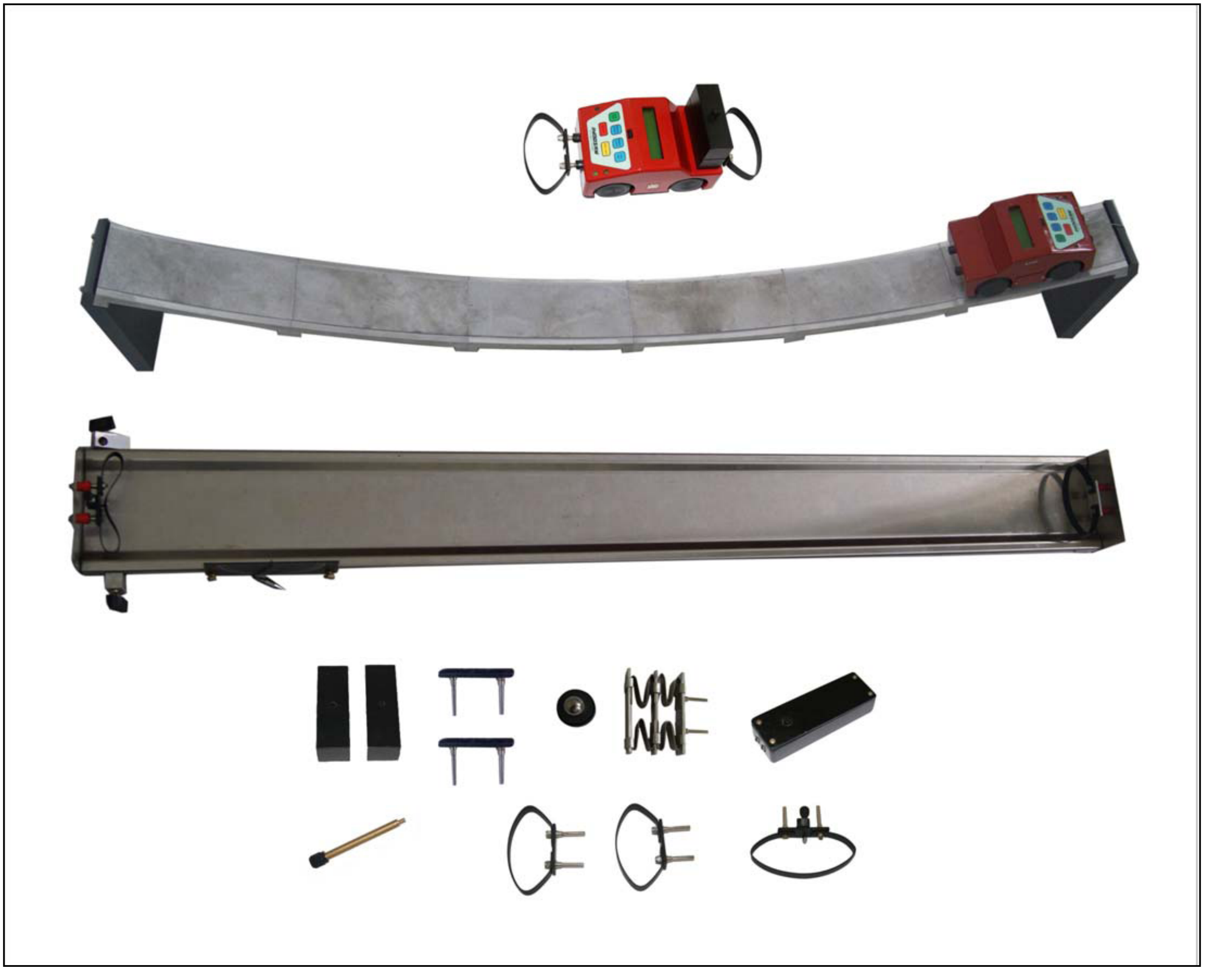
Study of Laws of Motion

Using

Advanced

Timing Car Kit



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1. Advanced INDOSAW Timing Car Kit for Study of laws of Motion

The advanced INDOSAW Timing Car kit for study of laws of motion is a novel and unique product designed to replace the conventional Air Track with Photo gate Timer for comprehensive study of linear motion experiments. The student can verify all the important Laws of motion and understand the practical implications due to analysis with a large amount of data. The experiments are easy to conduct and do not require any elaborate setups or disturbing noise unlike air track based setups. Additionally which is not possible in other Setups. Precise studies can be made regarding motion in one dimension, horizontal plane, inclined plane, up-down sloping planes and potential well. It consists of two low friction cars with built-in data-logging, tracks and bumper accessories.

Each car is an intelligent data-logging car with advanced electronics to accurately record Displacement VS Time data at Millimeter level movement and microsecond level time resolution. Each car can finely record up to 9999 readings independently in motion along with direction of movement which can be downloaded to PC for comprehensive analysis of Displacement VS Time data and study of laws of motion.

For collision experiments two cars can be used simultaneously and their time synchronization is automatically adjusted by a Remote.

Computer software for car is provided with features of plotting and graphically analyzing Time VS Displacement, Speed, Momentum, Kinetic Energy for different experiments. One can also analyze acceleration between two points.

It is provided with Low friction Linear track , Curve Potential Well track and several bumper accessories and weights for conducting various experiments including potential well, crash test, elastic and inelastic collisions with in-depth analysis which is not possible with any other product in the market.

The advanced kit consists of the following :

1.1 Timing Car

The Indosaw Timing Car is an essential requirement to perform several Laws of Motion Experiment. It is connected to the PC through USB cable operating at 57600 Baud Rate. It has in-built motion and direction detection with 2 channel sensor, Bright LCD display, remote detection sensor, a user replaceable 9v battery and an intelligent microcontroller based circuitry to sense millimeter level movement of car on Linear and Non-linear Motion.

1.2 Analysis Software

The Analysis software is a user friendly software meant for analyzing the data recorded by Timing Car in performing Motion experiments. The data recorded in Car(s) can be transferred to the Software and plot Time VS Displacement, Speed, Momentum and Kinetic Energy for different experiments which can be graphically analyzed. One can also analyze acceleration between two points. The software plays a vital role in understanding the basic concepts of various Laws of Motion as large amount of motion data recorded in Car(s) on any kind of Track can be graphically analyzed in fine detail.

1.3 Remote

Remote is used to remotely start the timers on cars and can synchronize the timers of two Cars in collision experiments. It is based on IR and is directional.

1.4 Tracks

Track is an important part for performing Laws of Motion experiments. There are two tracks provided. One is a straight track and is used to study Linear Motion and Inclined Plane Motion and other is a curved track to study Potential Well and Non-linear Motion Experiments. The tracks are low friction. However any kind of up-down or sloping track with or without friction can be used by the student for advanced experiments.

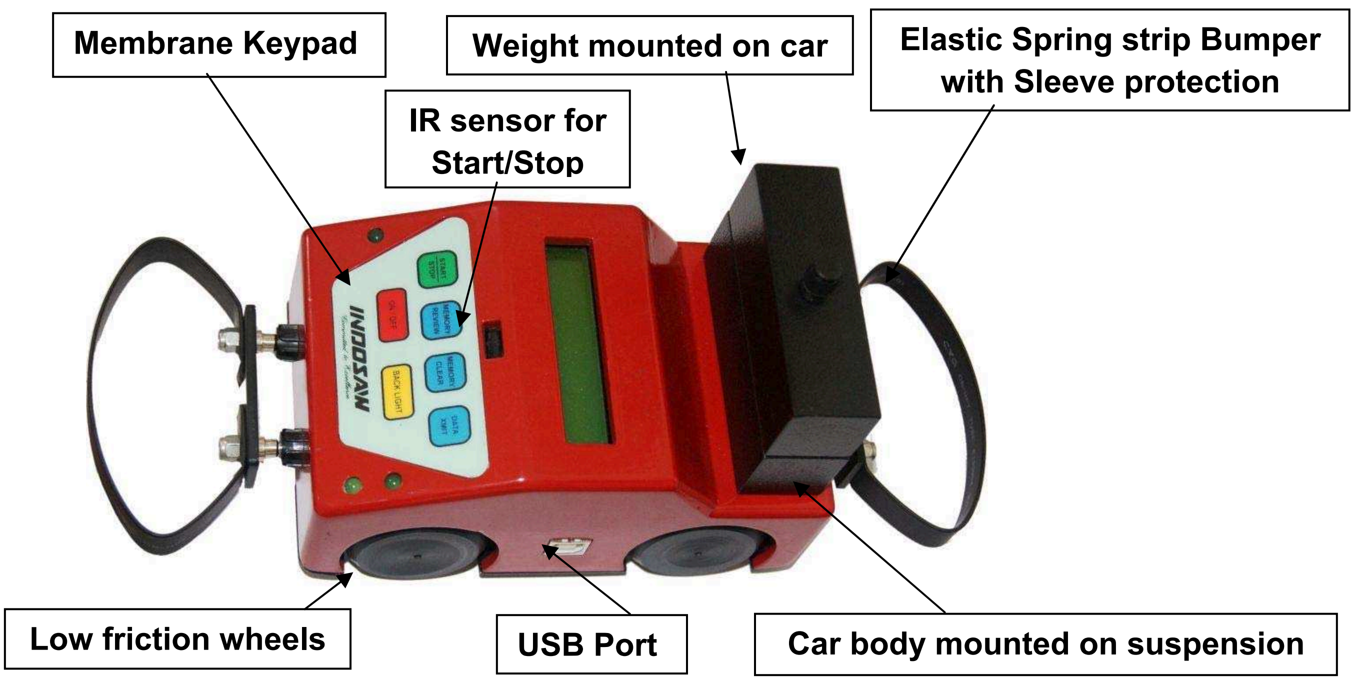
1.5 Accessories

There are several Bumper and Weight accessories that can be fitted to the Car and Track. Bumpers are used in mostly all linear Motion Experiments. Elastic Bumper, Velcro Bumper, Crash test Bumper are usually fitted on Timing Car, Striker Bumper accessory is fitted with the Track for initial Momentum to Car. Weights can also be mounted on the Car.

2. Timing Car

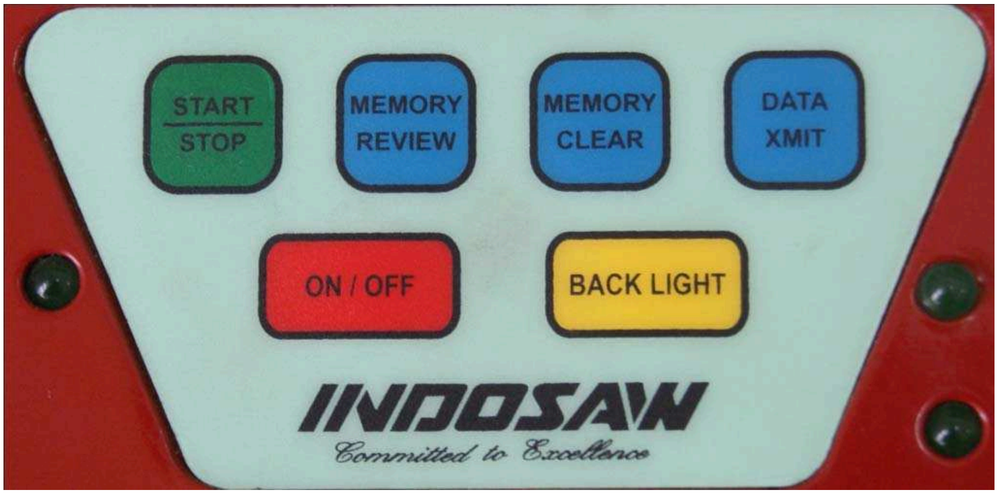
INDOSAW Timing Car is an intelligent data-logging low friction motion device with advanced electronics to accurately record Displacement Vs Time data at Millimeter level movement and microsecond level time resolution. It is a novel product and most important component of the kit. There are two Cars in the kit. Each Car can finely record up to 9999 readings independently in motion along with direction of movement which can be downloaded to PC for comprehensive analysis of Displacement VS Time data and Study of Laws of Motion.

The Car has two line Alphanumeric LCD display and 6 key membrane keypad as shown below.



The Car is low friction device and body is mounted on suspension at its wheels. The car has provision for mounting front and rear bumper accessories and weights. It has a 9v replaceable battery and USB port. It has an IR detector for remote timer on/off. The LEDs display the motion status. Duracell 9v battery is recommended.

The functions of the six keys on the keypad is described below.



2.1 ON/OFF Key:

The ON/OFF key on keypad helps in power ON of Timing Car and same is used to Power OFF. After power on the LCD screen displays Timing Car version in first line of LCD and zero Displacement and time readings in second line of LCD as shown below.

2.2 START/STOP Key:

This key is used to START the timer and the Car is ready to record data as shown below. Data is recoded at every 2 Millimeter movement alongwith direction of movement. The timer reading is displayed in seconds with a resolution of 1 Microsecond.

When Car is moved on track or plane, every 2 Millimeter of Displacement, the number reading increments on the left half of 2nd line on LCD. The maximum four digit reading reaches to 9999 after which the recording stops. Same START/STOP key is used to STOP the timer if counter has not reached to 9999 reading. When timer is stopped the display is shown below.

2.3 MEMORY REVIEW:

This key is used to review the memory data stored after experiment completion.This helps in plotting graph manually. LCD screen displays the distace movement in meters on first line and reading number, Direction and Time in second line of LCD as shown below.

The displacement is displayed in linear vector form considering the start of recording as zero Displacement. With every press of the Memory Review key the reading number is incremented and correspondingly displayed.

2.4 MEMORY CLEAR:

This key is used to clear the recorded memory of data.

Before recording of a new experiment readings it is required to clear the previous data otherwise the recording of new data will continue from previous reading number.

2.5 DATA TRANSMIT:

This key transmits the acquired data in Car memory through USB port at 57600 Baud Rate to PC based Analysis software for analyzing the data of experiment and understanding the concepts behind the experiment. While Data Transfer is in progress as shown below, please wait till the entire data is tranmitted.

2.6 BACK LIGHT:

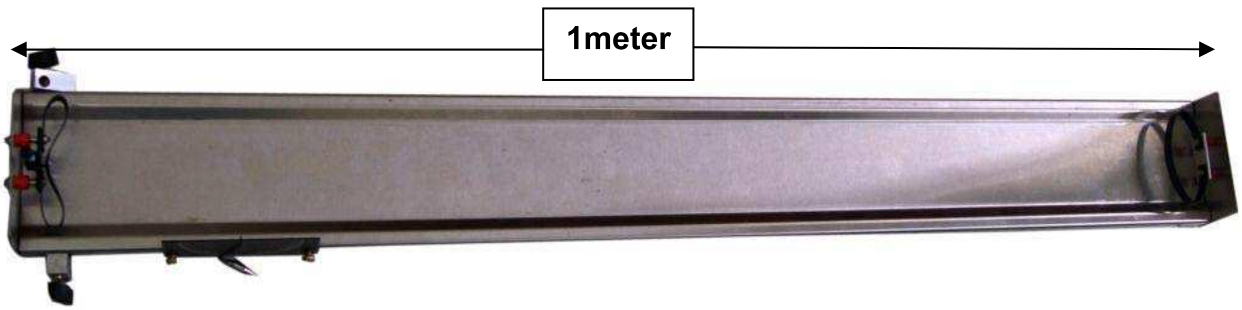
This key Switches ON/OFF the LCD BACK LIGHT to save battery while performing experiments. Pressing the key again will switch on the LCD BACK LIGHT for better viewing. Please note that the backlight consumes battery power.

3. Tracks and Accessories

This section describes the tracks and accessories used with the Cars.

3.1 Linear Track

Linerar track is a 1 meter Track as shown below.



It is Stainless Steel Track with an arrangement of mounting bumper accessory with 4mm jack fitted on both sides of track.Track is provided with Scale and marker to adjust an angle to perform inclined plane experiments. Stainless Steel material helps in decreasing the frictional losses while performing experiments. This track can be used to perform Linear Motion on Horizontal and Inclined plane experiments as well as Elastic and Inelastic collision experiments.

