# Module 10
# Force and Motion

## What this module is about

A lot of Physics can be observed in playing tug-of-war where both ends of the rope are being pulled in opposite directions. If the players on one end of the rope suddenly release the rope, the players on the other end will definitely tumble to the ground! Force and Motion!

**Fig. 1 Tug-of-War**

In this module you will learn many things about Physics particularly about forces that are the primary cause of changes in motion. This module includes these lessons such as:

- **Lesson 1 - Forces: The Secrets Unfold!**
- **Lesson 2 - Friction**
- **Lesson 3 - Newton's Laws of Motion**
- **Lesson 4 - The Universal Law of Gravitation**
- **Lesson 5 - Impulse and Momentum**

Read, enjoy, and discover the secrets of Physics!

## What you are expected to learn

At the end of the chapter, the students should be able to;

1. define and describe the fundamental principles of force and motion;
2. state the laws of motion;
3. apply the laws of motion to land transportation.
4. explain road safety measures using the concept of impulse and momentum
5. appreciate the contributions of Aristotle, Galileo, and Newton in the study of motion; and,
6. appreciate physics through its application to practical situations.

## How to learn from this module

Here's a simple guide for you in going about the module:

1. Read and follow the instructions very carefully.
2. Take the pretest. It is a simple multiple-choice test provided at the start to determine how much you know about the content of this module.
3. Check your answers against the correct answers provided at the last page of the module.
4. Be very honest in taking the test so you know how much knowledge you already have about the topic.
5. Read the different lessons included in this module.
6. Perform all the activities, as these will help you have a better understanding of the topic.
7. Take the self-tests at the end of each lesson.
8. Finally, take the post-test at the end of the module.

**Good Luck and have fun!**

## What to do before (Pretest)

**Direction: Choose the letter of the best answer. Write your answer on a separate sheet of paper.**

1. The law of inertia applies to _______________.
   A. moving objects
   B. objects that are not moving
   C. both moving and nonmoving objects

2. If you were in a space ship and fired a cannon ball into frictionless space, the amount of force needed to keep it going would be ________.
   A. twice the force with which it was fired
   B. the same amount of force with which it was fired
   C. one half the force with which it was fired
   D. zero, since no force is necessary to keep it moving

3. Which has more mass, a kilogram of feathers or a kilogram of iron?
   A. feathers
   B. iron
   C. They both have the same mass
   D. Cannot be determined from the given information.

4. The force required to maintain an object at a constant speed in free space is equal to ________________.

A. zero
B. the mass of the object
C. the weight of the object
D. the force required to stop it

5. You would have the largest mass of gold if your chunk of gold weighed 1 N on the __________.

A. Moon
B. Earth
C. planet Jupiter

6. An object weighs 30 N on earth. A second object weighs 30 N on the moon. Which has greater mass?

A. The one on earth
B. The one on the moon
C. They have the same mass

7. Suppose the force of friction on a sliding object is 10N. The force needed for it to maintain a constant velocity is _______________.

A. more than 10 N
B. less than 10 N
C. 10 N

8. Compared to its weight on earth, a 10-kg object on the moon will weigh ________.

A. less
B. more
C. the same amount

9. An apple weighs 1N. When held at rest above your head, the net force on the apple is _____________.

A. 0 N
B. 0.1 N
C. 1 N
D. 9.8 N

10. An apple weighs 1N. The net force on the apple when it is in free fall is _________.

A. 0 N
B. 0.1 N
C. 1 N
D. 9.8 N

11. When a woman stands with two feet on a scale, the scale reads 500 N. When she lifts one foot, the scale reads _____________.

A. less than 500 N
B. more than 500 N
C. 500 N

12. A block is dragged without acceleration in a straight-line path across a level surface by a force of 6 N. What is the frictional force between the block and the surface?

A. less than 6 N
B. 6 N
C. more than 6 N
D. Needs more information to say.

13. As a 500 N lady sits on the floor, the floor exerts a force on her equal to ______________.

A. 1000 N
B. 500 N
C. 250 N
D. 50 N

14. An unfortunate bug splatters against the windshield of a moving car. Compared to the force of the car on the bug, the force of the bug on the car is _____________.

A. larger
B. smaller
C. the same

15. An unfortunate bug splatters against the windshield of a moving car. Compared to the deceleration of the car on the bug, the deceleration of the bug on the car is _____________.

A. larger
B. smaller
C. the same

16. The person is attracted towards the center of the earth by a 500-N gravitational force. The force with which the earth is attracted toward the person is ______________.

A. very very small
B. very very large
C. 500 N

17. Two people pull on a rope in a tug-of-war. Each pulls with a 400 N force. What is the tension in the rope?

A. 0
B. 400 N
C. 600 N
D. 800 N

18. What is the minimum resultant possible when adding a 3-N force to an 8-N force?

A. 24 N
B. 11 N
C. 8 N
D. 5 N

19. How does the acceleration of an object change in relation to its mass? It is _________.

A. directly proportional
B. inversely proportional
C. acceleration doesn’t depend on mass at all

20. Forces always occur _____________.

A. by themselves
B. in pairs
C. as single quantities
D. in triplets

**Key to answers on page 38**

# Lesson 1 Forces: The Secrets Unfold!

*(by mpem)*
*In the beginning there was Aristotle*
*And the objects at rest tend to remain at rest*
*And the objects in motion tend to come to rest*
*And God saw that it was boring although restful*

*Then God created Newton*
*And objects at rest tend to remain at rest*
*And objects in motion tended to remain in motion*
*And energy was conserved and momentum was conserved,*
*And matter was conserved*
*And God saw that it was conservative…*

Did you know how the word "force" has come about? Who were the scientists and great men behind the concept? Here's a very good poem. Try reading it so you would have a good glimpse of who were behind the development of forces and motion!

## *What you will do*

**Activity 1.1 Men behind forces**

**Objective:** To be able to come up with a timeline of force and motion.

**Materials:** washer or 10 centavo-coin, centimeter ruler paper

**Procedure:**

1. The pictures, dialogues and dates on the next page show significant moments in the development of the concepts of force and motion.

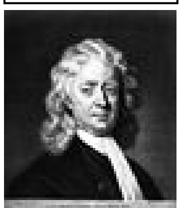
2. Label the picture, dialogue, and date with 1 if you think the set of picture, dialogue and date occurred first. Label the next set as 2 and so on until all sets are labeled forming a timeline.

No. _____ ***Johannas Philoponus (550 A.D.)***

No. _____

*Aristotle*

No. _____



*Newton*

No. _____

*Galileo*

No. _____ ***Jean Buriden (355 A.D.)***

Hey guys look at this. If I exert an impetus on an object moves. Ha! A new discovery indeed! ***Impetus keeps a body moving.*** No. _____

All right! And when that impetus diminishes, motion also diminishes. When the impetus is removed, the object stops moving! No. _____

I don't think that the force is proportional to the velocity. Velocity remains constant if no force, including friction, is applied. Force that affects vertical motion creates constant acceleration. No. _____

Let's rename impetus as force. I believe that force affects the velocity of moving objects. Thus, force is proportional to the velocity. If no force is applied an object has no velocity for an object. Thus, the object is at rest. No. _____

What if I push an object which is already moving horizontally? Wouldn't its velocity change and cause acceleration in the object? Thus, force would cause acceleration in horizontal motion. The natural acceleration actually observed in vertical motion must be the result of a vertical force on the body, without this force the natural vertical motion would also be at a constant speed, just like natural horizontal motion. This vertical force is of course the force of gravity. No. _____

**Key to answers on page 41**

**Terms to Remember!**

**Mass**

- Amount of matter in an object.

**Bodies in direct contact**

- Two bodies touching on another

So, now you know who coined the word "force". Let's now take a close look at what force is. Force is commonly described as a push or a pull. A body with mass is capable of interacting with another body. This interaction between two (2) bodies is known to be a *force*.

Force is not something a body has, like mass, but it is an interaction between one body and another.

Depending on the circumstances, a body may posses a capability of exerting force on another body but it cannot possess force as a thing in itself.

