Physics

Subject: Science
Grade: 11
Expectations: 47
Breakouts: 253

(a) Introduction.

1. Physics. In Physics, students conduct laboratory and field investigations, use scientific practices during investigations, and make informed decisions using critical thinking and scientific problem solving. Students study a variety of topics that include: laws of motion, changes within physical systems and conservation of energy and momentum, forces, characteristics and behavior of waves, and electricity and magnetism. Students will apply conceptual knowledge and collaborative skills to experimental design, implementation, and interpretation. By the end of Grade 12, students are expected to gain sufficient knowledge of the scientific and engineering practices across the disciplines of science to make informed decisions using critical thinking and scientific problem solving.
2. Nature of science. Science, as defined by the National Academy of Sciences, is the "use of evidence to construct testable explanations and predictions of natural phenomena, as well as the knowledge generated through this process." This vast body of changing and increasing knowledge is described by physical, mathematical, and conceptual models. Students should know that some questions are outside the realm of science because they deal with phenomena that are not currently scientifically testable.
3. Scientific hypotheses and theories. Students are expected to know that:
    a. hypotheses are tentative and testable statements that must be capable of being supported or not supported by observational evidence. Hypotheses of durable explanatory power that have been tested over a wide variety of conditions are incorporated into theories; and
    b. scientific theories are based on natural and physical phenomena and are capable of being tested by multiple independent researchers. Unlike hypotheses, scientific theories are well established and highly reliable explanations, but they may be subject to change as new areas of science and new technologies are developed.
4. Scientific inquiry. Scientific inquiry is the planned and deliberate investigation of the natural world using scientific and engineering practices. Scientific methods of investigation are descriptive, comparative, or experimental. The method chosen should be appropriate to the question being asked. Student learning for different types of investigations include descriptive investigations, which involve collecting data and recording observations without making comparisons; comparative investigations, which involve collecting data with variables that are manipulated to compare results; and experimental investigations, which involve processes similar to comparative investigations but in which a control is identified.
    a. Scientific practices. Students should be able to ask questions, plan and conduct investigations to answer questions, and explain phenomena using appropriate tools and models.
    b. Engineering practices. Students should be able to identify problems and design solutions using appropriate tools and models.
5. Science and social ethics. Scientific decision making is a way of answering questions about the natural world involving its own set of ethical standards about how the process of science should be carried out. Students should be able to distinguish between scientific decision-making methods (scientific methods) and ethical and social decisions that involve science (the application of scientific information).

6. Science consists of recurring themes and making connections between overarching concepts. Recurring themes include systems, models, and patterns. All systems have basic properties that can be described in space, time, energy, and matter. Change and constancy occur in systems as patterns and can be observed, measured, and modeled. These patterns help to make predictions that can be scientifically tested, while models allow for boundary specification and provide a tool for understanding the ideas presented. Students should analyze a system in terms of its components and how these components relate to each other, to the whole, and to the external environment.

7. Statements containing the word "including" reference content that must be mastered, while those containing the phrase "such as" are intended as possible illustrative examples.

(b) Knowledge and Skills Statements

(1) Scientific and engineering practices. The student, for at least 40% of instructional time, asks questions, identifies problems, and plans and safely conducts classroom, laboratory, and field investigations to answer questions, explain phenomena, or design solutions using appropriate tools and models. The student is expected to:

(A) ask questions and define problems based on observations or information from text, phenomena, models, or investigations;

(i) ask questions based on observations or information from text, phenomena, models, or investigations

(ii) define problems based on observations or information from text, phenomena, models, or investigations

(B) apply scientific practices to plan and conduct descriptive, comparative, and experimental investigations, and use engineering practices to design solutions to problems;