3.2 Potential Well Track

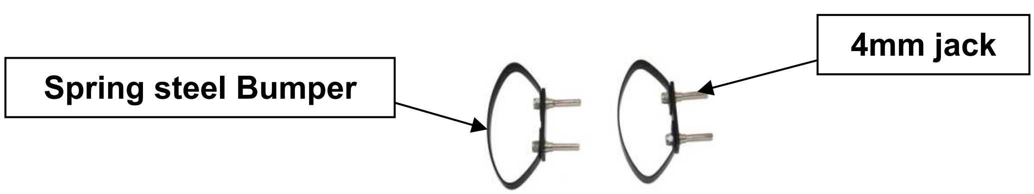
This track is a Curved Track and is made by assembling segments as shown below.

Separate blocks of potential well

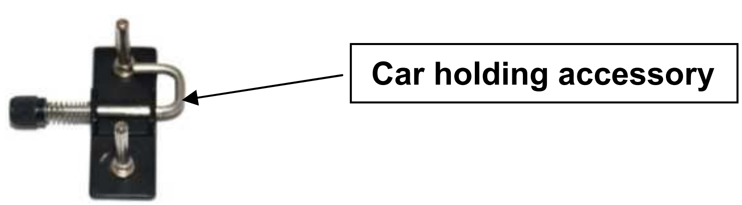
It is easy to install from Small Segments of Tracks using screws. This Track is used in Potential Well experiment to study the Law of Conservation of Energy together with frictional losses.Track is light weight in an arc shape.

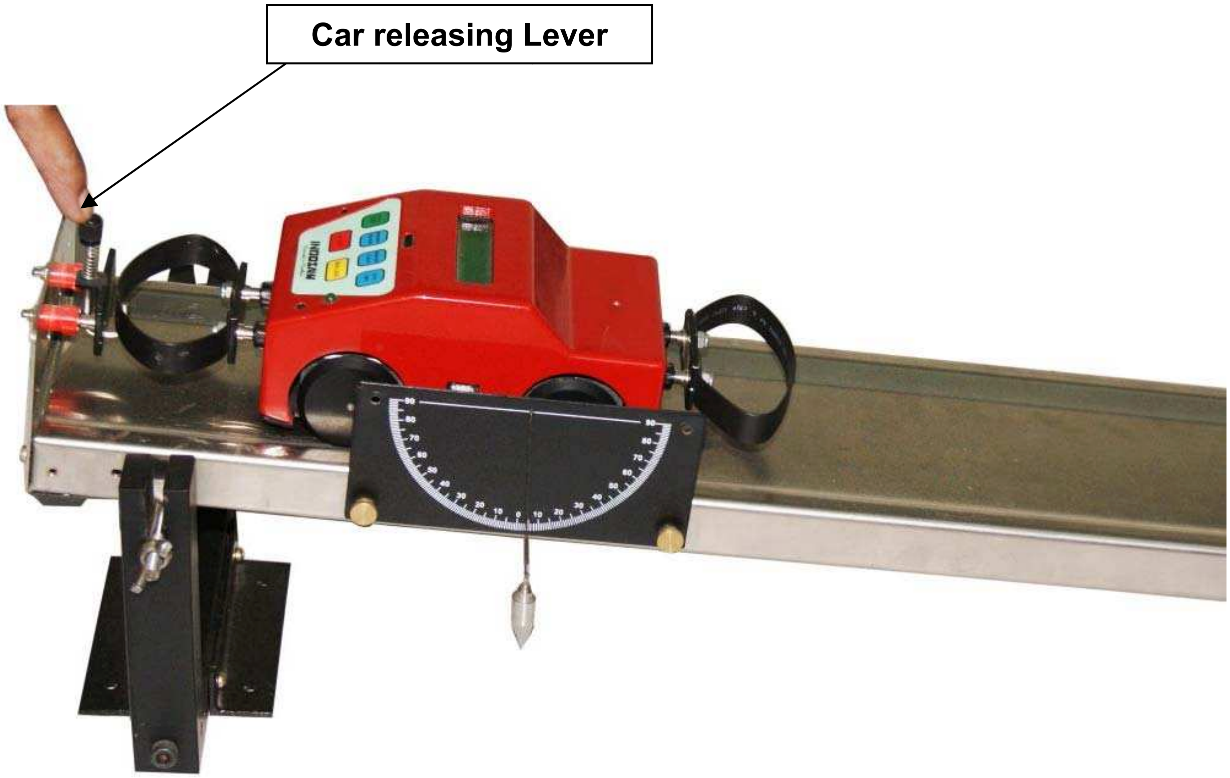
3.3 Accessories

3.3.1 Elastic Bumper Accessory : This accessory can be mounted on Car bumper as well as on Track to be used in Elastic Collision experiments. The Spring Strip provides the necessary Elastic action during collision. A set of two Eastic Bumper accessory is shown below. It is also used during holding the car on Inclined Track before release.

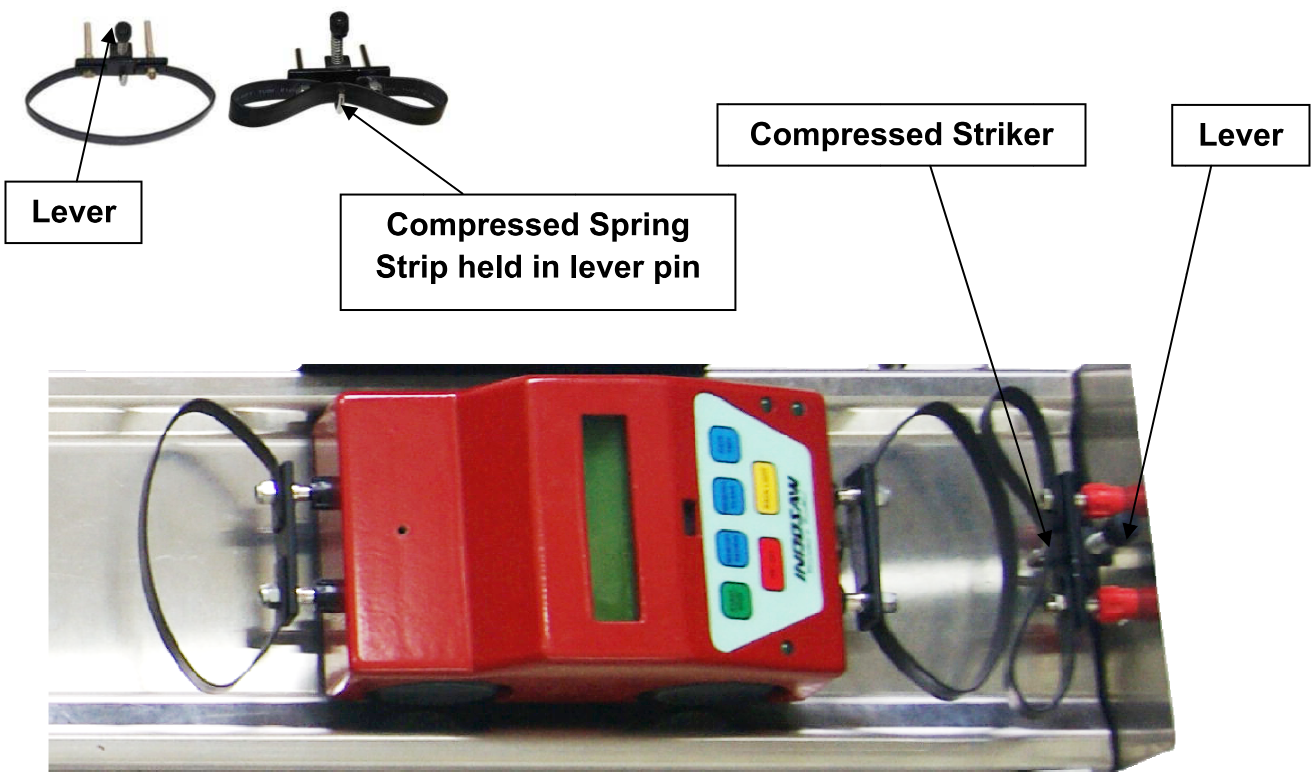


3.3.2 Release Bumper accessory: This accessory is used with Inclined plane to hold Car at height. It fits in the 4mm socket at the end of the track. The lever holds the Car with the Elastic Bumper. When lever is pressed the Car is released from the End of the track as shown below.

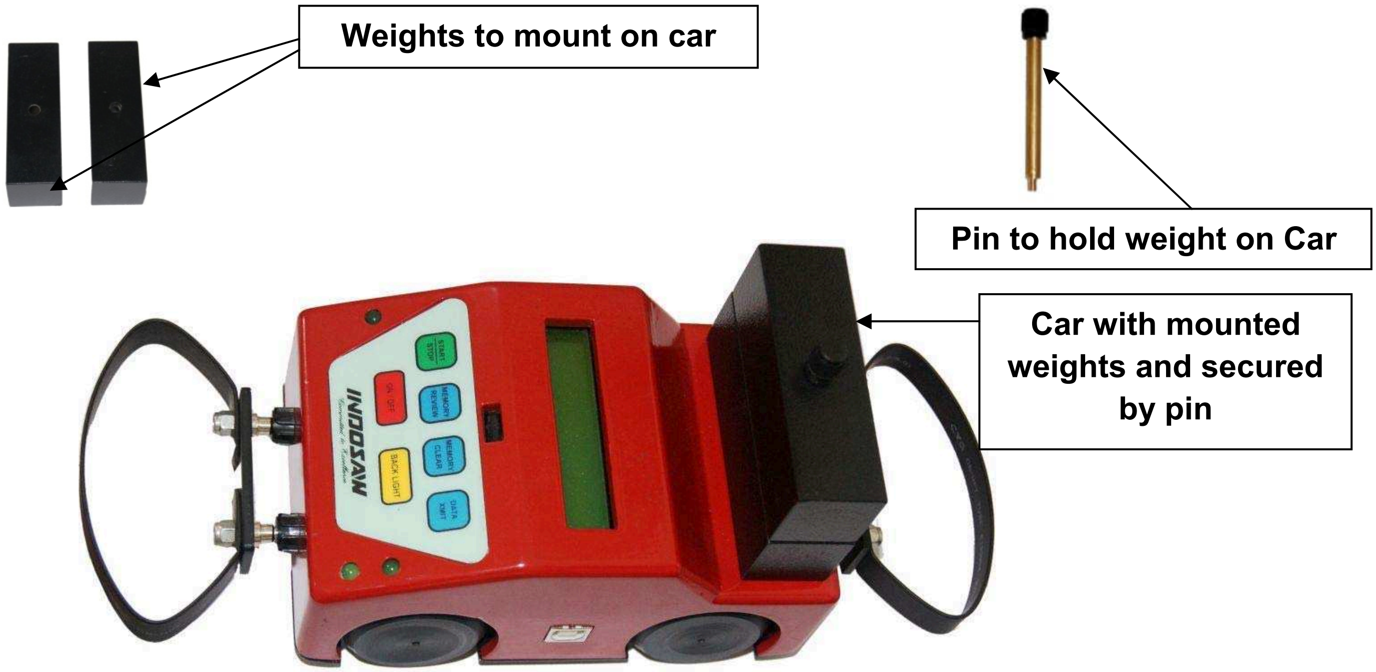




3.3.3 Striker Bumper accessory : This accessory is used on Track for striking or providing Initial Momentum to Car. The Spring Strip is compressed to hold in the lever as shown below. When lever is pressed the Spring gets released to strike the object placed near it with a force which provides initial Momentum.

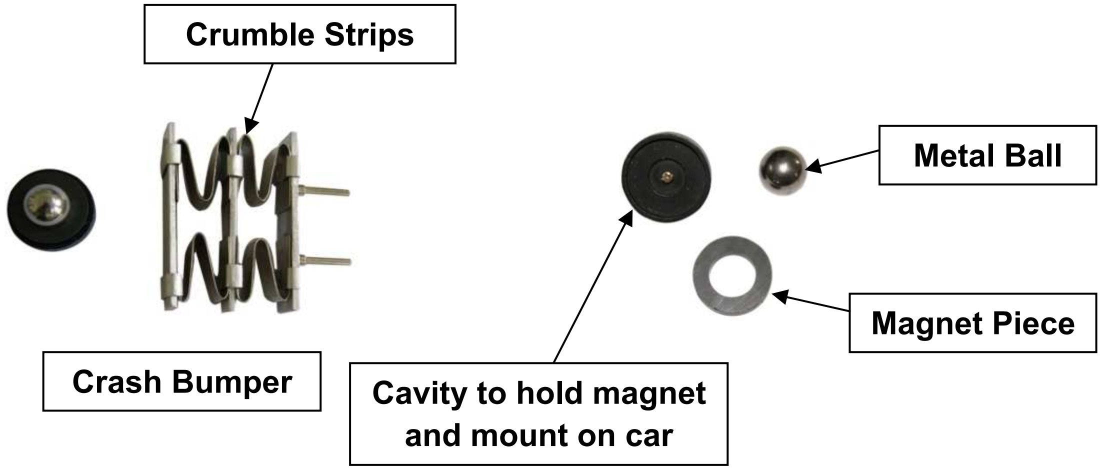


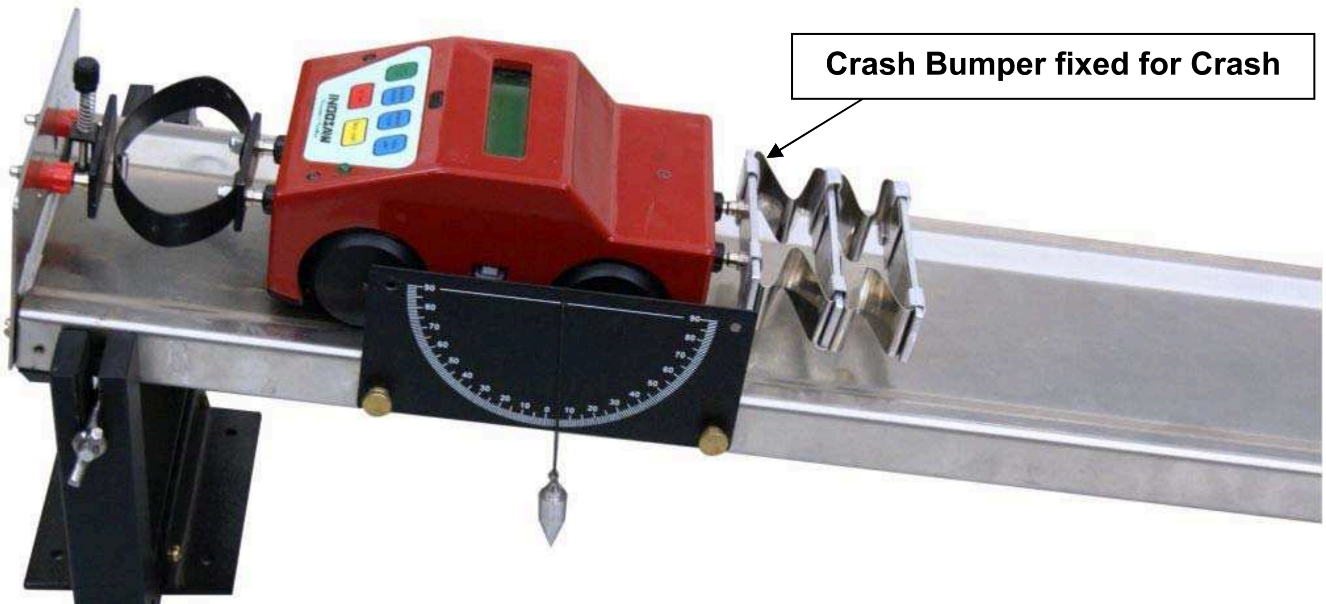
3.3.4 Weight Accessory wth Pin : This accessory is basically used to add weight on Car in Elastic Collision and Inelastic Collision Experiments. There is a set of two weights where each weight is about half the weight of the Car. The pin is used to secure the weights on the Car.