Forces can be contact or non-contact. Contact forces are forces that result when two (2) bodies in direct contact (touching each other) interact with one another. Direct contact must happen between two (2) bodies for the two (2) bodies to interact with each other.

Now try this one so you will have a better understanding of what contact force is!

## *What you will do*

**Activity 1.2 Contact and non-contact forces**

**Objective:** To be able to understand the concept of contact force.

**Materials:** chair, paper, bag

**Procedure:**

1. Push a chair.
2. Pull a paper out of your bag.
3. Lift your bag.

**Guide Questions:**

1. In which of the following cases were you able to have a direct contact with each of the three objects (chair, paper, bag)?
2. Were you able to exert a contact force? Why do you say so?

**Key to answers on page 39**

In all these cases, contact forces occur. To be able to push a chair your hand should be placed in contact with the chair. To be able to pull a paper out of your bag you must use your hand, and your hand must be touching the paper. To lift your bag, you must hold the bag.

**Terms to Remember!**
**Field**

- Space surrounding objects with mass or objects which are electrically charged or have magnetic properties

Non-contact forces, on the other hand, are forces that occur when the fields around objects (*e.g. gravitational field, electric field, or magnetic field)* interact with another field located around another body. It is a non-contact force since the bodies themselves are not directly touching each other rather only their fields interact with one another.

We may see the earth as constantly kept in orbit by the sun. But behind that scene we can actually attribute this effect to the gravitational fields of both the earth and the sun as interacting with each other. Thus, gravitational forces are examples of non-contact forces. Gravitational forces are always attractive in nature. This means that while the earth is attracted to the sun, earth also pulls the sun. However, since earth has a smaller mass than the sun, the earth tends to move around the sun instead of the other way around.

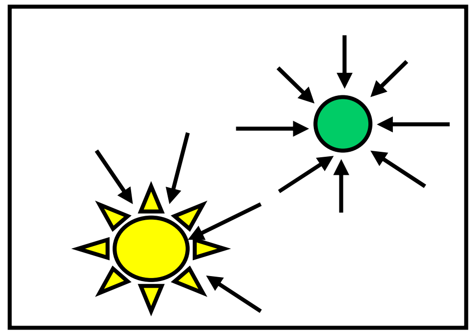


**Fig. 1.1. Earth-Sun System**

Magnetic fields also interact with each other. The magnetic fields may be pulling each other as in the case where opposite poles (North and South Poles) of the magnet are facing each other. They may also be pushing each other as in the case where the same poles of the magnets are facing each other. This interaction is called the magnetic force, is another example of a non-contact force.

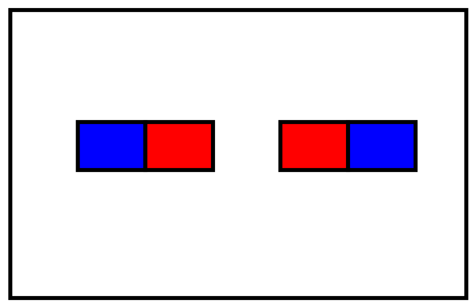


**Fig. 1.2. Magnets and their magnetic field**

Charged bodies are bodies whose number of electrons is not equal to the number of protons. Bodies that are not charged are called neutral bodies. These bodies have the same number of protons and electrons. It may have happened that some electrons left the atoms of the object thus causing the object to have protons than electrons. This body is said to be a negatively charged body. A body, which captures excess electrons, will eventually have more number of electrons and protons and are known as positively charged

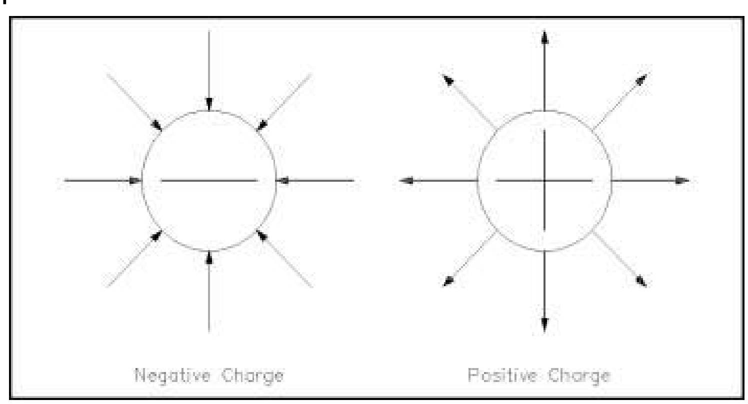



**Fig. 1.3. Electric field of charged particles**

bodies. Around every charged object is an electric field, which interacts with the electric field of another charged body. The interaction between the electric field of one charged body to another charged body is known as electrostatic force. Since only electric fields of two charged bodies interact and no direct contact can be observed between the two bodies, then electrostatic force is also considered a non-contact force. Take a look at how charges interact in Figure 1.3.

Here's an illustration of an atom. (Figure 1.4). Can you identify some of the subatomic particles? As you can see protons and neutrons are inside the nucleus of an atom. Protons are positively charged while neutrons are neutrally charged. Since like charges repel each other, protons inside the nucleus must be repelling each other. How then are they able to stay together inside the nucleus? This is because another non-contact force, believed to be the strongest among the non-contact forces keeps the protons inside the nucleus of the atom. This force is known as the nuclear force. Nuclear force is usually categorized as a weak or strong.

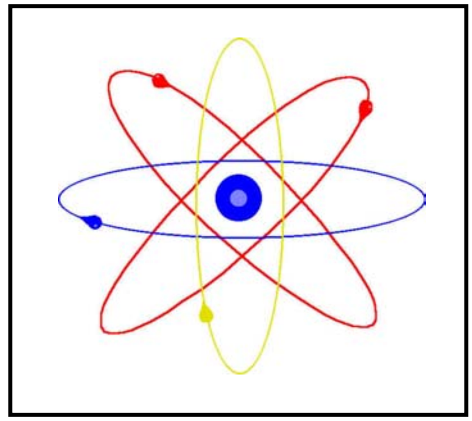


**Fig. 1.4.An Atom**

Remember Newton? He was the one who said that a vertical force directed towards the center of an object is called gravity. Both gravity and horizontal forces can be quantified using a force meter of a spring balance. The standard International (SI) unit of force is *newton* (N) to pay tribute to Sir Isaac Newton who was able to conceptualize the effect of forces on motion. In the English system, however, the standard unit of force is called *pound* (lb), which is defined in terms of Newton as:

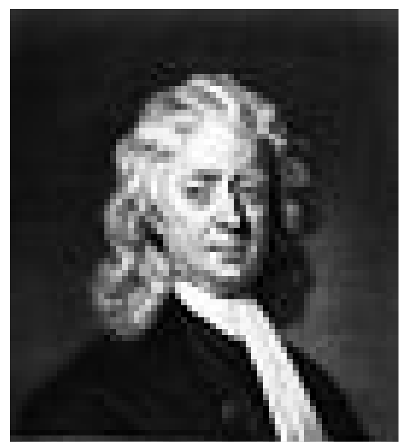


**Fig. 1.5 Newton**

**1 lb = 4.45 N**

***1N = 0.225 lb***

## *What you will do*

**Self-Test 1.1**

**Direction: Write "F" if a contact force has been exerted in the situation and "nF" if a non-contact force has been exerted.**

1. Pushing a cart
2. Touching a rock
3. Falling rock
4. Moon's attraction to Earth causing tides
5. Your hair being attracted to your comb after stroking it with the same comb.
6. Tissue being attracted to a plastic sheet
7. Kicking a ball
8. Sitting on a chair
9. Your skin hair being attracted to the TV screen when you switch it on or off.
10. Pulling a cart.

**Key to answers on page 39**

## Lesson 2 Friction

Did you ever experience slipping in a pavement? Did you feel embarrassed? What conditions caused you to slip? Did you slip when the pavement was wet or dry? Most accidents happen during rainy days because the road is slippery when wet. It is harder to stop a vehicle on wet roads You yourself will most likely to slip if you don't wear your pair of rubber shoes. This describes the effect of friction. What is friction?

**Figure 2.1. Road Intersection**

Friction is a contact force that is present in walking, running, playing, writing and pushing objects we still encounter friction.

