BIOZONE

Student Edition

Textbook Lite | Activities | Study Guide

PHYSICAL SCIENCES FOR NGSS

FREE SAMPLE

for classroom trial

This sample packet may be photocopied and trialled in the classroom.

PS2.A

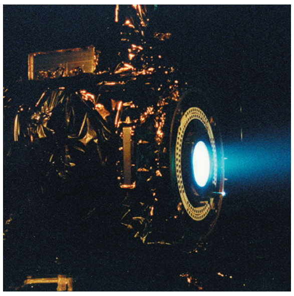
5: Forces and Motion

Activity number

Anchoring Phenomenon

Breaking Bricks How is it possible to break many bricks, blocks of ice, or boards of wood stacked on top of one another? What physical principles explain these feats of strength? 64 76

NASA



NASA

How can Newton's laws explain how and why things move?

☐ 1 The study of motion is an important part of physics. How do you describe the motion of objects around you? Identify the three main aspects of motion and construct diagrams *[SEP-2]* to describe these different aspects of movement. Understand the difference between speed and velocity. Use and interpret mathematical representations of the relationship between distance and time to determine velocity *[SEP-4]*. Working in groups, investigate this relationship for yourselves and plot your results *[SEP-3] [PS2.A] [CCC-2]*. 65 66

☐ 2 What do we mean when we say something is accelerating? Use a mathematical expression (equation) to calculate the acceleration for an object traveling in a particular direction. Given a known acceleration, time, and final velocity, how would you calculate distance traveled? *[SEP-5]* Draw and interpret graphs of displacement versus time and velocity versus time *[SEP-4] [PS2.A] [CCC-2] [HS-PS2-1]*. 66 67

☐ 3 What do you understand by the term force? What happens when unbalanced forces are applied to an object? Interpret data on the effect of friction on motion *[SEP-4]*. Explain why friction is an important consideration in the design and operation of moving objects. Weight is a specific kind of force due to gravity but forces can act on objects from any direction. Draw a simple model *[SEP-2]* to illustrate the effect of a constant force being applied to objects of increasing mass *[PS2.A] [CCC-2] [HS-PS2-1]*. 68 69 77

☐ 4 You now understand the difference between mass and weight and can analyze the motion of objects subjected to a constant force (gravity). Interpret data *[SEP-4] [PS2.A]* of the effect *[CCC-2]* of increasing mass on acceleration and explain the relationship between the force on an object, its mass, and its acceleration. Examples could include a falling object, and object rolling down a ramp, or a moving object being pulled by a constant force *[HS-PS2-1]*. 69 77

☐ 5 Understand that forces come in action-reaction pairs which are always equal and opposite. Why don't these action-reaction pairs cancel each other out? Draw and analyze free body diagrams *[SEP-2] [SEP-4]* to calculate *[SEP-5]* the net forces on known masses and thus determine their acceleration. 70

☐ 6 Extend your study of forces and motion to include an exploration of collisions and momentum. Investigate *[SEP-3]* the momentum of objects of different mass using marbles on a ramp. Use your results *[SEP-5]* to explain how momentum affects *[CCC-2]* the distance the marbles roll *[PS2.A]*. 71

☐ 7 Analyze the results *[SEP-5]* of investigations of the effect of collisions on the momentum of colliding objects in an isolated system *[PS2.A] [CCC-4]*. Explain the results in terms of conservation of momentum *[HS-PS2-2]*. 72 73 77

☐ 8 Extend your analysis to explain the effects of collisions between real objects, such as motor vehicles). Investigate *[SEP-3]* what happens when the force of a colliding object is spread out over a longer (or shorter) period of time. Use math *[SEP-5]* to demonstrate this and explain its significance to how much damage occurs during a collision *[PS2.A] [HS-PS2-2]*. 74 75 77

How can mathematical models of Newton's laws be used to test and improve engineering designs?