(i) apply scientific practices to plan descriptive investigations

(ii) apply scientific practices to plan comparative investigations

(iii) apply scientific practices to plan experimental investigations

(iv) apply scientific practices to conduct descriptive investigations

(v) apply scientific practices to conduct comparative investigations

(vi) apply scientific practices to conduct experimental investigations

(vii) use engineering practices to design solutions to problems

(C) use appropriate safety equipment and practices during laboratory, classroom, and field investigations as outlined in Texas Education Agency-approved safety standards;

(i) use appropriate safety equipment during laboratory investigations as outlined in Texas Education Agency-approved safety standards

(ii) use appropriate safety equipment during classroom investigations as outlined in Texas Education Agency-approved safety standards

(iii) use appropriate safety equipment during field investigations as outlined in Texas Education Agency-approved safety standards

(iv) use appropriate safety practices during laboratory investigations as outlined in Texas Education Agency-approved safety standards

(v) use appropriate safety practices during classroom investigations as outlined in Texas Education Agency-approved safety standards

(vi) use appropriate safety practices during field investigations as outlined in Texas Education Agency-approved safety standards

(D) use appropriate tools such as balances, ballistic carts or equivalent, batteries, computers, constant velocity cars, convex lenses, copper wire, discharge tubes with power supply (H, He, Ne, Ar), data acquisition probes and software, dynamics and force demonstration equipment, electrostatic generators, electrostatic kits, friction blocks, graph paper, graphing technology, hand-held visual spectroscopes, inclined planes, iron filings, lab masses, laser pointers, magnets, magnetic compasses, metric rulers, motion detectors, multimeters (current, voltage, resistance), optics bench, optics kit, photogates, plane mirrors, prisms, protractors, pulleys, resistors, rope or string, scientific calculators, stopwatches, springs, spring scales, switches, tuning forks, wave generators, or other equipment and materials that will produce the same results;

(i) use appropriate tools

(E) collect quantitative data using the International System of Units (SI) and qualitative data as evidence;

(i) collect quantitative data using the International System of Units (SI)

(ii) collect qualitative data as evidence

(F) organize quantitative and qualitative data using bar charts, line graphs, scatter plots, data tables, labeled diagrams, and conceptual mathematical relationships;

(i) organize quantitative data using bar charts

(ii) organize quantitative data using line graphs

(iii) organize quantitative data using scatter plots

(iv) organize quantitative data using data tables

(v) organize quantitative data using labeled diagrams

(vi) organize quantitative data using conceptual mathematical relationships

(vii) organize qualitative data using data tables

(viii) organize qualitative data using labeled diagrams

(ix) organize qualitative data using conceptual mathematical relations

(G) develop and use models to represent phenomena, systems, processes, or solutions to engineering problems; and

(i) develop models to represent phenomena, systems, processes, or solutions to engineering problems

(ii) use models to represent phenomena, systems, processes, or solutions to engineering problems

(H) distinguish among scientific hypotheses, theories, and laws.

(i) distinguish among scientific hypotheses, theories, and laws

(2) Scientific and engineering practices. The student analyzes and interprets data to derive meaning, identify features and patterns, and discover relationships or correlations to develop evidence-based arguments or evaluate designs. The student is expected to:

(A) identify advantages and limitations of models such as their size, scale, properties, and materials;

(i) identify advantages of models

(ii) identify limitations of models

(B) analyze data by identifying significant statistical features, patterns, sources of error, and limitations;

(i) analyze data by identifying significant statistical features

(ii) analyze data by identifying patterns

(iii) analyze data by identifying sources of error

(iv) analyze data by identifying limitations

(C) use mathematical calculations to assess quantitative relationships in data; and

(i) use mathematical calculations to assess quantitative relationships in data

(D) evaluate experimental and engineering designs.

