Physics Pathway Endorsement Specs

Purpose

This document describes the specifications associated with the Physics Pathway Science Endorsements. There are three endorsements in the Biology Pathway: Science Core, Physics 1, and Physics 2.

The **Science Core Endorsement**, when attached to a current Education License, verifies that the individual has the skills and knowledge necessary to teach students three-dimensionally in a secondary science classroom and is required to teach Middle School Science Courses in Grades 6, 7, or 8. Additionally, this endorsement is required as a prerequisite to earn any high school Level-1 or Level-2 content specific science endorsement.

The **Physics 1 Endorsement**, when attached to a current Education License, verifies that the individual has the skills and knowledge necessary to teach students in a secondary physical science classroom and is required to teach High School (9-12) General Physics Courses and the high school astronomy elective course. This endorsement is required as a prerequisite to earn the Physics 2 Endorsement.

The **Physics 2 Endorsement**, when attached to a current Secondary Education License, verifies that the individual has the skills and knowledge necessary to teach students in an advanced secondary physical science classroom and is required to teach Advanced Physics (AP, CE, and IB) courses. Those with this endorsement can also teach all the courses a Physics 1 endorsed educator can teach. NOTE: Advanced Physics (AP, CE, and IB) courses may also include additional requirements in order to be approved by the university or college board to teach.

Endorsement Requirement Areas

The Science Core endorsement is a prerequisite for the Physics 1 and Physics 2 Endorsements and has 7 requirement areas:

1. Earth Science Content Knowledge
2. Life Science Content Knowledge
3. Chemistry Content Knowledge
4. Physics Content Knowledge
5. Three-Dimensional Science & Engineering Pedagogical Knowledge
6. Science Education Teaching & Dispositions Knowledge
7. Science Classroom Lab Safety Knowledge

The Physics 1 Endorsement is a prerequisite for the Physics 2 Endorsement has 4 requirement areas:

8. Kinematics, Dynamics, and Conservation Laws Knowledge
9. Fields & Electromagnetism Content Knowledge 2
10. Physics Laboratory Content Knowledge
11. Waves & Their Applications in Technology Content Knowledge

The Physics 2 Endorsement has 2 requirement areas:

12. Advanced Quantitative Physics Reasoning Content Knowledge
13. Advanced Physics Content Knowledge

Endorsement Type

A professional endorsement will be awarded when all of the prerequisite and endorsement requirement areas have been met. An associate Science Core Endorsement will be awarded if the applicant has completed at least 3 of the 7 requirement areas. An associate Physics 1 Endorsement will be awarded if the applicant holds a Professional Science Core endorsement, has a college major or minor in Physics, **OR** has completed at least 5 of the 11 prerequisite and endorsement requirement areas. An associate Physics 2 Endorsement will be awarded if the applicant holds Professional Science Core and Physics 1 endorsements, has a college major in Physics, **OR** has completed at least 6 of the 13 requirement areas.

Requirement Area Options

The different options available to complete requirement areas 8-13 for the Physics 1 and Physics 2 Endorsements are described below. The options for requirement areas 1-7 associated with the Science Core Endorsement can be found in the Science Core Endorsement Specs. Quick links to the requirement area competencies are linked in parentheses.

Requirement Area 8: Kinematics, Dynamics, & Conservation Laws Content Knowledge (P1.1 and P1.2)

Complete one of the following options to show evidence of competency in this Requirement Area

University Courses

- Any 3+ credit university course (passed with a grade of C or higher) in General Physics I
    - Lab course is not required but recommended
    - This course can be the same General Physics used to meet course requirements for the Science Core (6-8) Endorsement (if applicable).

College Major or Minor (Meets Requirement Areas 8-11 for the Physics 1 endorsement)

- College Major or Minor in Physics, Physics Education, Physical Science Education, or a Physics Variation (e.g., Astrophysics, Theoretical Physics, Nuclear Physics)
- Other College Majors or Minors may be approved for this endorsement with approval of USBE Science Specialist based on a transcript review

Content Knowledge Exam (Meets Requirement Areas 8-11 for the Physics 1 endorsement)

- **Praxis Exam**
    - Physics Praxis (5266) with score of 140 or higher
- **NES Test**
    - Physics NES Test (323) with score of 220 or higher
- Other equivalent state or national exams that meet competencies and approved by USBE

Requirement Area 9: Fields & Electromagnetism Content Knowledge (P1.1 and P1.2)

Complete one of the following options to show evidence of competency in this Requirement Area

University Courses

- Any 3+ credit university course (passed with a grade of C or higher) in General Physics II

- Lab course is not required but recommended
- This course must indicate that it is a level-2 physics course and not simply a different level-1 physics course.