3.3.5 Velcrow Bumper Accessory : This accessory is mounted on two cars while performing inelastic collision experiment. When cars collide they get stuck with each other and then move as a single body on track.

3.3.6 Crash test Bumper Accessory : The Crash test bumper accessory consist of a magnet and metal cup to be secured on car. A metal ball (egg) is secured in the metal cup due to the magnet and acts as a person sitting in the car. The crash bumper is mounted on car front. The crash bumper consists of collapsible metal strips. The car is then rolled on an inclined plane and hits the end of the track. The crash strips of the bumper accessory crumbles after impact of car on hard surface of track end, to absorb and weaken the impact force. When impact force is considered safe the metal egg which denotes the occupant of the car does not get released from the magnet. Student can tryout by modifying the magnet power and crumble strips of the crash bumper.





Crash Test Set Up

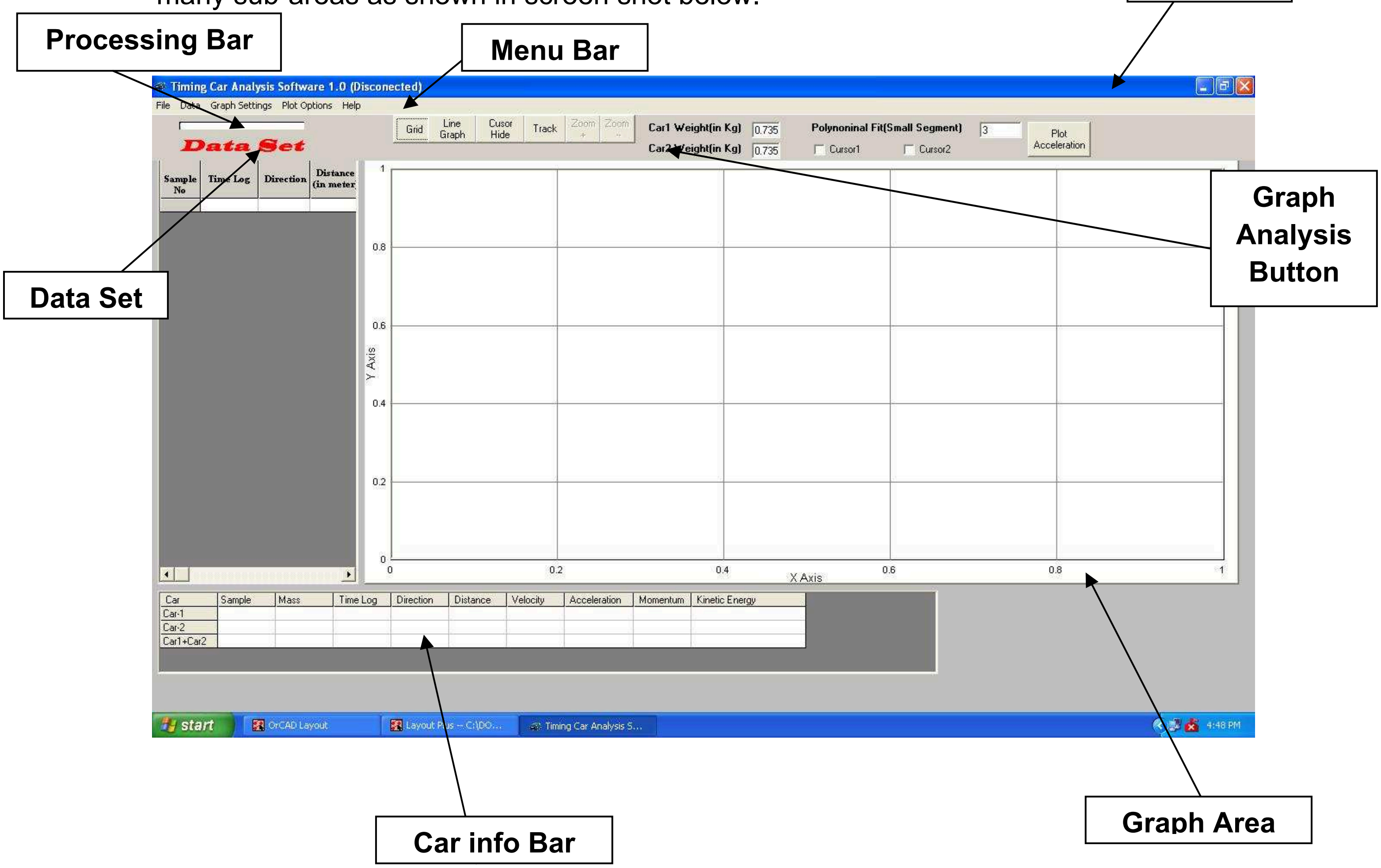
4. Analysis Software

After recording experiment data in the Car(s) the same can be transferred and analyzed on computer using the Analysis Software. The Analysis Software has features of plotting and graphically analyzing Time w.r.t. Displacement, Speed, Momentum and Kinetic Energy for different experiments. One can also Analyze Acceleration between two points. Since a large amount of motion data is recorded in the Car, precise studies can be made regarding motion in one dimension, Horizontal plane, Inclined plane, Up-Down sloping planes and Potential Well.

The Analysis Software frontend screen is partitioned into several working areas and Operational Menu which facilitate transfer of Car data and plotting of various graphs. It also has functions to smoothen the data presentation and finely analyze the data points as well as saving experiment data. The software description is organized in the form of Frontend Screen Description, Menu Description, Operational Procedures and Software Installation.

4.1 Frontend Screen Description:

Screen Area- The Timing Car software screen area is broadly divided into many sub-areas as shown in screen shot below.



These are briefly described below.

4.1.1 Title Bar : This represents the name of software and options for minimizing, restoring screen and for exiting software.

4.1.2 Menu Bar : This bar represents the Menu's that facilitate the various operational functions. These are organized in five categories represented as File, Data, Graph settings, Plot settings and Help.

4.1.3 Graph Analysis buttons : This area has several buttons for analyzing the plotted graph. These are Grid, Line graph/Dotted graph, Cursor hide/Examine, Zoom/Track/Move, Zoom+, Zoom- and Plot Acceleration. In addition there are two check boxes named Cursor1 and Cursor2 for placing cursors on the graph and calculating acceleration. Most of these buttons have more than one option which can be toggled.
The details of these buttons are explained as follows:

a. Grid : This button is used to turn On/Off the graph grid for viewing or printing. A Click on button shows the corresponding results on the screen.

b. Line graph/Dotted graph : This toggle button is used to draw the graph data with connecting lines when in Line graph selection.
In Dotted graph selection, the graph of the data set is in the form of a scatter plot with dots representing the data points. A click on button shows the corresponding results on the screen.

c. Cursor hide/Examine : This toggle button is used along with the cursor operations.
Cursor1 and Cursor2 can be placed by the user anytime by checking on the Cursor boxes and then selecting the desired points on the graph.
When Cursor hide is selected it removes any existing cursor on the graph.
The user can place or move cursors at selected points any time.
The Examine selection is used to dynamically examine the X and Y points. In this mode the Left click and hold of the mouse keeps displaying the X and Y points as the mouse cursor is moved along the graph line. The graph values of Time, Vector Displacement, Velocity, Momentum, Kinetic Energy and Instantaneous Acceleration are additionally displayed in the Car info bar. The release will automatically stop the **Examine** function display. Additionally cross lines on the graph denoting selection point are also dynamically displayed in this mode.

d. Zoom/Track/Move : This toggle button has multiple uses as described below.
In the Zoom selection a selected area of the graph can be zoomed to approximately fit the graph window. The desired area is selected using the mouse and left click and hold. Upon release the area selected will get enlarged or zoomed.
The Track selection is used to dynamically examine the X and Y points. In this mode the Left click and hold of the mouse keeps displaying the X and Y points as the mouse cursor is moved along the graph line. The graph values of Time, Vector Displacement, Velocity, Momentum, Kinetic Energy and Instantaneous Acceleration are additionally

displayed in the Car info bar. The release will automatically stop the tracking function display. No cross lines are displayed in this mode.
The Move selection is used to dynamically pan or move the graph. The user can anchor on any point in the graph by mouse left click and hold. The graph keeps shifting according to the movement of the mouse. The release deactivates the move operation. This way the user can analyze larger portions of graph data at a particular zoom level.

e. Zoom + : Clicking on this option the user can zoom in on the graph in steps.

f. Zoom - : Clicking on this option the user can zoom out on the graph in steps.

g. Plot Acceleration : This button is used to plot and analyze the changes in acceleration in portions of the graph between two points defined by Cursor1 and Cursor2.
The user can click on button to Plot Acceleration after placing Cursor1 and Cursor2..
To place Cursor1, check Cursor1 box and click on graph at point required. The Cursor1 line will appear on graph. Similarly check Cursor2 box and again click at another point on the graph.
Several portions of graph for Plot Acceleration can be selected with cursors in sequence.
To remove the Acceleration plots from the graph, the graph can be redrawn with selected Plot options from the Menu items.

4.1.4 Car info bar : This bar displays information about data points of Car1 and Car2. It displays Sample Number, Mass, Time Log, Direction, Displacement, Velocity, Acceleration, Momentum, Kinetic Energy of a particular Sample. Cursors, **Track** and **Examine** functions display information in this area.

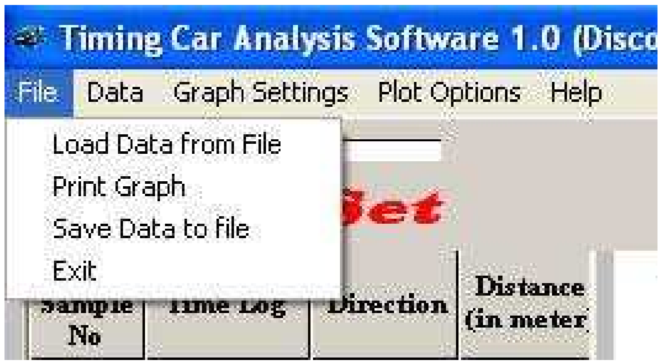
4.1.5 Data Set : This Area displays the motion data that was transferred from Car(s). It is presented in tabulated form after it is transferred from Car to the software. Its tabulated values hold direction, Time and Displacement columns when it is transferred. Additional columns also hold calculated values according to plot options.

4.1.6 Processing Bar : This bar represents the status of data being loaded from Car into the software. The data transfer from Car is carried out after clicking **Data> Load Data from Car** sub-menu in software and then pressing **Data XMIT key** on Car.

4.2 Menu Description:

There are five main Menu items in the menu bar. These are organized in five categories represented as File, Data, Graph settings, Plot settings and Help. Each main Menu has a sub-menu which represents its various functions. These are explained in the following sub sections.

4.2.1 File : There are four sub-menu items in the File menu namely Load Data from File, Print Graph, Save Data to File and Exit. The screen shot below shows the selections.



The functions of these menu items are explained below.

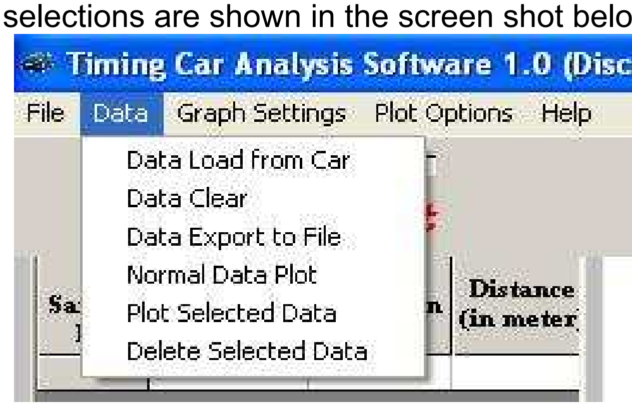
a. **Load Data from File :** This is used to open an existing data set earlier saved in computer.

b. **Print Graph :** This is used to take print of the graph plotted from current data set.

c. **Save Data to File :** This is used to save the current data set into a file at a user specified directory location.

d. **Exit :** This is used to exit from the software.

4.2.2 Data : This menu is useful for transferring data from car(s) and loading the data in the data set area. There are six sub-menu items in the Data menu. They are Data Load from Car, Data Clear, Data Export, Normal Data Plot, Plot Selected Data and Delete Selected Data. These selections are shown in the screen shot below.



a. Data Load from Car : This is used to transfer data from the Car(s) to the Data set area for analysis. It works only when Car is connected through USB cable to computer. Data Receive process window will open up and display that software is ready to receive Data from Car and also displays the **Comport Status** at which Car is attached. Once Car is connected, the Data XMIT key on Car can be pressed to actually initiate the transfer. The data while transferring also starts filling up in the data set area. Data from two Cars can be transferred through the same procedure one after the other in sequence for loading data of Cars in collision experiments.

b. Data clear : This is used to clear data present in the data set on Computer screen. It should be normally done before loading a new experiment data in the data set area.

c. Data Export to File : This is used to transfer data to any excel, word or text format.

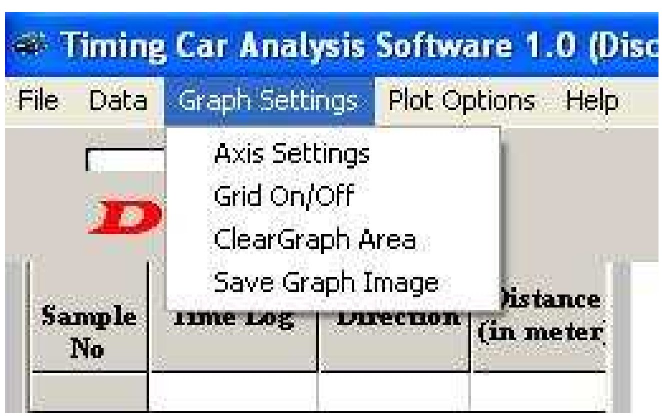
d. Normal Data Plot : This is used to plot the graph of the current data set.

e. Plot selected row : This is used to plot the selected row or rows of data set. A section of Data set can be analyzed with this option.

f. Delete selected row : This is used to delete the selected row of data from the data set. Unwanted data in the Data set can be removed by this option.

4.2.3 Graph Settings:

This is used for setting the graph area for presentation. There are four sub-menu items in the settings menu namely Axis Settings, Grid ON/OFF, Clear Graph Area and Save Graph Image.
The screen shot below shows these selections and are described further.



a. Axis Settings : This is used to select the display of Y-axis parameters namely Displacement, Velocity, Momentum and Kinetic Energy with respect to time on the X-axis. The parameters ticked by user are selected for Plotting together on a single time axis to enable the user to correlate the Displacement, Velocity and other parameters during the experiment. The Plot is produced upon selection in the **Plot Options** menu.

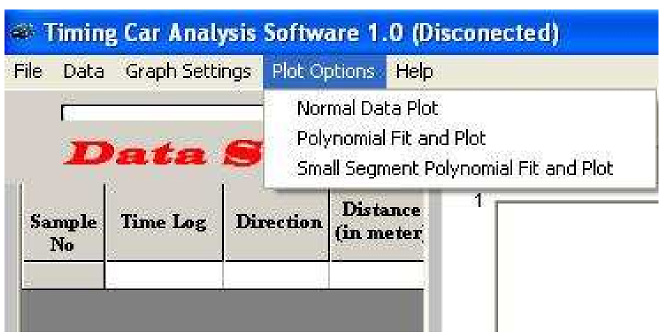
Normally with **Auto Scale selection**, the software will automatically select the Maximum X- axis and Maximum Y-axis values of parameters for plotting from the Data set.
The user can manually enter the value of Maximum X and Maximum Y axis value which would restrict values of X and Y axis during plotting.

b. Grid On/Off : This is used to turn On/Off the grid in the graph area.

c. Clear Graph Area : This is used to clear graph area. Whenever a new data set is loaded it is recommended to clear the graph area also.

d. Save Graph Image : This is used to save the displayed graph in a file on computer.

