PHYSICAL SCIENCE OVERVIEW

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for Educators

Fundamental Concepts in Physical Science

Introduction

The study of physical science is all about understanding the world around us. It includes things like chemistry, physics, and other natural sciences. In physical science, we learn about matter, which is anything that takes up space and has weight. Matter is made up of tiny particles called atoms, which are the building blocks of everything in the universe.

We also learn about the different states of matter, like solids, liquids, and gases. For example, water can exist as ice, liquid water, or steam. There's also a fourth state of matter called plasma, which we can see in things like lightning.

In chemistry, we study things like chemical reactions, solutions, acids, and bases. Chemical reactions involve changes in the structure of substances, while solutions are mixtures of two or more substances. Acids and bases are all around us, and they have important real-world applications.

In physics, we study things like motion and forces. Forces are what make objects move or change their motion. We use scientific practices and engineering skills to understand these concepts and apply them to the world around us.

High School Expectations

High school students, as they delve deeper into their studies, will encounter the four core ideas in the physical sciences. These ideas, drawn from the realms of chemistry and physics, are not just theoretical constructs. They have real-world applications that we encounter in our daily lives. The high school performance expectations in Physical Science, which build on middle school ideas and skills, aim to equip students with the ability to explain more complex phenomena that are central not just to the physical sciences, but also to life, Earth, and space sciences.

These performance expectations blend the core ideas with scientific and engineering practices and crosscutting concepts to support students in developing useable knowledge to explain ideas across the science disciplines. In the physical science performance expectations at the high school level, there is a focus on several scientific practices. These include developing and using models, planning, conducting investigations, analyzing, and interpreting data, using mathematical and computational thinking, constructing explanations, and using these practices to demonstrate understanding of the core ideas. Students must also demonstrate knowledge of several engineering practices, including design and evaluation.

The Study of Matter

Physical science, the scientific study of nonliving things, is not just a theoretical pursuit. It has practical applications in our daily lives. It includes the natural sciences that study inanimate natural objects, such as physics, chemistry, earth science, astronomy, and related subjects.

Matter is described as a "physical substance in general," as distinct from mind and spirit; (in physics) matter occupies space and has mass. Matter is different from energy.

In physics, a state of matter is one of the distinct forms in which matter can exist. You can observe these states of matter in your everyday life. For instance, water can exist as a solid (ice), a liquid (water), or a gas (steam). There's also a fourth state of matter, plasma, which you can see in things like neon signs or lightning.

Atoms and the Periodic Table

Atoms are the basic unit of a chemical element. An atom is a fundamental piece of matter. (Matter is anything that can be touched physically.) Everything in the universe (except energy) is made of matter, so everything is made of atoms.

The periodic table is a tabular arrangement of the chemical elements, ordered by their atomic number, electron configuration, and recurring chemical properties. Its structure shows periodic trends. The components are arranged in order of their atomic numbers so that elements with similar properties appear in the same vertical column or group.

High school students, as you learn about atoms, remember that this is just the beginning of your journey into the world of subatomic particles. Atoms are made from a nucleus of protons and neutrons and a cloud of electrons. Electrons constantly move around the nucleus, while the protons and neutrons move within it. Neutrons and protons are each composed of three quarks. This introductory topic doesn't dwell on 'quarks,' but some of you may want to delve deeper into this subject area in the student-selected topics provided later. So, keep your curiosity alive and let's explore the fascinating world of atoms together!

Chemical Reactions

Chemical reactions involve rearrangement of a substance's molecular or ionic structure. They contrast with a change in physical form (such as liquid water turning into ice) or a nuclear reaction.

In chemistry, a solution is a homogeneous mixture of two or more substances. In such a mixture, a solute is a substance dissolved in another substance, known as a solvent. "homogeneous" means "consisting of parts all of the same kind."

Acids and bases are all around us, including a diverse array of food, drink, and domestic products, providing many opportunities to explore real contexts and applications of chemistry. However, the exaggerated portrayal of acids in the media (like movies and TV shows) could be more helpful.

While acids often are highly corrosive substances that 'eat away' materials in their path – some bases are even more corrosive. Even so, bases don't usually share the reputation of their acidic counterparts in movies. Further – salt is more than just table salt (sodium chloride, NaCl) used for food. Salt is any chemical compound formed from the reaction of an acid with a base.

Nuclear Change

Nuclear change is distinct from chemical change. In an atomic change, the elements can change from one to another. An example of this is our own Sun. The Sun generates energy by nuclear fusion, which changes hydrogen nuclei into helium. Nuclei can also break apart to form more minor elements (called fission). Nuclei can fuse to make heavier elements. Neutrons can turn into protons, and protons into neutrons.