College Major or Minor (Meets Requirement Areas 8-11 for the Physics 1 endorsement)

- As described in Requirement Area 8 description

Content Knowledge Exam (Meets Requirement Areas 8-11 for the Physics 1 endorsement)

- As described in Requirement Area 8 description

Requirement Area 10: Physics Laboratory Content Knowledge (P1.4)

Complete one of the following options to show evidence of competency in this Requirement Area

University Courses

- Any 1+ credit university course (passed with a grade of C or higher) in a Physics Laboratory Experience
  - A course used for Requirement Areas 8 or 9 that is worth 4+ credits will meet this requirement if the course included a laboratory component.

College Major or Minor (Meets Requirement Areas 8-11 for the Physics 1 endorsement)

- As described in Requirement Area 8 description

Content Knowledge Exam (Meets Requirement Areas 8-11 for the Physics 1 endorsement)

- As described in Requirement Area 8 description

Requirement Area 11: Waves & Their Applications in Technology (P1.3 and P1.5)

Complete one of the following options to show evidence of competency in this Requirement Area

University Courses

- Any 3+ credit university course (passed with a grade of C or higher) in Advanced/Applied Physics (e.g., Modern Physics, Electricity and Magnetism, Waves, Acoustics, and Sound)
  - Lab course is not required but recommended

College Major or Minor (Meets Requirement Areas 8-11 for the Physics 1 endorsement)

- As described in Requirement Area 8 description

Content Knowledge Exam (Meets Requirement Areas 8-11 for the Physics 1 endorsement)

- As described in Requirement Area 8 description

Requirement Area 12: Advanced Quantitative Physics Reasoning Content Knowledge (P2.1)

Complete one of the following options to show evidence of competency in this Requirement Area

University Courses

- Any 3+ credit university course (passed with a grade of C or higher) in Calculus I or higher
  - A course in Precalculus or Business Calculus does not meet this requirement

College Major (Meets Requirement Areas 12-13 for the Physics 2 endorsement)

- College Major in Physics, Physics Education, or a Physics Variation (e.g. Physics, Astrophysics, Theoretical Physics, Nuclear Physics)
- Other College Majors may be approved for this endorsement with approval of USBE Science Specialist based on a transcript review

Teaching Experience and Professional Learning (Meets Requirement Areas 12-13 for the Physics 2 endorsement)

- Teach either AP Physics or IB Physics for 3 years.

- Attend the relevant Professional Learning for the course being taught.
  - AP Summer Institute for AP Physics.
  - Diploma Program Chemistry Workshop for IB Physics.
- Apply principles acquired in professional learning into teaching for 2 years.

Requirement Area 13: Advanced Physics Content Knowledge (P2.2)

Complete one of the following options to show evidence of competency in this Requirement Area

University Courses

- Complete **TWO** 3+ credit university courses (passed with a grade of C or higher) in any two of the following Advanced/Applied Physics in addition to the courses taken to meet Physics 1 Endorsement requirements (if applicable). *NOTE: Lab course is not required but recommended*
  - Astronomy or Astrophysics
  - Electricity and Magnetism
  - Mechanical Engineering;
  - Mechanics or Statics
  - Modern Physics
  - Thermodynamics
  - Waves, Acoustics, and Sound
  - Other upper division (3000+) physics course

College Major (Meets Requirement Areas 12-13 for the Physics 2 endorsement)

- As described in Requirement Area 12 description

Teaching Experience and Professional Learning (Meets Requirement Areas 12-13 for the Physics 2 endorsement)

- As described in Requirement Area 12 description

Requirement Area Competencies

The Secondary Physics 1 competencies are organized into 1 section:

1. **Physics 1 Core Ideas** – The Utah Secondary Physics 1 qualifies teachers to teach the core High School (9-12) General Physics course focused specifically in the High School Physics (Physical Science) disciplinary core ideas:
   P1.1 Motion and Stability
   P1.2 Energy
   P1.3 Waves and Their Applications in Technology
   P1.4 Physics Laboratory Experience
   P1.5 Modern Physics

The Secondary Physics 2 competencies are organized into 1 section:

1. **Physics 2 Core Ideas** – This endorsement is required to teach Advanced Physics (AP, CE, and IB) and high school physics elective courses. These competencies and requirements go above that of the core ideas found in the SEEd Physics Standards.
   P2.1 Advanced Quantitative Physics Reasoning
   P2.2 Advanced Physics Content Knowledge

Each of the requirement area competencies are described below. Quick links to each requirement area options are provided in the parentheses.

