ASTEROID COLLISION & MOMENTUM

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EDUCATIONAL CONTEXT

AGE

16-17 years old (11th year of education)
17-18 years old (12th year of education).

DURATION

2-3 didactical hours (each hour is 45 minutes).

PREREQUISITES

Mass, velocity, kinetic energy, scalar and vector products.

EDUCATIONAL OBJECTIVES

WHAT DO YOU AIM FOR YOUR STUDENTS TO LEARN THROUGH THIS ACTIVITY

COGNITIVE OBJECTIVES

- **Acknowledge that momentum of a certain object is proportional to its velocity.**
- **Acknowledge that momentum of different objects moving with the same velocity is proportional to their masses.**
- **Calculate the momentum of an incoming meteor and projectile.**
- **Identify and use momentum as a conservative property in collisions.**

AFFECTIVE OBJECTIVES

- **Increase students' confidence in science and scientific method of troubleshooting authentic life's situations (students-scientists).**
- **Increase students' confidence in themselves as being capable of handling real life's problems (morale boost).**

PSYCHOMOTOR OBJECTIVES

- **Enhance learners' ability to use computers, fine fingers mobility, work in teams.**

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CONNECTION TO THE CURRICULA

- – Physics, second year of Highschool. Second chapter, 2.3 Momentum
- Physics, second year of Highscho.ol. Second chapter, 2.4 Force and momentum.
- – Physics, second year of Highschool. Second chapter, 2.5 Conservations of Momentum.
- -– Physics, third year of Highschool. Fifth chapter, 5.2 Collisions
- -– Physics, third year of Highschool. Fifth chapter, 5.3 Central Elastic Collisions
- -– Physics, third year of Highschool. Fifth chapter, 5.2 Collisions
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EDUCATIONAL APPROACH

- Inquiry based learning approach
- Model Based approach
- Extensive use of simulations and interactive tools
- Metacognitive questions as reflection on students' beliefs, answers and way of thinking

ORIENTING & ASKING QUESTIONS

Orienting: Provide Contact with the content and/or provoke curiosity

In order to provoke students' curiosity and interest, I would choose to present them with images of craters on Moon, Mercury and Earth followed by questions such as the one below. Afterwards, I would show them Hubble Space Telescope's image from the collision of the fragments of Shoemaker-Levy 9 comet on planet Jupiter exactly 30 years ago, as a reminder than these phenomena are not happening in the past by even in or days, as we speak.

Define Goals and/or questions from current knowledge

What are these formations on Moon's surface?
How are they created?
Are they typical of Moon or are they evident on other solar system's bodies?
Why are they less impact craters on Earth?
Do these collisions always leave marks on planets?
Is it possible to avert a collision a collision of such an object with our planet, Earth?

HYPOTHESIS GENERATION AND DESIGN

Generation of Hypotheses or Preliminary Explanations

The main idea or hypothesis that would form the design of this teaching intervention is a scenario in which an asteroid is highly like to strike Earth. An international coalition of countries is trying to avert the disaster by launching a high kinetic energy and momentum projectile towards the asteroid, so as to change is speed by an average of 5% for example. This alteration is believed to be adequate so that the asteroid misses Earth. Therefore, the general hypotheses for the students to exams is:

- can the trajectory of an incoming asteroid be altered by a central, plastic collision with a projectile moving in high speed?
- If so, can the projectile's speed and mass be estimated?

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Design/Model

Students can draw a comparison of the above-mentioned situation using real life objects and situations like the ones available on a pool table. By using a billiards table, students can simulate elastic, central collisions, observe and monitor their results. Additional hands-on experiments with laboratory equipment, such as special designed carts capable joining each other on impact, can recreate and the plastic collision of two objects uniting in one single mass after collision. In addition, by using Information and Computer Technology (ICT), students can simulate these experiments and quantify the amount of momentum, i.e. the combination of mass and speed of an object, needed to alter a second's object momentum.