☐ 9 Use your understanding of changes in momentum and impulse to analyze the design of modern safety equipment, e.g. crash helmets for different sports and air bags and crumple zones in cars. Use math *[SEP-5]* to explain how these safety devices reduce the force delivered during a collision *[PS2.A] [CCC-2] [HS-PS2-2]*. 75

☐ 10 Demonstrate your understanding of forces and momentum by carrying out an investigation *[SEP-3]* to design a landing device to protect a raw egg from a fall of at least 5 m. Working in groups, discuss how you will make the lander and the different designs *[SEP-6]* you could use to cushion the egg at impact and/or slow its descent *[CCC-2]*. Justify your design choice in terms of Newton's laws of motion *[PS2.A] [ETS1.B] [ETS1.C] [HS-PS2-3] [HS-ETS1-2] [HS-ETS1-3]*. 75

71 Introduction to Momentum

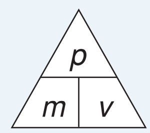
Key Question: How do we describe the quantity of motion in an object and how do we use it to explain why some objects are more difficult to stop than others?

Momentum

Ever played pool or gone bowling? These games operate on the same principle: using the movement of one ball to move or knock over other objects.

- In the game of pool (right) the white ball is used to maneuver the others around the table. Sometimes when it hits a target ball, the target will move away while the white ball stops moving. Other times, the white ball continues to move but more slowly after hitting the target ball, which also moves but more slowly.
- A important part of pool or bowling, is the concept of **momentum**. In pool, momentum for the white ball is transferred to the target ball to make it move. How this is done will determine the way the target ball and the white ball move after colliding.
- Momentum is a physics term referring to the quantity of motion an object has.
- Momentum can be defined as "mass in motion". All objects have mass, so if an object is moving, it has momentum.
- Momentum is dependent on two variables: mass and velocity.
- Momentum (p) is equal to the mass of an object (m) multiplied by the velocity of the object (v):

$$p = mv$$



- Momentum has units of kilogram meters per second (kg m/s).
- Because momentum has a velocity component, it is a vector with the same direction as the velocity.

1. Determine the momentum of:

   (a) a 60 kg running back running east at 10 m/s: ______________________

   ____

   (b) a 36,000 kg semi traveling north on interstate 95 at 30 m/s: ______________________

   ____

   (c) a 5.0 gram snail moving south at 2.0 meters per hour: ______________________

   ____

2. A car has 30,000 units of momentum. What would the car's new momentum be if:

   (a) its velocity was halved: ______________________

   (b) its velocity was doubled: ______________________

   (c) its mass was doubled: ______________________

   (d) its velocity was doubled and its mass halved: ______________________

3. Which has the greater momentum: a 25,000 kg truck moving at 5 m/s, or a 1200 kg car moving at 21 m/s?

   ____

   ____

4. A 990 kg car reduces its velocity from 22 m/s to 13 m/s. Calculate the change in the car's momentum:

   ____

   ____

PS2.A SSM

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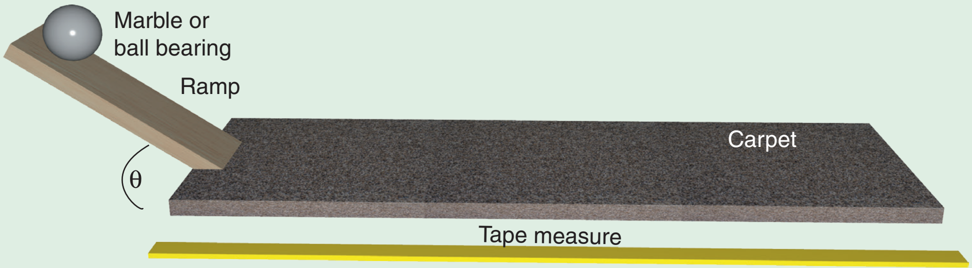
Marble momentum

- Marbles (or ball bearings) are great for exploring motion. Because they are made of glass or steel, they are smooth and hard. This means they roll with very little friction on smooth, hard surfaces and convert very little kinetic energy to heat and sound during collisions. When collisions are like this, they are said to be **elastic collisions**.

INVESTIGATION 5.2: Investigating momentum See appendix for equipment list.

You can work in pairs or small groups for this investigation.

1. You will need a marble and a ball bearing of similar size but different mass. Set up the following:



2. Measure the mass of marble.
3. Measure the length of the ramp and place the marble at the top.
4. The velocity of the marble at the bottom of the ramp can be calculated by combining the equation you derived in question 7 of page 141 and using right angle trigonometry to find the acceleration:

$$v = \sqrt{2g\sin\theta\Delta x}$$

where $g = 9.8\ m/s^2$, θ is the angle of incline of the ramp and Δx is the length of the ramp in meters.

