SI Physics - Full Discipline Demo

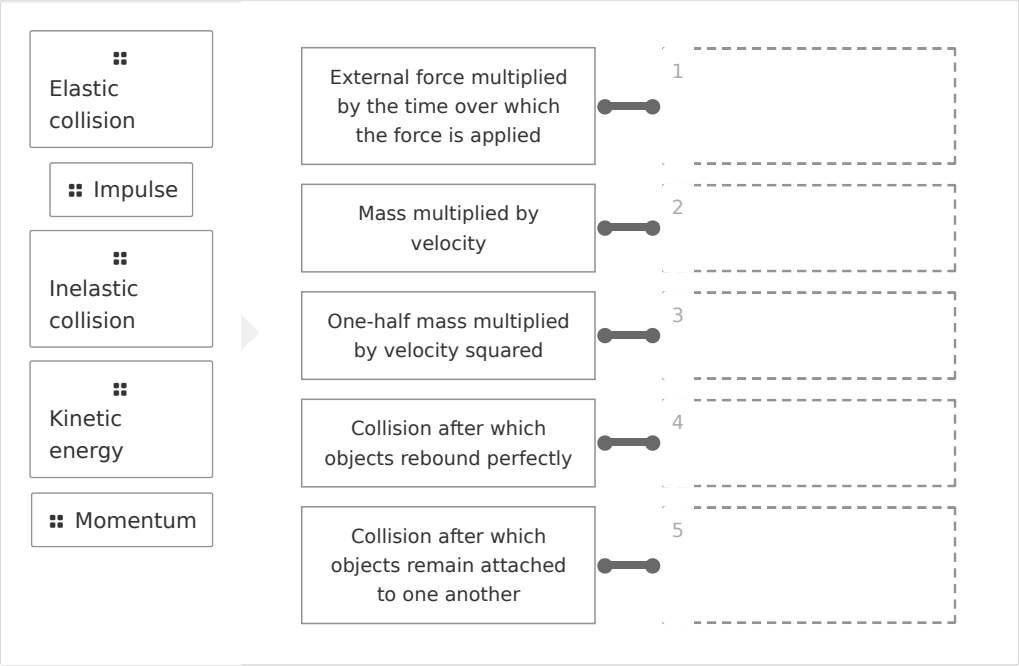
Conservation of Momentum

Final Report - Answer Guide

Institution	Science Interactive University
Session	SI Physics - Full Discipline Demo
Course	SI Physics - Full Discipline Demo
Instructor	Sales SI Demo

Test Your Knowledge

Match each term with the best description.



Correct answers:

1 Impulse 2 Momentum 3 Kinetic energy 4 Elastic collision

5 Inelastic collision

Identify each statement as true or false.

An impulsive force is constant over time.

Impulse is a measurement of the change in momentum of an object.

Momentum and kinetic energy are always conserved in every collision.

Momentum is a vector quantity.

True	False
1	2

Correct answers:

1 Impulse is a measurement of the change in momentum of an object.

Momentum is a vector quantity.

2 An impulsive force is constant over time.

Momentum and kinetic energy are always conserved in every collision.

Exploration

The momentum of an object depends on the _____ of the object.

- mass
- velocity
- both mass and velocity ✔
- None of the above

The impulse is measured by finding the area under the force - time curve.

- True ✔
- False

The force experienced during an interaction can be reduced by increasing the _____ of the interaction.

- [x] time duration
- [ ] impulse
- [ ] momentum change
- [ ] All of the above

The momentum of each individual object in an isolated system is conserved.

- [ ] True
- [x] False

Elastic collisions are interactions during which the interacting objects stick together.

- [ ] True
- [x] False

Momentum is conserved in both elastic and inelastic collisions, while kinetic energy is conserved only in elastic collisions.

- [x] True
- [ ] False

Exercise 1

What would happen to the momentum of a marble in this experiment if the angle of the inclined ruler were increased or decreased?

If the angle of the inclined ruler were increased, the speed and therefore momentum of a marble would increase. If the incline were decreased, the speed and momentum of a marble would decrease.