PLANNING AND INVESTIGATION

Plan Investigation

Students are in control of two independent parameters; the speed and the mass of the objects. As a result, they are capable of calculating and changing objects A and B momentum. To keep the simulation simple, collisions could be regarded as central meaning that vector velocities are applied to center mass of the objects and that the angle between them is zero. In this way we avoid taking into account the impact angle between the two objects. For simplicity reasons, we also consider that no debris is created from the collision of the two objects (in a more realistic approach the parameter of space debris could also be incorporated) and that the collision produces one singular body (plastic collision).

Perform Investigation

Students will:

1. Calculate the momentum of
    - three different bodies (tennis ball, bowling ball and a car) sharing the same speed.
    - a single object moving with three different speed values.
2. Calculate the momentum of an asteroid given its mass and speed values.
3. Calculate the momentum of a projectile given its values of mass and speed.
4. Calculate the projectile's speed and/or mass needed to change the asteroid's momentum and prevent its collision with Earth.
5. The necessary percentage change in the asteroid's momentum could be considered as given for each team but it can vary from team to team according to the distance of the asteroid from Earth. For example, intercepting the asteroid in a great distance would require a small percentage change in its momentum whereas intercepting it closer to Earth would require a significant amount of percentage change in its momentum.

ANALYSIS & INTERPRETATION

Analysis and interpretation: Gather result from data

Data analysis will be originally conducted by the students by themselves. Afterwards, their results will be compared with the results of their team members and finally with the results of other teams.
A creative way would be to use Microsoft Office software, in particular Excel application and tables with cells holding the values of mass and speed for different objects, as previously mention. This way students can have the values of momentum calculated with less effort.

CONCLUSION & EVALUATION

Conclude and communicate result/explanation

Students can conclude and communicate their results with:

- Oral presentations as teams.
- Poster presentation as teams.
- Short video as teams.

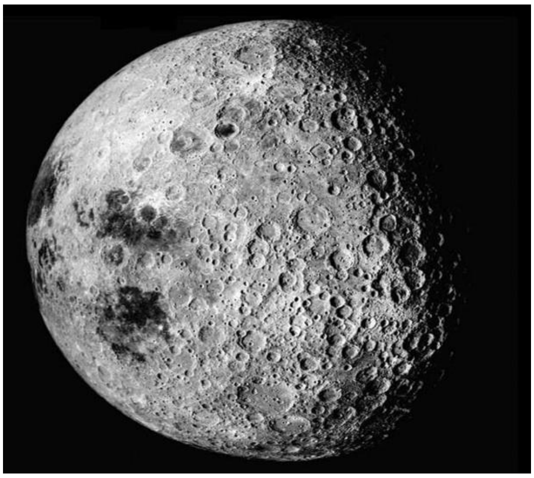
Evaluation/Reflection

In this teaching intervention we have used the context of asteroid collision as a scaffold for enhancing students' cognitive perception about momentum and collisions. After the completion of the teaching intervention students should be capable of:

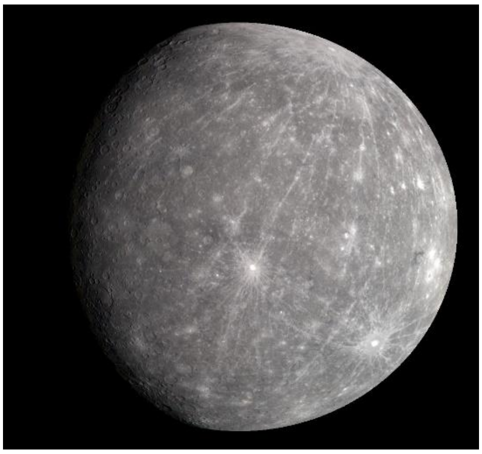
- Stipulating the parameters that momentum is dependable from.
- Explaining how the momentum of an object varies.
- Calculate the speed of a projectile needed to impact and stop an asteroid reaching Earth.
- Explaining why intercepting the asteroid farther away from Earth is preferable.

First Teaching Activity (45 minutes)

1. Look at the pictures below presenting the surface of Moon, Mercury and Earth.



Moon



Mercury

Arizona, USA

What is the name of the round geomorphological characteristics?