4.2.4 Plot Options : After performing the experiment and transferring the data values from car to software, the user can plot the graph of the acquired data set. The user can plot from raw data or perform polynomial fit on the data. There are three sub-menu items which are Normal Data Plot, Polynomial fit and Plot and Small Segment Polynomial fit and Plot. The screen shot below shows the menu sub-selections which are described further.



a. Normal Data Plot : This is used to plot the graph according to the selected graph setting parameters and options. Under this selection raw data set acquired from Car(s) is directly plotted for Time-Displacement graph and is used for the calculations of Velocity, Momentum and Kinetic Energy plots if selected.

b. Polynomial Fit and Plot : This is used to plot the graph after applying a large segment polynomial fit. One segment of data represents the continuous motion of Car in one direction. Whenever Car strikes and reverses direction a new segment is formed for polynomial fitting of the data. This function provides a smoother plot specially in potential well experiment by removing minor irregularities of potential well track used.

c. Small Segment Polynomial Fit and Plot : This is used to plot the graph after applying a polynomial fit by taking small segments of the data set. The user can define the length of segment on either side of a data point. This is defined on the text box named Polynomial fit (small segment) on the Graph analysis button area. This function provides a smoother plot specially in Elastic and Inelastic Collision experiments by removing minor irregularities of the linear track used.

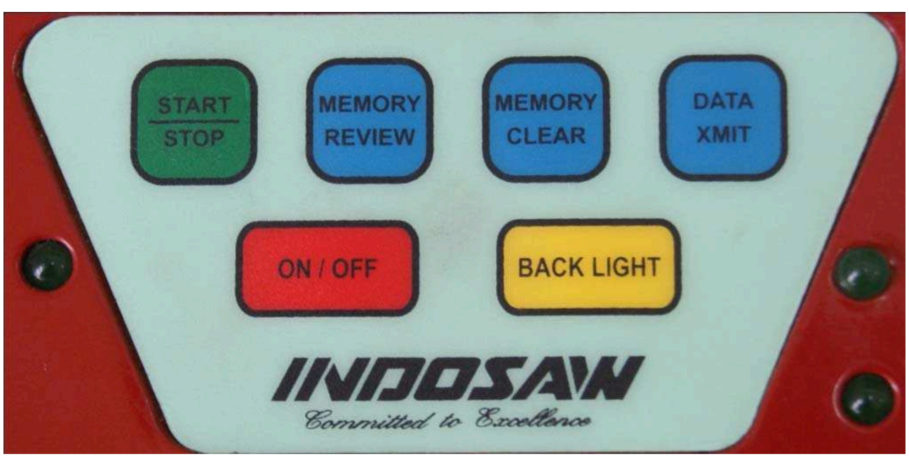
4.2.5 Help: This option is presently having only one sub menu named **Manual** which opens up the soft copy of the Manual.

4.3 Operational Procedures

Various experiments can be performed using a Track and single or two Cars with different accessories. Typically while conducting any experiment, the data-logging Cars while travelling on track keep recording the Time-Displacement data. This data recorded in individual Cars is then transferred to the Analysis software. Once data is transferred from Car it can then be plotted and analyzed as well as saved in a file. These operating procedures are explained in the following sub-sections in simple sequential steps.

4.3.1 Acquiring experiment Data in Car

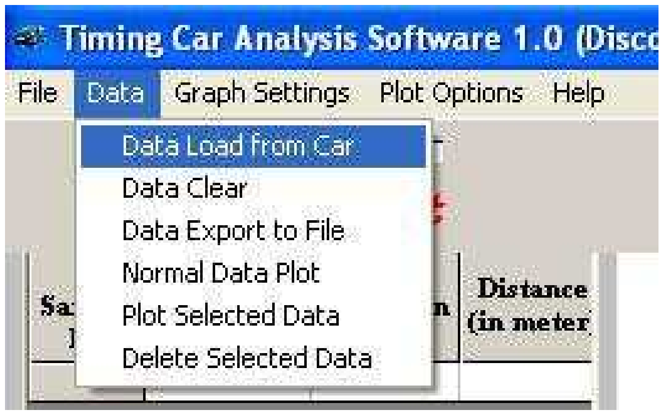
- Arrange the set –up required in the experiment
- Switch **ON** the Car by **ON/OFF** key.
- Start the timer with **START/STOP** key on Car keypad or remote and allow the Car to move in experimental set up.
- Stop the timer using **START/STOP** key or **Remote.**
- Once data is recorded it can be reviewed on LCD of Car or it can be transferred to Analysis Software.



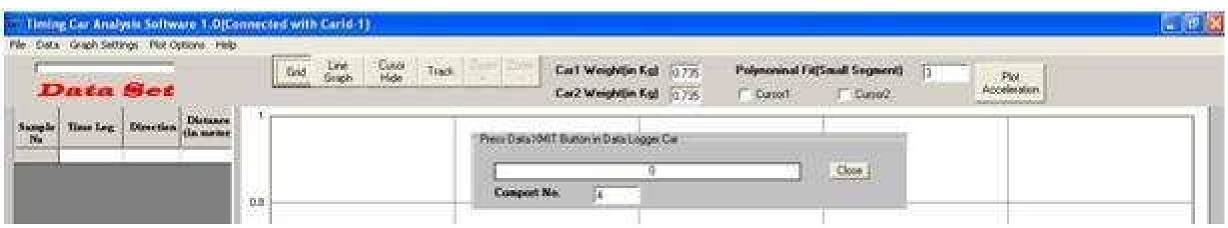
4.3.2 Transferring Data from Car to Software (Single Car and Two Cars)

- Attach Car with PC using a USB cable after data collection or experiment performed.
- Open the analysis software in PC which detects the connected Car and displays on Title Bar .

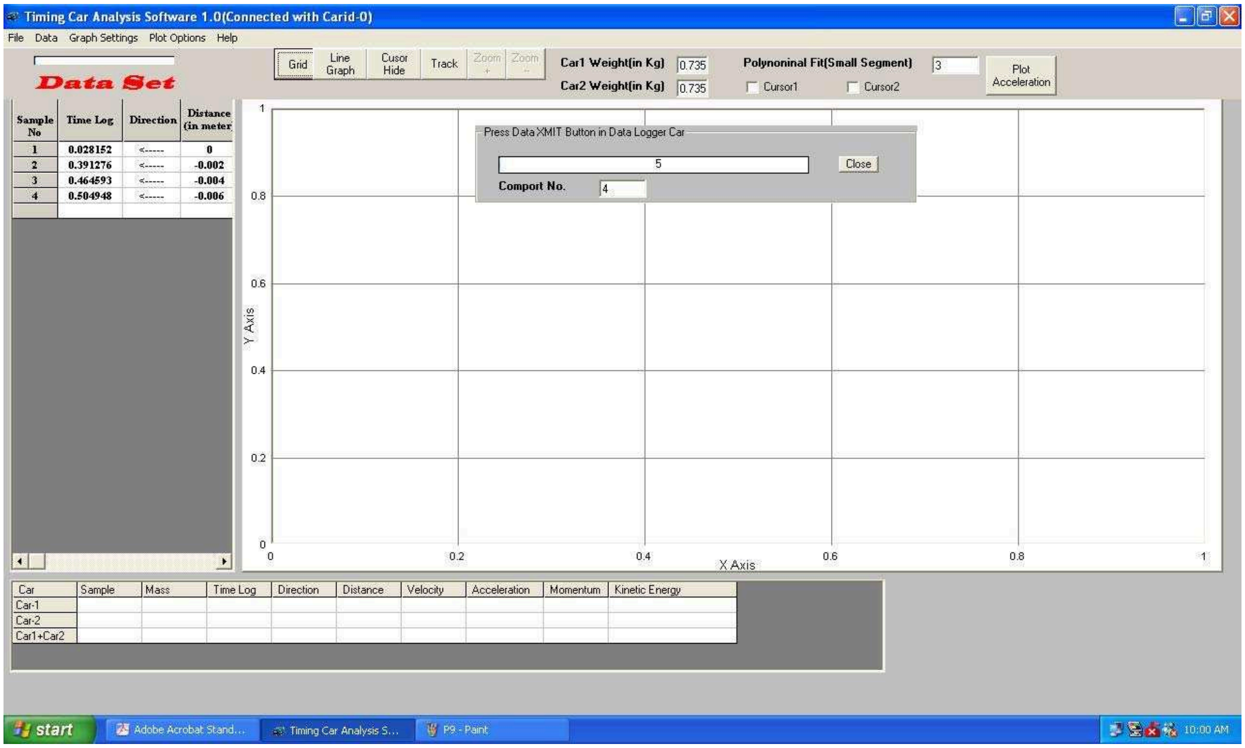
- Click on **Data>Data Load from Car** in Menu Bar in software as shown below



- Data Receive process window will open up in and the software is ready to receive Data from Car. **Comport Status** at which Car is attached is also displayed which is shown in the screenshot below.



- Now press **Data XMIT** key on Car keypad which transfers the data collected by the Car to Software. The Data set area starts filling up with the time direction and Displacement log as shown in screen shot below.



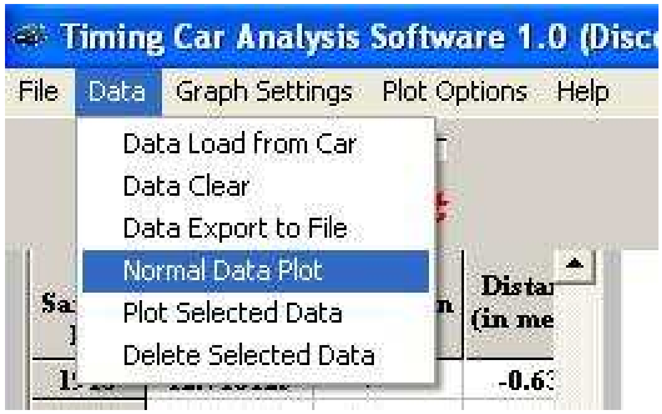
- After complete transfer of data the Process window will disappear itself.

With the above procedure we can transfer Car2 data to the analysis software. Two Cars are used in conducting collision experiment. Software automatically detects the Car number and displays the information in Title Bar.

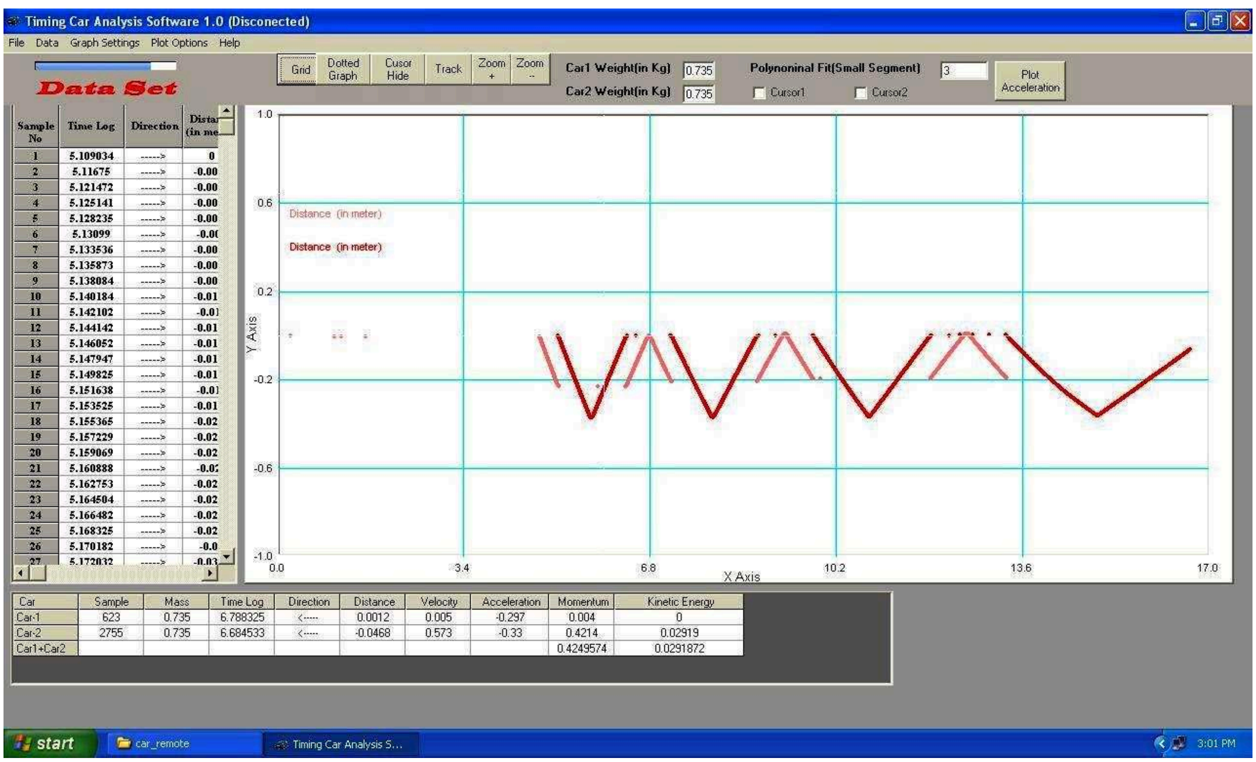
4.3.3 Plotting Data – Normal Fit

This procedure is elaborated using elastic collision of two Cars having same weight. Initially one Car is stationary while the other Car has a velocity. It demonstrates that after collision both Cars exchange their velocities. Once the data from both Cars is transferred the steps to plot Time-Displacement data are explained below.

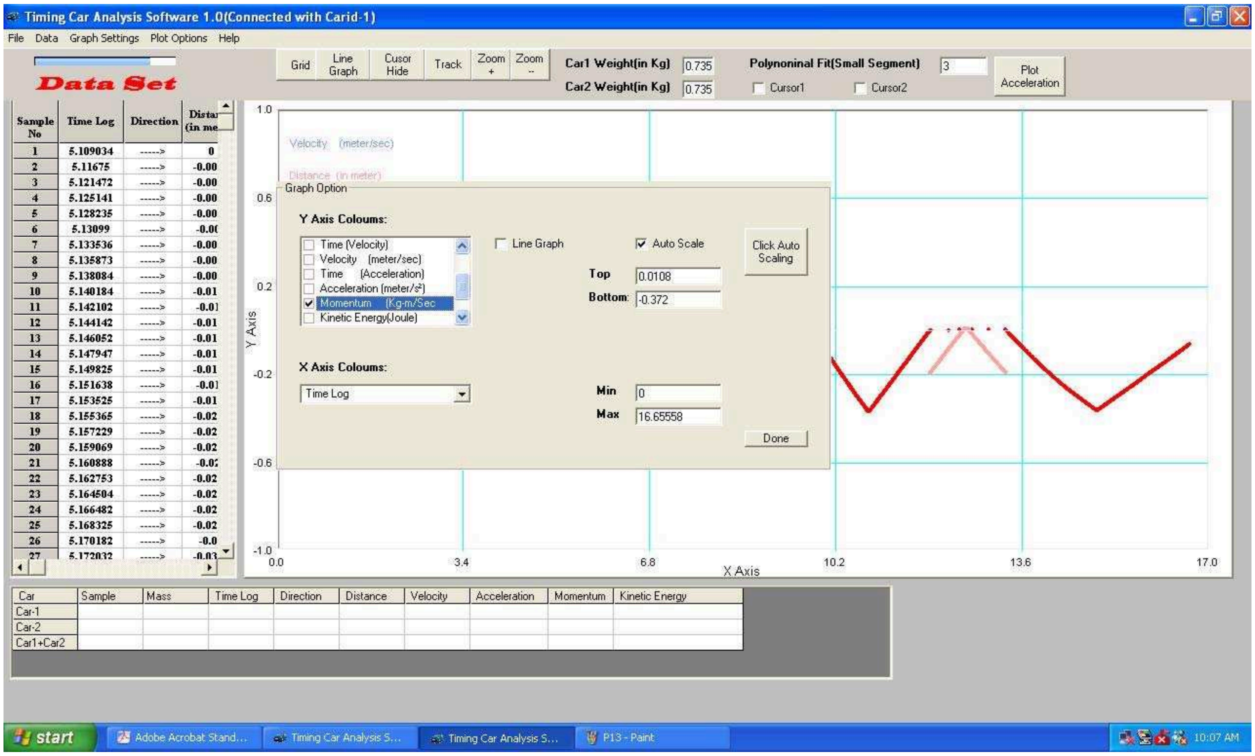
- Click on **Data> Normal Data Plot** to plot graph of the data set.



