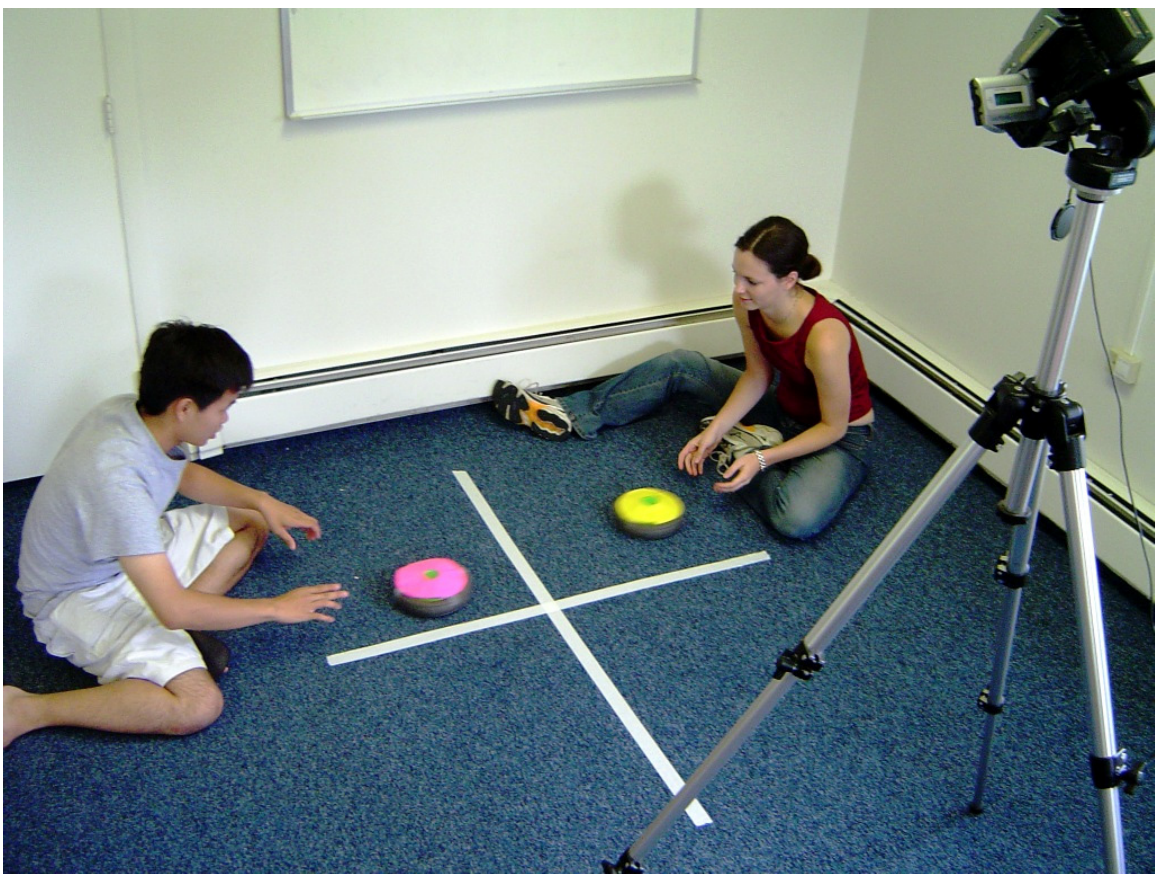
Momentum Conservation

Collision Activity in Motion Visualizer™ 2D



Written by Lick-Kong Tam. LK is a Brown University sophomore who spent the summer of 2004 working with Alberti's Window under the NSF's Research Experiences for Undergraduates program.

Purpose

In the activity, students analyze the collision of two Kick Dis™ air discs. The Motion Visualizer (MV) captures the collision at an angle of an air disc with another, stationary disc.

After the activity, students should be able to do the following:

√ Interpret velocity and position graphs of individual pucks to reconstruct events.

√ Construct vector representations of momentum.

√ Understand collisions in terms of initial and final momentum states.

√ Analyze collision in a center of mass frame.

√ Predict resultant momentum vectors given initial momentum vectors.

Materials

- Video Camera and Motion Visualizer Kit
- Tape measure
- Two Kick DisTM air discs.
- Sheet of bright pink paper
- Sheet of bright yellow paper
- Tape
- Scissors

Fig. 1-Kick Dis™ air disc.