5. Roll the marble down the ramp four times and record the distance that it runs along the carpet each time on the table below.
6. Calculate the average distance and record it in the appropriate table below.
7. Measure the mass of the ball bearing.
8. Replace the marble with the ball bearing and repeat steps 6 and 7.
9. Calculate the velocity of the marble and ball bearing as they leave the ramp and add to the table.

Test 1	Mass of marble (kg)	Length of ramp (m)	Velocity (m/s)	Distance rolled (m)
1				
2				
3				
4				
Average				

Test 2	Mass of ball bearing (kg)	Length of ramp (m)	Velocity (m/s)	Distance rolled (m)
1				
2				
3				
4				
Average				

5. Describe the investigation in terms of momentum and describe the effect that change in momentum had on the distance rolled by the marble and ball bearing:

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72 Investigating Collisions

Key Question: How do collisions influence the momentum of objects and how do we account for their relative influences mathematically?

Collisions

Moving objects have momentum. But what happens when two objects moving in opposite directions crash into each other? Where does the momentum go?

- Some students wanted to investigate this problem. They set up two carts on an air track to minimize friction. The mass of each cart was measured. Cart 1 had a mass of 0.75 kg, cart 2 had a mass of 0.73 kg
- The students noted that sometimes objects stick together when they collide (**completely inelastic collision**), and other times they rebound (**elastic collision**). To simplify their investigation, they fitted magnets to the carts so that they would stick together when they collided. A radar speed gun was available to measure velocity before and after the collisions.
- For the first investigation, cart 2 was made stationary in the center of the air track. Cart 1 was given a push in the direction of cart 2. The results of four trials that they carried out are shown in table 1

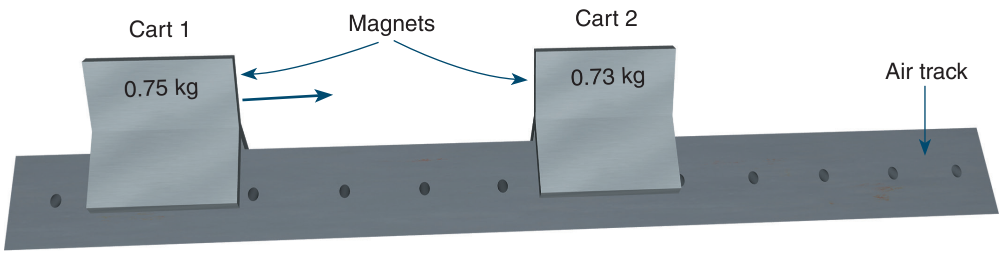

Table 1

Velocity cart 1 (m/s)	Momentum cart 1 (kg m/s)	Velocity cart 2 (m/s)	Momentum cart 2 (kg m/s)	Velocity cart 1&2 after collision (m/s)	Total momentum of carts (kg m/s)
0.52		0.00		0.26	
0.64		0.00		0.33	
0.32		0.00		0.16	
0.13		0.00		0.07	

- The students then decided to investigate both carts in motion. They pushed the carts in opposite directions towards each other. They kept the magnets in place so that the carts would stick together after the collision.
- Because cart 2 was moving in the opposite direction of cart 1, the students recorded this as a negative velocity. The results of four trials that they carried out are shown in table 2.

Table 2

Velocity cart 1 (m/s)	Momentum cart 1 (kg m/s)	Velocity cart 2 (m/s)	Momentum cart 2 (kg m/s)	Velocity cart 1&2 after collision (m/s)	Total momentum of carts (kg m/s)
0.41		–0.11		0.15	
0.12		–0.35		–0.11	
0.37		–0.36		0.01	
0.29		–0.30		0.00	

1. (a) Complete tables 1 and 2 (above) by calculating the momentum of each cart:

   (b) Explain the students' results: ____________________

   ____

   ____

   ____

PS2.A SSM

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Elastic collisions

- The students from the previous page decided to investigate collisions in which the objects rebound. They reversed the orientation of one set of magnets so that the magnets would repel each other as the carts came together. The carts would then "rebound" after the collision.
- In the first two trials cart 2 was stationary. In trials 3-5, cart 2 was moving. The results of the five trials that they carried out are shown in table 3:

Table 3

Trial	Velocity cart 1 (m/s)	Velocity cart 2 (m/s)	Velocity cart 1 after collision (m/s)	Velocity cart 2 after collision (m/s)
1	0.49	0.00	0.01	0.50
2	0.55	0.00	0.01	0.56
3	0.21	–0.56	–0.55	0.22
4	0.45	–0.43	–0.42	0.46
5	0.40	0.10	0.10	0.40

2. Complete table 4 (below) using the results in table 3. Recall that mass of cart 1 = 0.75 kg and mass of cart 2 = 0.73 kg.