Physics and Motion

The physics of motion is all about forces. Forces must act upon an object to get it moving or change its motion. Physical scientists (physicists) use some basic terms when looking at motion. For example, forces can influence how fast an object moves, its speed, or its velocity.

Forces are a push or pull on an object. Forces can be due to phenomena such as gravity, magnetism, or anything that might cause a mass to accelerate. In physics, a force is any interaction that, when unopposed, will change the motion of an object.

Work is done when a force applied to an object moves that object. The work is calculated by multiplying the force by the object's movement amount (W = F * d).

It is vital to use units of measure when performing work in science. In the United States, we use the Imperial System for day-to-day conversation, but the SI system is used in science. For example, a Newton is a unit of force, like a pound. Newtons are a measure of force. Another critical unit of measure is the Joule. Joules are a measure of energy (or work).

Heat

Often, we think that heat and temperature are the same thing. However, this is different. Heat and temperature are related but distinct concepts. Heat is the total energy of molecular motion in a substance, while temperature measures the average power of molecular motion in a substance.

Waves

In physics, a wave is a disturbance that travels through space and matter, transferring energy from one place to another. When studying waves, it's important to remember that they transfer energy, not matter. Sound and light travel in waves. Sound and light waves are similar in some ways, but they also differ.

A critical difference between sound and light is that sound can only travel through a solid, liquid, or gas. Sound cannot travel through a vacuum, such as outer space. Light, on the other hand, can travel through a vacuum. This topic explores the electromagnetic spectrum.

Light and sound can be reflected and refracted, just like water waves. Light and sound can also be diffracted, like water waves, but diffraction in light is less evident than in sound. Light and sound travel in waves, but different types. Visible light is part of the electromagnetic spectrum and can travel through a vacuum. Sound propagates as a longitudinal wave and needs a medium to travel through – such as air.

Alternative Perspective

This topic needs to include examining light and sound as natural sciences. Light and sound are explored here through a "social science" lens.

How might "light pollution" impact people in large cities? How do light and sound affect our emotions and well-being?

Have you ever considered that lighting professionals use light theory and "visual dynamics" ideas? How about in sales and marketing? How might a marketing pro use light, color, sound, and music to do their job?

Electricity and Magnetism

Electricity is the movement of electrons. This topic reviews similarities and differences between static electricity, mechanically generated electricity, and chemically generated electricity. All three types represent the movement of electrons.

In physics, magnetism is a force that can attract (pull closer) or repel (push away) objects that have a magnetic material like iron inside them (magnetic objects). Magnetism is a property of certain substances which pull closer or repel other objects. The motion of electric charges causes magnetism.

Natural Resources

Natural resources are natural materials or substances such as minerals, forests, water, and fertile land that can be used for economic gain. They exist without humankind's actions.

Some natural resources are renewable, and some are non-renewable. Natural resources such as coal, petroleum (crude oil), and natural gas take thousands of years to form naturally and cannot be replaced as fast as they are consumed. A renewable resource is a resource that can be used repeatedly and replaced naturally. Examples include oxygen, fresh water, solar energy, and biomass.

The climate is the weather conditions prevailing in an area or over a long period. Climate and weather are not the same thing. Weather is what the forecasters on the TV news predict each day. They tell people about the temperature, cloudiness, humidity, and whether a storm is likely in the next few days. In contrast, climate is the average weather in a place over many years.

Earth

Earth, our home, is the third planet from the Sun. It is the only planet with an atmosphere containing free oxygen, oceans of liquid water on its surface, and life.

Earth is the fifth largest of the planets in the solar system — smaller than the four gas giants, Jupiter, Saturn, Uranus, and Neptune, but more significant than the three other rocky planets, Mercury, Mars, and Venus. Earth has a diameter of 8,000 miles (13,000 kilometers) and is round because gravity pulls matter into a ball. However, it is not perfectly round; instead, it is more of an "oblate spheroid," whose spin causes it to squash at its poles and swollen at the equator.

The Solar System

The solar system comprises the Sun and everything that orbits around it, including planets, moons, asteroids, comets, and meteoroids. What many adults don't know is that our solar system is the ONLY solar system. Everything else is called a stellar system or star system. Sometimes, we call other star systems a "solar system,"… but they should be called star systems.