## *What you will do*

**Activity 1.2 Friction: The opposing force!**

**Objective:** To be able to understand the concept of friction as an opposing force

**Materials:** ball, clear pavement or pathway

**Procedure:**
1. Let a ball roll on a pavement or a clear path way.
2. Observe what happens to the ball as it rolls along the pavement.

**Guide Questions***:*
1. When you rolled the ball on the pavement, did you exert a force?
2. What kind of force did you exert? (contact or non-contact)
3. While the ball is rolling along the pavement are you still exerting a force?
4. What happened to the ball's motion after some time?
5. Why do you think the ball stopped rolling?

**Key to answers on page 39**

When you roll the ball on the pavement you did exert a contact force since your hands were in contact with the ball before you released the ball. While on the pavement, however, your hands were not anymore in contact with the ball thus there is no force was exerted by your hands on the ball. Eventually, the ball stopped rolling after sometime. Friction between the surface of the ball and the surface of the pavement caused the ball to stop rolling. Friction is a force that opposes motion. It is the resistance an object meets when its surface rubs against another surface like your feet and the floor when you're walking. It acts in a direction opposite the natural motion of the moving object.

Friction occurs because objects have bumps and grooves on their surfaces. Take a look at the microscopic view of a very smooth and shiny surface. Even smooth and shiny surfaces have bumps and tiny points on them, which catch and try to stick together when they come in contact with each other. Different objects have different bumps and grooves on their surfaces. Some surfaces have few points to catch and stick together. These are the smooth surfaces.

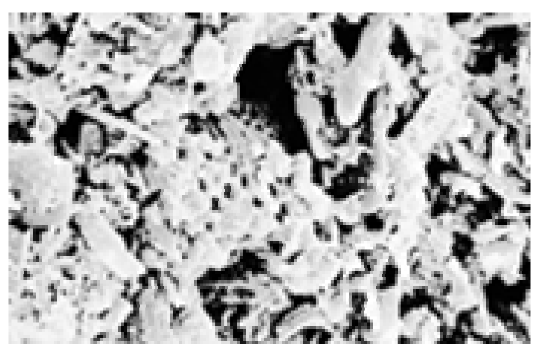


**Fig. 2.2. Grooves and bumps of surfaces**

The nature of friction force depends on the type of motion that occurs between two surfaces. If there is no relative motion between two surfaces, friction force that exists between their contact surfaces is called static friction. On the other hand, the type of friction that opposes sliding motion is called kinetic friction. This type is weaker than static friction. The friction force that exists in rolling motion is called rolling friction. This is the weakest frictional force that opposes motion.

## *What you will do*

### Activity 2.2 Factors affecting friction

**Objective:** To be able to determine how the kind of surface and the weight of an object affect friction.

**Materials:** plastic bag, 4 books, smooth floor (wooden) and a rough floor (concrete)

**Procedure:**

**A. Friction and Weight**

1. Place 2 books inside a plastic bag.
2. Drag the plastic bag containing 2 books along a smooth wooden floor. Observe how you drag the plastic bag.
3. Place 4 books inside the plastic bag.
4. Drag the plastic bag containing 4 books along a smooth wooden floor. Observe how you drag the plastic bag.

**B. Friction and the kind of surface**

1. Place 2 books inside a plastic bag.
2. Drag the plastic bag containing 2 books along a smooth wooden floor. Observe how you drag the plastic bag.
3. Drag the plastic bag containing 2 books along a rough concrete floor. Observe how you drag the plastic bag.

**Guide Questions:**

1. On which situation (plastic with 2 books or plastic with 4 books) did you experience difficulty in dragging the plastic bag?
2. On which case is friction greater: plastic with 2 books and the floor or plastic with 4 books and the floor)?
3. On which situation (plastic bag on a smooth floor or plastic bag on a rough floor) did you experience difficulty in dragging the plastic bag?
4. On which case is friction greater: plastic bag on a smooth floor or plastic bag on a rough floor?

**Key to answers on page 39**

Basically, friction is less when the weight of the object is less. Friction is also affected by the smoothness or roughness of the surfaces in contact. Rougher surfaces in contact usually offer greater frictional force as compared with smooth surfaces. Sliding or rolling on smooth surfaces is very easy because friction is less. Sliding and rolling on rough surfaces is hard because there is more friction on them.

What happens when you try to start running on a wet pavement? It is difficult to stop or start moving when little friction is around. But have you tried pushing a car or a tricycle in which the brakes are set? Too much friction can also be a problem.

Friction is always present in our world. Sometimes it needs to be increased. At times we need to decrease it. How do we do this? Did you notice the surfaces of the table tennis racket? Usually, these are padded with rubber so that the tennis balls will not slip when they hit the pad. While some handles of tennis rackets are wrapped with cloth to give a better hold on the racket. This way the racket will not fly off when the player swings it. So it's so simple! *If you want to increase the friction you just have to make the surface rough!* Soccer and softball players use spiked shoes so they can move with ease in slippery playgrounds.

There are cases when we do not need friction like when we want to move heavy objects from one room to another. How do we decrease friction?

**Figure 2.3 Bowling Alley**

One way to decrease friction is by POLISHING. Why do you think bowling lanes are shiny? Why do bowlers wipe their bowling balls before rolling it on the lanes? Polished lanes and shiny surfaces help decrease or reduce friction. This way the balls roll very quickly with much force to topple the bowling pins.

**Streamlining**

Have you tried running a 100-m dash through waist-deep water? Probably you had a really hard time. Friction is not restricted to solids sliding over one another. Friction also occurs in liquids and gases. Liquids or gases are called fluids thus they exhibit the ability to flow. Fluid friction occurs when an object moving through a fluid pushes aside some of the fluid. Air resistance is the friction that occurs when an object moves through air. Racing yatch is polished to a mirror finish so they can slide through the water very easily without the water slowing them down. How's that done?

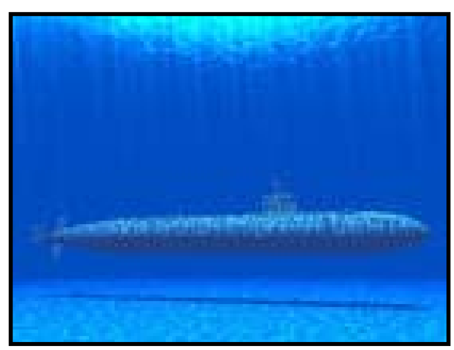


**Fig. 2.4 Submarine**

Racing cars, airplanes, submarines, rockets, racing boats, and motorcycles are designed specially to reduce friction with the air or with the water. They are specially shaped or streamlined to move more easily in water or in air. Submarines are shaped like fishes to let move easily in water. Airplanes are streamlined like birds so they could glide through air better.

**Oiling or lubricating**

Why do we usually put oil and lubricant in machines and engines? Why do lubricants and oil reduce friction? The oil we place in machines and car engines reduces the friction between the moving parts. The oil serves as a protective layer that prevents the moving parts from rubbing against each other. The lubricants like cream fill the grooves and bumps of the two surfaces in contact preventing the two surfaces to come in direct contact with each other. Thus, there will be less catching and sticking together of the points of the two surfaces that result to lesser friction.

**Using Bearings**

Did you know that wheels are used to transport heavy objects from one place to another? Ball bearings are used in bicycle wheels so that the bicycle will roll freely once it moves really fast (accelerates). Ball bearings and roller bearings are used in many engines and machines making the surfaces roll over one another instead of sliding or rubbing against each other. This reduces friction on the surfaces in contact!

**Fig. 2.5 Trolley**

Friction is a kind of force that acts between surfaces of materials that are moving past each other. They occur because of the irregularities in the surfaces of sliding objects. Galileo showed during his time that a force is needed to keep an object in motion. Otherwise, objects need no force to continue its state of motion.