Table 4. Momentum from table 3 results

Momentum cart 1 (kg m/s)	Momentum cart 2 (kg m/s)	Momentum cart 1 after collision (kg m/s)	Momentum cart 2 after collision (kg m/s)

3. Explain the students' results from tables 3 and 4: ____________________

4. Looking at the results from tables 1 and 2 from the previous page and tables 3 and 4 above, write a mathematical expression to model the results.

5. A car with a mass of 1000 kg is traveling east with a speed of 20 m/s. A 2000 kg pickup truck traveling west at 15 m/s crosses the median and the two vehicles collide.

   (a) If the two vehicles stuck together upon impact like the carts in the students' investigation on the previous page, what would the resulting velocity of the vehicles be immediately after impact?

   (b) In a perfectly elastic collision like the carts in the students' investigation above, what would the resulting velocity of the car be if the velocity of the truck after the impact was 9 m/s to the east?

   (c) Does this seem likely in reality? Explain: ____________________

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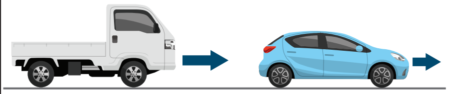
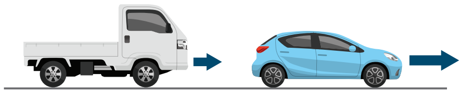
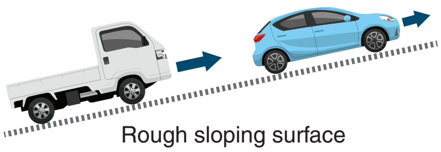
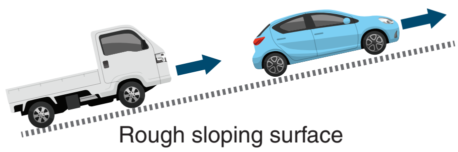
73 Law of Conservation of Momentum

Key Question: What does the law of conservation of momentum say and how does it explain why force pairs do not cancel each other out?

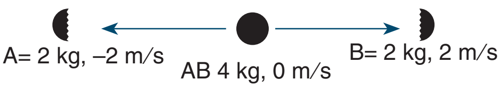
Conservation of momentum

Momentum (p) is always conserved (i.e. total momentum is the same before and after a collision or interaction) as long as there are no forces outside the immediate situation affecting the colliding objects (i.e. causing additional accelerations). The following examples illustrate these ideas.

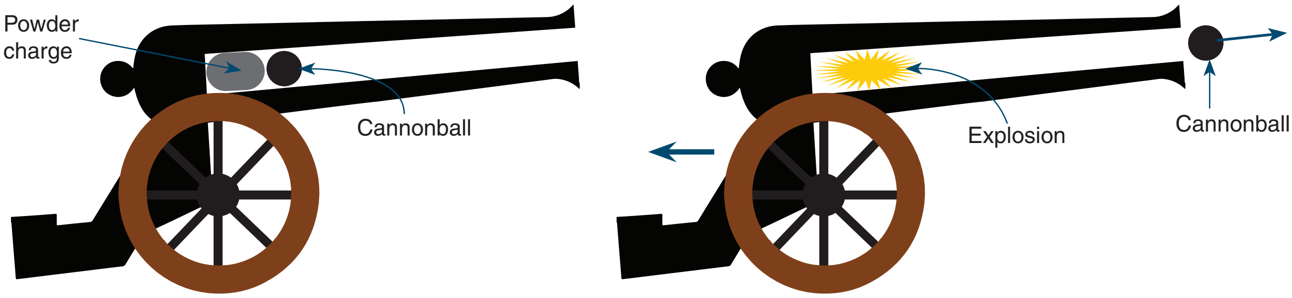
Before colliding	After colliding	Explanation
A m_1 = 1500 kg m_2 = 1000 kg v_1 = 30 m/s v_2 = 20 m/s  Relatively smooth horizontal surface	m_1 = 1500 kg m_2 = 1000 kg v_3 = 20 m/s v_4 = ?? m/s  Relatively smooth horizontal surface	No forces outside the immediate interaction causing significant accelerations of the colliding objects so… **p after = p before** $m_1v_1 + m_2v_2 = m_1v_3 + m_2v_4$
B m_1 = 1500 kg m_2 = 1000 kg v_1 = 30 m/s v_2 = 20 m/s  Rough sloping surface	m_1 = 1500 kg m_2 = 1000 kg v_3 = ?? m/s v_4 = ?? m/s  Rough sloping surface	There are at least two forces outside the immediate interaction that will cause significant extra accelerations **Momentum (p) will not be conserved!**