____

____

How are they created?

____

____

Are there as many impact craters on Earth's surface as on Moon and why?

____

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Is the collision of the meteorites/asteroids with planets an ongoing process? Use an internet search engine if necessary and report your findings (hint look for Shoemaker-Levy 9).

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____

Is it possible to avert a collision a collision of such an object with our planet, Earth?
Use an internet search engine if necessary and report your findings (hint look for DART mission).

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Real-life / Hands-on experiment No 1
"Create your own craters using everyday household materials" from
https://www.sciencebuddies.org/stem-activities/creating-craters#instructions

Materials

- Large baking pan or shallow cardboard box
- Flour (enough to fill the pan)
- Cocoa powder (enough to create a thin layer on top of the flour)
- Sieve or sifter
- Balls of various sizes
- Optional: ruler and meter stick

Instructions

1. Fill the baking pan with flour.
2. Use the sieve to put a thin layer of cocoa powder on top of the flour.
3. What would you think will be the results of dropping the same ball (same mass) from different height on the flour surface. Write down you expect to happen (prediction).

   ____
   ____
4. Now drop the same ball from different heights. Use the meter stick to drop the ball from heights of 10 cm, 20 cm and 30 cm. Write down your observations (observe).

   ____
   ____
5. Are your predictions in accordance with the results of your experiment? Yes or no and why (explain)?

   ____
   ____
6. Instead of using the same ball, try dropping three balls with different masses from the same height. What do you think will be their impact result of the surface of the flour? (prediction).

   ____
   ____
7. Execute the drop and examine the results of the impact craters created (observe).
8. Are your predictions in accordance with the results of your experiment (explain)?

   ____
   ____
9. Based on this experiment above, which parameters define the
10. You can even try throwing a ball sideways so it hits the pan at an angle, instead of coming straight down. How is the resulting impact pattern different from when you dropped the balls straight down?

Real-life / Hands-on experiment No 2
Bowling in the school yard.

Materials

- Three different kinds of balls, in particular a tennis ball, a basketball and a football.
- Ten traffic cones of orange color

Instructions

1. Set the traffic cones in a triangular pattern similar to that of bowling pins.
2. Imagine you want to drop as many traffic cones in triangular shaped pattern. Which ball would you rather use from the available ones? Write down your beliefs (prediction).
   ____
   ____
3. Try to hit the tennis ball on the traffic cones? How many did you manage to drop down?
   ____
4. Now use the football. Try to kick or throw it in a way it is moving with the same speed the tennis ball did. How many traffic cones did you manage to drop down this time?
   ____
5. Repeat the same process only this time use the basketball. Right down the number of traffic cones thrown to the ground.
   ____
6. According to your opinion, was it the speed of the balls that affected the number of the emergency cones that dropped? If not, which parameter made the difference?
   ____
7. Now use only the football. Kick it very gently, then harder and finally as hardest as you can towards the emergency cones. Write down how many of the cones drop in every case. Which parameter determines the number of emergency cones drooped on the ground?
   ____

With the help of the hands-on experiments, we can now define a new quantity **Momentum.** Momentum can be defined as "mass in motion." All objects have mass thus if an object is moving, then it has momentum. The amount of momentum that an object has is dependent upon two variables: how much *matter* is moving and how fast the *matter* is moving. Momentum depends upon the variables ***mass*** and ***velocity***. In terms of an equation, the momentum of an object is equal to the mass of the object times the velocity of the object.

Momentum = mass • velocity

In physics, the symbol for the quantity momentum is the lower-case p. Thus, the above equation can be rewritten as $\mathbf{p = m \bullet v}$ where m is the mass and v is the velocity. The equation illustrates that momentum is directly proportional to an object's mass and directly proportional to the object's velocity. The units for momentum would be mass unit times velocity unit. The standard metric unit of momentum is the kg•m/s. Momentum is a vector product.