Requirement Area 8 - Kinematics, Dynamics, & Conservation Laws Content Knowledge (Options)

Requirement Area P1.1: Motion and Stability

Area P1.1.A: Forces and Motion

- P1.1.A.a Newton's second law accurately predicts changes in the motion of macroscopic objects, but it requires revision for subatomic scales or for speeds close to the speed of light.
- P1.1.A.b Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. In any system, total momentum is always conserved.

Area P1.1.B: Types of Interactions

- P1.1.B.a Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.

Area P1.1.C: Stability and Instability in Physical Systems

- P1.1.C.a Systems often change in predictable ways; understanding the forces that drive the transformations and cycles within a system, as well as the forces imposed on the system from the outside, helps predict its behavior under a variety of conditions.
- P1.1.C.b When a system has a great number of component pieces, one may not be able to predict much about its precise future.

Requirement Area P1.2: Energy

Area P1.2.A: Definitions of Energy

- P1.2.A.a Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system.
- P1.2.A.b At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- P1.2.A.c "Mechanical energy" generally refers to some combination of motion and stored energy in an operating machine.
- P1.2.A.d "Chemical energy" generally is used to mean the energy that can be released or stored in chemical processes, and "electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. Historically, different units and names were used for the energy present in these different phenomena, and it took some time before the relationships between them were recognized.
- P1.2.A.e These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as either motions of particles or energy stored in fields (which mediate interactions between particles).

Area P1.2.B: Conservation of Energy and Energy Transfer

- P1.2.B.a Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- P1.2.B.b Mathematical expressions allow the concept of conservation of energy to be used to predict and describe system behavior.
- P1.2.B.c Uncontrolled systems always evolve toward more stable states

Requirement Area 9 - Fields & Electromagnetism Content Knowledge (Options)

Requirement Area P1.1: Motion and Stability

Area P1.1.B: Types of Interactions

- P1.1.B.a Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.
- P1.1.B.b Forces at a distance are explained by fields permeating space that can transfer energy through space.
- P1.1.B.c Magnets or changing electric fields cause magnetic fields; electric charges or changing magnetic fields cause electric fields.
- P1.1.B.d The strong and weak nuclear interactions are important inside atomic nuclei.

Requirement Area P1.2: Energy

Area P1.2.A: Definitions of Energy

- P1.2.A.f Radiation is a phenomenon in which energy is stored in fields as it moves across space.

Area P1.2.C: Relationships Between Energy and Forces

- P1.2.C.a Force fields (gravitational, electric, and magnetic) contain energy and can transmit energy across space from one object to another.
- P1.2.C.b When two objects interacting through a force field change relative position, the energy stored in the force field is changed.

Requirement Area 10 - Physics Laboratory Content Knowledge (Options)

Requirement Area P1.4: Physics Laboratory Experiences

Area P1.4.A: Laboratory Safety and Measurement Proficiency

- P1.4.A.a Demonstrate adherence to established laboratory safety protocols, including the correct handling, storage, and maintenance of physics equipment.
- P1.4.A.b Apply precise measurement techniques using appropriate instrumentation, while systematically identifying, calculating, and reporting measurement uncertainty and error.
- P1.4.A.c Utilize data analysis software or graphical representations to interpret experimental results and validate theoretical models.

Area P1.4.B: Experimental Investigation of Kinematics, Dynamics, & Conservation Laws

- P1.4.B.a Design and execute experiments to investigate motion, forces, and stability, verifying kinematic and dynamic relationships for objects under various conditions.
- P1.4.B.b Collect and analyze data from dynamic systems to provide empirical evidence for the conservation of momentum and energy.

Area P1.4.C: Experimental Investigation of Fields & Electromagnetism

- P1.4.C.a Design and conduct investigations to map, visualize, and quantify electric and magnetic fields and their interactions with matter.
- P1.4.C.b Assemble and troubleshoot electrical circuits and electromagnetic apparatus to explore relationships between electric charges, currents, and magnetic fields.

Requirement Area 11 - Waves & Their Applications in Technology (Options)

Requirement Area P1.3: Waves and Their Applications in Technology

Area P1.3.A: Wave Properties

- P1.3.A.a 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.
- P1.3.A.b The reflection, refraction, and transmission of waves at an interface between two media can be modeled on the basis of these properties.

