Honors Physics ________________________ **Instructor: Barton Clark**

Archie Williams High School **Spring 2023**

Conservation of linear momentum.

The stated objectives of this lab are to a) show that we can model the inertia of a complex system as the sum of the inertias of the parts and b) to show that the impulse an object will receive (area under the Force vs Time graph) will predict the change in momentum of any of the parts.

To accomplish this, place two cars on a track (one red and one blue) facing each other so that the rubber bumpers will collide upon impact. Give each car a different mass and a different starting velocity (one car can 'chase' another in the same direction or the two cars may collide 'head on'.

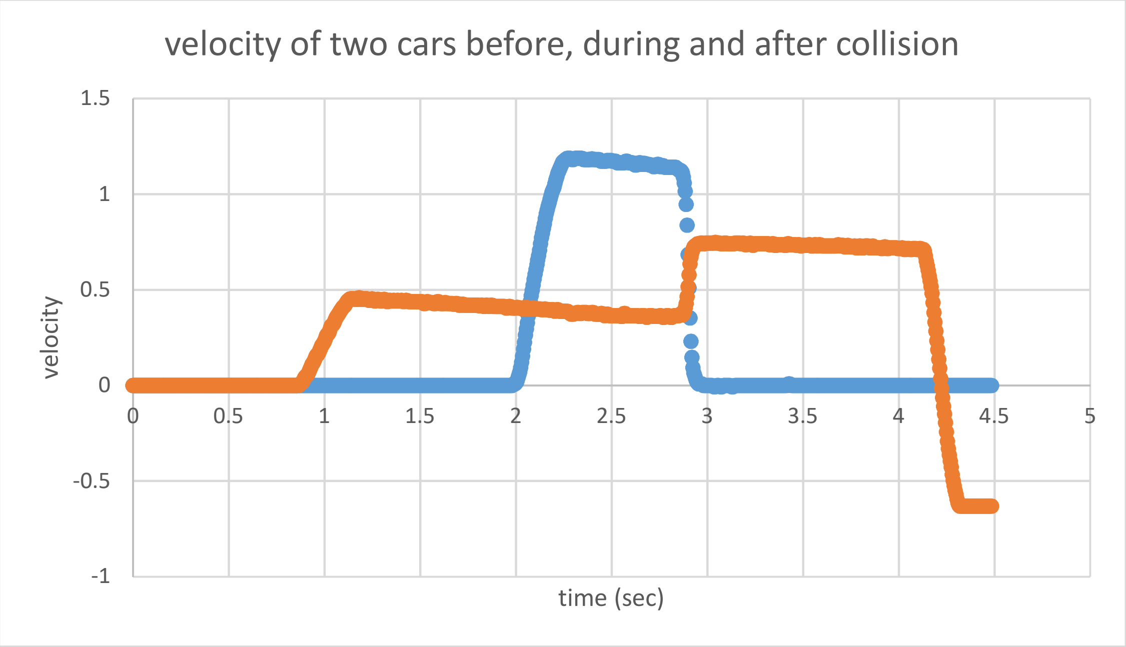
Background.

Unlike conservation of energy, momentum is conserved as momentum (energy can change form, momentum cannot).In this lab, two cars of unequal weight will engage in a collision event (you'll crash 'em into each other!) and we will show the following:

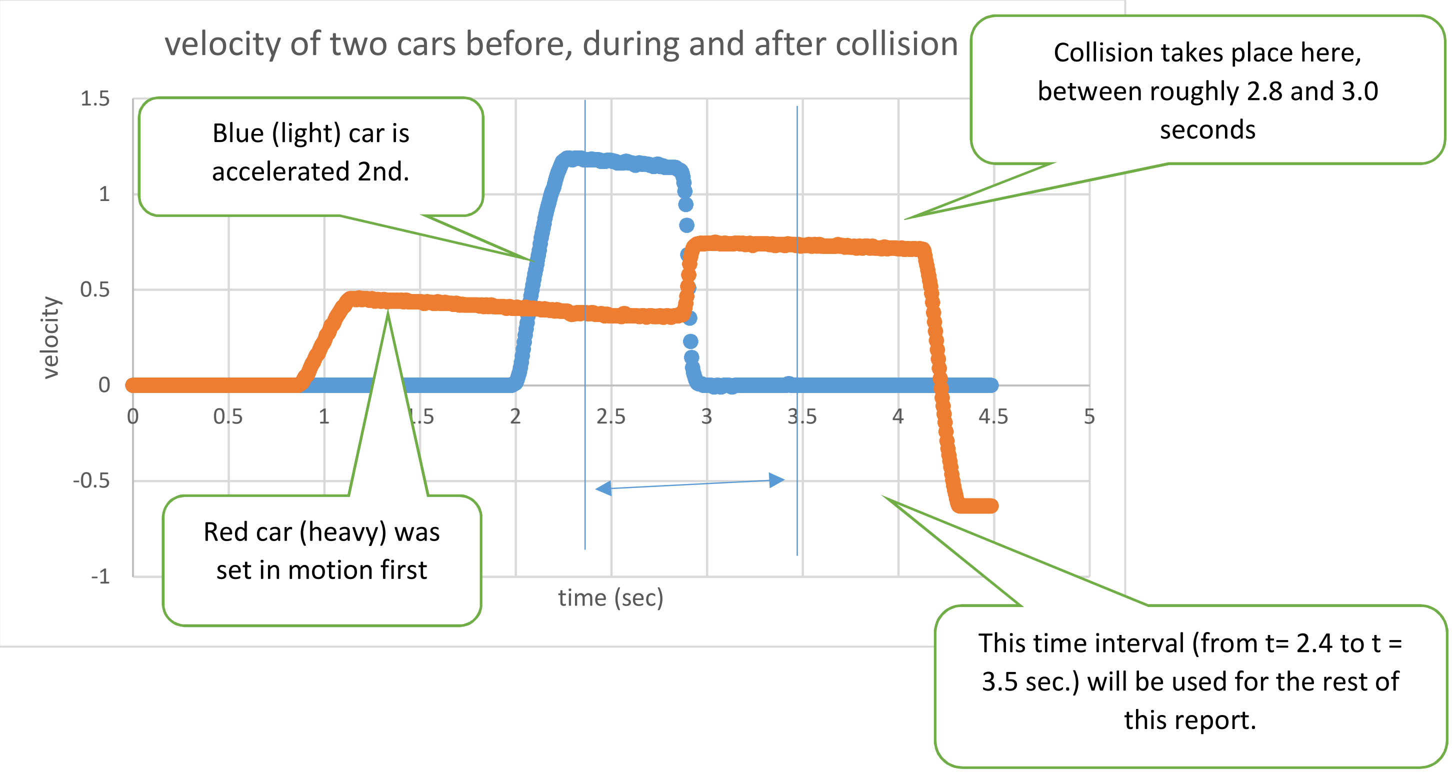
- ..that momentum is conserved during collision events.
- ..that the 'impulse' (the change in momentum for either car) can be determined by determining the area of a graph of force vs time.

In order to show these two results, the students will include the following sequence of data sets and graphs.

- Graph 1: Raw data from the cars.. (velocity data for both, force data for one)
  - Note: be sure to set frequency of data collection to 100 Hz and to 'zero' your force sensor before collecting data).
- Graph 2: "corrected" data for cars, *inverting the velocity data* of the car which was facing backwards.
  - On this graph, add 'call-outs' to 'tell the story' of the collision event (including when each car was initially accelerated, when the collision even took place, and which car was 'the heavy one' and which care was 'the light one' (please identify the mass of each car in kg in the callouts here).
  - Also, identify the 'span of time' which most clearly illustrates the transfer of momentum' (and noting the 'start and stop row numbers' to help put boundaries on the data sets for analysis).
- Graph 3: The same graph as above, but reduced down to show velocity data just before, during and just after the collision event.
- Graph 4: The momentum graph.
  - Write a new function (limited to the span of time which allows us to see momentum transfer) which multiplies the mass of each car by the 'corrected' velocity values.
  - Write an additional function which is 'the sum' of the two momenta before, during and after collision.
  - Use callouts to show a) the change in momentum on each car and b) the sum of the momentum for both cars.
- Graph 5: The graph of force as a function of time.
  - Note: this graph will only show the collision event itself (first examine your velocity graph to identify the 'moment' when the collision takes place, then restrict your forced data to that moment (likely spanning roughly 1/10th of a second.. ie, only a dozen or so data points, if they are being recorded in .01 second intervals (i.e., 100 data points per sec.).
  - Once you identify 'the moment' of time in which the collision takes place, write a new function which will plot 'the average force' across that entire span of time. Use callouts to identify the 'average force' value. When you are 'back in MS Word', show how multiplying the 'average force value by the time interval should equal the 'impulse' observed for each car. (i.e., our second, stated objective).



Raw velocity graph (with velocity of 2nd car already corrected).



Blue (light) car is accelerated 2nd.

