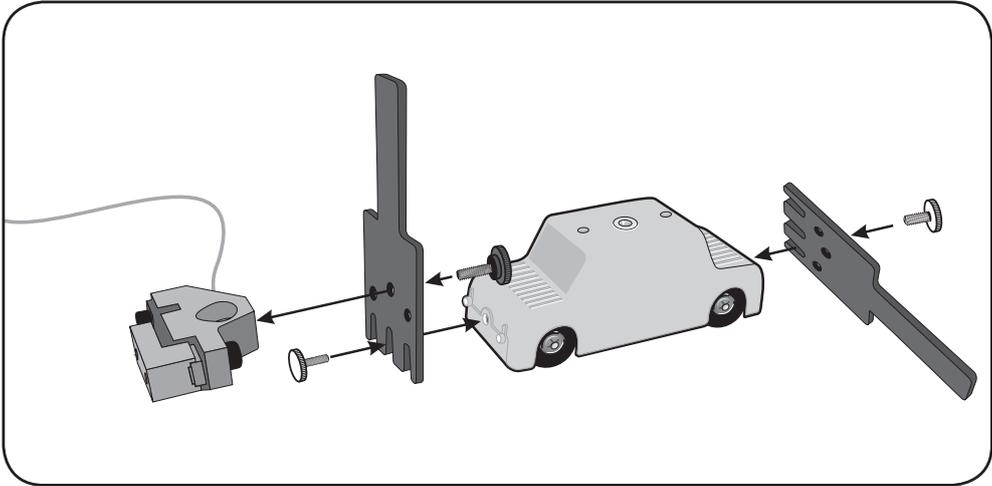
**Attaching end reflectors and a Force Sensor to a cart**