Explosions

- Explosions throw objects in all directions, but they still obey the law of conservation of momentum. Imagine the firework in the photograph has been fired straight up and has reached the highest point of its flight. Its momentum in that instant is zero.
- At that exact moment, it explodes. What is the combined momentum of all the fragments now? Conservation of momentum states that they must add up to zero.
- Consider the simplified diagram below:



- The momentum of fragment A is exactly opposite the momentum of fragment B.



1. Consider the cannon above. The cannon has a mass of 900 kg and is at rest before firing. The cannonball weighs 5 kg. When fired, the cannonball exits the barrel at 230 m/s.

   Calculate the velocity of the cannon after it is fired: ______________________________

   ____

2. An object at rest explodes into two equal parts, A and B. Part A flies off at 20 m/s. What is the velocity of part B?

   ____

PS2.A SSM

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74 Impulse

Key Question: How does changing the time over which a force is applied to an object influence the object?

Impulse

Collisions can be instantaneous, or they can occur slowly. Imagine falling out of a plane at an altitude of 5500 meters. You would expect that when you hit the ground, the force of the impact would be fatal. True? Not necessarily.

- In 1944 Royal Airforce tail gunner Nicholas Alkemade jumped from a flaming Lancaster Bomber at 5500 meters without a parachute after it was destroyed over Germany. He survived with only a few bruises and a sprained ankle because his fall was cushioned by thick tree branches and nearly 0.5 m of snow.
- Because the force of the impact was spread out over a long period, Alkemade was able to survive the fall. Vesna Vulovic, an air hostess in Yugosalvia, holds the record for surviving the highest fall, from a DC-9 that blew up at 10,160 m in 1972.
- • Recall $F=ma$. We know that $a = \Delta v/\Delta t$ so we can substitute a in the equation to give $F = \Delta(mv)/\Delta t$.
  • Multiplying both sides by Δt gives $F\Delta t = \Delta mv$.
  • Thus the force multiplied by the change in time (or **impulse J**) equals the change in momentum (p) of the object.
  • It has the unit of Ns (newton seconds).

Impulse (J) = $F\Delta t = \Delta mv$

1. Consider an object with a mass of 100 kg moving at 10 m/s. Its momentum is therefore 1000 kg m/s. How can this object be stopped? It can be stopped quickly by applying a large force or slowly by applying a small force.

   (a) The object mentioned above has a momentum of 1000 kg m/s. A force of 200N is applied to the object. How quickly will the object stop?

   (b) The object has a force of 10 N applied to it. How quickly does the object stop now?

2. A 3 kg object traveling with a velocity of 20 m/s experiences a force of 15 N for 5 seconds in the same direction of travel. Calculate the object's new velocity:

3. A car with an occupant weighing 80 kg is moving at 27 m/s (about 100 kmph). The car hits a tree head on and comes to a complete stop in 0.3 seconds.

   (a) The occupant is wearing seat belt and thus stops at the same rate as the car. Calculate the force experienced by the occupant:

   (b) In the case of an airbag inflating, the impact time is increased by 0.1 seconds. Calculate the force experienced by the occupant in this case:

4. A tennis racket hits a stationary ball (mass 60 g) at 40.0 m/s. The impact time is 0.001 seconds. Calculate the force exerted on the ball:

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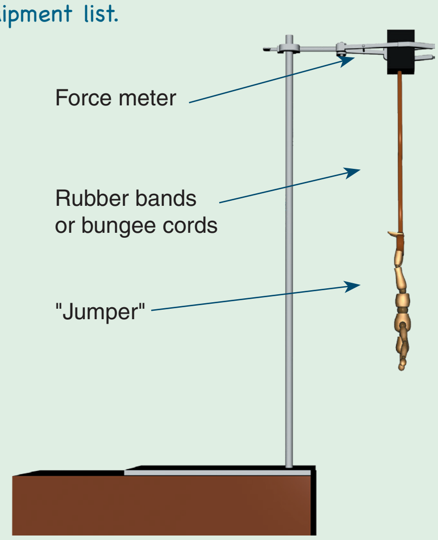
Impulse of bungee jumping

- To stop an object in motion, a large force can be applied to stop the object quickly or a small force can be applied to stop the object slowly.
- In both cases the object comes to a stop, but the effects of the stop on the object are very different.