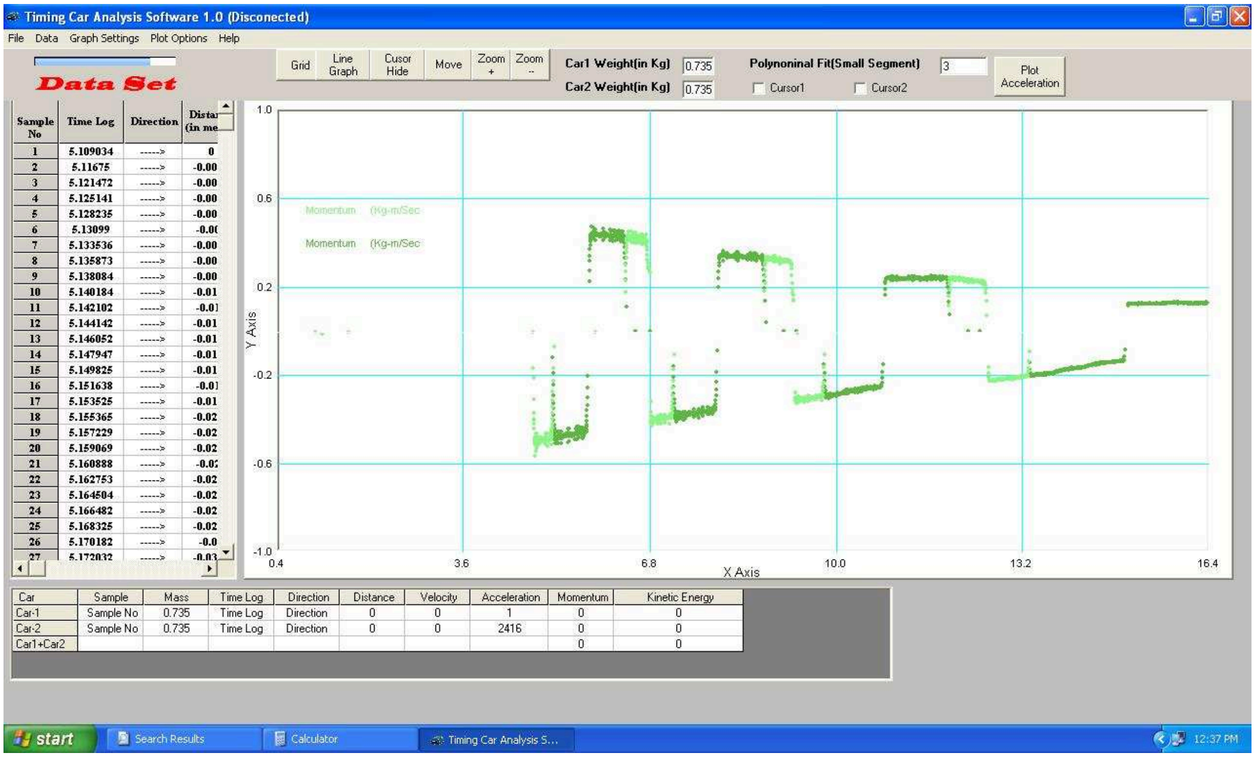
- This will plot the Displacement Vs Time graph in graph area.



- Now, click on **Graph Setting>Axis Setting** to select Momentum on Y-axis, time is the X-axis by default.



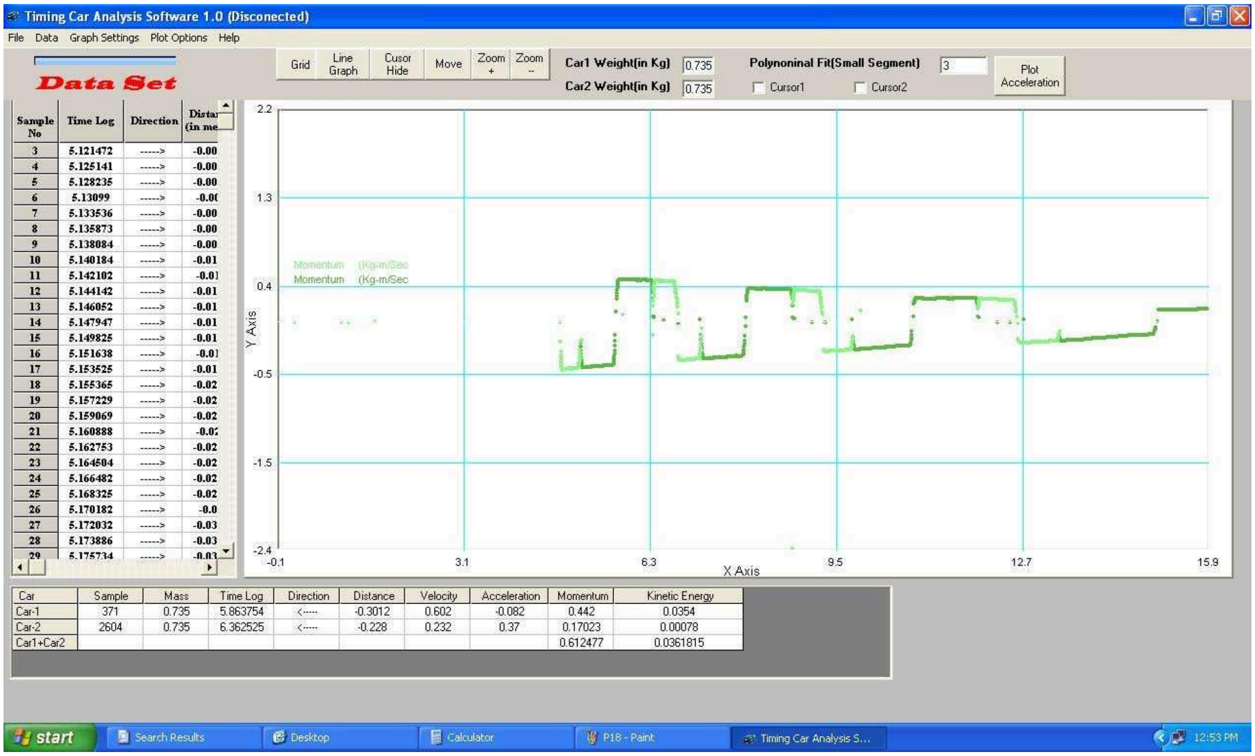
- After selecting the **Momentum** field, Click on **Plot Options>Normal Data Plot.** This will display the Graph between Momentum of both Cars on Y-axis and time on X-axis.
- The graph clearly shows that Momentum of the first Car is transferred to the second Car after Elastic Collision, which was initially stationary. After transferring its Momentum to second Car it comes to rest. The second Car gains Momentum and reaches one end of the track where it strikes and rebounds which changes its direction. This process continues repeating in the experiment where Cars keep interchanging their Momentum after each Elastic Collision. It clearly displays the Conservation of Momentum between two Cars while colliding with each other in Elastic conditions. The Momentum gradually decays as there will always be some Friction and Kinetic Energy will keep dissipating.
- Results of experiment would be different and can be graphically analyzed when the weight of Cars is not equal. However Law of Conservation of Momentum holds true and can be experimentally verified just before and after collision.



4.3.4 Plotting Data – Small Segment Polynomial Fit

This option is selected for removing irregularities of the Horizontal Track in collision experiments. This is explained taking the data set of the previous experiment.

- Again follow steps same as explained in **4.3.3** to Load Data, Plot the Data , to set Y-axis for the graph to be plotted.
- Normally fit graph is already shown in earlier section **4.3.3 Plotting Data - Normal Fit**. Graph plotted doesn't apply any filter on data and thus the result show some irregularities in the data. This is due to minor irregularities between Track and Car during movements.
- Click **Experiment>Calculate Small Segment Polynomial Fit** to replot data.
- Applying **Small Segment Polynomial Fit** on data will remove minor irregularities in data and plot a smoother graph in Graph Area.
- This demonstrates greater clarity while analyzing the momentum graph in collision experiment.

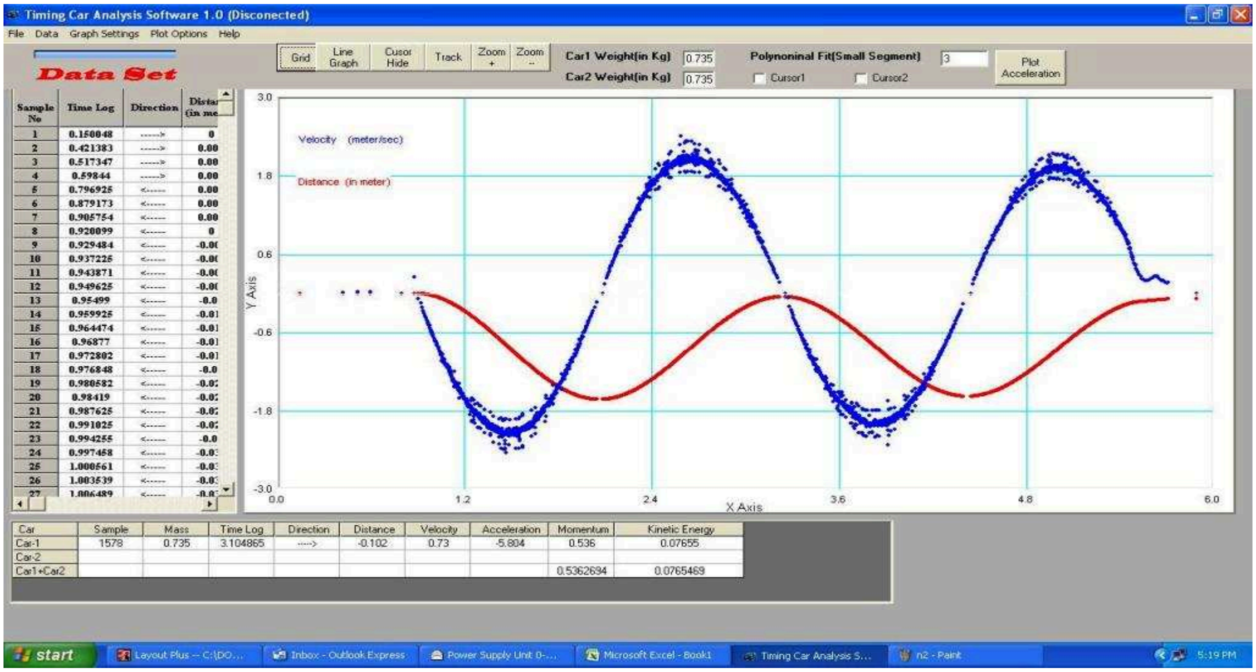


4.3.5 Plotting Data – Polynomial Fit

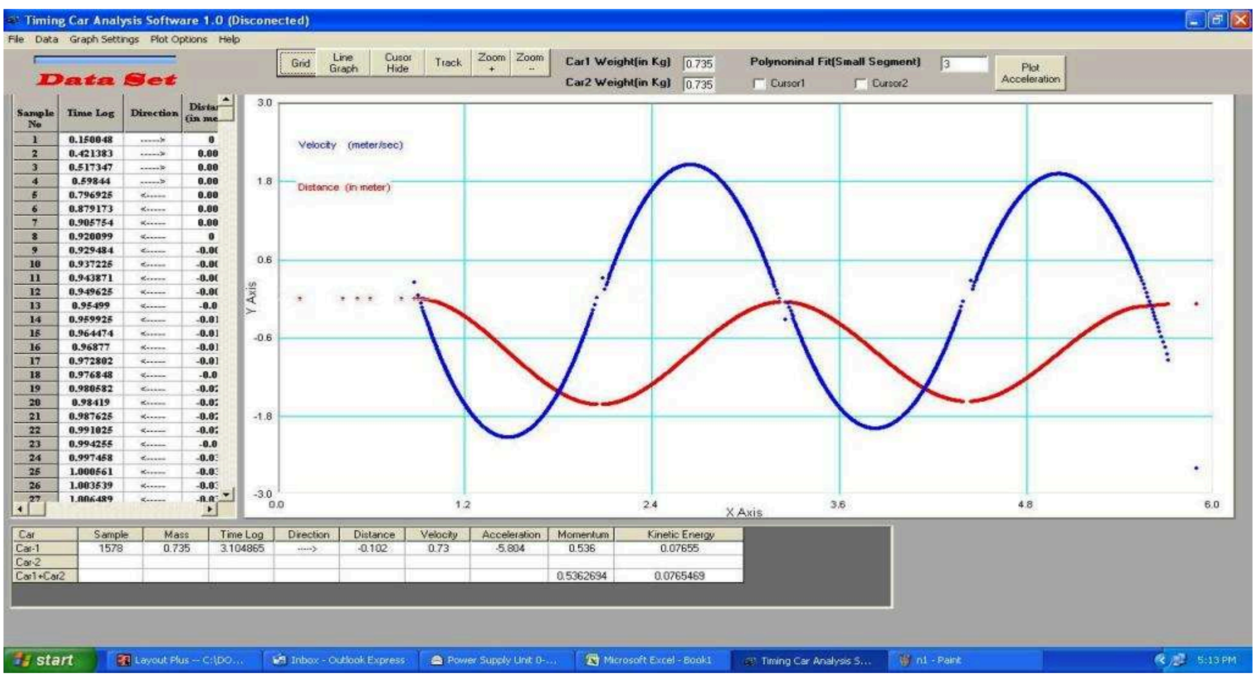
This plotting feature is useful for plotting potential well data. The software automatically segments the data in large segments and plots the fitted data. A single segment represents the Car motion in one direction. Whenever the Car changes direction a new segment is considered. This option plots a smoother data by removing irregularities in the Potential Well track.

- Follow the Steps same as in **4.3.3** to load a Potential Well data.
- Plot the data by selecting Displacement and Velocity to set Y-axis for the graph to be plotted.
- Now click **Plot Options>Normally Data Plot**, this will plot Displacement and Velocity VS Time of data acquired from Car.

- Data plotted from this option is shown below and is having some distortions specially at movements at the bottom of the track.