## *What you will do*

**Self-Test 2.1**

**Choose the letter of the best answer. Write your answer on a separate sheet of paper.**

1. Friction is a force that always acts ______________________.
   a. opposite to the object's natural motion
   b. in the same direction as the object's motion
   c. perpendicular to the object's motion

2. Which of the following is the best description of friction?

a. Friction is never a total advantage
b. Friction can never be eliminated
c. Both a and b

3. Friction increases with ____________.
   a. weight
   b. volume
   c. an increase in surface area

4. All materials below can help reduce friction EXCEPT ____________.
   a. ball bearings
   b. lubricants
   c. sand
   d. wax

5. All materials below can help increase friction EXCEPT ____________
   a. using rubber
   b. increasing the weight
   c. using rough surfaces
   d. applying wax

Key to answers on page 39

## Lesson 3 Newton's Laws of Motion

Take a look at a ball on top of a pool table. Imagine the ball roll and eventually slow down to stop. How would Aristotle interpret the observation? How about the interpretations of Galileo and Newton? How would you interpret it yourself?

**Fig. 3.1 Ball on top of a pool table**

It was a common thought for nearly 2000 years that if an object was moving "against its nature" then a force of some kind was responsible. Such motion was possible only because of an outside force. So the proper state of motion is one of rest. Objects, therefore, would always tend to seek a *rest* state of motion.

Let's have a close look at our three scientists: Aristotle, Galileo and Newton and see their contributions to forces and motion. Below are news bits about them.

# Bulletin:
## Yesterday, Yesterday for Today

### Aristotle: A Scientist?

Aristotle was born in 384 BC in Stagira, a Greek town of the Aegean coast. His father was a physician who looked after the King of Macedonia. As a child Aristotle lived with his uncle. When he was a teenager (17) he moved south to Athens, a very important city in the Greek world. He probably went alone. For some twenty (20) years Aristotle studied at the famous Academy in Athens. The principal teacher at the Academy was Plato, a Greek teacher of great reputation. Plato was interested in logical arguments.

In Middle Age, Aristotle turned his attention to writing books that would form an encyclopedia of knowledge. By 335 BC Aristotle has returned to Athens and has established the Peripatetic School in the Lyceum. In the course of his teaching at the Lyceum, he discussed logic, epistemology, physics, biology, ethics, politics, and aesthetics. The Posterior Analytics is Aristotle's principal work on the philosophy of science. In addition, the Physics and Metaphysics which contains some aspects of scientific method. His work, the Physics contains the first principles which includes:

*All motion is either natural or violent*
*All natural motion is motion towards its natural place.*
*Violent motion is caused by the continuing action of an agent.*
*A vacuum is impossible*
*There would be no motion without a cause.*
*The velocity of a body is inversely proportional to its own resistive power and directly proportional to the motive force applied. Thus, no force exerted, no motion for object.*
*The more earth the object has, the more it moves to the earth.*
*Objects with more earth tends to proceed to its natural rest place, earth*

Due to political unrest in 323 BC he had to leave the city and move north to the island of Euboea. He died there one year later at the age of 62.

## *What you will do*

### Activity 3.1 Find out about Galileo

**Below are clues about Galileo. You may use all the clues to be able to complete the data needed for his biography.**

BIOGRAPHICAL NOTE (GALILEO)

1. What is the full name of Galileo? ______________________________
2. When and where was Galileo born?
   a. date: ________________________
   b. location: ________________________
3. In what universities, colleges, and institutions did Galileo study?

____________________________________________________________
____________________________________________________________
____________________________________________________________

4. How was Galileo called by his classmates and schoolmates?
   Nickname: ________________________________________________

5. What were his discoveries in Mechanics?

____________________________________________________________
____________________________________________________________

6. Did he encounter difficulties in life? What are these?

____________________________________________________________
____________________________________________________________
____________________________________________________________

7. How old was he when he died? _________________________________

## CLUES

| | |
|---|---|
| 1. | Galileo is universally known by the first name only. |
| 2. | Guilia Ammannati bore the son of Vincenzo Galilei on the 15th of February 1564 at Pisa, Italy. |
| 3. | Vincenzo Galilei who was then a musician and a mathematician sent his son to University of Pisa to pursue medical studies. This is because physicians then receive salaries 30X that of mathematicians. |
| 4. | As a student, Galileo had a brilliant wit and he could not resist making bitter enemies due to his argumentativeness and nonconformity. He even refused to wear academic robe which cost him several fines. Because of such "the wrangler" was his pseudonym in school. |
| 5. | While Galileo was at the University of Pisa, he heard lectures on geometry by accident and came upon the works of Archimedes and later pursued mathematics and sciences. |
| 6. | Galileo performed an experiment on the inclined plane to prove that the rate of fall of an object is independent of its weight. The velocity of a falling ball increases steadily with time under the continuous pull of earth, but the total distance covered increases as the square of the time. |
| 7. | "As the explosion of a gun", a body could move under the influence of 2 forces at one time. One force applying an initial force horizontal could keep a body moving horizontally at a constant velocity. Another force applied constantly in a vertical direction could make the same body drop downward at an accelerated velocity. |
| 8. | Galileo said in his published books entitled “Mechanics” that if a structure increased in all dimensions equally, it would grow weaker. |
| 9. | The volume, he said further, increases as the cube of linear dimension by the strength only as the square. |
| 10. | A deer expanded to the size of an elephant and kept in exact proportion would collapse. Its legs would have to be thickened out of proportion. |
| 11. | During 1500-1600 Harvard believed in all theories held by Aristotle and Ptolemy. |
| 12. | Ptolemaic system: Earth is the center of the universe. |
| 13. | Galileo was greatly opposed by the church. |
| 14. | In his book, “Dialogue on the Two Chief World Systems, the characters were (1) a man holding the Copernican view, (2) a man holding the Ptolemaic view, and a spectator who is presented as a fool! |
| 15. | Galileo was recanted and was condemned to a penance of psalm recitation each week for 3 years. Before having completed his renunciation he said ”Eppur si muove” (And yet it moves!) |
| 16. | He died in Arceti on January 8, 1642 while dictating his idea on the result of a moving body striking an immovable one. The church refused to bury him in consecrated ground. |

Key to answers on page 39

And so you have met Galileo and Aristotle. Now, here's Newton.

### Sir Isaac Newton

*" In the beginning of 1665, I found the method of approximating series and the rule for reducing any dignity (power) and any binomial to such a series. The same year in May I have found the method of tangents of Gregory and Slusius, and in November (discovered) the direct method of Fluxion (elements of differential calculus). And in the next year in January had the theory of Colours, and in May following I had entrance into the Method of Fluxions (integral calculus), and in the same year I have began to think of gravity extending to the orb of the moon ...... and having thereby compared the force requisite to keep the Moon in her orb with the force of gravity at the surface of the earth, and found them to answer pretty nearly ....."*

Going back to our previous question, "How would Aristotle explain the observation that a rolling ball eventually slows down until it stops?" Aristotle would likely say that the ball comes to a stop because it seeks its proper state – rest. . How about the interpretations of Galileo and Newton? Galileo would likely say that once the ball is in motion, what prevents its continued motion is another force, called friction, between the table and the ball. How would you interpret it yourself? Of course! Only you can answer that!

In 1665, however, a new set of ideas has been established by the famous Sir Isaac Newton who has made great revolution in the growth of Science primarily in Physics with his famous Laws of Motion. His three (3) Laws of Motion include the 1$^{st}$ law of motion more popularly known as the Law of Inertia. In his original manuscript it was stated as:

*Law of Inertia*

*Everybody preserves in its state of rest, or uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon.*

In other words, an object at rest tends to stay at rest. And an object in motion continues to move in a straight line with a constant speed unless an external force acts on it.

This means that things tend to keep on doing what they are already doing. Books on top of the table are in a state of rest, they tend to stay at rest even when you quickly snap the tablecloth.

If you slide a penny or a coin along the road, the penny or the coin soon comes to rest. If you let is slide along an ice, it slides for a longer time and distance. If you let it slide along a table which constantly emits air it continuously moves. This is because the table offers no friction. In the absence of a force, a moving object tends to move in a straight line indefinitely!

## *What you will do*

### Activity 3.2 Going nuts!

**Objective**

To explore the concept of inertia.