INVESTIGATION 5.3: Investigating impulse See appendix for equipment list.

1. Work in pairs. You will need an old doll or small stuffed animal. Measure the mass of the "jumper" in kilograms.
2. Set up the following equipment as shown right (make sure the stand is securely clamped to the tabletop)
3. Create a bungee cord using elastic bands.
4. Attach one end of the cord to the "jumper" and the other end to a dual range force sensor attached to the stand.
5. Allow the bungee jumper to fall while you collect force time data using a program such as Logger Pro.
6. Sketch a graph of force vs time below. Take note of the peak force value.
7. Replace the elastic band bungee cord with a length of inelastic string or twine the same length as the elastic bungee cord.
8. Allow the bungee jumper to fall again and sketch the graph of force vs time below. Again note the peak force value.



With elastic band

Force (N)

Time (s)

Peak force = ____________ N

Without elastic band

Force (N)

Time (s)

Peak force = ____________ N

5. Measure the length of the elastic band bungee cord (or the length of inelastic string as they were the same length) in meters and the mass of the bungee jumper in kilograms.
   (a) Calculate the velocity of the jumper when it reached the end of the cord (before the cord applied a force to stop it):

   ____

   ____

   (b) What is the magnitude and direction of the impulse required to stop the bungee jumper: ____________________

   ____

   (c) Compare the peak forces identified in the investigation and calculate the time it took the cords to stop the jumper:

   ____

   ____

6. Using the data you collected from the investigation and what you know about impulse, explain why bungee cords are made out of elastic materials rather than something like rope:

   ____

   ____

   ____

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75 Crumple Zones and Crash Helmets

Key Question: How are the principles of momentum and impulse applied to limit damage to sensitive objects and save lives?

Landing on Mars

- NASA is by far the most successful of all the space agencies that have tried to land probes and rovers on Mars. They devised two main ways of landing probes and rovers on to the surface safely: using parachutes and retro-rockets, or parachutes and air bags.
- Viking 1 was the first of NASA's Mars landers to successfully touch down (in 1976). The lander used parachutes to slow its descent from 250 m/s to 60 m/s. It then used retro-rockets to slow its descent below 2.4 m/s before touchdown. Shock absorbers in the legs reduced the final force on landing to a slight jolt.
- The Mars Pathfinder lander, which touched down in 1997, used a slightly different landing technique. The lander also deployed a parachute to slow its descent after entering the atmosphere. Air bags around the lander's frame were inflated and retro-rockets were fired to bring the lander to a sudden halt at just 98 meters above the ground. The lander was then cut loose from the parachute and fell to the ground, using the inflated air bags to cushion its landing. When it hit the ground, it bounced up to 15 m high and experienced a maximum force of 18 G.
- Both the Spirit and Opportunity rovers, which landed in 2004, used similar landing devices to the Mars Pathfinder.
- The Curiosity rover landed in 2012 using an advanced retro-rocket package. The rover was so heavy (899 kg), it was not feasible to use parachutes and air bags to land. NASA therefore developed a sky crane (right) to lower the rover to the ground. The huge 16 m diameter parachute, deployed after entry into the atmosphere, produced up to 289 kN of drag. The powered descent stage was released at 1.8 km altitude. This used retro-rockets to hover above the surface and lower the rover 7.6 m to the ground. After detaching, it flew far enough away not to interfere with the rover. It later crashed into the Martian desert.


Mars Pathfinder lander


Curiosity rover and sky crane

NASA

1. (a) What are the two main methods used by NASA to land its rovers or landers on Mars?

   (b) Would these methods work on the Moon or Mercury?

2. (a) Explain why the Curiosity rover used a sky crane to lower it to the surface:

   (b) The acceleration due to gravity of Mars is 3.71 m/s^2. What is the weight of the Curiosity rover on Mars?

   (c) What equivalent mass on Earth would produce this weight?