The Solar System was formed approximately 4.6 billion years ago and consists of the Sun, dwarf planets, and other astronomical objects bound in its orbit. 99.86% of the system's mass is in the Sun, and most of the remaining 0.14% is within the solar system's eight planets. Other objects of note in the Solar System are the dwarf planets (Ceres, Pluto, Haumea, Makemake & Eris), moons, asteroids, the asteroid belt, comets, and the Kuiper belt.

The Universe

The universe is all matter, and space is considered a whole: the cosmos. It is believed to be at least 10 billion light years in diameter and contains many galaxies; it has been expanding since its creation in the Big Bang about 13 billion years ago.

The light year is a unit of length used to express astronomical distances. It is about 9.5 trillion kilometers or 5.9 trillion miles. The International Astronomical Union (IAU) defines a light year as the distance light travels in a vacuum in one Julian year (365.25 days). It is difficult to grasp the magnitude and expanse of our known universe. Understanding the concept of a light year helps us understand its hugeness.

Summary

Physical science encompasses the study of non-living things, such as chemistry, geology, astronomy, and physics. Throughout this course, students have been introduced to and reinforced concepts related to matter, electricity, energy, light and sound, Earth as a planet, our Solar System, and the known universe. It's a comprehensive array of topics! As we wrap up this module with the theme "end-of-year summary," let's take a moment to reflect. Students should take pride in the breadth of scientific subjects they have engaged with.

Test Yourself

True/False

1. Physical science encompasses the study of living organisms. (False)

2. Matter is anything that can be touched physically. (True)

3. The periodic table arranges elements based on their atomic number and recurring chemical properties. (True)

4. The nucleus of an atom is composed of protons, neutrons, and electrons. (False)

5. Chemical reactions involve a change in the physical form of a substance. (False)

6. Acids are generally less corrosive than bases. (False)

7. Salt is solely composed of sodium chloride (NaCl). (False)

8. Nuclear fusion is the process by which the Sun generates energy. (True)

9. The physics of motion is not related to forces acting upon an object. (False)

10. Forces are necessary to change the motion of an object. (True)

Multiple Choice

1. What are the four core ideas in the physical sciences?

   a) Biology, chemistry, physics, earth science

b) Chemistry, physics, earth science, astronomy

c) Theoretical constructs, real-world applications, scientific practices, engineering

d) Matter, energy, atoms, chemical reactions

Correct Answer: b) Chemistry, physics, earth science, astronomy

2. What is matter defined as in physics?

a) Anything that can be touched physically

b) Anything that can be seen

c) Anything that has mass

d) Anything that has volume

Correct Answer: a) Anything that can be touched physically

3. What is the purpose of the periodic table?

a) To arrange elements by their atomic number and recurring chemical properties

b) To list elements in alphabetical order

c) To categorize elements based on their color

d) To arrange elements based on their weight

Correct Answer: a) To arrange elements by their atomic number and recurring chemical properties

4. What is the basic unit of a chemical element?

a) Molecule

b) Atom

c) Compound

d) Proton

Correct Answer: b) Atom

5. What is the process by which the Sun generates energy?

a) Nuclear fission

b) Chemical reaction

c) Nuclear fusion

d) Combustion

Correct Answer: c) Nuclear fusion

6. Which of the following is a homogeneous mixture of two or more substances?

a) Compound

b) Solution

c) Element

d) Mixture

Correct Answer: b) Solution

7. What is the fourth state of matter?

a) Solid

b) Liquid

c) Gas

d) Plasma

Correct Answer: d) Plasma

8. What does the physics of motion primarily focus on?

a) Chemical reactions

b) Forces

c) Light

d) Sound

Correct Answer: b) Forces

9. What does a chemical reaction involve?

a) A change in the physical form of a substance

b) A change in the molecular or ionic structure of a substance

c) A change in the color of a substance

d) A change in the state of a substance

Correct Answer: b) A change in the molecular or ionic structure of a substance

10. What is the study of nonliving things known as in the scientific field?

a) Biology

b) Geology

c) Physical science

d) Ecology

Correct Answer: c) Physical science

Critical Thinking

1. How do the four core ideas in physical science, drawn from the realms of chemistry and physics, have real-world applications in our daily lives?

2. In what ways do the high school performance expectations in Physical Science aim to equip students with the ability to explain more complex phenomena that are central to the physical sciences and other science disciplines?

3. Why is it important for high school students to understand the fundamental concepts of matter, atoms, and the periodic table in the study of physical science?

4. How do nuclear changes differ from chemical changes, and what are some real-world examples of nuclear changes?

5. In what ways do acids, bases, and solutions play a role in our daily lives, and how can an understanding of these concepts be applied to real-world scenarios?