

# Tennessee Science Curriculum Framework

## Physics

### Course Description

Physics is a laboratory course that examines the relationship between matter and energy and how they interact. This course will have a strong emphasis in the mathematics of physics. Students explore physics concepts through an inquiry approach.

Physics students investigate:

- Inquiry
- Technology and Engineering
- Mathematics of Physics
- Mechanics
- Thermodynamics
- Waves and Sound
- Light and Optics
- Electricity and Magnetism
- Atomic and Nuclear Physics

### Embedded Inquiry

#### Conceptual Strand

*Understandings about scientific inquiry and the ability to conduct inquiry are essential for living in the 21<sup>st</sup> century.*

#### Guiding Question

*What tools, skills, and knowledge are needed to conduct scientific inquiry?*

#### Course Level Expectations

**CLE 3231.Inq.1** Recognize that science is a progressive endeavor that reevaluates and extends what is already accepted.

**CLE 3231.Inq.2** Design and conduct scientific investigations to explore new phenomena, verify previous results, test how well a theory predicts, and compare opposing theories.

**CLE 3231.Inq.3** Use appropriate tools and technology to collect precise and accurate data.

**CLE 3231.Inq.4** Apply qualitative and quantitative measures to analyze data and draw conclusions that are free of bias.

**CLE 3231.Inq.5** Compare experimental evidence and conclusions with those drawn by others about the same testable question.

**CLE 3231.Inq.6** Communicate and defend scientific findings.

### **Checks for Understanding (Formative/Summative Assessment)**

- ✓ **3231.Inq.1** Trace the historical development of a scientific principle or theory.
- ✓ **3231.Inq.2** Conduct scientific investigations that include testable questions, verifiable hypotheses, and appropriate variables to explore new phenomena or verify the experimental results of others.
- ✓ **3231.Inq.3** Select appropriate independent, dependent, or controlled variables for an experiment.
- ✓ **3231.Inq.4** Analyze the components of a properly designed scientific investigation.
- ✓ **3231.Inq.5** Perform an experiment to test a prediction.
- ✓ **3231.Inq.6** Select appropriate tools and technology to collect precise and accurate quantitative and qualitative data.
- ✓ **3231.Inq.7** Determine if data supports or contradicts a hypothesis or conclusion.
- ✓ **3231.Inq.8** Recognize, analyze, and evaluate alternative explanations for the same set of observations.
- ✓ **3231.Inq.9** Evaluate the accuracy and precision of data.
- ✓ **3231.Inq.10** State a conclusion in terms of the relationship between two or more variables.
- ✓ **3231.Inq.11** Defend a conclusion based on scientific evidence.
- ✓ **3231.Inq.12** Analyze experimental results and identify possible sources of bias or experimental error.
- ✓ **3231.Inq.13** Compare the results of an experiment with what is already known about the topic under investigation.
- ✓ **3231.Inq.14** Suggest alternative explanations for the same set of observations.
- ✓ **3231.Inq.15** Formulate and revise scientific explanations and models using logic and evidence.
- ✓ **3231.Inq.16** Compare conclusions that offer different, but acceptable explanations for the same set of experimental data.

## **Embedded Technology and Engineering**

### **Conceptual Strand**

*Society benefits when engineers apply scientific discoveries to design materials and processes that develop into enabling technologies.*

### **Guiding Question**

*How do science concepts, engineering skills, and applications of technology improve the quality of life?*

### **Course Level Expectations**

**CLE 3231.T/E.1** Explore the impact of technology on social, political, and economic systems.

**CLE 3231.T/E.2** Differentiate among elements of the engineering design cycle: design constraints, model building, testing, evaluating, modifying, and retesting.

**CLE 3231.T/E.3** Explain the relationship between the properties of a material and the use of the material in the application of a technology.

**CLE 3231.T/E.4** Describe the dynamic interplay among science, technology, and engineering within living, earth-space, and physical systems.

**Checks for Understanding (Formative/Summative Assessment)**

✓**3231.T/E.1** Select appropriate tools and procedures best suited to conduct a specified scientific inquiry.

✓**3231.T/E.2** Apply the engineering design process to construct a prototype that meets developmentally appropriate specifications.

✓**3231.T/E.3** Evaluate a protocol to determine the degree to which an engineering design process was successfully applied.

✓**3231.T/E.4** Explore how the unintended consequences of new technologies can impact human and non-human communities.

✓**3231.T/E.5** Evaluate the overall benefit to cost ratio of a new technology.

✓**3231.T/E.6** Present research on current engineering technologies that contribute to improvements in our daily lives.

