

HS-PS4-3 Waves and their Applications in Technologies for Information Transfer

California Science Test—Item Content Specifications

# HS-PS4-3 Waves and their Applications in Technologies for Information Transfer

Students who demonstrate understanding can:

Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.

[Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.] [*Assessment Boundary: Assessment does not include using quantum theory.*]

Continue to the next page for the Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts.

| Science and Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts |
| --- | --- | --- |
| Engaging in Argument from Evidence  Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.  Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.  Connections to Nature of Science  Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena  A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment. The science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. | PS4.A: Wave Properties  9. [From the 3–5 grade band endpoints] Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.)  PS4.B: Electromagnetic Radiation  9. 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. | Systems and System Models  Models (e.g., physical, mathematical, and computer models) can be used to simulate systems and interactions — including energy, matter and information flows — within and between systems at different scales. |

## Assessment Targets

Assessment targets describe the focal knowledge, skills, and abilities for a given three-dimensional Performance Expectation. Please refer to the Introduction for a complete description of assessment targets.

### Science and Engineering Subpractice(s)

Please refer to appendix A for a complete list of Science and Engineering Practices (SEP) subpractices. Note that the list in this section is not exhaustive.

7.2 Ability to compare, evaluate, and critique competing arguments

### Science and Engineering Subpractice Assessment Targets

Please refer to appendix A for a complete list of SEP subpractice assessment targets. Note that the list in this section is not exhaustive.

7.2.1 Ability to evaluate arguments about a natural phenomenon based on scientific concepts, principles, and big ideas

7.2.2 Ability to respond to a critique from others by revising an argument after analysis of the reasoning and evidence

7.2.3 Ability to evaluate competing perspectives/claims using reasoning and evidence

### Disciplinary Core Idea Assessment Targets

#### PS4.A.9

* Distinguish between constructive and destructive interference and describe the circumstances that lead to each
* Identify evidence of interference behavior between waves based on qualitative decreases or increases in amplitude

#### PS4.B.9

* Identify contexts in which a wave model of electromagnetic radiation, a particle model of electromagnetic radiation, or both are appropriate for describing, predicting, or explaining a phenomenon
* Use the photoelectric effect to describe the relationship between electromagnetic forces and photons
* Use the photoelectric effect to describe how we might measure amplitude changes due to interference

### Crosscutting Concept Assessment Target(s)

CCC4 Use models to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales

## Examples of Integration of Assessment Targets and Evidence

Note that the list in this section is not exhaustive.

Task provides both a description of a phenomenon involving the transfer of energy or information via electromagnetic radiation and a selection of arguments in support of the use of a particle model, wave model, or both as the best tool for explaining the phenomenon:

* Identifies which arguments provide scientific reasoning for the choice of model (7.2.1, PS4.B.9, and CCC4)
* Identifies which arguments are nonscientific on the basis that they include causal arguments that are missing evidence and/or reasoning, do not include scientific principles or concepts, or their focuses are supported by irrelevant examples or appeals to authority (7.2.1, PS4.B.9, and CCC4)

Task provides both a description of a phenomenon involving the transfer of energy or information via electromagnetic radiation and two flawed arguments for modeling radiation in a particular way (one as a particle, one as a wave) to best explain the phenomenon:

* Identifies missing/irrelevant features (e.g., nonscientific claim, irrelevant evidence, and/or lack of reasoning) of the arguments (7.2.1, PS4.B.9, and CCC4)
* Synthesizes the two arguments to generate (or select) an argument that supports the use of both models in tandem (7.2.1, PS4.B.9, and CCC4)

Task provides 1) a description of a phenomenon involving the transfer of energy or information via electromagnetic radiation, 2) an argument in support of the use of a particle model, wave model, or both as the best tool for explaining the phenomenon, and 3) a critique of that argument made by a peer:

* Evaluates the critique by analyzing the description of the phenomenon using scientific principles to determine whether the original argument was flawed (7.2.2, PS4.B.9, and CCC4)
* Revises the claim of the provided argument in light of the provided critique (7.2.2, PS4.B.9, and CCC4)
* Revises the stated evidence of the provided argument in light of the provided critique (7.2.2, PS4.B.9, and CCC4)

Task provides two arguments in support of the particle and wave models of electromagnetic radiation:

* Identifies phenomena in which one model may be more useful in supporting an explanation than another model is (7.2.3, PS4.A.9, and CCC4)

## Possible Phenomena or Contexts

Note that the list in this section is not exhaustive.

* Evidence to support the wave model or particle model of light
* The resonant transfer of electromagnetic energy across distances for the purposes of wireless powering of devices or wireless information transfer
* Technologies that rely on collisions between photons and regular matter (e.g., light sensors on elevators, X-ray machines, mirrors, etc.)
* Diffraction, refraction, and reflection of laser light

## Common Misconceptions

Note that the list in this section is not exhaustive.

* When waves collide, they act like solids, bouncing off each other.
* Superposition can only be applied if the peaks of the waves interact.
* Only objects that are glowing and/or are hot can transfer energy in the form of electromagnetic radiation.
* Only hot or warm objects transfer thermal energy.
* Only the Sun transfers energy in the form of electromagnetic radiation.
* The photoelectric effect can be explained by the wave model of light.

## Additional Assessment Boundaries

None listed at this time.

## Additional References

HS-PS4-3 Evidence Statement [https://www.nextgenscience.org/sites/default/files/evidence\_statement/black\_white/HS-PS4-3 Evidence Statements June 2015 asterisks.pdf](https://www.nextgenscience.org/sites/default/files/evidence_statement/black_white/HS-PS4-3%20Evidence%20Statements%20June%202015%20asterisks.pdf)

The *2016 Science Framework for California Public Schools Kindergarten through Grade 12*

Appendix 1: Progression of the Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts in Kindergarten through Grade 12 <https://www.cde.ca.gov/ci/sc/cf/documents/scifwappendix1.pdf>

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