(i) evaluate experimental designs

(ii) evaluate engineering designs

(3) Scientific and engineering practices. The student develops evidence-based explanations and communicates findings, conclusions, and proposed solutions. The student is expected to:

(A) develop explanations and propose solutions supported by data and models and consistent with scientific ideas, principles, and theories;

(i) develop explanations supported by data and consistent with scientific ideas

(ii) develop explanations supported by data and consistent with scientific principles

(iii) develop explanations supported by data and consistent with scientific theories

(iv) develop explanations supported by models and consistent with scientific ideas

(v) develop explanations supported by models and consistent with scientific principles

(vi) develop explanations supported by models and consistent with scientific theories

(vii) propose solutions supported by data and consistent with scientific ideas

(viii) propose solutions supported by data and consistent with scientific principles

(ix) propose solutions supported by data and consistent with scientific theories

(x) propose solutions supported by models and consistent with scientific ideas

(xi) propose solutions supported by models and consistent with scientific principles

(xii) propose solutions supported by models and consistent with scientific theories

(B) communicate explanations and solutions individually and collaboratively in a variety of settings and formats; and

(i) communicate explanations individually in a variety of settings

(ii) communicate explanations individually in a variety of formats

(iii) communicate explanations collaboratively in a variety of settings

(iv) communicate explanations collaboratively in a variety of formats

(v) communicate solutions individually in a variety of settings

(vi) communicate solutions individually in a variety of formats

(vii) communicate solutions collaboratively in a variety of settings

(viii) communicate solutions collaboratively in a variety of formats

(C) engage respectfully in scientific argumentation using applied scientific explanations and empirical evidence.

(i) engage respectfully in scientific argumentation using applied scientific explanations

(ii) engage respectfully in scientific argumentation using empirical evidence

(4) Scientific and engineering practices. The student knows the contributions of scientists and recognizes the importance of scientific research and innovation on society. The student is expected to:

(A) analyze, evaluate, and critique scientific explanations and solutions by using empirical evidence, logical reasoning, and experimental and observational testing, so as to encourage critical thinking by the student;

(i) analyze scientific explanations and solutions by using empirical evidence so as to encourage critical thinking by the student

(ii) analyze scientific explanations and solutions by using logical reasoning so as to encourage critical thinking by the student

(iii) analyze scientific explanations and solutions by using experimental testing so as to encourage critical thinking by the student

(iv) analyze scientific explanations and solutions by using observational testing so as to encourage critical thinking by the student

(v) evaluate scientific explanations and solutions by using empirical evidence so as to encourage critical thinking by the student

(vi) evaluate scientific explanations and solutions by using logical reasoning so as to encourage critical thinking by the student

(vii) evaluate scientific explanations and solutions by using experimental testing so as to encourage critical thinking by the student

(viii) evaluate scientific explanations and solutions by using observational testing so as to encourage critical thinking by the student

(ix) critique scientific explanations and solutions by using empirical evidence so as to encourage critical thinking by the student

(x) critique scientific explanations and solutions by using logical reasoning so as to encourage critical thinking by the student

(xi) critique scientific explanations and solutions by using experimental testing so as to encourage critical thinking by the student

(xii) critique scientific explanations and solutions by using observational testing so as to encourage critical thinking by the student

(B) relate the impact of past and current research on scientific thought and society, including research methodology, cost-benefit analysis, and contributions of diverse scientists as related to the content; and

(i) relate the impact of past research on scientific thought, including research methodology

(ii) relate the impact of past research on scientific thought, including cost-benefit analysis

(iii) relate the impact of past research on scientific thought, including contributions of diverse scientists as related to the content

(iv) relate the impact of past research on society, including research methodology

(v) relate the impact of past research on society, including cost-benefit analysis

(vi) relate the impact of past research on society, including contributions of diverse scientists as related to the content

(vii) relate the impact of current research on scientific thought, including research methodology

(viii) relate the impact of current research on scientific thought, including cost-benefit analysis

(ix) relate the impact of current research on scientific thought, including contributions of diverse scientists as related to the content

(x) relate the impact of current research on society, including research methodology

(xi) relate the impact of current research on society, including cost-benefit analysis

(xii) relate the impact of current research on society, including contributions of diverse scientists as related to the content

(C) research and explore resources such as museums, libraries, professional organizations, private companies, online platforms, and mentors employed in a science, technology, engineering, and mathematics (STEM) field in order to investigate STEM careers.