**Attaching the end reflector to the cart**

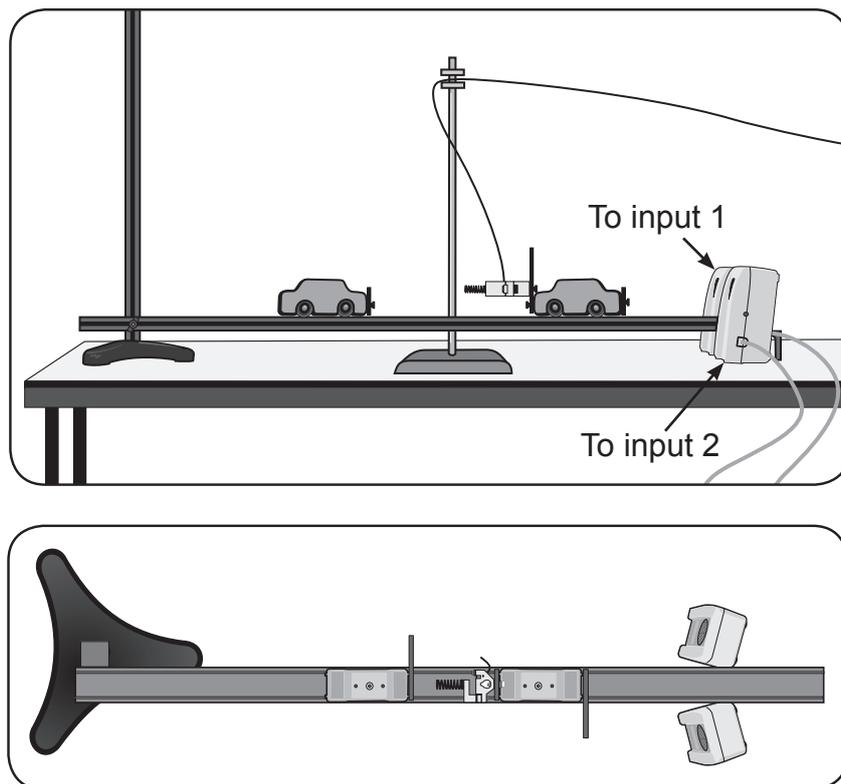


**Attaching the end reflector to a Force Sensor**



**Attaching the end reflectors and Force Sensor to the cart**

## Collisions: Using two Motion Sensors and a Force Sensor

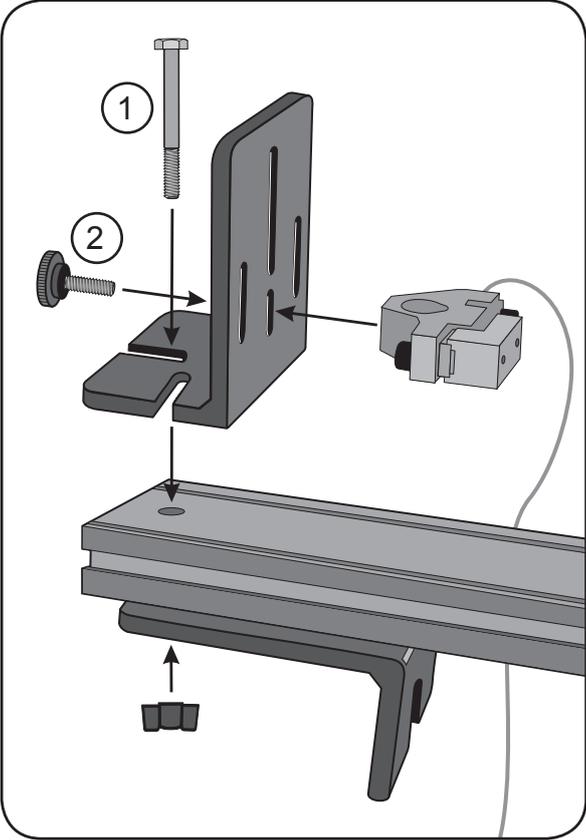
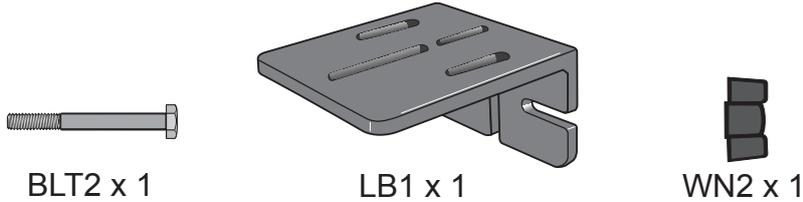


1. On one end of the target cart, attach a reflector in the horizontal position. At the other end of this cart, attach an upright reflector. Then attach the Force Sensor to this reflector and a spring to the Force sensor.
2. On the other cart, attach a reflector in the horizontal position.
3. Measure the mass of each cart and attachments (reflector, spring, etc.) to make sure they are both equal. Use masses and or modeling clay to adjust until they are.
4. Place the track in its lowest position, supported at the end by a large bracket. Adjust the track to be horizontal.
5. Connect the Motion Sensors to input 1 and 2 on the **EASYSense** logger. The range of the Sensors should be set to Distance. Connect the Force Sensor to input 3.
6. 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 48 to give the correct angle.
7. Support the Force Sensor cable vertically above the carts. **Zero** the Force Sensor.
8. Open the **EASYSense** program and select **Graph** from the Home page. From the wizard select the following:

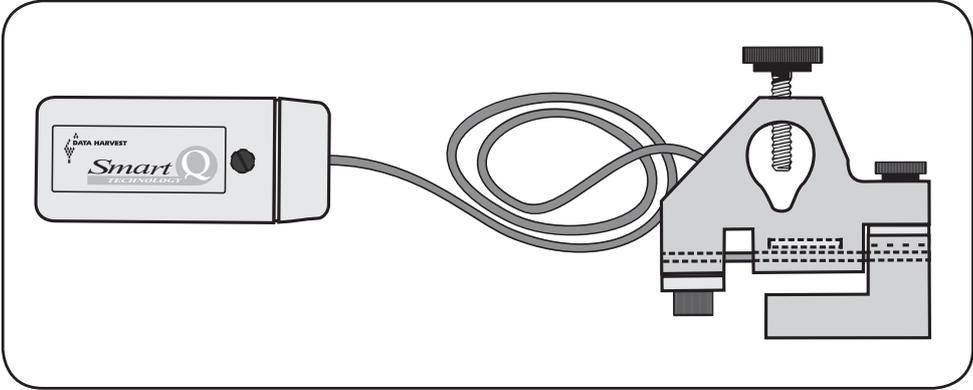
Time	Interval	Trigger
2 seconds	20 ms	When Distance (input1) falls below 0.5 m

9. Position the target cart at least 17 cm away from the Motion Sensor. Start with this cart stationary.
10. Click on the **Start** icon and push the other cart towards the target cart.