✓**3231.T/E.7** Design a series of multi-view drawings that can be used by others to construct an adaptive design and test its effectiveness.

## **Embedded Mathematics**

### **Conceptual Strand**

*Physics applies mathematics to investigate questions, solve problems, and communicate findings.*

### **Guiding Question**

*What mathematical skills and understandings are needed to successfully investigate physics?*

### **Course Level Expectations**

**CLE.3231.Math.1** Graph relationships and functions between manipulated (independent) variables and responding (dependent) variables.

**CLE.3231.Math.2** Solve for variables in an algebraic formula.

**CLE.3231.Math.3** Apply statistical techniques to manipulate data.

**CLE.3231.Math.4** Investigate trigonometric connections to physics.

**CLE.3231.Math.5** Utilize calculus to understand physics principles.

### **Checks for Understanding (Formative/Summative Assessment)**

✓**3231.Math.1** Plot points on the Cartesian coordinate graphing system.

✓**3231.Math.2** Graph basic relations and functions.

✓**3231.Math.3** Determine the slope of a linear function.

✓**3231.Math.4** Determine the frequency, range, mode, median, and mean from a data set.

- ✓ **3231.Math.5** Utilize a graphing calculator to enter data and find basic statistics: frequency, range, means, mode, median, and standard deviation.
- ✓ **3231.Math.6** Solve for all variables based on a formula.
- ✓ **3231.Math.7** Solve for the  $t$  – value,  $p$  (probability), and % of confidence between two lists of data (manipulated variables and responding variables).
- ✓ **3231.Math.8** Reject or accept a null hypothesis based on statistical analysis.
- ✓ **3231.Math.9** Find the regression line (equation) between data for manipulated and responding variables.
- ✓ **3231.Math.10** Utilize trigonometric functions (sine, cosine, and tangent) to solve simple vector problems.
- ✓ **3231.Math.11** Apply the laws of sine and cosine to solve vector problems.
- ✓ **3231.Math.12** Solve mechanics problems using the quadratic formula.
- ✓ **3231.Math.13** Find the derivative (velocity function) of a distance (displacement) function.
- ✓ **3231.Math.14** Find the derivative (acceleration function) of a velocity function.
- ✓ **3231.Math.15** Link various calculus procedures to solve physics problems.

## Standard 1 – Mechanics

### Conceptual Strand 1

*Laws and properties of mechanics are the foundations of physics.*

### Guiding Question 1

*How do the laws and properties of mechanics govern the basic understanding of physics.*

### Course Level Expectations

- CLE 3231.1.1** Investigate fundamental physical quantities of mass and time.
- CLE 3231.1.2** Analyze and apply Newton’s three laws of motion.
- CLE 3231.1.3** Understand work, energy, and power.
- CLE 3231.1.4** Investigate kinematics and dynamics.
- CLE 3231.1.5** Investigate and apply Archimedes’s Principle.
- CLE 3231.1.6** Explore Pascal’s Principle.
- CLE 3231.1.7** Analyze applications of Bernoulli’s Principle.

### Checks for Understanding (Formative/Summative Assessment)

- ✓ **3231.1.1** Explore displacement, velocity, and acceleration [Average Velocity:  $v_{av} = (d_f - d_i) / (t_f - t_i)$ ; Final Velocity:  $v_f = v_i + a\Delta t$ ; Final Velocity of Falling:  $v_f = v_i + g\Delta t$ ; Average Acceleration:  $a_{av} = (v_f - v_i) / (t_f - t_i)$ ; Displacement:  $d = v_i \Delta t + (1/2) a \Delta t^2$ ; Displacement of Falling:  $\Delta d = v_i \Delta t + (1/2) g \Delta t^2$ ].
- ✓ **3231.1.2** Analyze vector diagrams and solve composition and resolution problems for force and momentum.
- ✓ **3231.1.3** Explore characteristics of rectilinear motion and create distance-time graphs (velocity), velocity-time graphs (acceleration and distance).
- ✓ **3231.1.4** Investigate the characteristics of centripetal motion and centripetal acceleration [Centripetal Force:  $F_c = (mv^2)/r$ ; Angular Velocity:  $\omega = \Delta \theta / \Delta t$ ; Angular Acceleration:  $\alpha = \Delta \omega / \Delta t$ ].

✓ **3231.1.5** Evaluate the dynamics of systems in motion including friction, gravity, impulse and momentum, change in momentum, and conservation of momentum. [Coefficient of Friction:  $\mu = F_f/F_N$ ; Law of Universal Gravitation:  $F_G = (G m_1 m_2)/d^2$ ; Impulse and Change of Momentum:  $F \Delta t = m\Delta t$ ].