(i) research STEM careers

(ii) explore resources in order to investigate STEM careers

(5) Science concepts. The student knows and applies the laws governing motion in a variety of situations. The student is expected to:

(A) analyze different types of motion by generating and interpreting position versus time, velocity versus time, and acceleration versus time using hand graphing and real-time technology such as motion detectors, photogates, or digital applications;

(i) analyze different types of motion by generating position versus time using hand graphing

(ii) analyze different types of motion by generating position versus time using real-time technology

(iii) analyze different types of motion by generating velocity versus time using hand graphing

(iv) analyze different types of motion by generating velocity versus time using real-time technology

(v) analyze different types of motion by generating acceleration versus time using hand graphing

(vi) analyze different types of motion by generating acceleration versus time using real-time technology

(vii) analyze different types of motion by interpreting position versus time using hand graphing

(viii) analyze different types of motion by interpreting position versus time using real-time technology

(ix) analyze different types of motion by interpreting velocity versus time using hand graphing

(x) analyze different types of motion by interpreting velocity versus time using real-time technology

(xi) analyze different types of motion by interpreting acceleration versus time using hand graphing

(xii) analyze different types of motion by interpreting acceleration versus time using real-time technology

(B) define scalar and vector quantities related to one- and two-dimensional motion and combine vectors using both graphical vector addition and the Pythagorean theorem;

(i) define scalar quantities related to one-dimensional motion

(ii) define scalar quantities related to two-dimensional motion

(iii) define vector quantities related to one-dimensional motion

(iv) define vector quantities related to two-dimensional motion

(v) combine vectors using graphical vector addition

(vi) combine vectors using the Pythagorean theorem

(C) describe and analyze motion in one dimension using equations with the concepts of distance, displacement, speed, velocity, frames of reference, and acceleration;

(i) describe motion in one dimension using equations with the [concept] of distance

(ii) describe motion in one dimension using equations with the [concept] of displacement

(iii) describe motion in one dimension using equations with the [concept] of speed

(iv) describe motion in one dimension using equations with the [concept] of velocity

(v) describe motion in one dimension using equations with the [concept] of frames of reference

(vi) describe motion in one dimension using equations with the [concept] of acceleration

(vii) analyze motion in one dimension using equations with the [concept] of distance

(viii) analyze motion in one dimension using equations with the [concept] of displacement

(ix) analyze motion in one dimension using equations with the [concept] of speed

(x) analyze motion in one dimension using equations with the [concept] of velocity

(xi) analyze motion in one dimension using equations with the [concept] of frames of reference

(xii) analyze motion in one dimension using equations with the [concept] of acceleration

(D) describe and analyze acceleration in uniform circular and horizontal projectile motion in two dimensions using equations;

(i) describe acceleration in uniform circular motion in two dimensions using equations

(ii) describe acceleration in horizontal projectile motion in two dimensions using equations

(iii) analyze acceleration in uniform circular motion in two dimensions using equations

(iv) analyze acceleration in horizontal projectile motion in two dimensions using equations

(E) explain and apply the concepts of equilibrium and inertia as represented by Newton's first law of motion using relevant real-world examples such as rockets, satellites, and automobile safety devices;

(i) explain the concept of equilibrium as represented by Newton's first law of motion using relevant real-world examples

(ii) explain the concept of inertia as represented by Newton's first law of motion using relevant real-world examples

(iii) apply the concept of equilibrium as represented by Newton's first law of motion using relevant real-world examples

(iv) apply the concept of inertia as represented by Newton's first law of motion using relevant real-world examples