# Attaching a Force Sensor to the end of the track

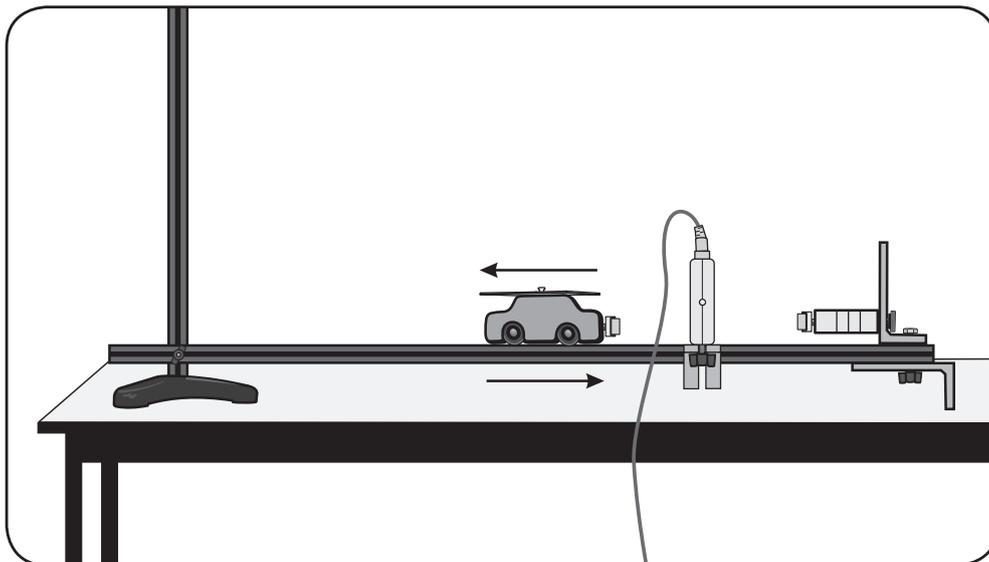


- 1. Attach a large bracket to the track using a BLT2 bolt and wing nut.
- 2. Attach the Force Sensor to the large bracket using the thumbscrew.