✓ **3231.1.6** Investigate projectile motion. [Parabolic Equations with Quadratic Formula:

$$X = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}].$$

✓ **3231.1.7** Apply mathematics to solve motion problems.

✓ **3231.1.8** Experiment with elastic and inelastic collisions.

✓ **3231.1.9** Experiment with pendulums [Pendulum period:  $T = 2\pi \sqrt{l/g}$ ].

✓ **3231.1.10** Utilize trigonometry and vector analysis to solve force and momentum problems [Sine, Cosine, Tangent Functions, Law of Sine, and Law of Cosine].

✓ **3231.1.11** Apply elementary calculus to solve motion problems [Velocity = derivative of and acceleration = derivative of velocity].

✓ **3231.1.12** Experiment with elastic and inelastic collisions [Elastic Collisions in One Dimension:  $m_1 v_1 + m_2 v_2 = m_1 v_3 + m_2 v_4$ ; Inelastic Collision in One Dimension:  $m_1 v_1 + m_2 v_2 = (m_1 + m_2) v_3$ ].

✓ **3231.1.13** Distinguish between mass and weight using base units in the SI system.

✓ **3231.1.14** Associate time with the independent variable in most experiments.

✓ **3231.1.15** Relate inertia, force or action-reaction forces to Newton's three laws of motion.

✓ **3231.1.16** Compare, contrast, and apply characteristic properties of scalar and vector quantities.

✓ **3231.1.17** Investigate the definitions of force, work, power, kinetic energy, and potential energy. [Force:  $F = ma$ ; Work:  $W = Fd$ ; Power:  $P = (F\Delta d)/\Delta t$ ; Kinetic Energy:  $E_K = 0.5mv^2$ ; Potential Energy:  $E_P = mg\Delta h$ ].

✓ **3231.1.18** Analyze the characteristics of energy, conservation of energy including friction, and gravitational potential energy [Gravitational Potential Energy:  $E_p = mg\Delta h$ ].

✓ **3231.1.19** Relate work and power to various simple machines, mechanical advantage of different machines, and recognize simple machines that are combined to form compound machines [Work:  $W = F\Delta d$ ; Power:  $p = (F\Delta d)/\Delta t$ ; Efficiency, Efficiency =  $(W_{OUT}/W_{IN}) \times 100\%$ ].

✓ **3231.1.20** Describe rotational equilibrium and relate this factor to torque [Rotational Inertia:  $T = I\alpha$ ; Torque:  $T = Fr$ ].

✓ **3231.1.21** Determine the magnitude of the buoyant force exerted on floating and submerged objects ( $F_B = m_f g = \rho_f V_f g$ ).

✓ **3231.1.22** Investigate the apparent weight of an object submerged in a fluid ( $F_{net} = F_B - F_g$ ).

✓ **3231.1.23** Explain why objects float or sink in terms of force and density.

✓ **3231.1.24** Calculate the pressure exerted by a fluid according to Pascal's Principle ( $P_{inc} = F_1/A_1 = F_2/A_2$ ).

- ✓ **3231.1.25** Calculate how pressure varies with depth ( $P = P_0 + \rho gh$ ).
- ✓ **3231.1.26** Examine the motion of a fluid using the continuity equation ( $A_1v_1 = A_2v_2$ ).
- ✓ **3231.1.27** Recognize the effects of Bernoulli's principle on fluid motion (e.g., lift, ball trajectories, and wind around/over object).

## **Standard 2 – Thermodynamics**

### **Conceptual Strand 2**

*The principles and laws of thermodynamics explain the concepts of energy.*

### **Guiding Question 2**

*How do the laws of thermodynamics relate to the conservation of energy?*

### **Course Level Expectations**

- CLE 3231.2.1** Develop a deep understanding of heat and internal energy.
- CLE 3231.2.2** Compare Celsius, Kelvin and the Absolute temperature scales.
- CLE 3231.2.3** Investigate exchanges in internal energy.