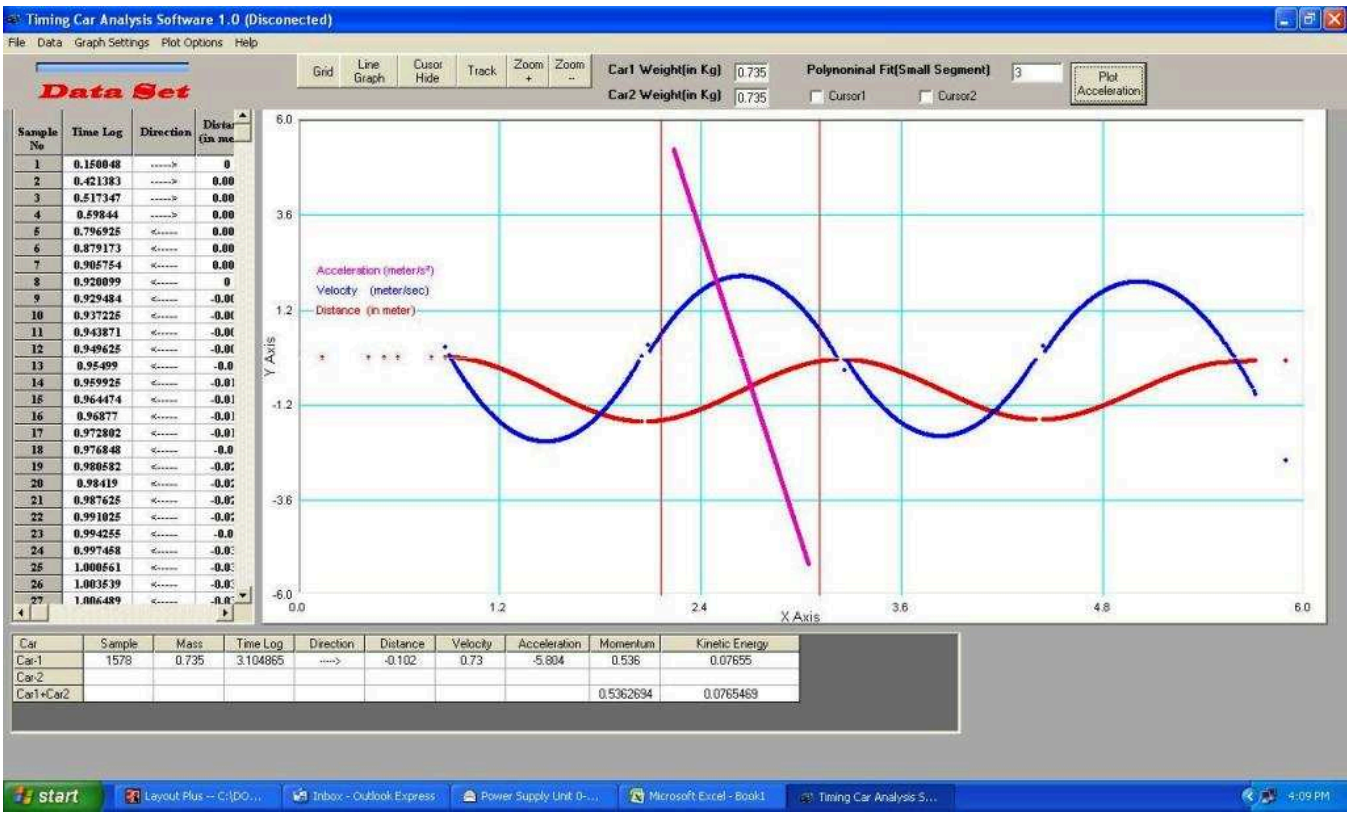
- To remove distortions in the plot click **Plot Options>Polynomial Data Fit and Plot**. This will provide a smooth graph as shown in Graph below removing all distortions and making it easier to analyze the results of experiment.



- This clearly shows that the speed of Car is zero at the top of Track and maximum at the bottom of Track and again becomes zero towards the other end of the Track. This process continues and Kinetic Energy gets converted to Potential Energy and vice-versa.

4.3.6 Analyze and Plot Acceleration

- Plot Displacement and Velocity versus Time Graph of Potential Well data with Polynomial fit as shown in above section 4.3.5.
- Acceleration between two selected points can be plotted using **Cursor1** and C**ursor2** check box on the software screen. Check **Cursor1** on software screen and mark Cursor1 point on graph with mouse. Again check **Cursor2** on software and place Cursor2 point.
- Now press **Plot Acceleration Key** to plot acceleration between two marked grid points.
- Acceleration is plotted between the two Cursor points which is shown in the screen shot below.

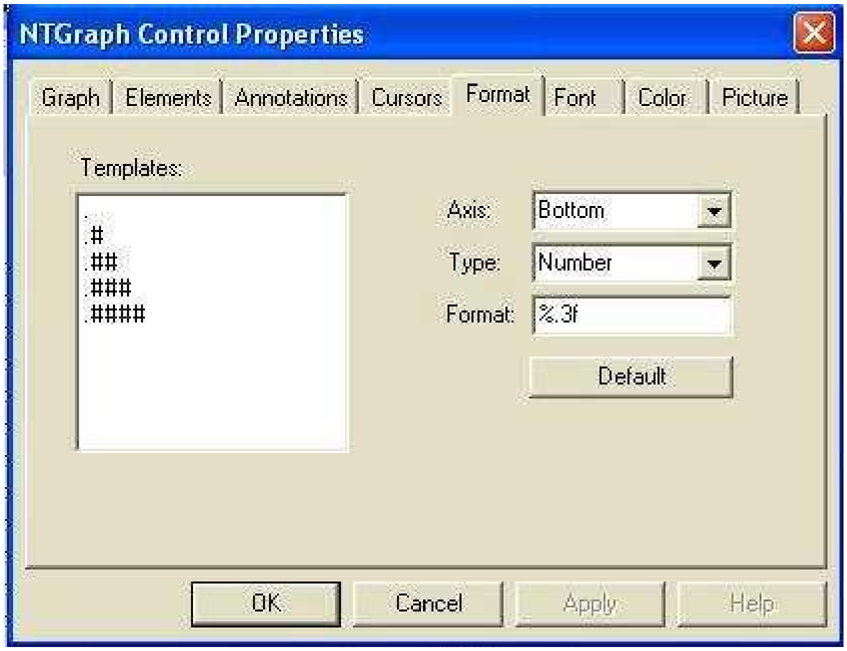


- The Displacement graph displays the movement of Car from one end of Track to other end on Potential Well Track.
- The Acceleration increases towards the ends of the track and Velocity approaches zero. At the farthest end the Acceleration is maximum and velocity is zero. After that the car reverses direction.
- The Velocity is maximum at the centre(bottom most point of track) where Acceleration is zero.

- Additionally one can also use **Examine** and Track buttons to analyze the Graph data in the Car info bar and study the instantaneous Acceleration values.

Resolution of X-axis , Y-axis can be set to required decimal for analyzing finer resolution data points. This can be done by double clicking in the vacant graph areausing Left click of mouse.

A pop-up window appears as shown below.



Several graph formatting options can be selected.

- To set resolution of X-Axis :

  Select **Format**

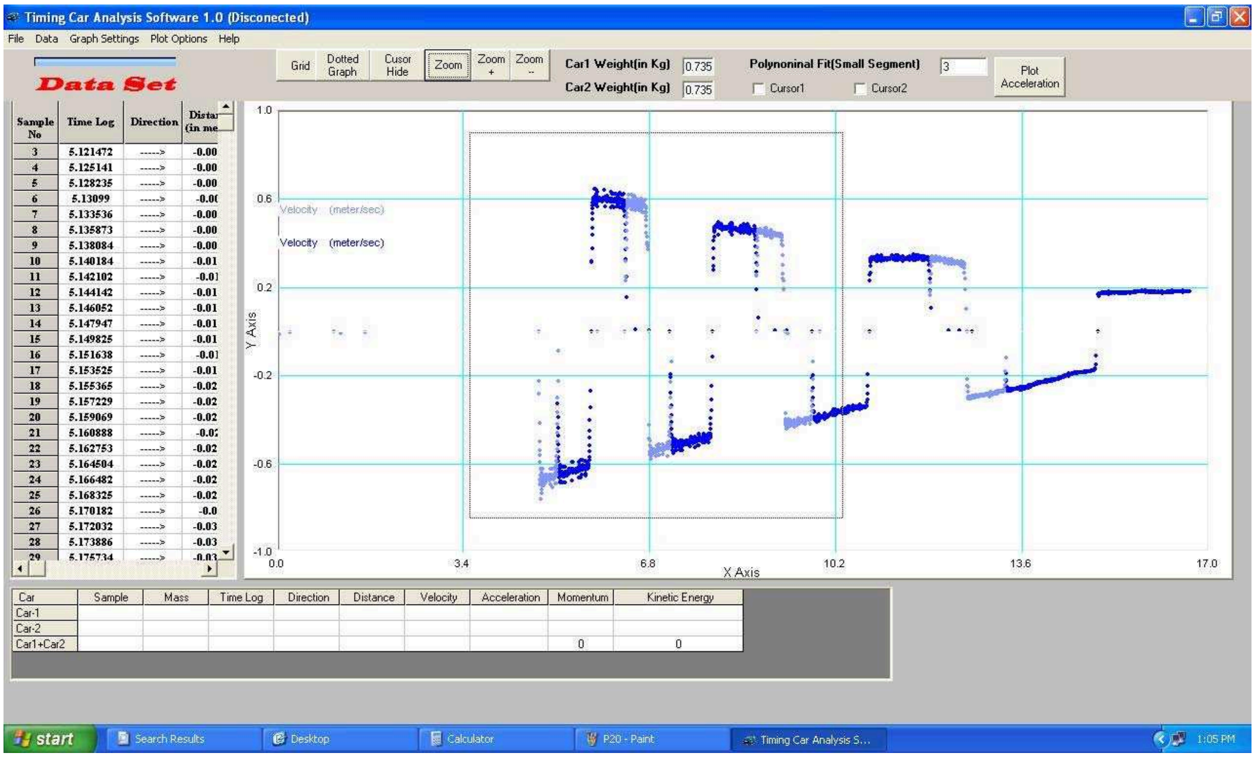
  Select **Axis > Bottom**

  Set Resolution by appropriately selecting the required number of decimal points such as **.####** for 4 decimal resolution on X-axis.
- For selecting Y-Axis Select **Axis > Left** and again select required Templates for bit resolution.
- Click **OK** to implement selection.

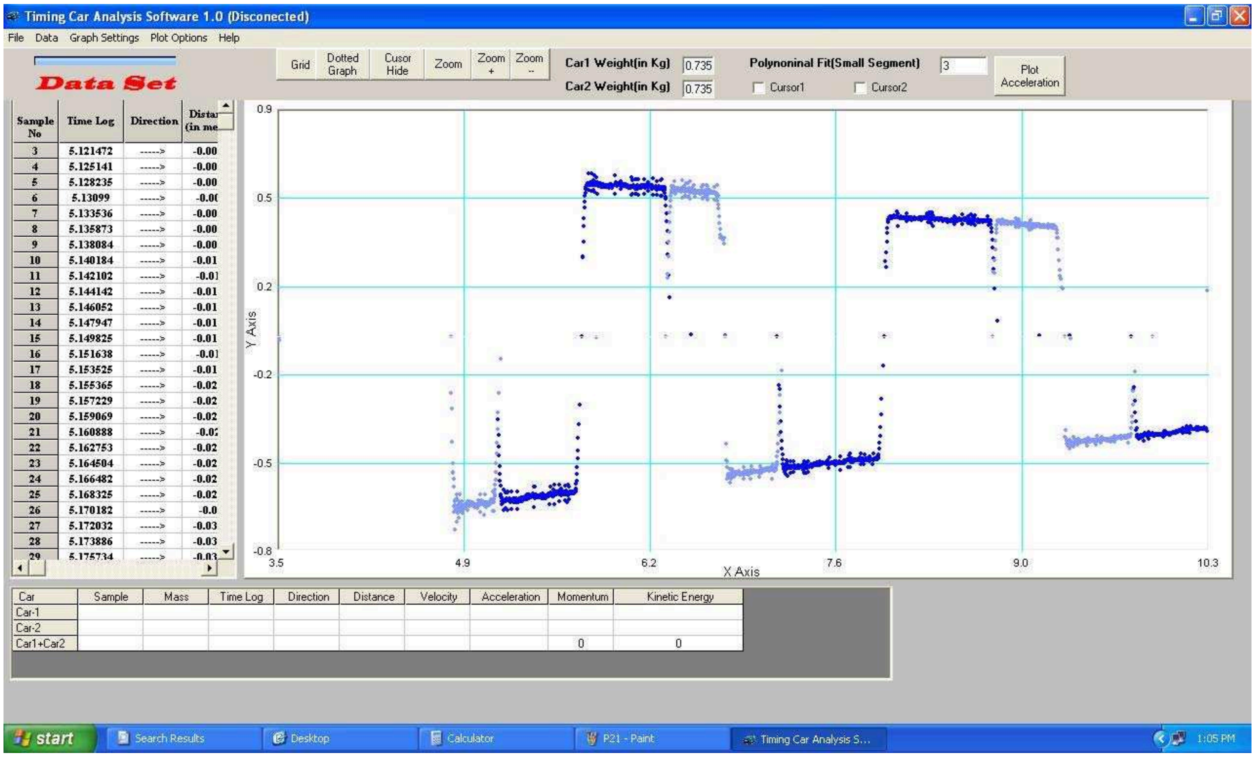
4.3.7 Zooming selected Plot Data

- A section of Plot on the screen can be Zoom in for analysis.

- This is facilitated through the Zoom selection in the toggle button **Zoom/Track /Move**
- After selecting Zoom the desired area can be selected using the mouse left click and hold. A rubber band box is dynamically displayed by dragging the mouse representing the selected area.



- Upon release of the left click the selected portion of graph is displayed as shown in screen shot below.



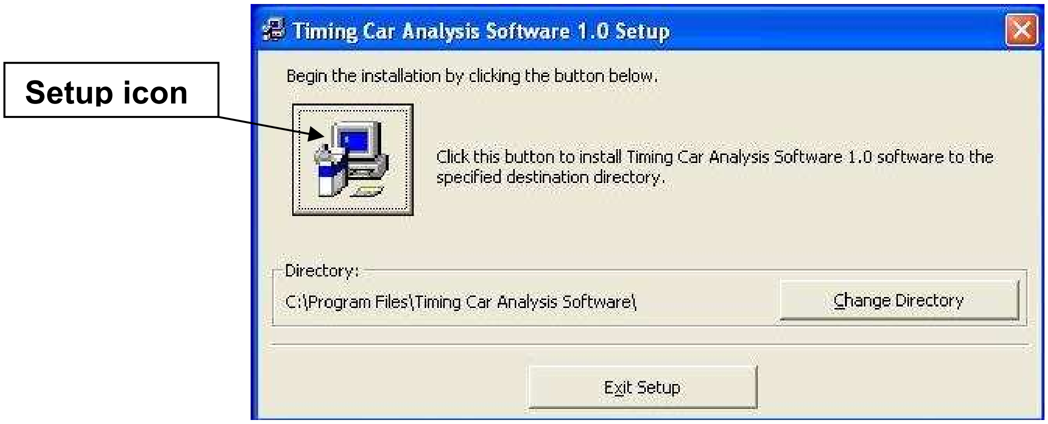
4.4 Initializing Software:

4.4.1 Installing Software

Follow the following steps (1 to 9) below to install the Timing Car software. All steps are illustrated with screen shots.

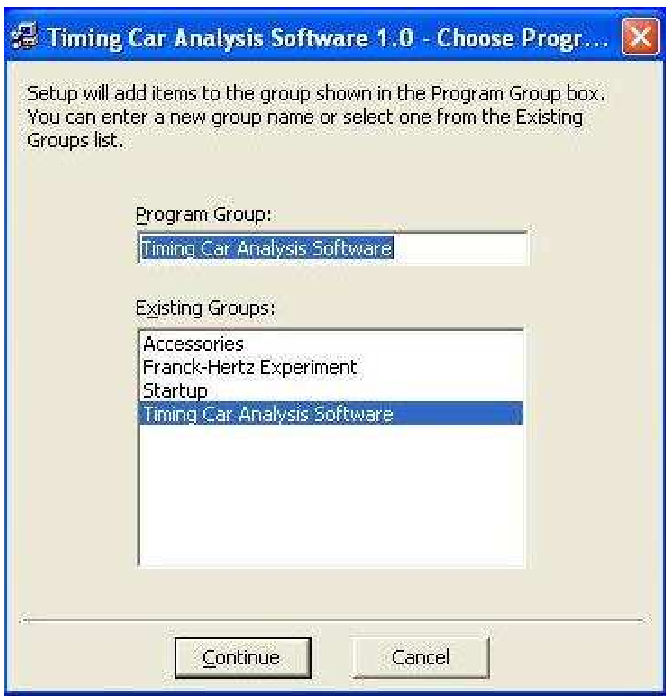
1. Power ON your computer.
2. Insert the software CD into your CD Drive and click to open the CD when ready.