**Force Sensor - Product Code 3143**

## Collisions: Using a Force Sensor and a Light Gate

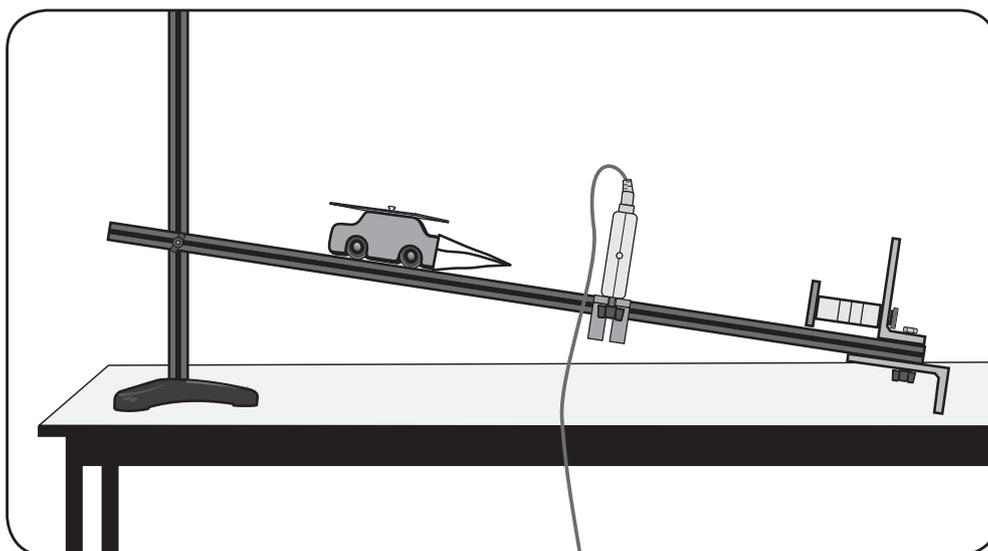


1. Fit the interrupt card and a magnet to the cart so the single interrupt edge will pass through the Light Gate. Measure the mass of the cart and attachments (interrupt card, magnet, etc.).
2. Attach the Force Sensor (with magnet and holder attached) to the large bracket at the end of the track. Adjust the height of the Sensor so the magnet is level with the magnet on the cart.
3. Place the track in its lowest position, supported at the end by a large bracket. Adjust the track to be horizontal.
4. Connect the Force Sensor to input 1 and the Light Gate to input 2 on the **EASYSense** logger (the Light Gate is to be used in analogue mode to measure how long it takes the interrupt card to pass through).
5. Arrange the position of the Light Gate so the cart passes through at its maximum speed on the rebound. The interrupt card must be able to pass through and rebound fully through the Light Gate.
6. Open the **EASYSense** program and select **Graph** from the Home page. From the wizard select the following:

Time	Interval
5 seconds	20 ms

7. **Zero** the Force Sensor using **Test Mode** from the Tools menu. Click on the **Start** icon and push the cart towards the Force Sensor; let it rebound completely through the Light Gate.

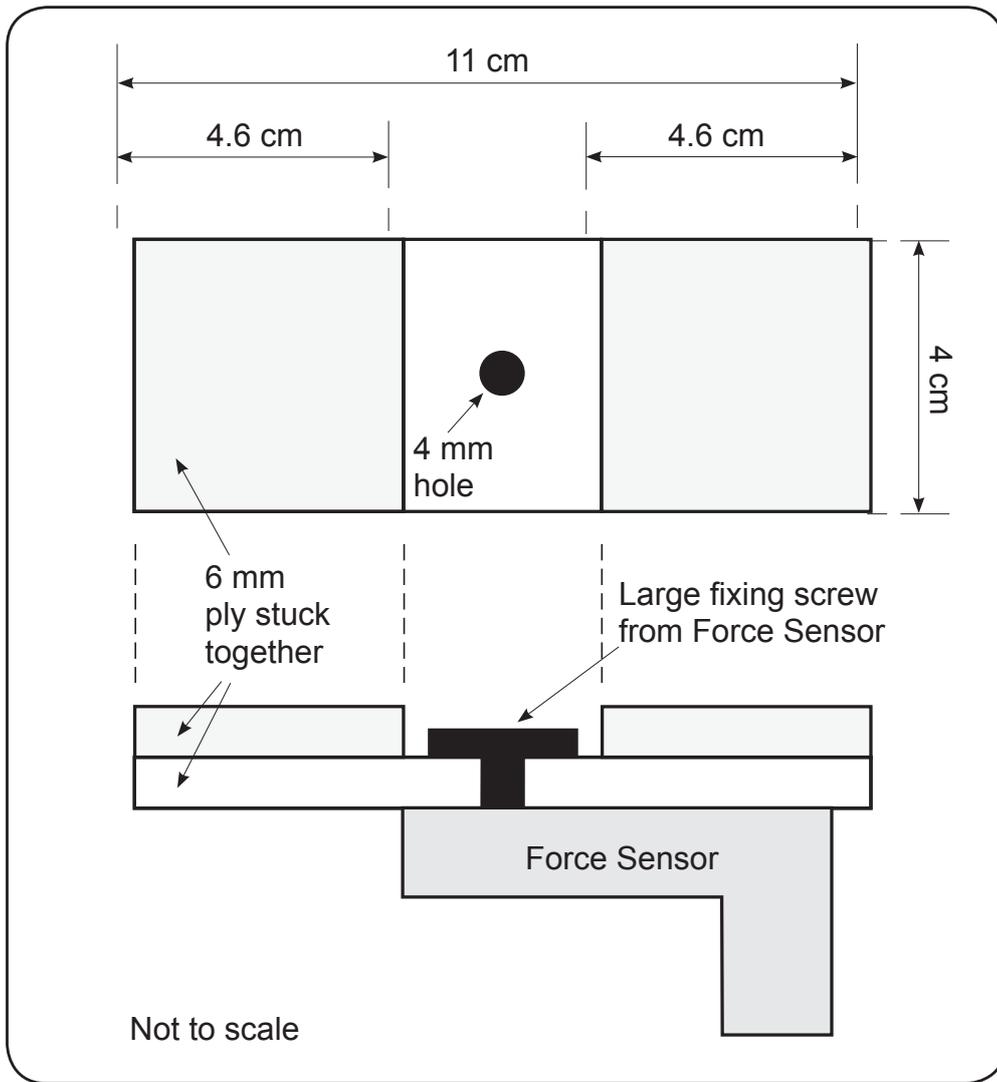
## Collisions: Using a Force Sensor and a Light Gate to investigate crumple zones