### **Checks for Understanding (Formative/Summative Assessment)**

- ✓ **3231.2.1** Investigate temperature in relationship to kinetic energy.
- ✓ **3231.2.2** Identify the characteristics of internal energy and temperature/heat (joules/calories).
- ✓ **3231.2.3** Investigate changes in heat content (quantity of thermal energy) and relate to kinetic energy and specific heat.
- ✓ **3231.2.4** Investigate potential energy changes (phase changes) of heat of fusion, heat of vaporization, and heat of sublimation [Change in Heat:  $\Delta Q = mH_v$  and  $\Delta Q = mH_s$ ].
- ✓ **3231.2.5** Explore thermal expansion and contraction [Linear Expansion:  $\Delta l = l_i \alpha \Delta T$ ; Volumetric Expansion:  $\Delta V = V_i \beta \Delta T$ ].
- ✓ **3231.2.6** Apply the second law of thermodynamics to the Carnot engine.
- ✓ **3231.2.7** Apply the Laws of Thermodynamics to the atmospheric levels of the earth (i.e., greenhouse effect and global warming).
- ✓ **3231.2.8** Recognize that absolute zero is the absence of molecular kinetic energy.
- ✓ **3231.2.9** Relate the First Law of Thermodynamics as an application of the Law of Conservation of Energy and heat transfer through conduction, convection, and radiation. [Heat Lost = Heat Gained,  $Q_L = Q_G$ ].
- ✓ **3231.2.10** Relate change in heat content (quantity of thermal energy) to kinetic energy and specific heat [Change in Heat:  $\Delta Q = mC\Delta T$ ].

## Standard 3 – Waves

### Conceptual Strand 3

*Investigating wave behavior reveals information about sound and light.*

### Guiding Question 3

*How do the properties of mechanical waves, sound, and light explain the behavior of waves?*

#### Course Level Expectations

**CLE 3231.3.1** Explore conditions associated with simple harmonic motion.

**CLE 3231.3.2** Investigate Hooke's law.

**CLE 3231.3.3** Understand wave mechanics.

**CLE 3231.3.4** Examine the Doppler Effect.

**CLE 3231.3.5** Explore the characteristics and properties of sound.

#### Checks for Understanding (Formative/Summative Assessment)

✓ **3231.3.1** Investigate simple harmonic motion.

✓ **3231.3.2** Investigate and analyze wavelength, frequency, and amplitude of longitudinal and transverse waves.

✓ **3231.3.3** Describe a wave interaction as reflection, refraction, diffraction, or interference.

✓ **3231.3.4** Explore Hooke's Law.

✓ **3231.3.5** Investigate reflection, refraction, diffraction, and interference of sound waves.

✓ **3231.3.6** Compare mechanical and electromagnetic waves.

✓ **3231.3.7** Explain the Doppler Effect.

Source moving toward stationary listener:

$$f_{LF} = f_s \frac{v}{v - v_s}$$

Source moving away from stationary listener:

$$f_{LB} = f_s \frac{v}{v + v_s}$$

Listener moving toward stationary source:

$$f_{LC} = f_s \frac{v + v_{LC}}{v}$$

Listener moving away from stationary source:

$$f_{LO} = f_s \frac{v - v_{LO}}{v}$$

✓ **3231.3.8** Determine the speed of sound experimentally and describe the effects various materials and temperatures on sound transmission.

✓ **3231.3.9** Measure spring constants.

✓ **3231.3.10** Solve problems related to wave length, frequency and speed [wave velocity:  $v = f\lambda$ ].

- ✓ **3231.3.11** Determine the speed of sound experimentally using various materials and temperatures [sound velocity:  $v_s = f\lambda$ ; Sound velocity (using air temperature):  $v_s = 331.5\text{m/s} + (0.56\text{ m/s } ^\circ\text{C}) (T)$ ].
- ✓ **3231.3.12** Describe simple harmonic motion.
- ✓ **3231.3.13** Compare the wave characteristics of natural auditory phenomena.

## Standard 4 – Optics

### Conceptual Strand 4

*Understanding optics is accomplished by investigating the behavior and laws of light.*

### Guiding Question 4

*How do the properties and behavior of light relate to the basic principles of optics?*

### Course Level Expectations

- CLE 3231.4.1** Describe the characteristics of the electromagnetic spectrum.
- CLE 3231.4.2** Investigate the interaction of light waves.
- CLE 3231.4.3** Explore the optics of lenses.
- CLE 3231.4.4** Analyze the optics of mirrors.
- CLE 3231.4.5** Investigate the phenomenon of color.