- P1.3.A.c Combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information.
- P1.3.A.d Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.
- P1.3.A.e Resonance is a phenomenon in which waves add up in phase in a structure, growing in amplitude due to energy input near the natural vibration frequency.
- P1.3.A.f Structures have particular frequencies at which they resonate. This phenomenon (e.g., waves in a stretched string, vibrating air in a pipe) is used in speech and in the design of all musical instruments.

Area P1.3.B: Electromagnetic Radiation

- P1.3.B.a 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. Quantum theory relates the two models.
- P1.3.B.b Because a wave is not much disturbed by objects that are small compared with its wavelength, visible light cannot be used to see such objects as individual atoms.
- P1.3.B.c All electromagnetic radiation travels through a vacuum at the same speed, called the speed of light. Its speed in any other given medium depends on its wavelength and the properties of that medium.
- P1.3.B.d When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat).
- P1.3.B.e Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.
- P1.3.B.f Photovoltaic materials emit electrons when they absorb light of a high enough frequency.

Area P1.3.C: Information Technologies and Instrumentation

- P1.3.C.a Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.
- P1.3.C.b Knowledge of quantum physics enabled the development of semiconductors, computer chips, and lasers, all of which are now essential components of modern imaging, communications, and information technologies.

Requirement Area P1.5: Modern Physics

Area P1.5.A: Quantum and Relativistic Concepts

- P1.5.A.a Explain the wave-particle duality of matter and energy, citing evidence such as the photoelectric effect and electron diffraction.
- P1.5.A.b Describe the fundamental postulates of special relativity, including the constancy of the speed of light and the equivalence of mass and energy ($E=mc^2$).

Area P1.5.B: Atomic and Nuclear Structure

- P1.5.B.a Model the structure of the atom, explaining how electron energy levels and transitions produce characteristic emission and absorption spectra.
- P1.5.B.b Analyze nuclear processes, including radioactive decay, fission, and fusion, in terms of binding energy and the conservation of mass-energy.

Requirement Area 12 - Advanced Quantitative Physics Reasoning Content Knowledge (Options)

Requirement Area P2.1: Advanced Quantitative Physics Reasoning

Area P2.1.A: Question, Methods, and Argumentation

- P2.1.A.a Identify a testable scientific question based on an observation, data, or a model
- P2.1.A.b Formulate a hypothesis or predict the results of an experiment.
- P2.1.A.c Identify experimental procedures that are aligned to a scientific question (which may include a sketch of a lab setup).
- P2.1.A.d Make observations or collect data from representations of laboratory setups or results, while attending to precision where appropriate.
- P2.1.A.e Identify or describe potential sources of experimental error.
- Explain how modifications to an experimental procedure will alter results.
- P2.1.A.f Make a scientific claim. and support it with evidence from experimental data.
- P2.1.A.g Support a claim with evidence from representations or models at the particulate level, such as the structure of atoms and/or molecules.
- P2.1.A.h Provide reasoning to justify a claim using chemical principles or laws, or using mathematical justification.
- P2.1.A.i Provide reasoning to justify a claim using connections between particulate and macroscopic scales or levels.
- P2.1.A.j Explain the connection between experimental results and chemical concepts, processes, or theories.
- P2.1.A.k Explain how potential sources of experimental error may affect the experimental results.

Area P2.1.B: Models, Data, Analysis, and Mathematical Routines

- P2.1.B.a Describe the components of and quantitative information from models and representations that illustrate particulate-level properties only.
- P2.1.B.b Describe the components of and quantitative information from models and representations that illustrate both particulate-level and macroscopic level properties.
- P2.1.B.c Represent chemical phenomena using appropriate graphing techniques, including correct scale and units.
- P2.1.B.d Represent chemical substances or phenomena with appropriate diagrams or models (e.g., electron configuration).
- P2.1.B.e Represent visually the relationship between the structures and interactions across multiple levels or scales (e.g., particulate to macroscopic).
- P2.1.B.f Explain chemical properties or phenomena (e.g., of atoms or molecules) using given chemical theories, models, and representations.
- P2.1.B.g Explain whether a model is consistent with chemical theories.
- P2.1.B.h Explain the connection between particulate-level and macroscopic properties of a substance using models and representations.
- P2.1.B.i Explain the degree to which a model or representation describes the connection between particulate-level properties and macroscopic properties.
- P2.1.B.j Identify quantities needed to solve a problem from given information (e.g., text, mathematical expressions, graphs, or tables).
- P2.1.B.k Identify an appropriate theory, definition, or mathematical relationship to solve a problem.
- P2.1.B.l Explain the relationship between variables within an equation when one variable changes.