Collision takes place here, between roughly 2.8 and 3.0 seconds

Red car (heavy) was set in motion first

This time interval (from t= 2.4 to t = 3.5 sec.) will be used for the rest of this report.

Suggestions for writing formulas:

Note the start and stop row numbers of the time span you will be examining.

- Time stamp start = 2.4 seconds = row 483
- Time stamp stop = 3.5 seconds = row 703

Create a new graph focusing in on the range of time 'of interest'. (using the features below to narrow the range of axis displayed).

Note: to change the 'range' of time displayed (In Excel).

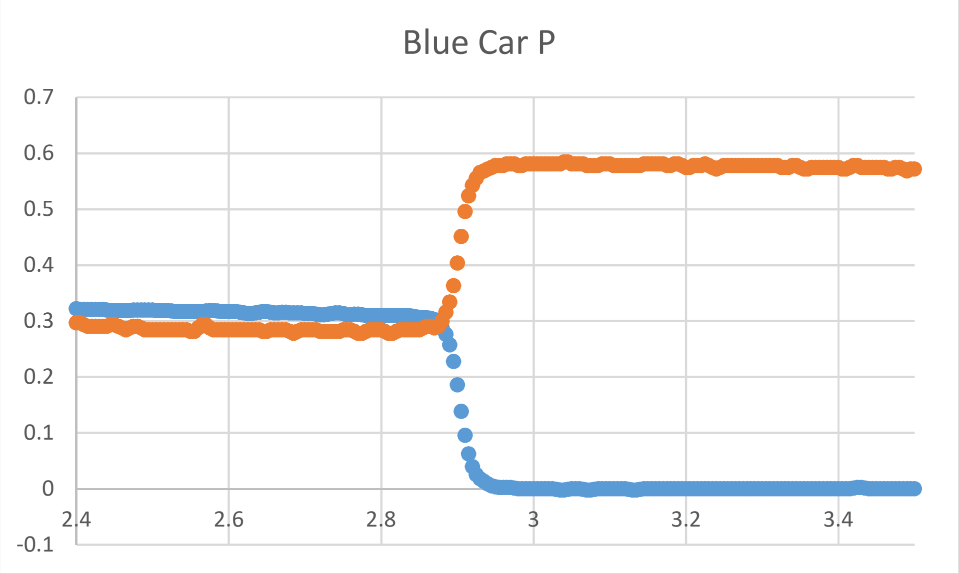
- Select the chart (click on outer border)
- Select the [Design] tab under [chart tools] tab.
- Select [add element] (at far left)
- Select [Axis] then [more axis options]..
- Change the [bounds] to the range of interest (in this case, to [2.4 = min.] and [3.5 = max])

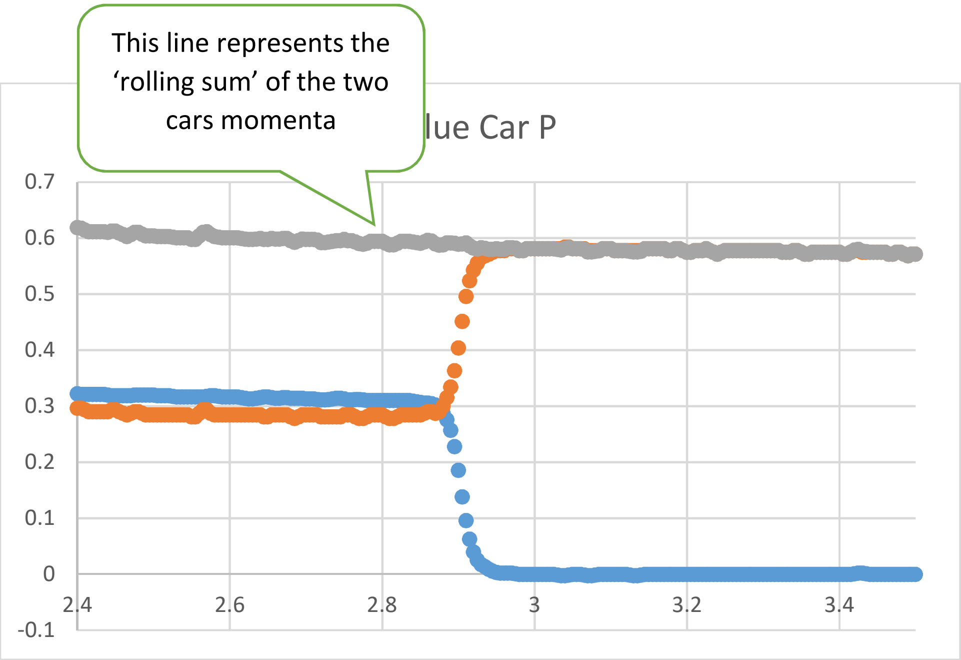
Collision occurs between 2.85 seconds and 2.95 seconds.