Based on your observations in Data Table 1, what can you conclude about the momentum of the released marble(s) just before the impact and the momentum of the marble(s) knocked away after the impact? Include how your observations support that momentum is conserved or not conserved in your answer.

Because the marbles of the same size seem to move with about the same speed, and the same number of marbles move before and after the collisions, the momentum appears to be conserved (the same) before and after the collision. When marbles of different sizes are used, the speed changes inversely with the size (larger marbles hit with small marbles move more slowly, while smaller marbles hit with large marbles move faster) to counteract the apparent difference in mass between the marbles so that the momentum is conserved.

Data Table 1: Observation of Collisions
(SAMPLE ANSWER BELOW)

Trial #	Marbles on incline		Marbles on board		Predicted: # of marbles to move	Observed: # of marbles moved	Observations
	Number	Size	Number	Size			
1	1	Small	4	Small	1	1	Same speed
2	2	Small	4	Small	2	2	Same speed
3	3	Small	4	Small	3	3	Same speed
4	1	Small	1	Small	1	1	Same speed
5	2	Small	1	Small	1	1	Faster
6	3	Small	1	Small	1	1	Much faster
7	1	Small	2	Small	1	1	Same speed
8	1	Small	3	Small	1	1	Same speed
9	1	Medium	4	Small	1	1	Faster
10	1	Large	4	Small	1	1	Much faster
11	2	Small	1	Medium	1	1	Slower
12	2	Small	1	Large	1	1	Much slower

Exercise 2

What type of collision(s) did you observe in this exercise? Do you expect kinetic energy to be conserved? Explain your answer.

The collisions in this exercise are all elastic collisions. Kinetic energy should be conserved, though there were some losses due to friction and the sounds produced when the marbles collide.

Was momentum conserved before and after the collisions in this exercise? Use your data from Data Table 3 and Graph 1 to support your answer.

Momentum was conserved for the most part before and after the collisions in this exercise. Data Table 3 shows that the momentum loss was less than 10% in all cases, and less than 5% in most cases. Within uncertainty and small losses due to friction, this qualifies as conserved. The graph in Graph 1 shows a perfectly straight line with slope of almost exactly 1.0, indicating a one-to-one correlation between the momentum before and after the collision. The R^2 value is 0.9976, indicating a very good fit to the data.

Use the data in Data Table 2 to relate the momentum of the largest marble to the momentum of the smallest marble for a variety of circumstances.

When the largest marble starts out with zero initial momentum, it has less momentum than the smallest marble. When the smallest marble starts out with zero initial momentum, it has less momentum than the largest marble. Not all of the momentum is transferred from the moving marble to the stationary marble. Momentum is mass x velocity, so the marble with the larger mass has a larger momentum if they have the same velocity. However, during a collision, the velocity of the hit marble varies up and down to make the total momentum of the system the same before and after the collision. After a collision, the marble that was stationary has less momentum than the initial momentum of the system, but more momentum than the marble that was originally moving after the collision.

A ball is moving at 4 m/s and has a momentum of 48 kg m/s. What is the mass of the ball? Show your work.

M = p/v = 48 kg m/s / 4 m/s = 12 kg. The mass of the ball is 12 kg.

Data Table 2: Velocity and Momentum
(SAMPLE ANSWER BELOW)

Setup	Marble size	Mass (g)	Measured distance (m)	Trial 1 time (s)	Trial 2 time (s)	Trial 3 time (s)	Trial 4 time (s)	Trial 5 time (s)	Average time (s)	Velocity (m/s)	M (I
A. Marble 1 Initial	Small	3.70	0.355	0.61	0.65	0.72	0.63	0.69	0.66	0.53	0
A. Marble 2 Final	Small	3.80	0.355	1.12	1.01	1.04	1.05	1.07	1.06	0.33	0
A. Marble 1 Final	Small	3.70	0.150	1.07	0.80	0.90	0.82	0.94	0.91	0.17	0
B. Marble 1 Initial	Small	3.70	0.355	0.61	0.65	0.72	0.63	0.69	0.66	0.53	0
B. Marble 2 Final	Medium	8.30	0.250	1.36	1.44	1.42	1.17	1.31	1.34	0.29	0
B. Marble 1 Final	Small	3.70	0.150	1.02	1.04	0.98	1.03	0.98	1.01	0.15	0
C. Marble 1 Initial	Medium	8.30	0.355	0.62	0.63	0.61	0.72	0.69	0.65	0.54	0
C. Marble 2 Final	Small	3.80	0.355	0.62	0.67	0.74	0.66	0.61	0.66	0.53	0
C. Marble 1 Final	Medium	8.30	0.250	0.85	0.87	0.97	0.89	0.92	0.90	0.28	0
D. Marble	Small	3.70	0.355	0.61	0.65	0.72	0.63	0.69	0.66	0.53	0