Setup

1. Turn a Kick Dis™ upside down on top of one of the bright sheets of paper. Trace around the perimeter of the disc and cut out the shape.
2. Place the cutout on top of the Kick Dis™. Tape the paper to the top of the disk. Repeat steps 1 and 2 for the other disk, using the other color of paper.
3. Place box on a linoleum floor (or other smooth surface) approximately 2 meters from the camera.
4. Turn on the Kick Dis™ and capture collision with Motion Visualizer.

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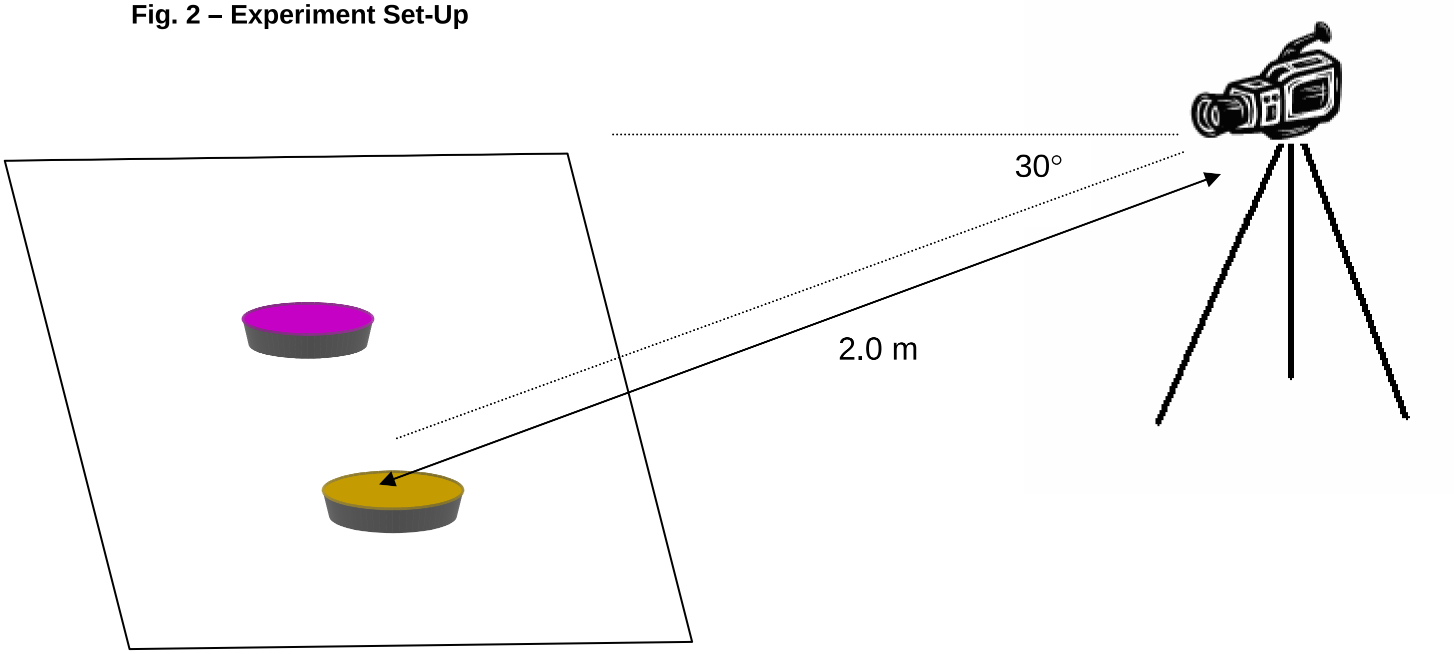
Experiment Type	**2 Object**
Motion	**Horizontal**
Camera Angle	**-30°**
Camera Distance	**2.0 m**

Fig. 2 – Experiment Set-Up



Data Analysis and Presentation

In the analysis of collisions, there is one clear principle, conservation of linear momentum. The physical principle translates well into equations for the experiment.

Momentum $_{ini}$ = Momentum $_{fin}$
Specifically:
$MV_{1\ x\ ini} = MV_{1\ x\ fin} + MV_{2\ x\ fin}$
$MV_{1\ y\ ini} = MV_{1\ y\ fin} + MV_{2\ y\ fin} = 0$

