

# Light

## Novice

- White light is composed of many colors.
- Objects can be seen if light is available to illuminate them or if they give off their own light.
- Different kinds of matter exist and many of them can be solid, liquid, or gas.
- Matter can be described and classified by its observable properties.
- A great variety of objects can be built up from a small set of pieces.
- Heating or cooling a substance may cause changes that can be observed.
- Objects may break into smaller pieces and be put together into larger pieces, or change shapes.
- Different sense receptors are specialized for particular kinds of information.
- Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means.
- Measurements of a variety of properties can be used to identify materials.

## Intermediate

- Fireworks have different colors due to the chemicals of which they are composed.
- Kirchoff's Laws: Light can be continuum (all colors, a hot dense body), emission (only some colors, a hot thin gas), or absorption (all but some colors, a cool thin gas blocking a hot dense body).
- Emission and absorption spectra are caused by electrons changing energy levels in their orbitals around atomic nuclei. Specific colors of spectra depend upon the energy, which depends upon the type of atom.
- Substances are made from different types of atoms, which combine with one another in various ways.
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a gas, the molecules are widely spaced except when they happen to collide.
- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.
- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.

## Expert

- Stellar spectra can be used to determine the chemicals present.
- Doppler shift allows us to determine the speed of other galaxies.
- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.

- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.
- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.
- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features.
- When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.
- Photoelectric materials emit electrons when they absorb light of a high-enough frequency.
- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
- Nuclear fusion processes in the center of the Sun release the energy that ultimately reaches Earth as radiation.
- Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities.

### Related NGSS

Grade Level	Student Performance Expectations
3-5	4-PS4-2 <b>Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.</b>
MS	MS-PS-2 <b>Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.</b>
HS	HS-ESS1-2 <b>Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.</b> HS-PS4-1 <b>Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.</b>

## Related CCSSM

Grade Level	Student Performance Expectations
3-5	<p><b>CCSS.MATH.PRACTICE.MP4 Model with mathematics.</b> Mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace. In early grades, this might be as simple as writing an addition equation to describe a situation. In middle grades, a student might apply proportional reasoning to plan a school event or analyze a problem in the community. By high school, a student might use geometry to solve a design problem or use a function to describe how one quantity of interest depends on another. Mathematically proficient students who can apply what they know are comfortable making assumptions and approximations to simplify a complicated situation, realizing that these may need revision later. They are able to identify important quantities in a practical situation and map their relationships using such tools as diagrams, two-way tables, graphs, flowcharts and formulas. They can analyze those relationships mathematically to draw conclusions. They routinely interpret their mathematical results in the context of the situation and reflect on whether the results make sense, possibly improving the model if it has not served its purpose.</p> <p><b>CCSS.MATH.CONTENT.4.G.A.1</b> Draw points, lines, line segments, rays, angles (right, acute, obtuse), and perpendicular and parallel lines. Identify these in two-dimensional figures.</p>
MS	<p><b>CCSS.MATH.PRACTICE.MP2 Reason abstractly and quantitatively.</b> Mathematically proficient students make sense of quantities and their relationships in problem situations. They bring two complementary abilities to bear on problems involving quantitative relationships: the ability to <i>decontextualize</i>—to abstract a given situation and represent it symbolically and manipulate the representing symbols as if they have a life of their own, without necessarily attending to their referents—and the ability to <i>contextualize</i>, to pause as needed during the manipulation process in order to probe into the referents for the symbols involved. Quantitative reasoning entails habits of creating a coherent representation of the problem at hand; considering the units involved; attending to the meaning of quantities, not just how to compute them; and knowing and flexibly using different properties of operations and objects.</p> <p><b>CCSS.MATH.CONTENT.6.EE.A.2</b> Write, read, and evaluate expressions in which letters stand for numbers.</p>

	<p><b>CCSS.MATH.CONTENT.7.EE.B.3</b> Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.</p> <p><b>CCSS.MATH.CONTENT.7.EE.B.4</b> Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.</p>
HS	<p><b>CCSS.MATH.PRACTICE.MP2 Reason abstractly and quantitatively.</b> Mathematically proficient students make sense of quantities and their relationships in problem situations. They bring two complementary abilities to bear on problems involving quantitative relationships: the ability to <i>decontextualize</i>—to abstract a given situation and represent it symbolically and manipulate the representing symbols as if they have a life of their own, without necessarily attending to their referents—and the ability to <i>contextualize</i>, to pause as needed during the manipulation process in order to probe into the referents for the symbols involved. Quantitative reasoning entails habits of creating a coherent representation of the problem at hand; considering the units involved; attending to the meaning of quantities, not just how to compute them; and knowing and flexibly using different properties of operations and objects.</p> <p><b>CCSS.MATH.PRACTICE.MP4 Model with mathematics.</b> Mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace. In early grades, this might be as simple as writing an addition equation to describe a situation. In middle grades, a student might apply proportional reasoning to plan a school event or analyze a problem in the community. By high school, a student might use geometry to solve a design problem or use a function to describe how one quantity of interest depends on another. Mathematically proficient students who can apply what they know are comfortable making assumptions and approximations to simplify a complicated situation, realizing that these may need revision later. They are able to identify important quantities in a practical situation and map their relationships using such tools as diagrams, two-way tables, graphs, flowcharts and formulas. They can analyze those relationships mathematically to draw conclusions. They routinely interpret their mathematical results in the context of the situation and reflect on whether the results make sense, possibly improving the model if it has not served its purpose.</p>

**CCSS.MATH.CONTENT.HSN.Q.A.1 Quantities**

Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

**CCSS.MATH.CONTENT.HSN.Q.A.2 Quantities**

Define appropriate quantities for the purpose of descriptive modeling.

**CCSS.MATH.CONTENT.HSN.Q.A.3 Quantities**

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

**CCSS.MATH.CONTENT.HSA.SSE.A.1 Seeing structure in Expressions**

Interpret expressions that represent a quantity in terms of its context.

**CCSS.MATH.CONTENT.HSA.SSE.B.3 Seeing structure in Expressions**

Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.

**CCSS.MATH.CONTENT.HSA.CED.A.4 Creating Equations**

Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.