1. 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.
2. 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.).
3. Attach an extension target to the front of the Force Sensor to increase its frontal surface area (See page 58 for a possible design). Attach the Force Sensor to the large bracket at the end of the track.
4. Connect the Force Sensor to input 1 and the Light Gate to input 2 on the **EASYSense** logger (the Light Gate is to be used in analogue mode to measure how long it takes the interrupt card to pass through).
5. 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.
6. 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.
7. Open the **EASYSense** program and select **Graph** from the Home page. The suitability of a recording setup 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  $5^\circ$ ) a suitable set up was:

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

8. **Zero** the Force Sensor. Click on the **Start** icon and release the cart cleanly to run down the track towards the Force Sensor.
9. Repeat with a variety of different crumple zones.



**Extension target for Force Sensor**

# Attaching a Force Sensor to the pillar and the track



MT1 x 1



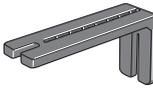
TS1 x 3



WN1 x 2



WN2 x 3



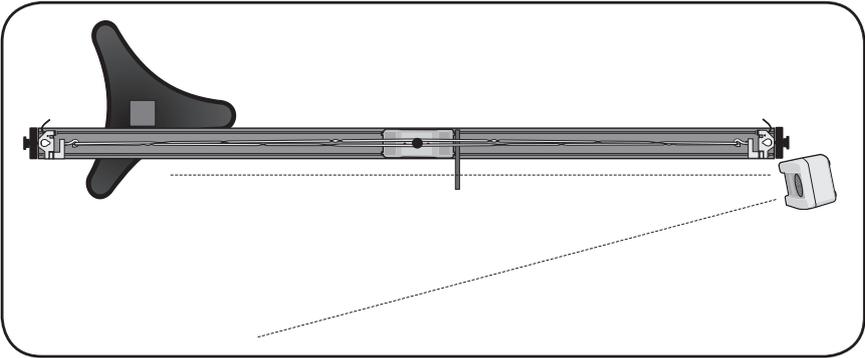
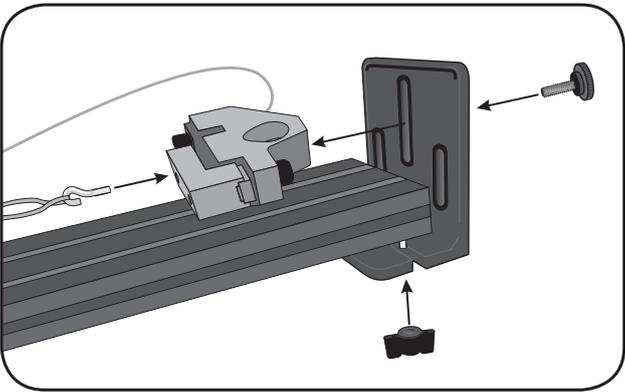
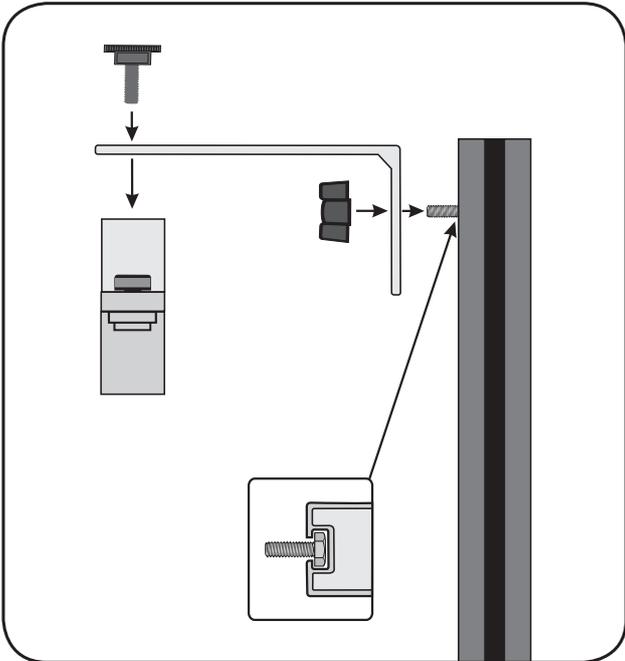
SB1 x 1