**Materials:** 12-in wooden embroidery hoop, coke bottle (sakto), ten – ¼ -in nuts

**Procedure**

1. Carefully balance the embroidery hoop vertically on the mouth of the coke-bottle. Stack the nuts at the lower portion of the hoop. Quickly remove the hoop from the bottle and get as many nuts as possible into the bottle without touching them. Do this twice.

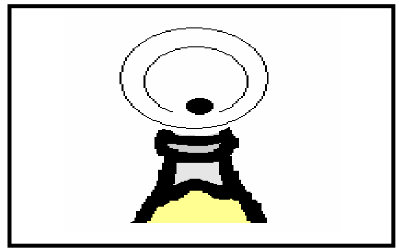


**Fig. 3.2 Hoop on top of the bottle**

2. Carefully balance the embroidery hoop vertically on the mouth of the coke-bottle. This time stack the nuts on top of the hoop. Quickly remove the hoop from the bottle and get as many nuts as possible into the bottle without touching them. Repeat the same procedure for the second trial.

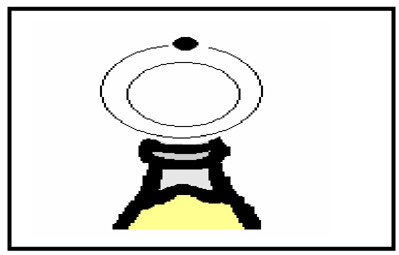


**Fig. 3.3 Hoop on top of the bottle**

**Data and Results**

| Condition | No of nuts inside the bottle | | | No. of nuts inside the bottle | | |
|---|---|---|---|---|---|---|
| | Trial 1 | Trial 2 | Ave | Trial 1 | Trial 2 | Ave |
| Nuts placed at the lower portion of the hoop | | | | | | |
| Nuts placed on top of the hoop | | | | | | |

**Guide Questions:**

1. Describe the technique that you used in order to have the highest number of nuts inside the bottle.
2. Relate your observation to the concept of inertia.

**Key to answers on page 39**

Objects “tend to keep on doing what they are already doing.” In fact, it is the natural tendency of objects to resist changes in their state of motion. This tendency to resist changes in their state of motion is described as inertia. Thus, inertia is the resistance an object has to any changes in its state of motion. But how would we know how big inertia is?

**Mass: A Measure of Inertia**

Have you ever tried kicking an empty tin can? Compare it when you kick a tin can full of cement. Which tin can doesn’t move as much? Definitely, the solid tin can (the one with cement). This is because the solid tin can is more inert and has more mass than an empty tin can. This means that the greater the mass the object has, the more inert the object is and thus, the greater is its inertia. A measure of inertia – MASS!

**Mass vs. Volume**

Most people believe that if an object has a large mass, it must have a large volume. Mass is the amount of matter in an object. It is a constant for every object and is usually expressed in kilograms. Volume, on the other hand, is the measure of the space occupied by the object. It is expressed in units such as cubic meter or liter. A kilogram of cotton in a pillow obviously has more volume than a kilogram of nail although they have the same mass.

*What you will do*

**Activity 3.3 Rolling Ball**

Place a ball along the corridor. Push the ball lightly. While the ball is still moving along the corridor, ask someone to push it again. Observe what happens to the ball’s speed.

What happened to the ball’s motion or speed right after the second push? In this case the ball moved faster. Thus, the speed of the ball has changed. In other words, the ball has accelerated. In symbols;

$$a = \frac{\Delta v}{\Delta t}$$

*Law of Acceleration*

*The acceleration of motion is ever proportional to the motive force and is made in the direction of the right line in which that force is impressed..*

When you pushed the ball, which was initially at rest and then the ball moved. Thus, the ball accelerated during that instance. Your friend pushed the moving ball and the object changed its speed – accelerates. Forces are what produce acceleration. When your hands are no longer in contact with the ball, the ball experiences no force, thus it moves with a constant velocity. This is the second law of motion according to Newton. He realized that the acceleration produced when something is moved depends not only on how hard the exerted force is but also on the mass of the object. The greater the force applied on the object the greater is its change in motion or acceleration if the mass of the object is unchanged. However, as we increase the mass of the object, the acceleration decreases if the force applied to the object is unchanged.

More often than not, the force applied is not a single force. Other forces may act as well. The combination of all the forces that act on an object is called the net force. The presence of an unbalanced force, usually called the net force, creates an acceleration of an object. In other words,

$$a = \frac{F_{net}}{m}$$

where:

| | | |
|---|---|---|
| $F_{net}$ | = | sum of all the forces acting on the object |
| | = | expressed in newton (N) [ 1kg.$\frac{m}{s^2}$ = 1 N] |
| m | = | mass of the object |
| a | = | acceleration |

**Here's an example:**

Problem: What acceleration is produced by a 3000-N force on a 1000-kg car?

Solution:

Given:

m = 1000 kg

$F_{net}$ = 3000 N

RTF: a?

Equation: $$a = \frac{F_{net}}{m}$$

$$a = \frac{3000N}{1000kg}$$

$$a = \frac{3000kg\frac{m}{s^2}}{1000kg}$$

$$a = 3\ \frac{m}{s^2}$$

## *What you will do*

**Self-Test 3.1**

If a crate accelerates at 2.5 $m/s^2$ and if the net force exerted is about 500 N, what is the mass of the crate?

**Key to answers on page 39**

**Mass vs. Weight**

What is your weight? What about your mass? Many are usually confused between mass and weight. We usually say something has a lot of matter if it is heavy. Mass is a measure of the actual material in a body and is expressed in units like kilogram or gram. It also depends on the number and kinds of atoms that compose it. Weight, on the other hand, is a measure of the gravitational force that acts on the material and is dependent on the location of the material relative to the center of the earth. On higher grounds you encounter lesser weight. It is computed as the product of your mass or the mass of the body and the acceleration due to gravity. In symbols;

Weight = mass x acceleration due to gravity

**Fig. 3.4 Boy leaning on a wall**

where the value of the acceleration due to gravity is about 9.8 $m/s^2$.

Weight, like force, is expressed in a unit known as newton. Take for example a kilogram of rice. It has a mass equivalent to a kilogram whether it is on earth or on the moon. But the weight of 1 kilogram of rice would be very different on earth and on the moon.

Did you know that you could not touch without being touched and that we always get even?

*Law of Interaction*

*To every action there is always opposed an equal reaction or the mutual actions of two bodies upon each other are always equal, and directed to contrary parts.*

Imagine yourself leaning against a tree. Did you topple over while you are still in contact with the tree? Definitely not! This is because while you push or exert a force on the tree, the tree pushes as hard back on you. That's why you are supported.

Newton realized that force is not isolated. But it is a part of the mutual interaction between one object and another. Consider the interaction between a bat and a baseball. The bat exerts a force on the baseball and lets it fly into the air. Of course, there must also be a force on the bat. What exerts this force? – The baseball.

The third law of motion also known as the Law of Interaction is stated as: "Whenever one object exerts a force on a second object, the second object exerts an equal force on the first."

One of the pair of forces is called the "action" force. The other is called the "reaction" force. It is important to note that for every interaction, force always occur in pairs.

The action force in a falling stone is the pull of the earth on the stone. The reaction to this force is the pull of the stone on the earth. Interestingly enough, the pull of the earth on the stone is the same in magnitude to the pull of the stone on earth. But obviously, the earth will never move towards the stone.

## *What you will do*

**Self-Test 3.2**

Identify the action and reaction forces while launching a rocket ship.

**Key to answers on page 40**

## *What you will do*
**Self-Test 3.3**

**Direction: Choose the letter of the best answer. Write your answer on a separate sheet of paper.**

1. The law of inertia applies to ____________.
   a. moving objects
   b. objects at rest
   c. both moving and not moving objects

2. If you were in a spaceship and fired a cannonball into frictionless space, the amount of force needed to keep it moving would be ___________.
   a. twice the force with which it was fired
   b. the same amount of force with which it was fired
   c. one half the force with which it was fired
   d. zero, since no force is necessary to keep it moving

3. An object maintains its state of motion because it has __________.
   a. mass
   b. velocity
   c. speed
   d. acceleration

4. You would have the largest mass of gold if your chunk of gold weighed 1 N on the ________.
   a. moon
   b. earth
   c. Jupiter

5. Suppose a cart is being moved by a force. If suddenly a load is dumped into the cart so that the cart's mass doubles, what happens to the cart's acceleration?
   a. It quadruples.
   b. It doubles.
   c. It halves.
   d. It quarters.