(F) calculate the effect of forces on objects, including tension, friction, normal, gravity, centripetal, and applied forces, using free body diagrams and the relationship between force and acceleration as represented by Newton's second law of motion;

(i) calculate the effect of forces on objects, including tension, using free body diagrams

(ii) calculate the effect of forces on objects, including tension, using the relationship between force and acceleration as represented by Newton's second law of motion

(iii) calculate the effect of forces on objects, including friction, using free body diagrams

(iv) calculate the effect of forces on objects, including friction, using the relationship between force and acceleration as represented by Newton's second law of motion

(v) calculate the effect of forces on objects, including normal, using free body diagrams

(vi) calculate the effect of forces on objects, including normal, using the relationship between force and acceleration as represented by Newton's second law of motion

(vii) calculate the effect of forces on objects, including gravity, using free body diagrams

(viii) calculate the effect of forces on objects, including gravity, using the relationship between force and acceleration as represented by Newton's second law of motion

(ix) calculate the effect of forces on objects, including centripetal, using free body diagrams

(x) calculate the effect of forces on objects, including centripetal, using the relationship between force and acceleration as represented by Newton's second law of motion

(xi) calculate the effect of forces on objects, including applied forces, using free body diagrams

(xii) calculate the effect of forces on objects, including applied forces, using the relationship between force and acceleration as represented by Newton's second law of motion

(G) illustrate and analyze the simultaneous forces between two objects as represented in Newton's third law of motion using free body diagrams and in an experimental design scenario; and

(i) illustrate the simultaneous forces between two objects as represented in Newton's third law of motion using free body diagrams

(ii) illustrate the simultaneous forces between two objects as represented in Newton's third law of motion in an experimental design scenario

(iii) analyze the simultaneous forces between two objects as represented in Newton's third law of motion using free body diagrams

(iv) analyze the simultaneous forces between two objects as represented in Newton's third law of motion and in an experimental design scenario

(H) describe and calculate, using scientific notation, how the magnitude of force between two objects depends on their masses and the distance between their centers, and predict the effects on objects in linear and orbiting systems using Newton's law of universal gravitation.

(i) describe, using scientific notation, how the magnitude of force between two objects depends on their masses

(ii) describe, using scientific notation, how the magnitude of force between two objects depends on the distance between their centers

(iii) calculate, using scientific notation, how the magnitude of force between two objects depends on their masses

(iv) calculate, using scientific notation, how the magnitude of force between two objects depends on the distance between their centers

(v) predict the effects on objects in linear systems using Newton's law of universal gravitation

(vi) predict the effects on objects in orbiting systems using Newton's law of universal gravitation

(6) Science concepts. The student knows the nature of forces in the physical world. The student is expected to:

(A) use scientific notation and predict how the magnitude of the electric force between two objects depends on their charges and the distance between their centers using Coulomb's law;

(i) use scientific notation

(ii) predict how the magnitude of the electric force between two objects depends on their charges using Coulomb's law

(iii) predict how the magnitude of the electric force between two objects depends on the distance between their centers using Coulomb's law

(B) identify and describe examples of electric and magnetic forces and fields in everyday life such as generators, motors, and transformers;

(i) identify examples of electric forces in everyday life

(ii) identify examples of electric fields in everyday life

(iii) identify examples of magnetic forces in everyday life

(iv) identify examples of magnetic fields in everyday life

(v) describe examples of electric forces in everyday life

(vi) describe examples of electric fields in everyday life

(vii) describe examples of magnetic forces in everyday life

(viii) describe examples of magnetic fields in everyday life

(C) investigate and describe conservation of charge during the processes of induction, conduction, and polarization using different materials such as electroscopes, balloons, rods, fur, silk, and Van de Graaf generators;

(i) investigate conservation of charge during the processes of induction using different materials

(ii) investigate conservation of charge during the processes of conduction using different materials

(iii) investigate conservation of charge during the processes polarization using different materials

(iv) describe conservation of charge during the processes of induction using different materials