3. Why was it so important for these rovers to reduce the force experienced during landing?

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Crumple zones


NHTSA: National Highway Traffic Safety Administration

"Cars today, they're just not built tough. A small crash and they're just wrecked". Have you heard this before? Or how many times have you heard someone say, "I like being in a SUV or four-wheel drive, they're solid, tough, and can take a crash."

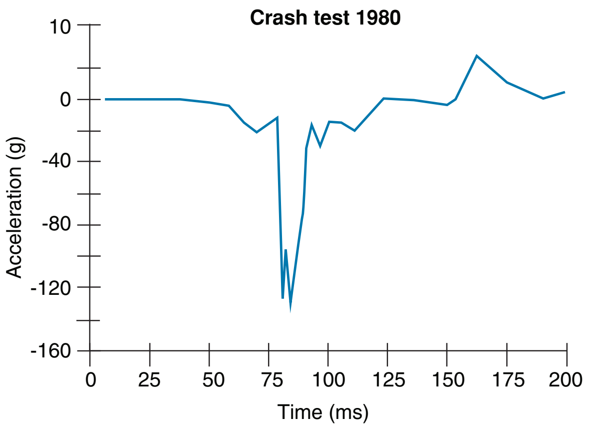
- Is this thinking logical when it comes to a crash? From your studies of force, momentum, and impulse, would you rather be in a car that crumpled when it had a crash or was rigid and kept its shape?
- Cars today have sophisticated safety systems that often allow the car to avoid a collision. However these do not prevent all crashes. In the case of a crash, the frame of the car is designed to crumple up.
- The crumpling effect increases the time the force of the crash is applied, reducing the force felt by the occupants.

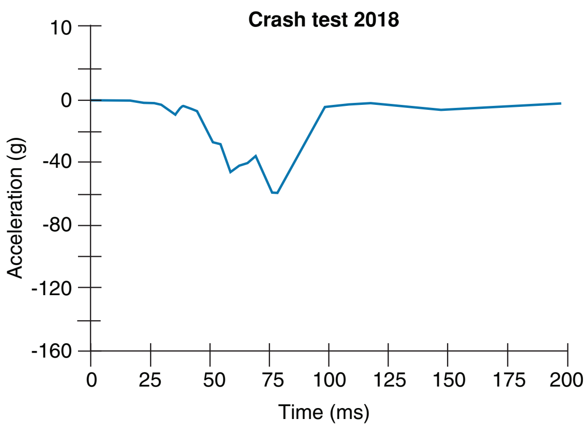
1. Why do cars have crumple zones? ____________________

2. What other safety devices do modern cars regularly have installed to protect the occupants in the event of a crash?

3. Motorbikes have little capacity for crumple zones (although this is performed to a degree by the front wheel and steering system). Bicycles have virtually no capacity for a crumple zone. How do riders protect themselves in a crash?

4. The graphs below show acceleration data from crash tests performed on a modern 2018 vehicle and a vehicle from 1980.





(a) If the masses of each car were 1000 kg, calculate the peak forces the occupants would experience in both crashes:

(b) Which car do you feel would keep you safer in a crash? Explain your reasoning using ideas of impulse and the forces experienced during the crash tests:

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Crash helmets

Helmets come in all shapes and sizes and serve many purposes. In virtually all cases, protecting the head has at least some importance in the helmet design.

- Crash helmets are specifically designed to reduce the force of impact during a crash. The design of the helmet is constrained by the conditions under which it will be used.
- Motorcycle helmets (right) are normally designed to protect the entire skull and face. For a pedal cyclist this design would be very heavy and would quickly become much too hot. The much lower speeds involved allow cycle helmets to be designed with air gaps and protect only the skull.

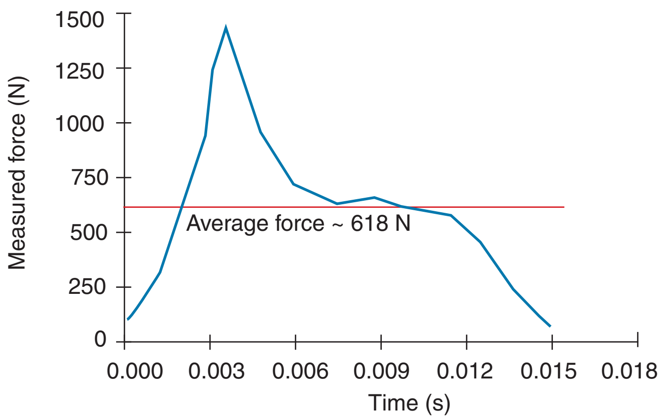
Mats

Mats are used for a variety of reasons and serve many purposes. On the workfloor, they are used to reduce the stress on the joints of workers who spend a lot of time walking or standing on hard surfaces. On the gym floor, they are used to lessen impact as cheerleaders, gymnasts, and martial artists practice their tumbles, jumps and flips. In track and field, they protect high jumpers and pole vaulters when they fall.