6. A tennis ball and a solid steel ball of the same size are dropped at the same time. Which ball has the greater weight?
   a. tennis ball
   b. solid steel ball
   c. They both have the same weight.

7. An apple weighs 1N. When held at rest above your head, the net force on the apple is __________.
   a. 0 N
   b. 0.1 N
   c. 1 N
   d. 9.8 N

8. An apple weighs 1 N. The net force on the apple when it is in freefall is _______.
   a. 0 N
   b. 0.1 N
   c. 1 N
   d. 9.8 N

9. An unfortunate bug splatters against the windshield of a moving car. Compared to the force of the car on the bug, the force of the bug on the car is _________.
   a. larger
   b. smaller
   c. the same

10. Two people pull on a rope in a tug-of-war. Each pulls with a 400-N force. What is the tension in the rope?
   a. Zero
   b. 400 N
   c. 600 N
   d. 800 N

**Key to answers on page 40**

## Lesson 4 Impulse and Momentum

What do you think is the purpose of a seatbelt? Does it really prevent us from bumping into the dashboard of a car? Did you know that it is a lot better for a falling clay pot to break onto your head than bounce off your head? Did you know that a "follow through" is very important in playing golf, baseball, and boxing? Why are karate experts able to brake several stacks of cement bricks with their bare hands? Why do we need to strap our seatbelts when inside a moving vehicle? All these are concerned with momentum – the inertia of moving objects.

**Fig. 4.1. Wearing seatbelts**

**Momentum**

Which is harder to stop - a massive truck or a bicycle moving at the same speed? Obviously, the truck has more momentum than the bicycle. Momentum means "inertia in motion". It tells us how difficult it is to stop a moving object. Operationally, momentum is defined as the product of mass and velocity. It is expressed in units like kg-m/s and N-s. In symbols.

**Fig. 4.2. Truck and Bicycle**

$$p = mv$$

where:

| | | |
|---|---|---|
| p | = | momentum |
| m | = | mass of the moving body |
| v | = | velocity of the moving body |

A truck, for example has momentum. Since the truck has mass, m and velocity, v then the momentum of the truck is p. In short p = m x v. A moving bicycle, on the other hand, has mass, m and velocity, v equals the velocity of the truck. Thus the momentum of the bicylcle is p. In short; p = m x v. In the case of the car and a skateboard, the car has greater momentum because it is much more massive than the skateboard. On the other hand, a truck parked on the side of the road has no momentum at all. How would you make the momentum of the truck equal to the momentum of the bicycle initially moving at the same speed?

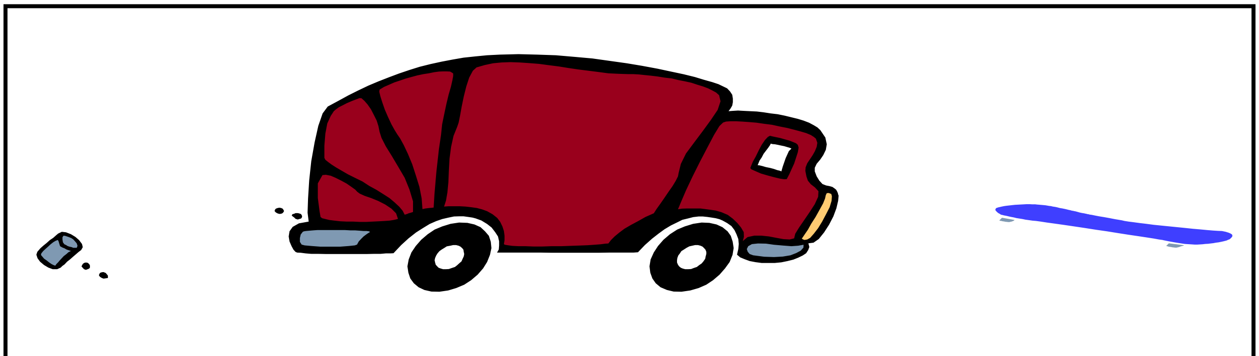
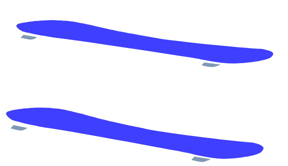


**Fig. 4.3 Car and a skateboard**

If we make the skateboard move very fast, then its veloctiy will increase. In turn, the magnitude of its momentum will increase and will



$$p = m \times v$$

equal the momentum of the truck. Therefore, an object can have large momentum if its velocity is increased.

$$p = m \times v$$

**Here's a sample problem:**

**Example 1**

a) Calculate the momentum of a 30-kg dog running at a speed of 8.0 m/s toward the west. (b) How fast must a 70-kg person run to have the same momentum as the dog?

Solution:

1.

| Given | RTF |
|---|---|
| $m_{dog}$ = 30 kg<br>v = 8.0 m/s<br>$m_{man}$ = 70 kg | V |

2. Equation: $p = mv$
3. Solution:

$$p = mv$$
$$p_{dog} = p_{man}$$
$$m_{dog}v_{dog} = m_{man}v_{man}$$

$$v_{man} = \frac{m_{dog}v}{m_{man}}$$

$$v_{man} = \frac{(30kg)(8.0m/s)}{70kg}$$

$$v_{man} = 3.43\ m/s$$

## Impulse: The Change in Momentum

**Figure 4.4. Car on the road**

When a moving cart hits a wall, the cart stops and so its momentum changes. If the momentum of an object changes, either the mass or the velocity, or both, changes. If the mass of the object remains constant, as is often the case, the velocity changes, then acceleration occurs.

This acceleration is produced by an applied force. Hence, whenever a force is applied on an object, the momentum of the object changes.

Time of contact or how long the force acts is also a significant factor. Apply a force briefly to an automobile and it produces a small change in momentum. Apply the same force for a longer time and a big change in momentum happens. A long-sustained force produces large change in momentum. Thus, for the momentum of the object to change, we consider both the applied force and the time of contact.

Impulse is a quantity, which is known as the force multiplied by the time of contact. If impulse is present, definitely there is a change in momentum.

$$I = \Delta p$$

where:

$I$ = impulse

$\Delta p$ = change in momentum

since $I = Ft$

where:

$F$ = applied force

$T$ = time of contact

$$= mv$$

thus: $Ft = m\Delta v$

Therefore, the application of force over a certain period of time changes the momentum of the body. In other words;

**Impulse = Change in Momentum**

The impulse-momentum relationship is a good tool in analyzing varied circumstances where momentum is changed. This includes (1) increasing momentum and (2) decreasing momentum over a long time and decreasing momentum over a short time.

## *What you will do*

### Activity 4.1 Impulse and Momentum

**Objectives**

1. To find the relationship between impulse and change in momentum.
2. To determine how impact force works with the time of impact if the change in momentum is constant.

**Materials**

2 balls of different masses, 1 raw egg, 1 piece of used fishing net, inclined plane,

**Procedure**

A.

1. Let your friend roll the ball on an inclined plane placed about $30^o$ from the horizontal. Stop the ball at the lower end of the inclined plane.
2. Repeat procedure 1 using the other ball released from the same position. Be sure that its velocity is the same as that of the first ball just before it is stopped.

B.

1. Ask a friend to throw the ball twice towards you.
2. The first catch should be done without moving your hands backwards. For the second throw move your hands backwards. (Note: Be sure that you use the same ball and that the force exerted by your classmate in throwing the ball is the same.)

C.

1. Throw a ball horizontally against the concrete wall.
2. Mark the point where the ball first strikes the ground after hitting the wall.
3. From the same position, repeat procedure 1 with greater force.
4. Repeat procedure 2.

D.

1. Using a fishing net, try to catch a raw egg positioned from a height of about 3 meters.
2. Observe what happens.

**Guide Questions**

A.