1 Initial											
D. Marble 2 Final	Large	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	N a
D. Marble 1 Final	Small	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	N a
E. Marble 1 Initial	Large	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	N a
E. Marble 2 Final	Small	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	N a
E. Marble 1 Final	Large	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	No sample answer	N a

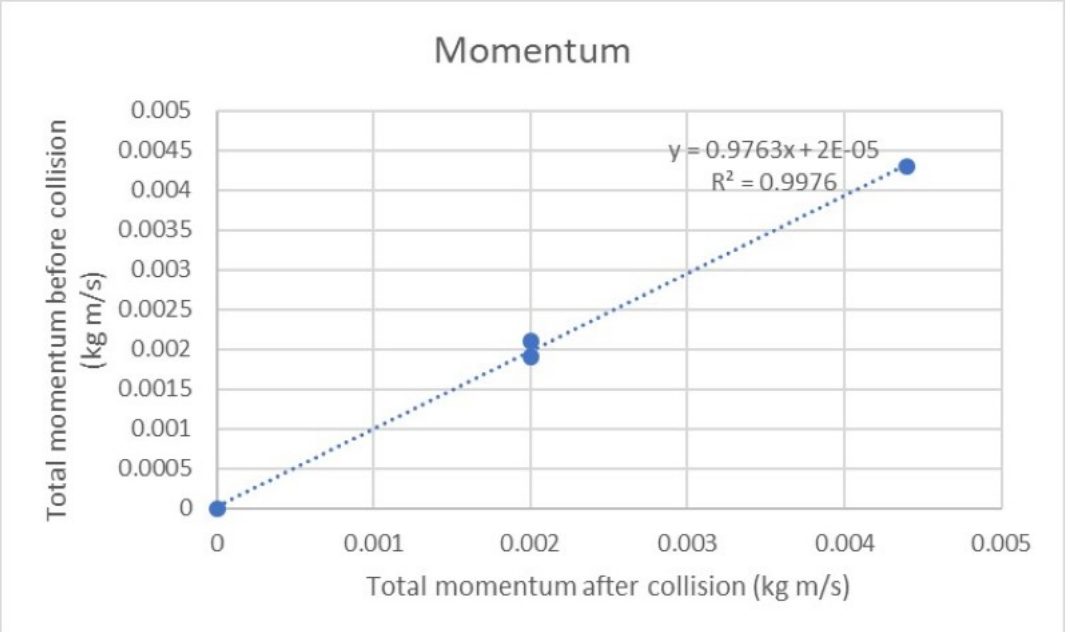
Data Table 3: Total Momentum

(SAMPLE ANSWER BELOW)

Setup	Total momentum before	Total momentum after	Percentage momentum loss
A	0.0020	0.0019	4.7
B	0.0020	0.0021	6.9
C	0.0044	0.0043	2.7
D	0.0020		
E			

Graph 1: Momentum Before and After Collision

(SAMPLE ANSWER BELOW)



Exercise 3

What is the result of colliding a moving curling stone of lower mass with a stationary curling stone of higher mass? How is this supported by your calculations in Data Table 3?

The lower mass stone will slide backwards after the collision. This is supported by the negative vf and pf values recorded for Trial 3 in Data Table 3 of -0.56 m/s and -11.20 (kg·m/s) respectively.

How do the results of this simulation exercise support the law of conservation of momentum? Explain your answer.