3. Click on the Setup.exe to run the installation as shown.

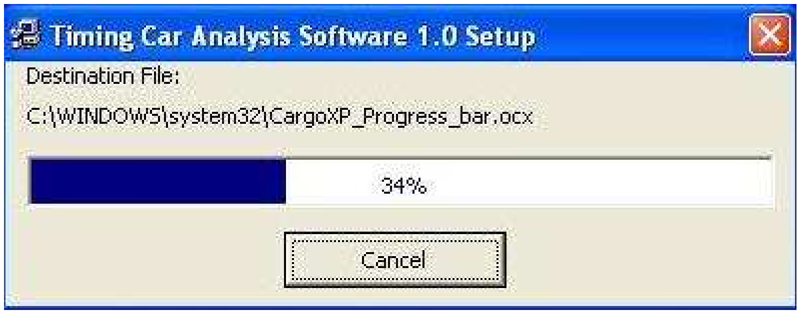


4. Click on OK button to proceed. You can now change the default location of installation files to be installed.

5. Now click on the **Setup Icon** which is indicated with the arrow mark as Shown in the Fig. above



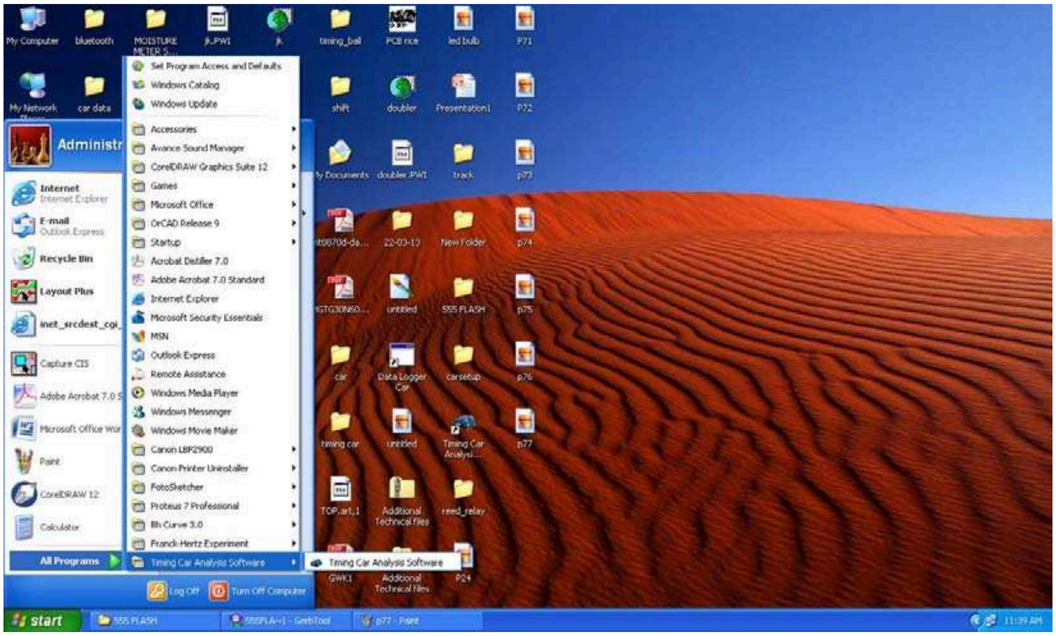
6. Click on **Continue** to proceed as shown in the screen shot above.
7. if any dialog boxes appears on your computer screen then click **Yes** to continue.



8. The software installation is initiated as shown above.

9. Finally click OK to complete the installation .
10. Install the FTD software provided along with Timing Car Analysis Software to enable communication between Car and software. Just click on set-up will install the software and display the screen shot shown below.

Now Click Start→Programs→ Timing Car Analysis Software → Click on the Timing Car Analysis Software Car icon as shown in the figure

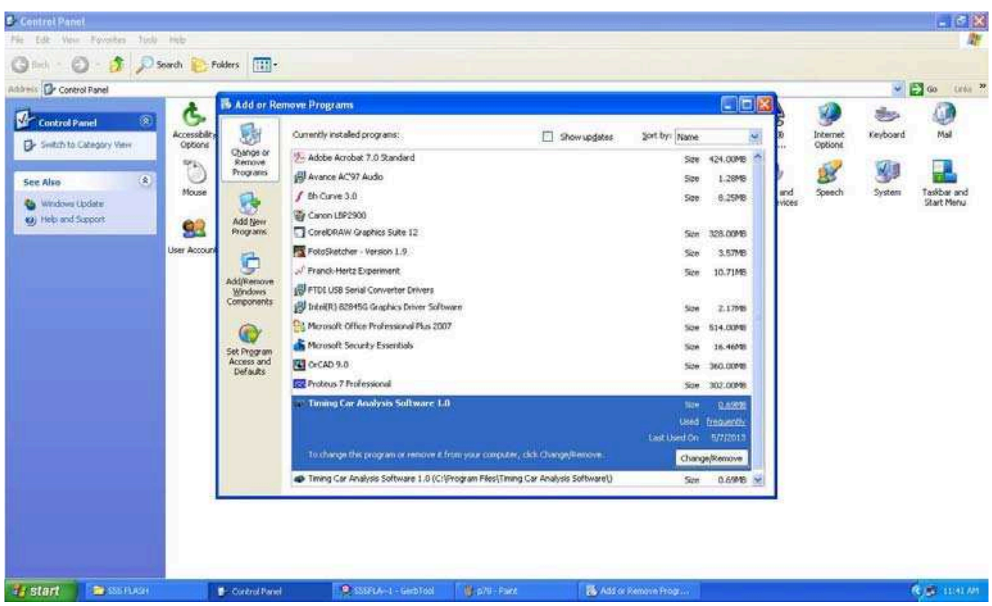


4.4.2 Uninstalling Software

To remove a faulty installation open "Add/Remove Programs" in the control panel and select Timing Car Analysis Software.Choose "Remove" to completely remove the Timing Car Analysis Software installation.

Follow steps 1 to 6 to uninstall the software for Indosaw Data Acquisition System:

1. Click Start→Settings→Control Panel→Add/Remove Programs and locate Data Logger Car as shown.



2. Click Add/Remove tab to remove the current Timing Car Analysis Software

installation.

3. Click Yes to proceed with the uninstallation process as shown.

4. This will completely uninstall the software from your PC. If otherwise, the software is not completely uninstalled, go to the installation folder (C:|\Program Files\), and manually remove the “ Timing Car Analysis Software“ Folder.

Note: Pressing SHIFT when the CD is inserted will temporarily disable the Autorun function.

Important Notes:

Installation conflicts may result with more than one installation of software.

Please remove any previous installations of Timing Car software before installing a new one.

5 Experiments

The advanced Timing Car based Law of Motion kit from INDOSAW can be used to conduct a number of experiments and comprehensively study concepts and Laws of motion. In this section three important experiments namely Study of Motion in Potential Well, Study of Elastic Collision and Study of In-Elastic Collision are discussed. Also the student can verify all the important Laws of Motion and understand the practical implications due to in-depth analysis with a large amount of data. The experiments are easy to conduct and do not require any elaborate setups or disturbing noise unlike air track based setups.

5.1 Study of Motion in Potential well

Aim: The experiment is performed to understand the concept of Motion in potential well and Conversion of Energy from one form to another i.e. Kinetic Energy to Potential Energy and vice-versa. It is useful in studying Velocity and Acceleration at different points on a Curved Track. Also provides experimental proof that Energy is conserved but can be transferred from one form to another.

Required: Timing Car, Curved Track, IR Remote is optional.

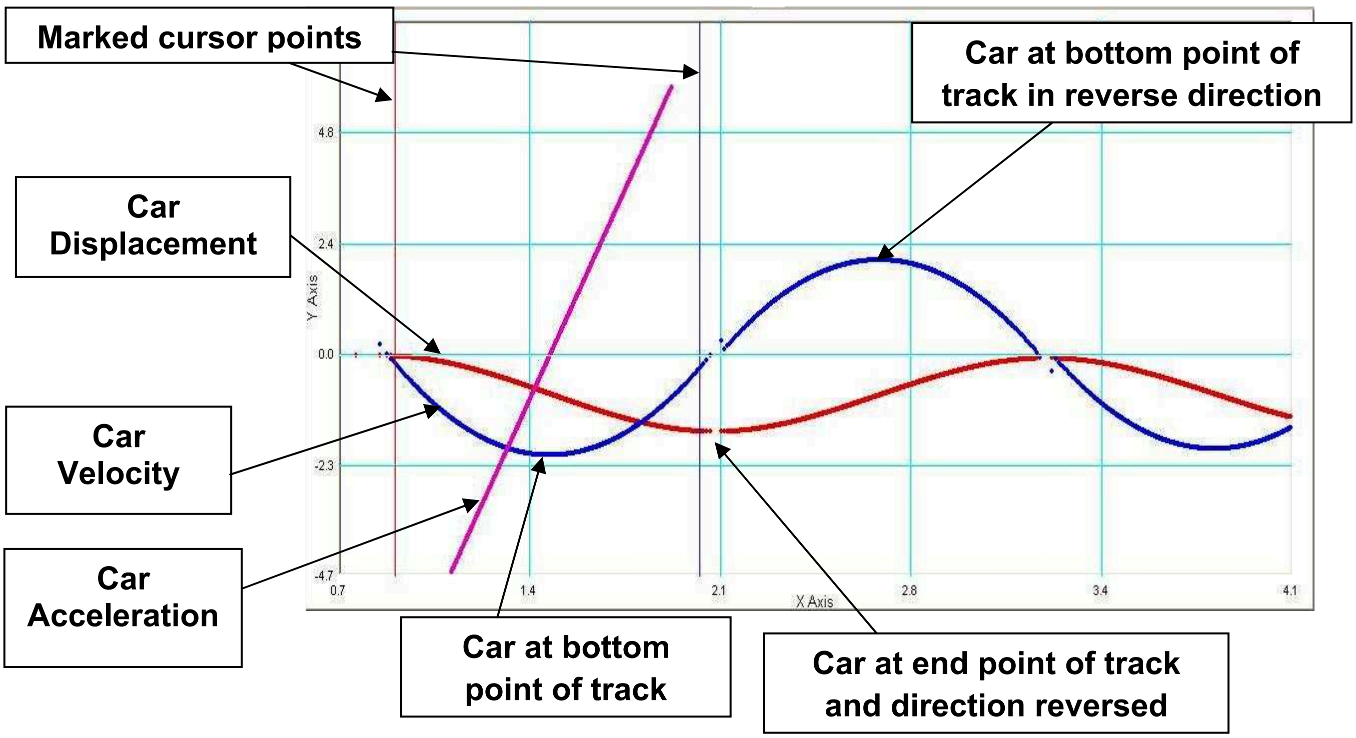
Segments of the curved track is assembled which takes the shape in the form of an arc. One timing Car is required in the experiment. Place the Car towards one end of the track which forms an approximate angle of about 30 degrees downhill as shown below.

Switch ON the Car by pressing **ON/OFF** key. Place Car on the track. Start the timer using **START/STOP** key on Car or **IR REMOTE**. Release and allow the Car to move in to and fro motion on the Potential Well Track to record motion data. After few movements stop the recording by pressing **START/STOP** key on Car or **IR REMOTE**. Data collected can be reviewed through key pad or can be loaded in software for analysis by selecting menu **Data>Data Load from Car** as explained in section 4.3.

1. Click on **Graph Setting >Axis Settings** to select Displacement and Velocity VS Time graph.

2. Click on **Plot options > Polynomial Fit and Plot**. This will plot smooth graphs of data for Displacement and Velocity.

Select Cursor 1 and Cursor 2 points and Plot Acceleration.



Interpretation:

Energy is stored in the form of Potential Energy when Car is placed at the top end of track due to its height. As soon as the Car is released the Car starts gaining speed downhill and the Potential Energy is converted to Kinetic Energy which is the maximum at the lowest point and in middle of track. The Car continues moving further and loosing Speed as it is climbing uphill thus again gaining Potential Energy and loosing Kinetic Energy. It reaches back to the same height on the track and stops and then reverses its direction. This process continues indefinitely. In practice there is always some friction and some energy is lost which is demonstrated by the slowly damped oscillations and Sine wave like shape in the Velocity plot. The Acceleration plot shows a linear type of plot.

By theory Acceleration is given by **g . Sin(**angle of slope**)**

The maximum angle is at the track end (about 35 degrees) and reduces to zero at the centre where the track is horizontal. One can verify that in the Sine function the values are quite linear for these degrees. This shows the linear nature of the Acceleration plot.

The student can also verify the energy Conservation at any point where Kinetic Energy + Potential Energy is conserved.

Kinetic Energy is given by $\frac{1}{2} . m . v^2$

Potential Energy is given by $m . g . h$

where

m = mass of the car **v =** velocity of car on track

g = acceleration due to gravity **h =** height of car from the lowest point.

Additionally as projects the student can build any kind of up down sloping, curved or roller coaster Track and analyze motion in detail.

5.2 Study of Elastic collision on Linear Track

Aim: This experiment is performed to experimentally verify Law of Conservation of Momentum. Additionally the student can understand the Concept of Linear Motion on a straight track. In Elastic Collisions there is Conservation of Energy which can also be experimentally verified.

Required : Two Timing Cars, Stainless Steel Low Friction Track, Elastic Bumper Accessories on Car and one end of Track and a Striker Accessory on other end of Track. You will also require an IR Remote to simultaneously start timers of both Cars.

Arrange the Stainless Steel track on a Horizontal surface. Fix an Elastic Bumper on one side and Striker Bumper with compressed spring strip at another end of track. Place two cars with elastic bumpers. Place one Car touching the compressed striker and other Car approximately at the middle of the track. The assembled set up is shown below.

Switch **ON** the both Cars using **ON/OFF** key.

Then start timers of both Cars using **IR-REMOTE** to synchronize timers in both Cars.

Press striker pin attached to track to release its spring strip and strike the Car in contact with it with an initial force. This Car will travel towards the other end of the track and strike with the stationary Car in the middle of the track.

Elastic Collision will occur between two Cars and since both Cars are of the same weight they will exchange their Velocities. Therefore the Collision will stop the Car, which was in motion earlier, and set the other Car in motion. This Car will travel till the end of track and rebound back with the same Velocity to strike the stationary Car in the middle of the track. This process will keep repeating indefinitely. In practice there is a small friction which will keep dampening the motion of the Cars.

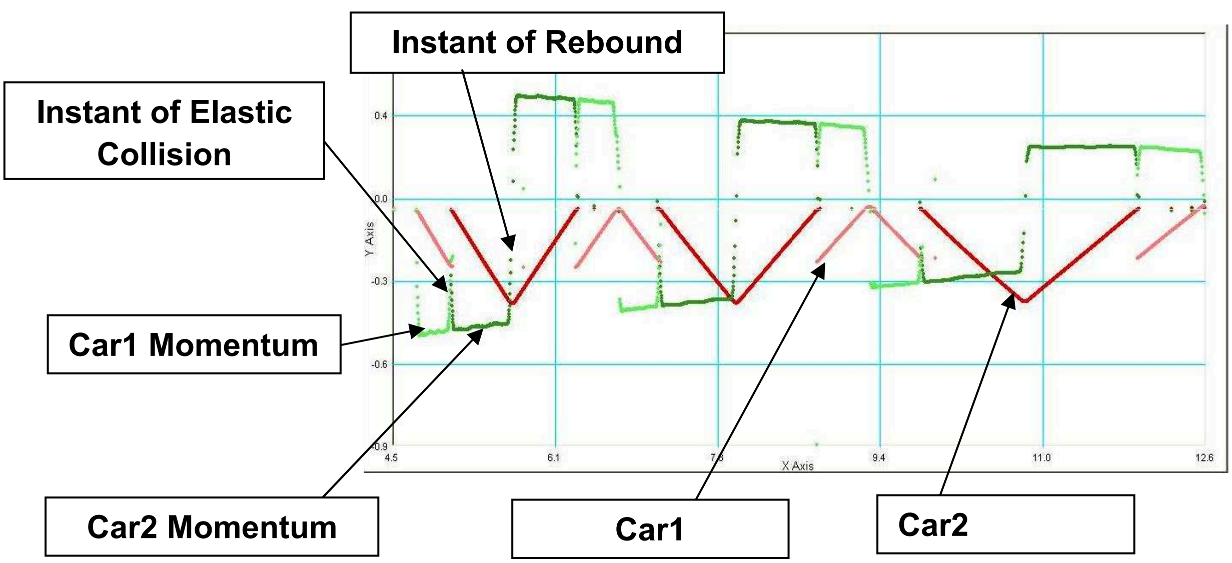
The Data collected in both Cars can be down loaded to the software as explained in section 4.3.