1. Which ball is harder to stop? Why?
2. What can you do to make the less massive ball harder to stop than the other ball?
3. What factors affect the ease or difficulty in stopping objects in motion?

4. Answer Q.1 in terms of momentum.

B.
1. In which catch do you feel greater stopping force?
2. Compare the amount of the first with the second impact force.
3. In which catch did you notice a stopping force of greater period of time?
4. What relationship exists between impact force and duration of time?

C.
1. In which throw did the ball land farther from the wall?
2. What does longer distance traveled from the wall indicate about the velocity of the ball after impact with the wall?
3. Compare the momentum of the $1^{st}$ and $2^{nd}$ throw of the ball after it leaves the wall?
4. In which instance is the impact force greater?

**Key to answers on page 40**

### Increasing Momentum

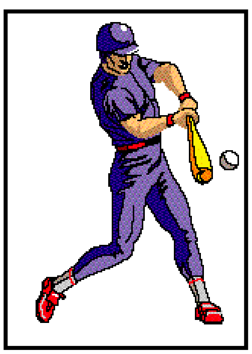


**Fig. 4.5. Batter**

A "follow through" is an important thing in playing golf, baseball, and boxing. "Follow through" helps increase the momentum of an object. In increasing the momentum of an object, increasing the force is a requirement. But if the time of contact is increased the greater the change in momentum occurs – the larger the impulse.

The forces involved in impulses are usually not uniform, they vary from instant to instant. A bat, for example, that strikes a baseball exerts no force until it comes in contact with the baseball. Then the force increases rapidly as the bat and the baseball are distorted.

### Decreasing Momentum over a Long Time and Decreasing Momentum over a Short Time

If you were to catch a raw egg with your bare hands while playing egg catch and throw, how would you do it without breaking the egg? Playing catch and throw is very familiar to us. Usually we move our hands backward when the object thrown at us starts touching our hands. Try moving your hands forward and you will end up washing off the egg yolk from your hands. In these cases momentum is decreased by the same impulse. The only difference is how long the egg touches the hand. The longer the time of contact, the lesser the force applied; and the shorter the time of contact, the greater force is applied.

Ft = Impulse

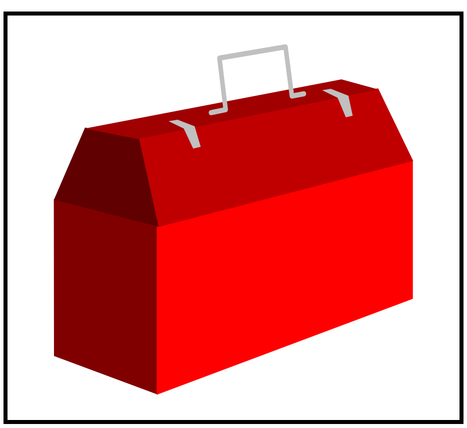
Ft = Impulse

For this reason, why seatbelts and air bags are used as safety devices in a vehicle. They make the time of contact between you and the dashboard of the car longer, which lessens the force of impact.

**Conservation of Momentum**

If one wishes to change the momentum of an object, impulse must be applied on it. This impulse must be applied on the object by something located outside the object. Internal forces, however, are not considered. Try pushing the seat of your car while it is in motion and it doesn't affect the motion of the car at all. This is because the force you have just exerted is an internal force. Internal forces always occur in pairs (Law of Interaction). They act and react within the body.

Consider a rifle being fired. The force that pushes on the bullet when it is inside the rifle is equal and opposite to the force that makes the rifle recoil. These forces are internal to the "system" comprising the rifle and the bullet, so they don't change the momentum of the system. The momentum of the rifle, which is at rest, is zero (0) before firing. Since momentum is a vector quantity, after firing, the momentum of the rifle cancels the momentum of the bullet. No external force act on the system before and after firing. This means that no impulse is present to change the momentum of the system. Momentum is said to be conserved.



Consider a box as our system. Inside the box are a gun and a bullet. If at this moment the box is at rest, then the momentum of the box is zero.

If the box is pushed sideward, the momentum is changed. But if the box remains at rest and the gun fires the bullet, still the momentum of the box is zero! Thus we can conclude that the momentum of the body in the absence of an external force before and after firing remains unchanged.

The Law of Conservation of Momentum:

**In the absence of an external force, the momentum of the system remains unchanged.**

When cars collide, when nuclei decay and when stars explode, the net momentum before and after the event is the same. An explosion is actually a consequence of Newton's third law of motion. Since no external force is applied on the bomb, then the momentum of the bomb is conserved!

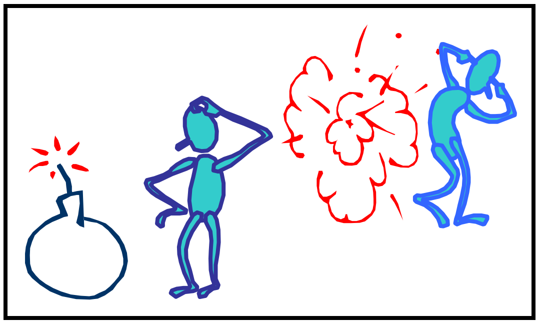


**Fig. 4.7 Explosion**

## *What you will do*

**Self-Test 4.1**

1. A bug and a windshield of a fast-moving car collided. Tell whether the following statements are true or false.

   a. The forces of impact on the bug and on the car are the same. ___________
   b. The impulses on the bug and on the car are the same. _____________
   c. The changes in speed of the car and of the bug are the same. _____________
   d. The changes in momentum of the bug and of the car are the same. ____________

2. When you ride a bicycle at full speed, which has the greater momentum – you or the bike?

3. You cannot throw an egg against a wall without breaking it, but you can throw it with the same speed into a sagging sheet without breaking it. Why?

Key to answers on page 40

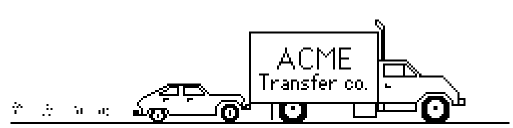
## Let's summarize

1. Force is described as the interaction between two (2) bodies.
2. Force can either be a contact or a non-contact force.
3. Contact force is the interaction between two bodies directly touching one another.
4. Non-contact force is the interaction of the fields that exist around the two bodies.
5. The Law of inertia states that a body at rest will remain at rest and a body in motion will continue to move in a straight line with a constant speed unless an external force acts on it.
6. Mass is a measure of inertia.
7. The Law of acceleration states that the acceleration of an object is directly proportional to the net force and is in the same direction as the net force but inversely proportional to the mass of the body.
8. The Law of interaction states that for every action there is an equal but opposite reaction.
9. Weight is the gravitational attraction exerted by the earth on objects.
10. Mass is the amount of matter in an object.
11. Volume is the measure of space taken up by an object.
12. Momentum is the product of mass and velocity. In symbols; $p = m \times v$.
13. If the velocity of a moving object is increased or decreased, the momentum of the moving body changes.
14. All less massive objects can have the same momentum as that of more massive objects if these less massive objects will move very fast.
15. For an equivalent change in momentum, the larger the time of impact results to lesser force. This can be the reason why we use seatbelts and airbags in cars. - To lessen the impact force!
16. The momentum of a system is conserved if no external force acts on it.
17. Conservation of momentum is also applicable in elastic and inelastic collisions.

## Posttest

**Direction: Choose the letter of the best answer. Write your answer on a separate sheet of paper.**

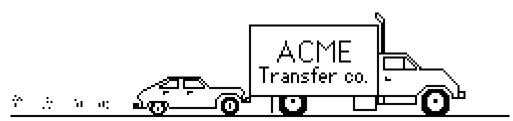
1. A large truck breaks down on the road and receives a push back into town by a small compact car as shown in the figure below. While the



car, pushing the truck is speeding up to get up to cruising speed:

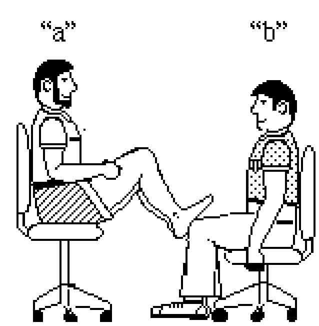
a. the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
b. the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car
c. the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
d. the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
e. neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

2. A large truck breaks down on the road and receives a push back into town by a small compact car as shown in the figure. After the car reaches the constant cruising speed at which its driver wishes to push the truck:




a. the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
b. the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
c. the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
d. the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
e. neither the car nor the truck exerts any force on the other. The truck is pushed forward simply because it is in the way of the car.