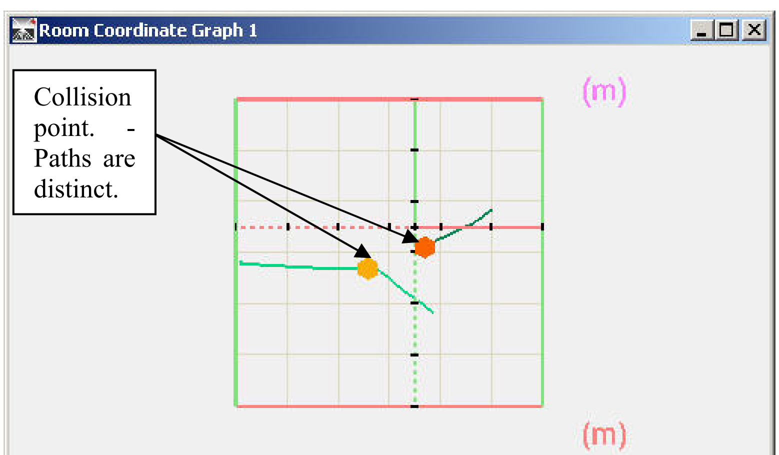


Fig 3. – Room Coordinate Graph at Collision

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Vector analysis is used to interpret the data. The construction of initial momentum vectors starts the analysis. Use MV to bring up a speed versus time graph. In the displayed graph to the right, a representative initial point is selected. The speed displayed is the magnitude of the vector.

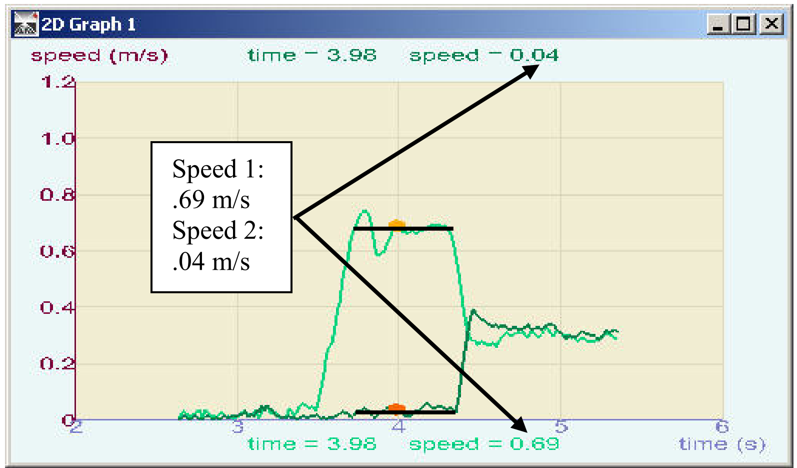

Fig 4. – Speed Graph Initial

To find direction, construct arrows on the disc path with an appropriate scale. Once the vectors have been constructed, all the tools needed for a vector analysis of momentum are present!

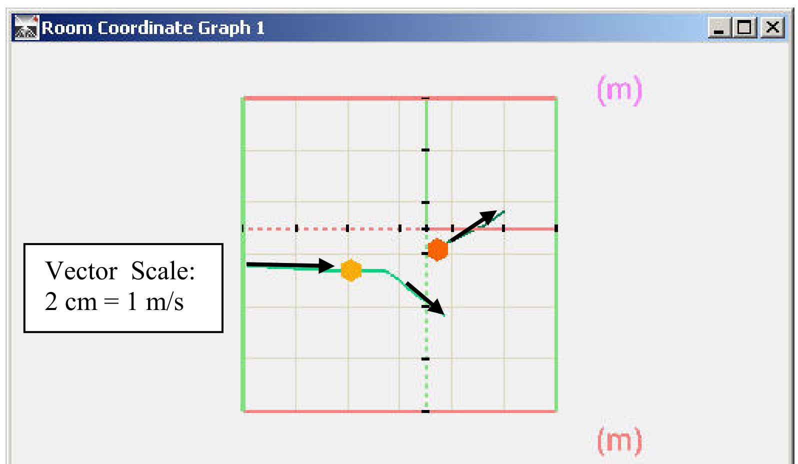

Fig 5. – Vector Graph

The graphical approach to momentum conservation reveals momentum is conserved.

Resultant vectors sum to initial vectors.

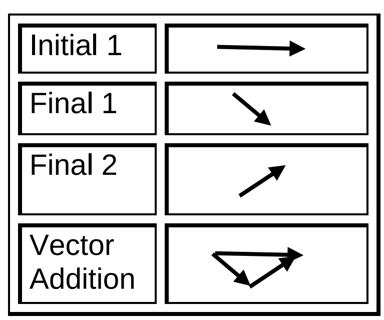

Fig. 6 – Vector Table

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Fig. 7 – Velocity Components Initial and Final

Another valid approach to momentum conservation is component analysis. MV graphs may greatly assist with the component approach. Use MV to bring up the component graphs. Like the previous approach, select representative points to read data.