Row 573 to 593

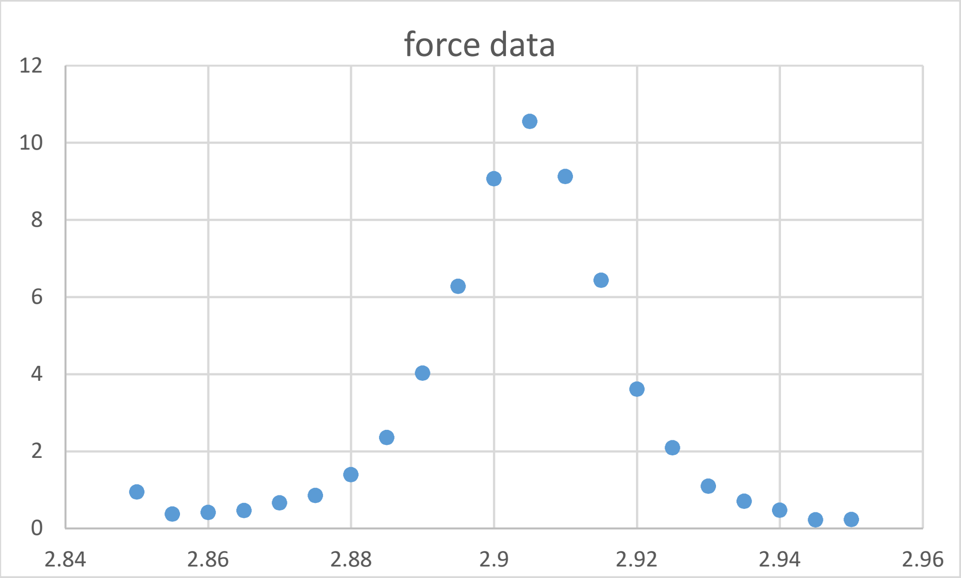
Write new functions to convert velocity data during that time frame into momentum data for each car (note: all you have to do is multiply the mass of each car by the velocity of each car, as shown below).

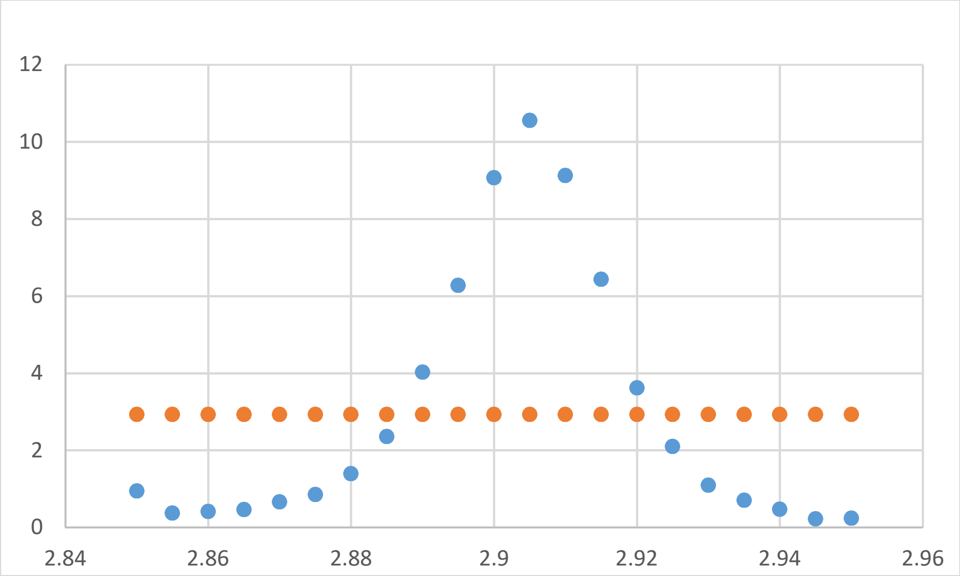
Create a new function which shows the SUM of the momenta of the two cars continuously.





This line represents the ‘rolling sum’ of the two cars momenta





From the momentum graph (2).

We see momentum of .28 t0 .58 kg-m/sec.

This equates to a delta P of + .3 kg-m/sec

Comparing this to the delta P predicted by formula (Newton's second law);

(ave) Force x delta T = delta P

3 newtons x (2.95 – 2.86= .09 seconds) = **.27 kg-m/sec.**