3. Student "a" has a mass of 95 kg and student "b" has a mass of 77 kg. They sit in identical office chairs facing each other. Student "a" places his bare feet on the knees of student "b", as shown. Student "a" then suddenly pushes outward with his feet, causing both chairs to move. During the push and while the students are still touching one another:




a. neither student exerts a force on the other.
b. student "a" exerts a force on student "b", but "b" does not exert any force on "a".
c. each student exerts a force on the other, but "b" exerts the larger force.
d. each student exerts a force on the other, but "a" exerts the larger force.

e. each student exerts the same amount of force on the other.

4. As a 500 N lady sits on the floor, the floor exerts a force on her equal to______________.
   a. 1000 N
   b. 500 N
   c. 250 N
   d. 50 N

5. An unfortunate bug splatters against the windshield of a moving car. Compared to the force of the car on the bug, the force of the bug on the car is _____________.
   a. larger
   b. smaller
   c. the same

6. An unfortunate bug splatters against the windshield of a moving car. Compared to the deceleration of the car on the bug, the deceleration of the bug on the car is _____________.
   a. larger
   b. smaller
   c. the same

7. The force required to maintain an object at a constant speed in free space is equal to ________________.
   a. zero
   b. the mass of the object
   c. the weight of the object
   d. the force required to stop it

8. You would have the largest mass of gold if your chunk of gold weighed 1 N on the __________.
   a. Moon
   b. earth
   c. planet Jupiter

9. An object weighs 30 N on earth. A second object weighs 30 N on the moon. Which has greater mass?
   a. The one on earth
   b. The one on the moon
   c. They have the same mass

10. Which has more mass, a kilogram of feathers or a kilogram of iron?
    a. feathers
    b. iron
    c. They both have the same mass

11. A rifle with a muzzle velocity of 100 m/s is fired horizontally from a tower. Neglecting air resistance, where will the bullet be 1 second later?
    a. 50 m range
    b. 98 m range
    c. 100 m range
    d. 490 m range

12. The reason a ball rolls down a slope is ______________.
    a. there is no friction between the ball and the slope
    b. gravity acts parallel to the slope pulling it along
    c. there is a component of weight parallel to the slope
    d. the ball is being pushed along by an unknown force

13. A Ping-pong gun is fired. Compared to the force on the ball, the force on the gun is ______________.
    a. larger
    b. smaller
    c. the same

14. A Ping-pong gun is fired. Compared to the impulse on the ball, the impulse on the gun is _______________.
    a. larger
    b. smaller
    c. the same

15. Suppose a gun is made of a strong but very light materials. Suppose also that the bullet is more massive than the gun itself. For such a weapon _________________.
    a. the target would be a safer place than where the shooter is located
    b. recoil problems would be lessened
    c. conservation of energy would not hold
    d. conservation of momentum would not hold.

16. Which has more momentum, a large truck moving at 30 km/h or a small truck moving at 30 km/h?
    a. large truck
    b. small truck
    c. Both have the same momentum.

17. The momentum change of an object is equal to the _______________.
    a. force acting on it
    b. impulse acting on it
    c. velocity change of the object
    d. force acting on it times its velocity
    e. object's mass times the force acting on it

18. A heavy object and a light object are released from rest at the same height and time in a vacuum. As they fall, they have equal _____________.
   a. weights
   b. momenta
   c. energies
   d. acceleration

19. Which of the following is the correct description of momentum?
   a. The product of force and time
   b. The change in velocity per unit time
   c. The product of force and distance
   d. The product of mass and velocity

20. Which of the following is the correct unit of momentum?
   a. $N.m^2$
   b. $N/m^2$
   c. N.s
   d. $N/s^2$

**Key to answers on page 42**

## *Key to answers*

**Pretest**

1. C
2. D
3. C
4. A
5. A
6. B
7. C
8. A
9. A
10. C
11. C
12. B
13. B
14. C
15. A
16. C
17. B
18. D
19. B
20. B

**Lesson 1**

**Activity 1.2**

1. chair, paper and bag
2. Yes. There was contact between me and the object

**Self-Test 1.1**

1. F
2. F
3. nF
4. nF
5. nF
6. nF
7. F
8. F
9. nF
10. F

**Lesson 2**

**Activity 2.1**

1. yes
2. contact force
3. no
4. ball stopped moving
5. friction

**Activity 2.2**

1. The one with 4 books
2. The one with 4 books
3. The one on the rough floor
4. The one on the rough floor

**Self-Test 2.1**

1. A
2. C
3. A
4. C
5. D

**Lesson 3**

**Activity 3.1**

1. Galileo A. Galilee
2. February 15, 1564 at Pisa, Italy
3. University of Pisa
4. Wrangler
5. Uniformly Accelerated Motion
6. Galileo was recanted and condemned to a penance of psalm recitation
7. 77 years

**Activity 3.2**

1. The hoop should be removed very quickly.
2. If the hoop is removed very quickly, contact force is only applied on the hoop and not on the nuts leaving the nuts undisturbed.

**Self-Test 3.1**

Given:

$a = 2.5\ m/s^2$

$F = 500\ N = 500\ kg\ m/s^2$

RTF: m

Solution:

$$m = \frac{F}{a}$$

$$m = \frac{500kg\frac{m}{s^2}}{2.5\frac{m}{s^2}}$$

m = 200 kg

**Self-Test 3.2**

1. Action Force: Push of the rocket on the ground
   Reaction Force: Push of the ground on the rocket.

**Self-Test 3.3**

1. C
2. D
3. A
4. A
5. C
6. B
7. A
8. C
9. C
10. B

**Lesson 4**

**Activity 4.1**

A.

1. The more massive ball
2. Let the ball roll slowly or slower
3. Momentum of an object depends on its mass and velocity.
4. The lesser the momentum of an object the easier it is to stop.

B.

1. The one on which the hands were not moved backwards.
2. The first throw has greater impact force
3. The $2^{nd}$ throw
4. The longer the time the lesser the impact force

C.

1. The one with greater time
2. The longer the distance means the more velocity it has.
3. The first throw has lesser momentum
4. The first throw.

**Self Test.4.1**

1. a) True b) True c) False d) False
2. It depends on which has greater mass
3. It makes the time of contact longer thereby decreasing the impact force.

## Lesson 1

### Activity 1.1

No. 3 — ***Johannas Philoponus (550 A.D.)***

No. 1

*Aristotle*

No. 5

*Newton*

No. 4

*Galileo*

No. 2 — ***Jean Buriden (355 A.D.)***

Hey guys look at this. If I exert an impetus an object moves. Ha! A new discovery indeed! ***Impetus keeps a body moving.*** — No. 1

All right! And when that impetus diminishes motion also diminishes. When the impetus is removed, the object stops moving! — No. 2

Let's not call it an impetus anymore. Instead a force. I believe that force affects the velocity of moving objects. Thus, force is proportional to the velocity. If no force is applied no velocity for an object. Thus, the object is at rest. — No. 3

I don't think that the force is proportional to the velocity. All I know is that the velocity remains constant if there is no force including friction is applied. Force that affects vertical motion creates constant acceleration. — No. 4

What if I push an object, which is already moving horizontally? Isn't it that its velocity would also change and acceleration will be created? Thus, force would cause acceleration in horizontal motion, the natural acceleration actually observed in vertical motion must be the result of a vertical force on the body. Without this force the natural vertical motion would also be at a constant speed, just like natural horizontal motion. This vertical force is of course the force of gravity. — No. 5

**Posttest**

1. A
2. A
3. E
4. B
5. C
6. A
7. A
8. A
9. B
10. C
11. C
12. C
13. C
14. C
15. A
16. A
17. B
18. D
19. D
20. C

**- End of Module -**

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