7th Grade
Forces and Energy

Chapter 2: Forces

Lesson 1 (The Nature of Forces)

Speed – the distance an object travels per unit of time

Examples: feet per second (fps, or ft./s)
miles per hour (mph, or mi./h)
meters per second (m/s)
kilometers per hour (km/h)

$$Speed = \frac{distance}{time}$$

Examples:

If a person ran a 400 meter race in 54 seconds, what was his speed?

$$Speed = \frac{400\ m}{54\ s} = 7.4\ m/s$$

If a person walked at 3.7 mph for 90 minutes, how far did he / she walk?

$$3.7\ mph = \frac{x\ mi}{1.5\ hr} \qquad x = 5.55\ miles$$

If a person rode a bike for 45 miles at an average speed of 7.5 mph, how long did the trip take?

$$7.5\ mph = \frac{45\ mi}{x\ hr} \qquad x = 6\ hours$$

Instantaneous speed – the speed of an object at one specific time

Average speed – the overall rate of speed an object travels

$$average\ speed = \frac{total\ distance}{total\ time}$$

Examples:

If a triathlete swims a distance of 3 kilometers in 1 hour, bikes a distance of 50 kilometers in 3 hours, and runs a distance of 12 kilometers in 1 hour, what was the average speed of the triathlete?

$$average\ speed = \frac{3\ km + 50\ km + 12\ km}{1\ h + 3\ h + 1\ h} = \frac{65 km}{5\ h} = 13\ km/h$$

A triathlete swam a distance of 3 kilometers in 1.5 hours, biked a distance of 43 kilometers in 3.5 hours, then ran for 10 kilometers. If his average speed for the race was 8 *km/h*, how long did it take him to finish the running portion of the race?

$$8\ km/h = \frac{3\ km + 43\ km + 10\ km}{1.5\ h + 3.5\ h + X\ h} = \frac{56\ km}{5\ h + Xh} \qquad x = 2\ hours$$

Velocity – speed in a given direction
– tells us both the speed of an object **and the direction** of its travel

Examples: 25 *km/h* eastward
13 *km/h* northward

Acceleration – the rate at which velocity changes
– Refers to increasing speed, decreasing speed, or changing direction.
– Decreasing speed is sometimes called **deceleration**, or negative acceleration.
– An object that is traveling at a constant speed can be accelerating if it changes direction.
– To determine acceleration, you calculate the change in speed (m/s) per second, so the unit (label) is meters per second per second, or **m/s^2**.

To determine the acceleration of an object moving in a **straight line**:

$$acceleration = \frac{final\ speed - initial\ speed}{time}$$

Examples:

If an airplane travels for 5 seconds during a takeoff and reaches a speed of 40 *m/s*, what is the airplane's acceleration rate?

$$acceleration = \frac{40\ m/s - 0 m/s}{5\ s} = \frac{40\ m/s}{5\ s} = 8\ m/s^2$$

At this rate, what will the airplane's speed be after 8 seconds during takeoff?

40 *m/s* + 8 *m/s* + 8 *m/s* + 8 *m/s* = 64 *m/s*

A roller coaster accelerates from a speed of 4 *m/s* to 25 *m/s* in 3 seconds. What is the average acceleration of the ride? How fast was it going 1 second later? 3 seconds later?

$$acceleration = \frac{25\ m/s - 4\ m/s}{3\ s} = \frac{21\ m/s}{3\ s} = \mathbf{7\ m/s^2}$$

25 *m/s* + 7 *m/s* = **32 *m/s*** after 1 second

25 *m/s* + 7 *m/s* + 7 m/s + 7 m/s = **46 *m/s*** after 3 seconds

Force – a push or a pull exerted (applied) on an object

- Like velocity and acceleration, a force is described by its strength and by the direction in which it acts.
- Direction and strength are represented by arrows.
  - The arrow points to the direction of the force.
  - The length of the arrow tells you the strength of the force. (The longer the arrow, the stronger the force.)

Newton – a unit of force

- tells us the strength of a force

Net force – the overall force on an object when all the individual forces acting on it are considered

- the combination of all the forces on an object
- determines if and how an object will accelerate

Understand p. 34-35 of you book!

Lesson 2 (Friction and Gravity)

Friction – the force that two surfaces exert on each other when they rub against each other

- Friction acts in a direction opposite to the direction of the object's motion.

2 Factors That Affect Friction :

1. Types of surfaces involved.(smooth vs. rough)
2. How hard the surfaces are pushing together.

Types of Friction :

1. **Sliding friction** – occurs when two solid surfaces are slipping past each other
2. **Static friction** – occurs when neither object is moving
   - can become sliding friction when one or both objects move
3. **Fluid friction** – occurs when a solid object moves through a fluid

   Fluid – materials that flow easily (such as water or air)
4. **Rolling friction** – occurs when an object rolls or tumbles across a surface

Gravity – a force that pulls objects towards each other
- keeps the moon orbiting Earth
- keeps all the planets orbiting the sun

The Law of Universal Gravitation :

- Gravity acts on all things in the universe that have mass.
- Any two objects with mass are attracted to each other.