Initial X velocity component 1	**.69 m/s**
Final X velocity component 1	**.23 m/s**
Final X velocity component 2	**.34 m/s**
Final Y velocity component 1	**-.19 m/s**
Final Y velocity component 2	**.16 m/s**
Final Sum X velocity components	**.57 m/s**
Final Sum Y velocity components	**-.03 m/s**

Fig. 8 – Velocity Components

Do the results of the component analysis agree with the results of the vector analysis?

Somewhat. Here is an error calculation to see how numerical methods match graphical methods.

$$1 - \frac{\sqrt{.57^2 + (-.3)^2}}{.69} = 13\ \%$$

The careful experimenter notes sources of error during experimentation. In the experiment performed, the tilt of a floor may have lead to increased error. In addition, the discs did rotate. Transformation of linear momentum to rotational momentum is an explanation for the momentum deficit.

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Arguably the most powerful method of analysis is a center of mass (COM) frame analysis. With the aid of MV data collection and Microsoft Excel computation, the analysis is easily done.

MV data can be saved into a comma separated value (.csv) file which may be opened and manipulated in excel.

Fig. 9 – MV Raw Data

	A	B	C	D	E	F	G	H	I	J	K
1											
2	t	X1	Y1	Vx1	Vy1	Speed1	X2	Y2	Vx2	Vy2	Speed2
3	2.633333	4.96E-02	-7.96E-02	2.70E-03	0	2.70E-03	-0.6802	-0.13746	5.70E-03	6.43E-03	8.60E-03
4	2.65	4.99E-02	-8.08E-02	3.90E-03	5.55E-17	3.90E-03	-0.68081	-0.13689	1.83E-02	-6.43E-03	1.94E-02
5	2.666667	4.95E-02	-7.96E-02	-1.62E-02	0	1.62E-02	-0.68004	-0.13801	2.29E-02	-1.93E-02	2.99E-02
6	2.683333	4.90E-02	-8.08E-02	-1.32E-02	5.55E-17	1.32E-02	-0.67783	-0.13885	1.69E-02	-1.93E-02	2.57E-02
7	2.7	0.048848	-7.96E-02	-3.90E-03	0	3.90E-03	-0.67799	-0.13877	-0.01051	-3.22E-03	1.10E-02
8	2.716667	4.89E-02	-8.08E-02	-4.20E-03	5.55E-17	4.20E-03	-0.67892	-0.13854	-1.00E-02	-1.29E-02	0.016309

The COM calculations are easily done since the objects are of equal mass. The x position and y position of the discs are simply averaged.

$$X_{COM} = \frac{X1 + X2}{2}, Y_{COM} = \frac{Y1 + Y2}{2}.$$

COM X pos	COM Y pos
-0.315322194	-0.108543107
-0.315476637	-0.108827463
-0.315249783	-0.108821432
-0.314413048	-0.109808622
-0.314568991	-0.109197203
-0.315019051	-0.109655543
-0.315023236	-0.109440748
-0.31548023	-0.109836485

Fig. 10 – COM Data

The startling result reproduced is that the COM does not change in situations where momentum is conserved. The results invite further investigation – quantities such as collision angle, velocity, and mass offer a wide-selection for further experiment. An appropriate goal would be the eventual prediction of initial and final momentum vectors. Both experiment and theory are required.

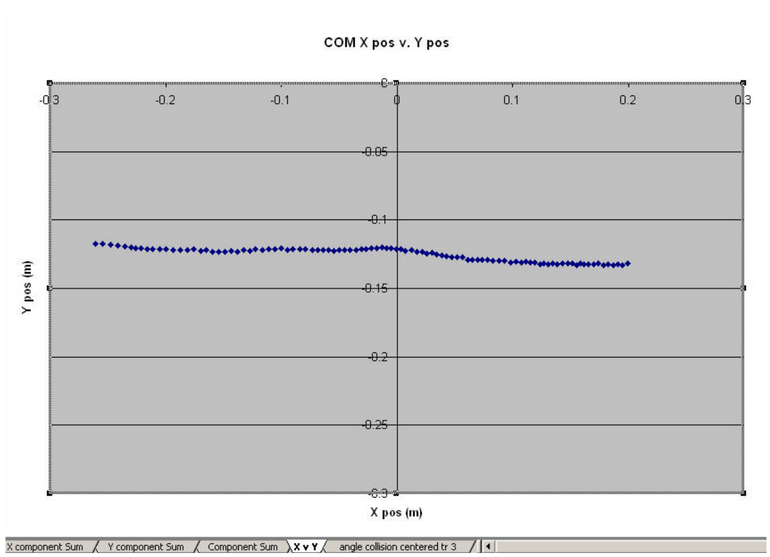

Fig. 11 – COM graph of X pos v. Y

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