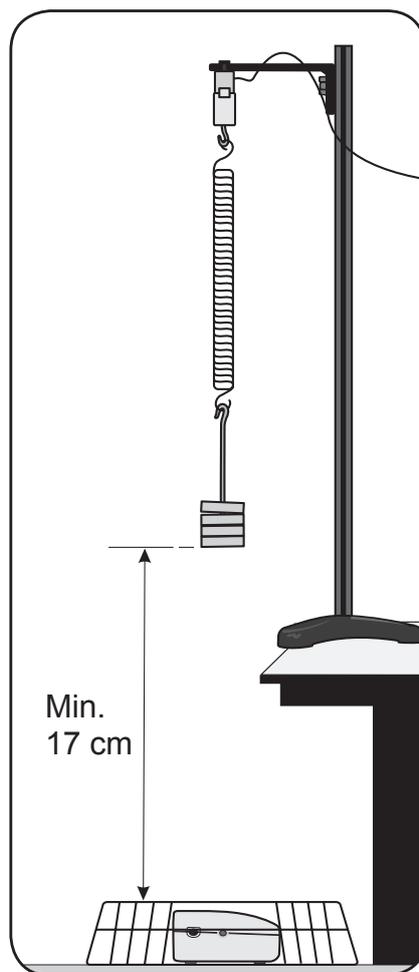
LB1 x 1



ER1 x 1



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

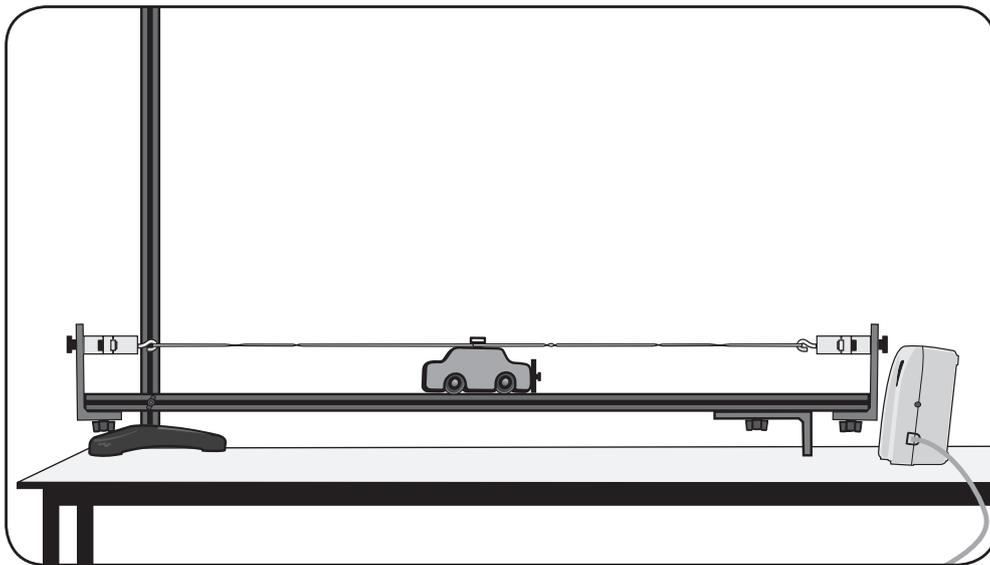


1. Weigh both the spring and the suspended mass (added together they are the oscillating mass).
2. Make sure that the apparatus is as rigid as possible, if necessary use clamps to secure the base.
3. When the mass is stationary, it should be about 50 cm from the Motion Sensor.
4. Connect the Motion Sensor to input 1 and the Force Sensor to input 2 on the **EASYSense** logger. The range of the Motion Sensor should be set to Distance.
5. Open the **EASYSense** program and select **Graph** from the Home page. From the wizard select the following:

Time	Interval
5 seconds	20 ms

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

## **Simple Harmonic Motion: Using elastic with two Force Sensors and a Motion Sensor and a cart oscillating horizontally**

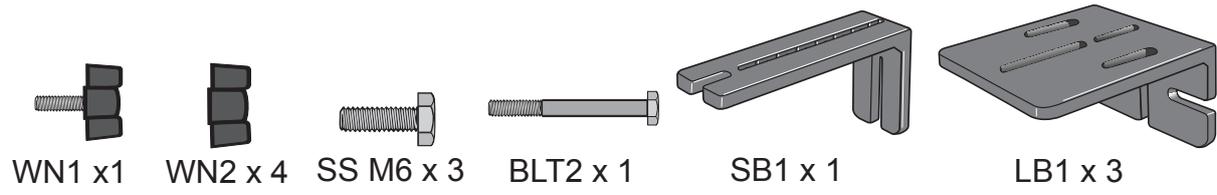


1. Assemble the apparatus as shown with the reflector card facing the Motion Sensor. Adjust the track to be horizontal. When the cart is stationary, it should be in the middle of the track. Do not use fabric-covered elastic.
2. Connect the Force Sensors to inputs 1 and 2 and a Motion Sensor to input 3 on the **EASYSense** 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.
3. Open the **EASYSense** program and select **Graph** from the Home page. From the wizard select the following:

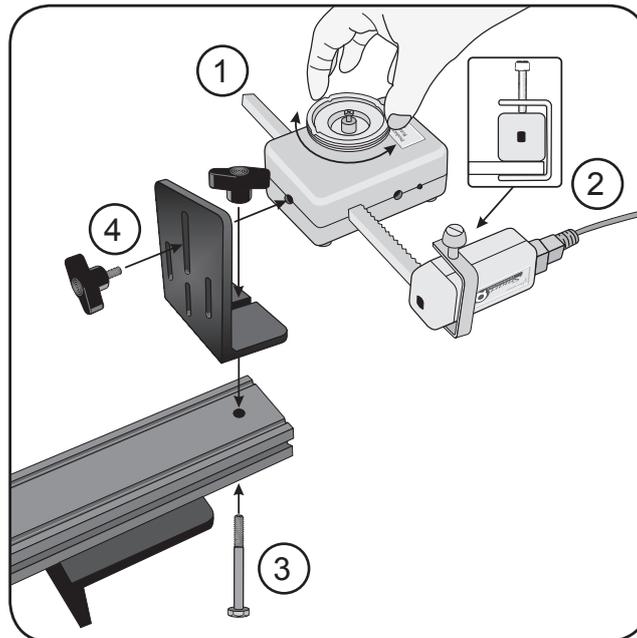
Time	Interval
5 seconds	20 ms

4. Select **Test Mode** from the **Tools** menu and without the elastic attached **zero** the Force Sensors. Attach the elastic and adjust the tension to give a reading of about 5 Newton with a period of oscillation of about a second.
5. **Zero** the Force Sensors while they are under tension.
6. Pull the cart to about 80 cm on the scale. Click on 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