- P2.1.B.m Identify information presented graphically to solve a problem.
- P2.1.B.n Determine a balanced chemical equation for a given chemical phenomenon.
- P2.1.B.o Calculate, estimate, or predict an unknown quantity from known quantities by selecting and following a logical computational pathway and attending to precision (e.g., performing dimensional analysis and attending to significant figures).

Requirement Area 13 - Advanced Physics Content Knowledge (Options)

Requirement Area P2.2: Advanced Physics Content Knowledge

Area P2.2.A: Kinematics and Dynamics

- P2.2.A.a All forces share certain common characteristics when considered by observers in inertial reference frames.
- P2.2.A.b The acceleration of the center of mass of a system is related to the net force exerted on the system.
- P2.2.A.c The internal structure of a system determines many properties of the system
- P2.2.A.d At the macroscopic level, forces can be categorized as either long-range (action-at-a-distance) forces or contact forces.
- P2.2.A.e Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles
- P2.2.A.f All forces share certain common characteristics when P2.2.A.g considered by observers in inertial reference frames.
- P2.2.A.g The acceleration of an object interacting with other objects can be predicted.
- P2.2.A.h The acceleration of the center of mass of a system is related to the net force exerted on the system.

Area P2.2.B: Motion, Energy, and Momentum

- P2.2.B.a A field associates a value of some physical quantity with every point in space. Field models are useful for describing interactions that occur at a distance (long-range forces), as well as a variety of other physical phenomena.
- P2.2.B.b Certain types of forces are considered fundamental.
- P2.2.B.c Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles.
- P2.2.B.d The acceleration of the center of mass of a system is related to the net force exerted on the system.
- P2.2.B.e All forces share certain common characteristics when considered by observers in inertial reference frames.
- P2.2.B.f Certain quantities are conserved, in the sense that the changes of those quantities in a given system are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems.
- P2.2.B.g A force exerted on an object can change the kinetic energy of the object.
- P2.2.B.h A force exerted on an object can change the momentum of the object.
- P2.2.B.i Interactions with other objects or systems can change the total linear momentum of a system.
- P2.2.B.j Certain quantities are conserved, in the sense that the changes of those quantities in a given system are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems.
- P2.2.B.k The linear momentum of a system is conserved.
- P2.2.B.l A force exerted on an object can cause a torque on that object.

Area P2.2.C: Electric Charge and Force

- P2.2.C.a Electric charge is a property of an object or a system that affects its interactions with other objects or systems containing charge
- P2.2.C.b Make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes, including conservation of charge in simple circuits.
- P2.2.C.c Choose and justify the selection of data needed to determine resistivity for a given material.
- P2.2.C.d Apply conservation of energy concepts to the design of an experiment that will demonstrate the validity of Kirchhoff's loop rule in a circuit with only a battery and resistors either in series or in, at most, one pair of parallel branches.
- P2.2.C.e Apply conservation of electric charge (Kirchhoff's junction rule) to the comparison of electric current in various segments of an electrical circuit with a single battery and resistors in series and in, at most, one parallel branch and predict how those values would change if configurations of the circuit are changed

Area P2.2.D: Mechanical Waves and Sound

- P2.2.D.a A wave is a traveling disturbance that transfers energy and momentum
- P2.2.D.b A periodic wave is one that repeats as a function of both time and position and can be described by its amplitude, frequency, wavelength, speed, and energy.
- P2.2.D.c Interference and superposition lead to standing waves and beats.

Area P2.2.E: Astronomy and Astrophysics

- P2.2.E.a Patterns in ancient structures, instruments, philosophies, and civilizations influenced the study of astronomy.
- P2.2.E.b Patterns in telescopic data of various electromagnetic spectra to explain astronomical phenomena.
- P2.2.E.c Significance of historical and future space exploration as they relate to affecting leaps in technology, cultural cooperation, knowledge, and inspiration.
- P2.2.E.d Structure and properties of objects in our solar system and the zones they inhabit.
- P2.2.E.e Explain the formation of the solar system leading to differing proportions of matter and energy within varying areas of the system.
- P2.2.E.f Model gravitational force at varying scale and proportion that explain motion and interaction of objects in the solar system.
- P2.2.E.g Explain stability and change during the process of stellar evolution from birth to death of a star.
- P2.2.E.h Evidence from the Hertzsprung-Russell diagram to investigate properties (structure) of stars.
- P2.2.E.i Explain the patterns that describe the formation of the universe. Emphasize the scientific theory of the Big Bang and evidence that supports it.
- P2.2.E.j Evidence to support the existence of dark matter and dark energy.