The curling stones from the simulation support the law of conservation of momentum because the momentum of the colliding stones remained constant as displayed by the pi, net equaling the pf, net values in each trial.

How does the simulation exercise compare to your observations and results from Exercises 1 and 2? Do you feel the simulation improved your understanding of the conservation of momentum of colliding objects?

Students should state the simulation mirrored the observations and results from Exercises 1 and 2. The simulation should also allow the students to record more consistent and conclusive data than the physical exercise. Student responses may vary regarding how much the simulation improved their overall understanding of the concept.

A ball with a mass of 3 kg moving at 5 m/s collides with a 9 kg ball at rest. After the collision, the impacting (3 kg) ball bounces back at a speed of 2.5 m/s. How fast does the 9 kg ball move and in what direction?

$p_{net,i} = m_1v_{1,i} + m_2v_{2,i} = 3\text{ kg} * 5\text{ m/s} + 9\text{ kg} * 0\text{ m/s} = 15\text{ kg m/s}$

$p_{net,i} = p_{net,f}$

$p_{net,f} = 3\text{ kg} * (-2.5\text{ m/s}) + 9\text{ kg} * v_{2,f} = -7.5\text{ kg•m/s} + 9\text{ kg x } v_{2,f} = 15\text{ kg m/s}$

$9\text{ kg} * v_{2,f} = 22.5\text{ kg m/s}$

Dividing both sides by 9 kg, this results in a velocity of 2.5 m/s moving in the original direction of the 3 kg ball's motion.

Data Table 4: Curling Ball Momentum Simulation
(SAMPLE ANSWER BELOW)

Trial	Stone Color	Mass (kg)	v_i (m/s)	p_i (kg·m/s)	$p_{i,net}$(kg·m/s)	v_f (m/s)	p_f (kg·m/s)	$p_{f,net}$ (kg·m/s)
1	Red	20	5.00	100	100	0.71	14.20	99.85
	Yellow	15	0	0		5.71	85.65	
2	Red	20	5.00	100	100	0.00	0.00	100.00
	Yellow	20	0	0		5.00	100.00	
3	Red	20	5.00	100	100	-0.56	-11.20	99.80

Yellow	25	0	0		4.44	111.00

Competency Review

The units of momentum are _____.

- kg m
- m/s
- kg m/s ✔
- All of the above

Impulse is calculated by multiplying average force by _____.

- time duration ✔
- distance traveled
- change in momentum
- All of the above

The _____ is a measurement of the change in momentum of an object.

- kinetic energy
- impulse ✔
- velocity
- All of the above

Momentum is conserved for any interaction.

- True
- False ✔

Kinetic energy is conserved for both elastic and inelastic collisions.

- True
- False ✔

An explosion a type of reverse _____ collision.

- elastic
- inelastic ✔
- interaction
- All of the above

Collisions between marbles are _____ collisions.

- elastic ✔
- inelastic
- interaction
- All of the above

As the mass of an impactor (such as a marble rolling down an incline) increases, the _____ of the impactor increases.

- momentum
- force
- impulse
- All of the above ✔

The mass of a marble is 0.003 kg and the velocity of the marble is 2 m/s. The momentum of the marble is _____ kg m/s.

- 0.002
- 0.006 ✔
- 700
- None of the above

A less massive impacting object colliding elastically with a more massive stationary object produces _____ velocity in the stationary object after the collision.

- a larger
- the same
- a smaller ✔
- All of the above

Extension Questions

A ball bouncing against the ground and rebounding is an example of an elastic collision. Describe two different methods of evaluating this interaction, one for which momentum is conserved, and one for which momentum is not conserved. Explain your answer. (SAMPLE ANSWER BELOW)

Momentum is not conserved if the system consists of only the ball, because the momentum of the ball changes before and after the collision, even if the speed is the same immediately before and after the collision. The ball changes directions of motion, so its momentum is changed. Momentum is conserved if the system consists of the ball and the Earth together, because the momentum of the Earth is slightly altered by its interaction with the ball. The change is not observed because the mass of the Earth is so much larger than that of the ball, but it occurs nonetheless.