Factors That Affect Gravitational Pull :

1. Mass of the objects.
   - The more mass something has, the more gravitational pull it has.
   - Mass is **not** the same as weight.
2. Distance between the objects.
   - The closer the objects are to each other, the stronger the force.

Mass – the measure of the amount of matter in an object
- Your mass is the same on Earth as it would be on any planet.

Weight – a measure of the force of gravity on an object
- Your weight would vary on each planet since the strength of each planet's gravity is different.

Lesson 3 (Newton's Laws of Motion)

Newton's First Law of Motion :

1. An object at rest will remain at rest unless acted upon by a nonzero net force.
2. An object moving at a constant velocity will continue moving at a constant velocity unless acted upon by a nonzero net force.
3. Also called "The Law of Inertia".

Inertia – resistance to change in motion
- The greater the mass of an object, the greater the inertia, and the greater the force required to change its motion.
- Objects with greater inertia are harder to get moving, and are harder to stop once they are in motion.

Newton's Second Law of Motion :

An object's acceleration depends on its mass and on the net force acting on it.

$acceleration = \frac{net\ force}{mass}$ **OR** $force = mass\ x\ acceleration$

Examples:

What is the net force on a 7 *kg* sled accelerating at a rate of 6 m/s^2 ?

$f = m\ x\ a \qquad f = 7\ kg\ x\ 6\ m/s^2 = 42\ N$

If a 159 *N* force acts on a 53 *kg* toy car, what will the acceleration of the car be?

$acceleration = \frac{net\ force}{mass} = \frac{159\ N}{53\ kg} = 3\ m/s^2$

If a ball accelerates at 6 m/s^2 with a force of 18 *N* applied, what is the mass of the ball??

$f = m\ x\ a \qquad 18 = m\ x\ 6 \qquad m = 3\ kg$

Newton's Third Law of Motion :

- If one object exerts a force on another object, then the second object exerts a force of equal strength in the opposite direction on the first object.
- Another way of saying this is "For every action there is an equal and opposite reaction".
- Action and reaction forces do not cancel each other out because they act on different objects.

Lesson 4 (Momentum)

Momentum – a characteristic of a moving object that is related to the mass and the velocity of the object

Momentum = Mass x Velocity

- The unit for momentum is *kg* times meters per second.

(***kg·m/s***)

- The momentum of an object is in the same direction as its velocity.
- The more momentum a moving object has, the harder it is to stop.

Examples:

What is the momentum of a 0.3 *kg* ball moving at 30 *m/s* ?

Momentum = 0.3 kg x 30 m/s = ***9 kg·m/s in the direction it is moving***

What is the momentum of a 0.6 *kg* ball moving at 30 *m/s* ?

Momentum = 0.6 kg x 30 m/s = ***18 kg·m/s***

Which would be harder to stop: a 1,200 *kg* car moving at 40 *m/s*, or a 1,600 *kg* car moving at 30 *m/s* ?

Momentum = 1,200 kg x 40 m/s = ***48,000 kg·m/s***

Momentum = 1,600 kg x 30 m/s = ***48,000 kg·m/s***

Law of Conservation of Momentum :

– The total momentum of any group of objects that interact remains the same (is conserved), unless outside forces act on the objects.

Example:

If you are running at 5 *m/s* and have a mass of 45 *kg* your momentum is ***225 kg·m/s***.

If a 30 *kg* monkey jumps on your back and slows you down to 3 *m/s* your momentum will be ***225 kg·m/s***.

Lesson 5 (Free Fall and Circular Motion)

Free fall – the motion of a falling object when the only force acting on it is gravity

– When something falls on Earth, there is friction from the air around it.

– Friction tends to slow things down.

– Air friction increases as an object falls.

– If an object falls for long enough, friction will reduce its acceleration to zero.

– The object continues to fall, but at a constant velocity.

acceleration due to gravity = 9.8 m/s²

– Without friction, all falling objects would have a velocity of 9.8 *m/s* after one second, a velocity of 19.6 *m/s* after two seconds, a velocity of 29.4 *m/s* after three seconds, and so on..

Satellite – any object that orbits around another object in space

– Satellites in motion around Earth continuously fall towards Earth, but because Earth is curved, they travel around it. (They keep missing the ground as they fall.)

Centripetal force – a force that causes an object to move in a circular path

– Centripetal means “center seeking”.

Examples:

The string of a yo-yo being swung in a circle provides centripetal force.

Gravity provides centripetal force on satellites.

Centrifugal force – the **apparent** force that is felt by an object moving in a curved path that acts outwardly away from the center of rotation

– This is **not really a force**, but is the result of inertia – or the tendency of object to want to move in a straight line.

– If you could “turn off” a centripetal force, inertia would cause the object to fly off in a straight line.

Example:

Centrifugal “force” makes you lean against the car door when a turn is taken too sharply.