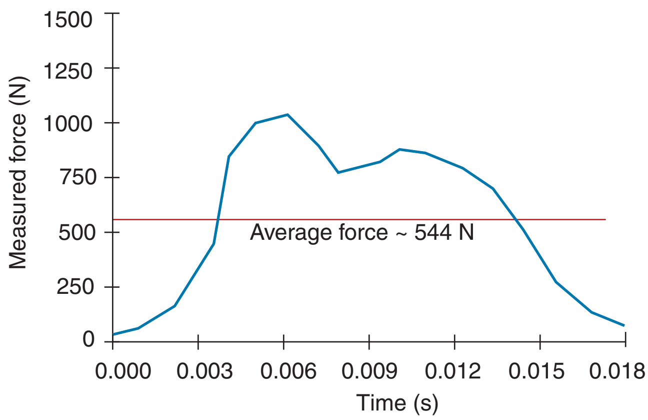
- During a routine, gymnasts can leap to incredible heights before landing on the floor. Over time repeated jumps can lead to damage to the joints. Floor mats reduce these injuries by increasing the time it takes for the gymnast to come to a stop after landing.
- The mats used by individuals doing yoga are much thinner than those used by gymnasts. Yoga is a low-impact activity and does not require the same level of joint protection. This means that yoga mats are easier to transport.

5. The graphs below show the simulated force experienced on the head during a crash with and without a helmet.

Without helmet



With helmet



(a) What is the peak force experienced without a helmet? ______

(b) What is the peak force experienced with a helmet? ______

(c) Why would both the peak and average force experienced be lower when wearing a helmet? ______

______

6. A 40 kg gymnast is practicing her routine. On her final jump, she reaches a height of 2.0 meters before landing on the gym mat. The mat stops the gymnast in 0.05 seconds.

(a) What is the magnitude and direction of the impulse required to stop the gymnast? ______

______

(b) What is the average force the mat exerts on the gymnast? ______

______

(c) Our gymnast decides to practice her routine at home on the driveway and sprains her ankle. The driveway stops the gymnast in 0.01 seconds. Explain why the gymnast injured herself at home (use calculations to justify your answer):

______

______

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INVESTIGATION 5.4: Building a lander See appendix for equipment list.

1. You will now have the opportunity to put your knowledge of forces and momentum to the test. The objective of this investigation is to build a device that will protect a lander from descent of at least five meters.
2. The conditions: You will build a landing device that will protect a raw egg from a fall of at least 3 m. Your are free to use the equipment (below) in any way but there may be no platform for the lander to fall onto (landers don't have convenient foam landing pads to fall onto when they reach their destination).
3. The equipment: 1 egg, 60 cm of tape, 5 rubber bands, 1 small garbage or plastic bag, 10 paper clips, 1 m string, 20 plastic or paper straws, 1 plastic egg or similar sized object for testing. Your teacher may modify this equipment as they wish.
4. Building time will be determined by your teacher.
5. Before you begin, discuss with your group how you will construct the lander and in what ways you could cushion the egg at impact or slow its descent to reduce the shock of landing.

Lander design

7. Now that you have built and tested your egg lander you must evaluate its structure and performance.

(a) Describe the structure of your lander: ____

(b) On a scale of 1-5, how did your egg survive the fall? (1= completely scrambled, 5 = safe and sound): ____________

(c) If your egg cracked, what could have been done to keep it from cracking if you repeated the test?

(d) Recall the landing devices designed used by other groups in your class. Which of these where the most effective? Can you explain why?

(e) Given enough material, it would be easily possible to design a lander than would protect the egg from a much higher fall than 5 m. The same applies to planetary landers. However, there are numerous constraints on the development of these devices, one of which is cost. Discuss with your group what other constraints there might be on the design on a lander for Mars:

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