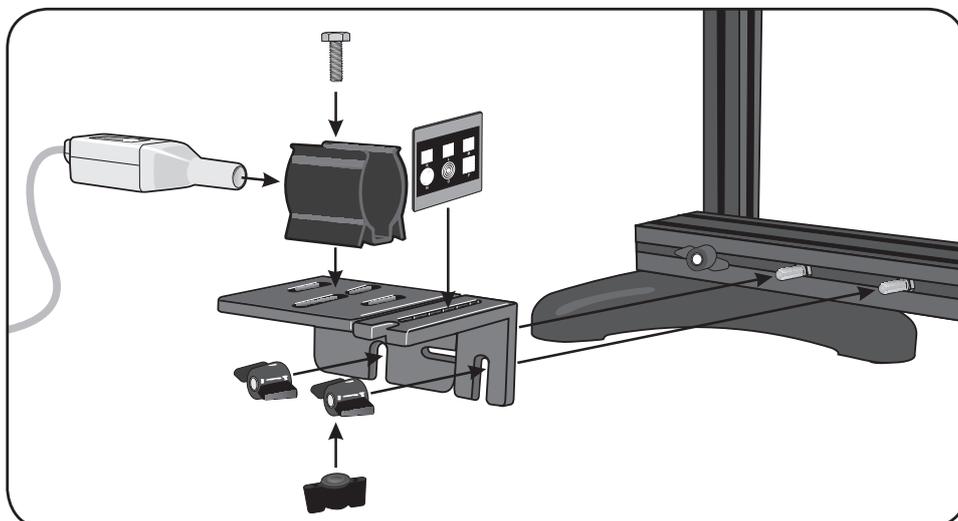


## Attaching a Rotary Motion Sensor, Light Sensor and Rack attachment



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 (BLT2) 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

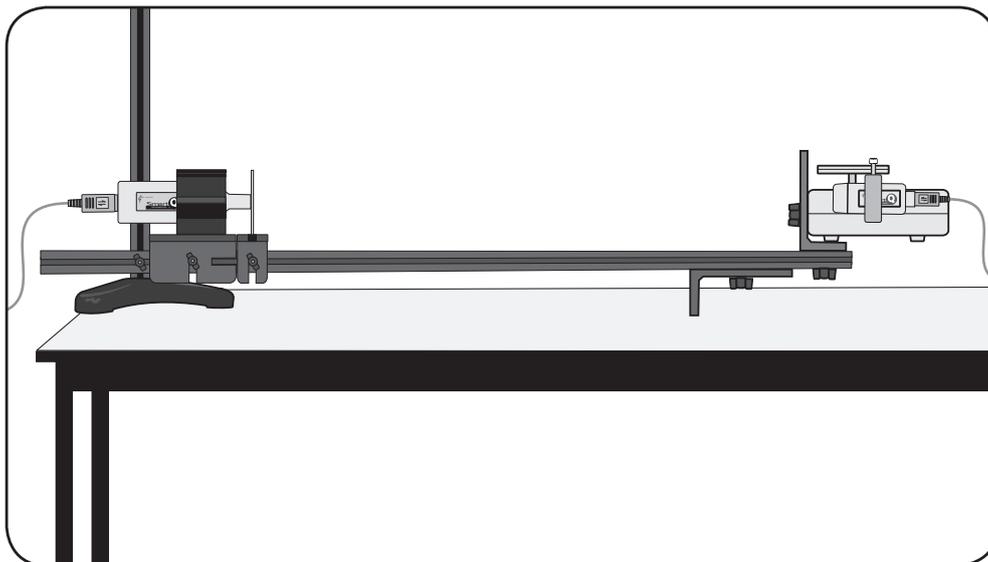


1. Slide 2 SS M6 Hex screws into the side groove of the track.
2. Attach a large and thin bracket (thin bracket to the front).
3. Attach a laser module holder to the large bracket; fit a diffraction slide into the slot on top of thin bracket.
4. Align the laser beam to strike the Light Sensor's sensing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

### **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 code 3285.*
- 1000 lx Fast Light Sensor. *Product code 3123*

## 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.

1. Assemble the apparatus as shown. Mount the Light Sensor so the sensing window is at right angles to the rack attachment.
2. 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.
3. Connect the Rotary Motion Sensor to input 1, the Light level Sensor to input 2 and the Laser to any other input on the **EASYSense** logger. The range of the Rotary Motion Sensor should be set to Linear rack.
4. Open the **EASYSense** program and select **Graph** from the Home page. From the wizard select the following:

Time	Interval
10 seconds	5 ms

5. Move the Light Sensor so it is next to the Rotary Motion Sensor. Press the **zero** button on the Rotary Motion Sensor.
6. Click on 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 the **Options** icon, the **X-Axis** tab 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.