(v) describe conservation of charge during the processes of conduction using different materials

(vi) describe conservation of charge during the processes polarization using different materials

(D) analyze, design, and construct series and parallel circuits using schematics and materials such as switches, wires, resistors, lightbulbs, batteries, voltmeters, and ammeters; and

(i) analyze series circuits using schematics

(ii) analyze series circuits using materials

(iii) analyze parallel circuits using schematics

(iv) analyze parallel circuits using materials

(v) design series circuits using schematics

(vi) design series circuits using materials

(vii) design parallel circuits using schematics

(viii) design parallel circuits using materials

(ix) construct series circuits using schematics

(x) construct series circuits using materials

(xi) construct parallel circuits using schematics

(xii) construct parallel circuits using materials

(E) calculate current through, potential difference across, resistance of, and power used by electric circuit elements connected in both series and parallel circuits using Ohm's law.

(i) calculate current through electric circuit elements connected in series circuits using Ohm's law

(ii) calculate current through electric circuit elements connected in parallel circuits using Ohm's law

(iii) calculate potential difference across electric circuit elements connected in series circuits using Ohm's law

(iv) calculate potential difference across electric circuit elements connected in parallel circuits using Ohm's law

(v) calculate resistance of electric circuit elements connected in series circuits using Ohm's law

(vi) calculate resistance of electric circuit elements connected in parallel circuits using Ohm's law

(vii) calculate power used by electric circuit elements connected in series circuits using Ohm's law

(viii) calculate power used by electric circuit elements connected in parallel circuits using Ohm's law

(7) Science concepts. The student knows that changes occur within a physical system and applies the laws of conservation of energy and momentum. The student is expected to:

(A) calculate and explain work and power in one dimension and identify when work is and is not being done by or on a system;

(i) calculate work in one dimension

(ii) calculate power in one dimension

(iii) explain work in one dimension

(iv) explain power in one dimension

(v) identify when work is being done by or on a system

(vi) identify when work is not being done by or on a system

(B) investigate and calculate mechanical, kinetic, and potential energy of a system;

(i) investigate mechanical energy of a system

(ii) investigate kinetic energy of a system

(iii) investigate potential energy of a system

(iv) calculate mechanical energy of a system

(v) calculate kinetic energy of a system

(vi) calculate potential energy of a system

(C) apply the concept of conservation of energy using the work-energy theorem, energy diagrams, and energy transformation equations, including transformations between kinetic, potential, and thermal energy;

(i) apply the concept of conservation of energy using the work-energy theorem

(ii) apply the concept of conservation of energy using energy diagrams

(iii) apply the concept of conservation of energy using energy transformation equations, including transformations between kinetic, potential, and thermal energy

(D) calculate and describe the impulse and momentum of objects in physical systems such as automobile safety features, athletics, and rockets; and

(i) calculate the impulse of objects in physical systems

(ii) calculate the momentum of objects in physical systems

(iii) describe the impulse of objects in physical systems

(iv) describe the momentum of objects in physical systems

(E) analyze the conservation of momentum qualitatively in inelastic and elastic collisions in one dimension using models, diagrams, and simulations.

(i) analyze the conservation of momentum qualitatively in inelastic collisions in one dimension using models

(ii) analyze the conservation of momentum qualitatively in inelastic collisions in one dimension using diagrams

(iii) analyze the conservation of momentum qualitatively in inelastic collisions in one dimension using simulations

(iv) analyze the conservation of momentum qualitatively in elastic collisions in one dimension using models

(v) analyze the conservation of momentum qualitatively in elastic collisions in one dimension using diagrams

(vi) analyze the conservation of momentum qualitatively in elastic collisions in one dimension using simulations

(8) Science concepts. The student knows the characteristics and behavior of waves. The student is expected to:

(A) examine and describe simple harmonic motion such as masses on springs and pendulums and wave energy propagation in various types of media such as surface waves on a body of water and pulses in ropes;