Graphs can be plotted to study Conservation of Momentum and Conservation of Energy.

5.2.1 Conservation of Momentum

Graph Settings > Axis Settings select Displacement and Momentum on Y-axis.

Plot Options > Small Segment Polynomial Fit and Plot for plotting Graph shown below.



<u>**Interpretation:**</u>

The Graph shown gives a clear picture of the data acquired in Elastic Collision of two Cars. Graph displays the linear Displacement movement of two Cars as observed and the student can see the instances of movements of both Cars and the instances when they are at rest. During movement the Cars travel with a slightly decaying Momentum (and also Velocity) which shows the role of friction during movement. The instances of Collision between Cars can be observed clearly and it shows that the Momentum of one Car completely transfers to the other, and so is the Velocity which experimentally verifies the Conservation of Momentum for the system of two Cars in Elastic Collision. Other notable instances are when a Car strikes the end of the track and rebounds back with the same Momentum (Velocity) which is clearly inferred from the graph. This is similar to Elastic Collision with an infinite stationary mass.

The Conservation of Momentum is shown in equations given below:

$$m1 \,.\, u1 + m2 \,.\, u2 = m1 \,.\, v1 + m2 \,.\, v2$$

m1 = m2 = mass of Car1 and Car2

u1 = Initial Velocity of Car1 before collision

u2 = Initial Velocity of Car2 before collision

v1 = Final Velocity of Car1 after collision

v2 = Final velocity of Car2 after collision

In practice a very small Energy is lost during Elastic Collision due to non-ideal springs.

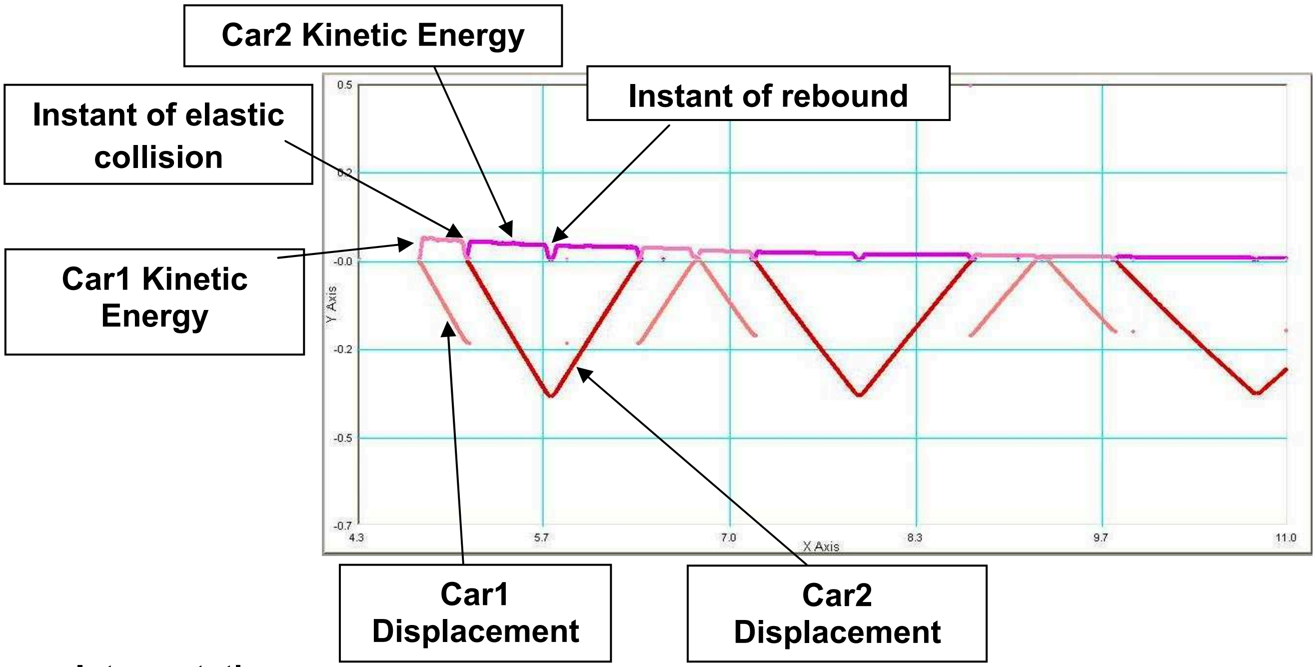
The numerical values of individual and combined Momentum at various time instant points can be observed using Examine and Track functions.

The student can also experiment Elastic Collision experiments when cars have different weights and verify the Law of Conservation of Momentum.

5.2.2 Conservation of Kinetic Energy.

Graph Settings > Axis Settings select Kinetic Energy on Y-axis.

Plot Options > Small Segment Polynomial Fit and Plot for plotting Graph shown below.



<u>Interpretation:</u>

The Graph shown gives a clear picture of the data acquired in Elastic Collision of two cars. Graph displays the linear Displacement movement of two Cars as observed and the student can see the instances of movements of both Cars and the instances when they are at rest. During motion, the Cars travel with a slightly decaying Kinetic Energy (and also Velocity) which shows the role of friction during movement. The instances of Collision between Cars can be observed clearly and it shows that the Kinetic Energy of one Car completely transfers to the other, and so is the Velocity which experimentally verifies the Conservation of Energy for the system of two Cars in Elastic Collision. Kinetic Energy transfer takes place at each Collision between Cars or Car with infinite stationary mass (i.e. at rebound from end of track). When a Car strikes the end of the track and rebounds back it has the same Kinetic Energy (Velocity) which is clearly inferred from the graph when zoomed in. This is similar to Elastic Collision with an infinite stationary mass.

It is assumed that the Linear Track is placed horizontally so that there is no effect of gravity in conducting the experiment and entire Energy contained in the system of two Cars is in the form of Kinetic Energy.

The Conservation of Energy equations is given below:

$$\frac{1}{2} . m1 . u1^2 + \frac{1}{2} . m2 . u2^2 = \frac{1}{2} . m1 . v1^2 + \frac{1}{2} . m2 . v2^2$$

Where

m1= m2 = mass of Car1 and Car2

u1 = Initial Velocity of Car1 before Collision

u2 = Initial Velocity of Car2 before Collision

v1 = Final Velocity of Car1 after Collision

v2 = Final Velocity of Car2 after Collision

u2 and v1 are always zero if system is ideal with respect to masses of Car and the track horizontal alignment. However in non-ideal case U2 and V1 can deviate slightly from zero value.

5.3 Study of In-elastic collision experiments

Aim: This experiment is performed to verify the concept of Conservation of Momentum in inelastic collision between two Cars on a Linear Track. Conservation of Energy does not hold true is the other concept which can be experimentally verified for Inelastic Collisions.

Required : Two Timing Cars, Low Friction Stainless Steel Track, Elastic Bumper Accessories , Inelastic Velcro bumper accessory , a Striker bumper and an IR remote to synchronize timers.

Arrange the set-up as shown in above picture with Inelastic Velcro bumpers mounted on Cars for Collision so that the Cars stick together after Collision. Switch ON the Cars using **ON/OFF** key and start timer of both Cars using **IR-REMOTE** for synchronization of timers. Press striker pin to release the Car with an initial force .Car1 after getting initial momentum from Striker bumper will move towards the stationary Car2 placed at middle of track. Due to Velcro bumper fixed on the Cars, on collision both Cars will stick together and move as a single entity.

In practice there is a small friction which will keep dampening the motion of the Cars.

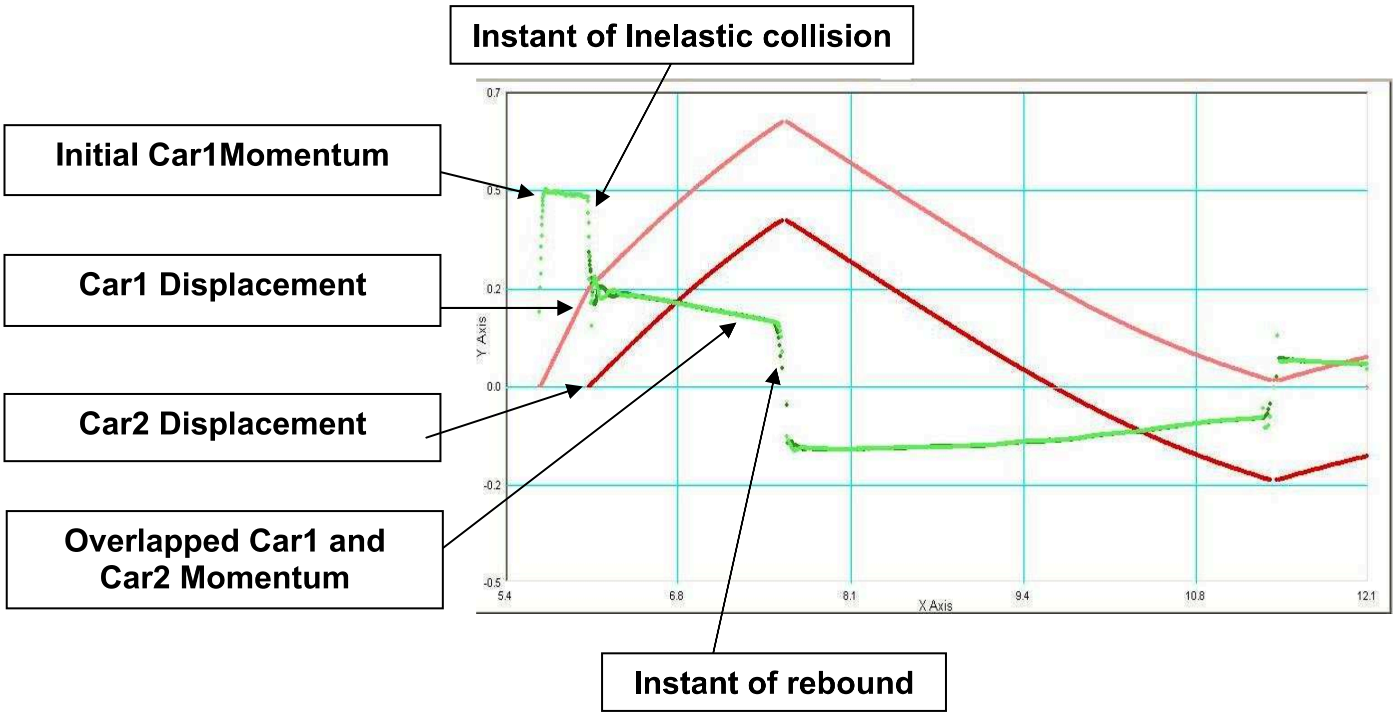
The Data collected in both Cars can be downloaded to the software as explained in section 4.3.

Graphs can be plotted to study for Conservation of Momentum and Conservation of Energy in Inelastic Collision.

5.3.1 Conservation of Momentum

Graph Settings > Axis Settings select Momentum and Displacement.

Select **Plot Options > Small Segment Polynomial Fit and Plot**



Interpretation:

Graph shown above represents the Displacement and Momentum graph of Inelastic Collision of two cars. At first instance when striker is released Car1 attains Velocity and Car2 is at rest which is clearly displayed in graph. Collision of Car1 with Car2 makes them stick together and they then travel same Displacement as depicted in the graph.

Momentum (also Velocity) initially attained by first Car is transferred to combined Momentum of Cars that travel with the same Velocity and the Displacement.

Momentum is conserved in Inelastic collision which is depicted from the graph. Initially only first car has Momentum and then after Inelastic Collision this Momentum is equally shared between Cars as both the Cars then have equal Momentum (as they have equal Mass and equal Speed). This is also clear from the overlapping Momentum plots of two Cars.

$$m1 \cdot u1 = (m1 + m2) \cdot v$$

m1 = m2 = mass of Car1 and Car2

u1= Initial velocity of Car1

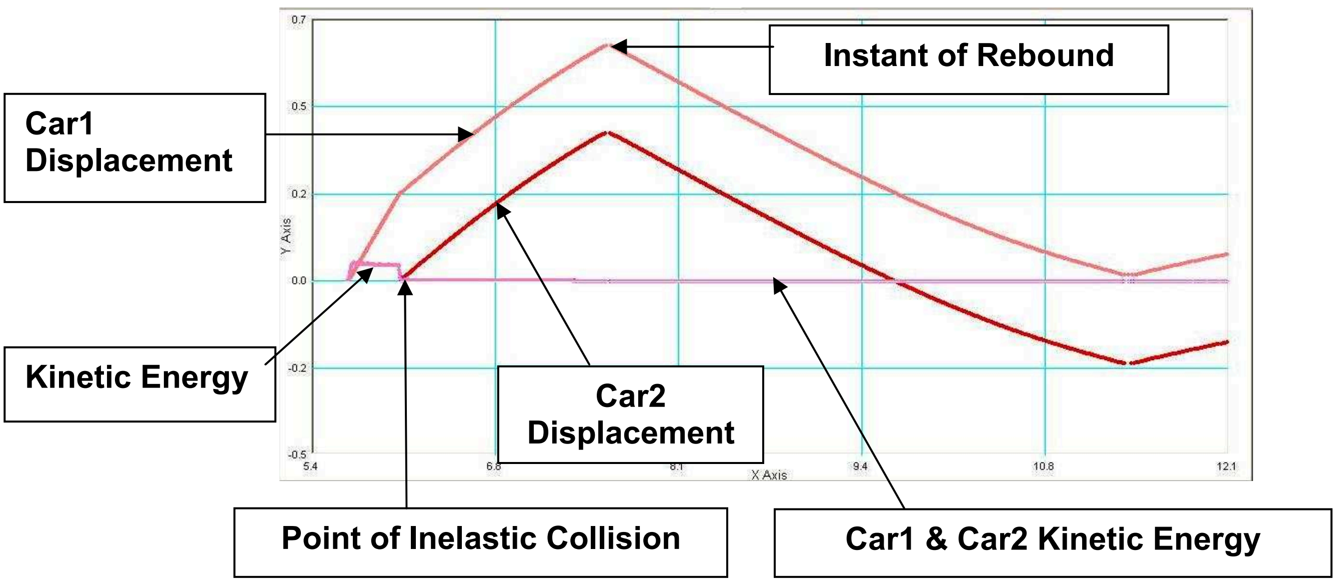
v= Final velocity of Car1 and Car2

The same is shown with Momentum curve in the graphical representation. In practice there is a slight friction which slows down the Velocity of the Cars.

5.3.2 Kinetic Energy.

Graph Settings > Axis Settings select Kinetic Energy as Y-axis.

Plot Options > Small Segment Polynomial Fit and Plot for plotting Graph shown below.



Interpretation:

The Graph shown gives a clear picture of the data acquired in Inelastic Collision of two Cars. Graph displays the linear Displacement movement of two Cars as observed and the student can see the instances of movements of both Cars and the point of Inelastic collision. At the instance of Inelastic collision between Car, it shows that the Kinetic Energy of first Car is not conserved after they stick together. In fact a portion of Kinetic Energy gets dissipated into other forms of Energy. During movement the cars travel with a slightly decaying Kinetic Energy (and also Velocity) which shows the role of friction during movement. Kinetic Energy is more or less conserved when Cars strike the end of track i.e. infinite stationary mass) and rebound back.

The Energy equations is shown below:

$$\frac{1}{2} \cdot m1 \cdot u1^2 + \frac{1}{2} \cdot m1 \cdot u2^2 = \frac{1}{2} \cdot (m1 + m2)\, v^2$$

m1= m2 = mass of Car1 and Car2

u1 = Initial Velocity of Car1 before Collision

u2 = Initial Velocity of Car2 before Collision

v = Final Velocity of Car1 and Car2 after Collision

u2 is zero at first instant .However after Collision both Cars attain a Single Velocity that is the Final Velocity.