Complete the following table

Item	Mass m (kg)	Velocity v (m/s)	Momentum p (kg. m/s)
Tennis ball	0,006	10	
Football	0,4	10	
Basketball	0,6	10	
Football	0,4	15	
Football	0,4	20	

Second Teaching Activity (45+45 minutes)

Virtual experiments with computer simulations "Collision Lab" from Phet Colorado

Instructions

1. Use an internet browser and type https://phet.colorado.edu/sims/html/collision-lab/latest/collision-lab_en.html
2. Select the rightmost image of inelastic collisions. Two different objects of blue and pink color appear.
3. Select the icon which is two spaces right from "custom", on the bottom of the screen. This way a central inelastic collision between bodies of the same mass and speed is selected.
4. Press the "Play" button.
5. What is the result of the collision? Is the object created from the collision of the two original bodies moving? What is the total amount of systems' momentum after the collision?

   ____

   ____
6. Both items were moving before the collision in opposite directions. As a result, both items have momentum of equal values but opposite directions. This means that the sum of system's momentum before the collision is equal to ________.
7. Press the rewind button and the systems is restored to its original state.
8. Set the velocity of the pink object to zero using the graphic interface.
9. Taking into consideration that only the blue object has velocity, then towards which direction will the object that is created after the collision will move and why?

   ____
10. Press the rewind button and the systems is restored to its original state.
11. Set the velocity of the blue object to zero using the graphic interface.
12. Taking into consideration that only the pink object has velocity, then towards which direction will the object that is created after the collision will move and why?

    ____

Complete the table below and estimate the direction of the movement of the single body which is created after the collision.

Blue mass (kg)	Blue velocity (m/s)	Blue momentum (kg.m/s)	Pink mass (kg)	Pink velocity (m/s)	Pink momentum (kg.m/s)	Total system momentum (kg.m/s)	Direction of movement
0,5	+ 1		0,5	-1			
1	+1		0,5	-1			
2	+2		2	-1			
2	+1		4	-2			
2	+4		2	0			

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StAnD

Incoming asteroid

Astronomers have recently discovered a Near Earth Object (NEO) asteroid, that is an asteroid which orbital characteristics bring it extremely close to Earth's orbit. In order to eliminate any possibility, scientists are planning to launch an unmanned space mission in which a spaceship will crush on the surface of the asteroid in an attempt to alter its momentum. This way the asteroid will slow down enough as to miss Earth's orbit. The sooner the spaceship is launched, the less change in the asteroid's momentum is needed to avoid collision with Earth.

As mentioned, scientist are planning to launch a rocket into space. On the top of this rocket a 5000 Kg lead constructed object serves as the projectile that will collide with the incoming asteroid. Based on their calculations, if the collision takes place at a relatively far distance, then only a 5% change in asteroid's momentum is needed to avert disaster. If the asteroid is intercepted in a medium range, then then a 25% change in its momentum will be needed whereas the necessary change in case of close distance interception is 90%. The asteroids mass is estimated at 5 10^9 Kg and its velocity at 1000 m/s. According to these estimates, calculate the asteroid's momentum and the minimum rocket velocity needed for successful interception of the asteroid in each case.

Interception scenario	**Asteroid mass (Kg)**	**Asteroid velocity (m/s)**	**Asteroid momentum (Kg m /s)**	**Need % change of asteroid's momentum**	**Momentum change (Kg m /s)**
Far					
Medium range					
Close					

The calculated asteroid's momentum change will be the result of its impact with the projectile or in other words the asteroid's momentum change is equal to the projectile's momentum. Since the mass of the projectile is finite, thus its momentum is purely depended on its velocity.

Interception scenario	**Projectile mass (Kg)**	**Projectile's momentum (Kg m /s)**	**Projectile's velocity (m/s)**	**Projectile's velocity (km/s)**
Far				
Medium range				
Close				

Based on the velocity values needed for the successful interception of the asteroid, when do you think an interception attempt would have more chances of being successful and why?

____

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Why it becomes more difficult to divert an asteroid from its collision course with Earth as it closes in? What is needed for the projectile to have in excess and why is this challenging?

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