(i) examine simple harmonic motion

(ii) describe simple harmonic motion

(iii) examine wave energy propagation in various types of media

(iv) describe wave energy propagation in various types of media

(B) compare the characteristics of transverse and longitudinal waves, including electromagnetic and sound waves;

(i) compare the characteristics of transverse and longitudinal waves, including electromagnetic waves

(ii) compare the characteristics of transverse and longitudinal waves, including sound waves

(C) investigate and analyze characteristics of waves, including velocity, frequency, amplitude, and wavelength, and calculate using the relationships between wave speed, frequency, and wavelength;

(i) investigate characteristics of waves, including velocity

(ii) investigate characteristics of waves, including frequency

(iii) investigate characteristics of waves, including amplitude

(iv) investigate characteristics of waves, including wavelength

(v) analyze characteristics of waves, including velocity

(vi) analyze characteristics of waves, including frequency

(vii) analyze characteristics of waves, including amplitude

(viii) analyze characteristics of waves, including wavelength

(ix) calculate using the relationships between wave speed, frequency, and wavelength

(D) investigate behaviors of waves, including reflection, refraction, diffraction, interference, standing wave, the Doppler effect and polarization and superposition; and

(i) investigate behaviors of waves, including reflection

(ii) investigate behaviors of waves, including refraction

(iii) investigate behaviors of waves, including diffraction

(iv) investigate behaviors of waves, including interference

(v) investigate behaviors of waves, including standing wave

(vi) investigate behaviors of waves, including the Doppler effect

(vii) investigate behaviors of waves, including polarization

(viii) investigate behaviors of waves, including superposition

(E) compare the different applications of the electromagnetic spectrum, including radio telescopes, microwaves, and x-rays;

(i) compare the different applications of the electromagnetic spectrum, including radio telescopes

(ii) compare the different applications of the electromagnetic spectrum, including microwaves

(iii) compare the different applications of the electromagnetic spectrum, including x-rays

(F) investigate the emission spectra produced by various atoms and explain the relationship to the electromagnetic spectrum; and

(i) investigate the emission spectra produced by various atoms

(ii) explain the relationship [of the emission spectra] to the electromagnetic spectrum

(G) describe and predict image formation as a consequence of reflection from a plane mirror and refraction through a thin convex lens.

(i) describe image formation as a consequence of reflection from a plane mirror

(ii) describe image formation as a consequence of refraction through a thin convex lens

(iii) predict image formation as a consequence of reflection from a plane mirror

(iv) predict image formation as a consequence of refraction through a thin convex lens

(9) Science concepts. The student knows examples of quantum phenomena and their applications. The student is expected to:

(A) describe the photoelectric effect and emission spectra produced by various atoms and how both are explained by the photon model for light;

(i) describe the photoelectric effect

(ii) describe the emission spectra produced by various atoms

(iii) describe how [the photoelectric effect is] explained by the photon model for light

(iv) describe how [emission spectra produced by various atoms is] explained by the photon model for light

(B) investigate Malus's Law and describe examples of applications of wave polarization, including 3-D movie glasses and LCD computer screens;

(i) investigate Malus's Law

(ii) describe examples of applications of wave polarization, including 3-D movie glasses

(iii) describe examples of applications of wave polarization, including LCD computer screens

(C) compare and explain how superposition of quantum states is related to the wave-particle duality nature of light; and

(i) compare how superposition of quantum states is related to the wave-particle duality nature of light

(ii) explain how superposition of quantum states is related to the wave-particle duality nature of light

(D) give examples of applications of quantum phenomena, including the Heisenberg uncertainty principle, quantum computing, and cybersecurity.

(i) give examples of applications of quantum phenomena, including the Heisenberg uncertainty principle

(ii) give examples of applications of quantum phenomena, including quantum computing

(iii) give examples of applications of quantum phenomena, including cybersecurity