### Checks for Understanding (Formative/Summative Assessment)

- ✓ **3231.4.1** Explore properties of electromagnetic radiation.
- ✓ **3231.4.2** Examine properties of light waves.
- ✓ **3231.4.3** Investigate the polarization of light.
- ✓ **3231.4.4** Investigate the optical properties of plane and curved mirrors [Focal length:  $1/f = 1/d_o + 1/d_i$ ; Images in mirrors and lens,  $h_i/h_o = d_i/d_o$ ].
- ✓ **3231.4.5** Investigate the optical properties of plane and curved mirrors.
- ✓ **3231.4.6** Draw, explain, and solve problems for the optics of mirrors and lenses.
- ✓ **3231.4.7** Investigate optical phenomena (i.e., mirage, optical illusions, and dichromatic lens effect).
- ✓ **3231.4.8** Solve problems related to Snell's law [Index of refraction:  $n = (\sin \theta_r / \sin \theta_i)$ ; Snell's law:  $n_i \sin \theta_i = n_r \sin \theta_r$ ].
- ✓ **3231.4.9** Differentiate among transmission, reflection, refraction, diffraction, and interference of light waves.
- ✓ **3231.4.10** Explore the formation of color (both additive and subtractive properties) [Additive Color Theory:  $W = B+G+R$ ;  $Y = G+R$ ;  $\text{=B+G}$ ;  $M = R+B$ ; Subtractive Color Theory:  $B=W-Y$ ;  $C = W-R$ ;  $M=W-G$ ].

# Standard 5 – Electricity and Magnetism

## Conceptual Strand 5

*Understanding electricity and magnetism is explained by the physics of electrons and magnets.*

## Guiding Question 5

*How do the properties of electricity and magnetism relate to the physics of electrons and magnets?*

### Course Level Expectations

**CLE 3231.5.1** Examine the properties of electric forces, electric charges, and electric fields.

**CLE 3231.5.2** Explore the flow of charge and electric currents.

**CLE 3231.5.3** Investigate Ohm's law.

**CLE 3231.5.4** Compare and contrast series and parallel circuits.

**CLE 3231.5.5** Analyze components of electrical schematic diagrams.

**CLE 3231.5.6** Understand magnetic poles, magnetic fields, and investigate electromagnetic induction.

### Checks for Understanding (Formative/Summative Assessment)

✓ **3231.5.1** Create a simple electromagnet.

✓ **3231.5.2** Draw an electric field based on a description of the charged particles.

✓ **3231.5.3** Solve problems of resistance using Ohm's law [ $\mathcal{E} = IR$  (or  $V = IR$ )].

✓ **3231.5.4** Draw and explain series and parallel circuits.

✓ **3231.5.5** Solve problems related to voltage, amperage, and resistance [voltage,  $V = IR$ ; series circuit formulas,  $R_T = R_1 + R_2 + \dots$ ,  $I_T = I_1 = I_2 = \dots$ ,  $V_T = V_1 + V_2 + \dots$ ; parallel circuit formulas,  $1/R_T = 1/R_1 + 1/R_2 + \dots$ ,  $I_T = I_1 + I_2 + \dots$ ,  $V_T = V_1 = V_2 = \dots$ ].

✓ **3231.5.6** Build series and parallel circuits and explain how they function.

✓ **3231.5.7** Demonstrate a generated current by electromagnetic induction.

✓ **3231.5.8** Design an experiment to demonstrate the flow of charged particles and an electric current.

✓ **3231.5.9** Analyze a group of charges for repulsion and attraction.

✓ **3231.5.10** Distinguish between charged particles related to repulsion and attraction.

✓ **3231.5.11** Describe the electric field that fills the space around a charged particle or group of charges [Coulomb's law of electrostatics,  $F = k(Q_1Q_2)/d^2$ ].

✓ **3231.5.12** Identify components of series and parallel circuits and solve problems related to voltage, amperage, and resistance.

✓ **3231.5.13** Describe how current is generated by electromagnetic induction.

## Standard 6 – Nuclear Physics

### Conceptual Strand 6

*A deep understanding of particle physics is accomplished by investigating the properties of nuclear physics.*

### Guiding Question 6

*How is the investigation of the properties of nuclear physics related to understanding nuclear particles?*

### Course Level Expectations

**CLE 3231.6.1** Investigate the properties and structure of the atom.

**CLE 3231.6.2** Compare and contrast the Bohr model and the quantum model of the atom.

**CLE 3231.6.3** Explore the dynamics of the nucleus: radioactivity, nuclear decay, radiocarbon/uranium dating and half-life.

**CLE 3231.6.4** Compare and contrast nuclear fission and nuclear fusion.

**CLE 3231.6.5** Investigate the quantum theory.

### Checks for Understanding (Formative/Summative Assessment)

✓ **3231.6.1** Write and balance equations for the three forms of radioactive decay.

✓ **3231.6.2** Solve half-life problems [decay constant:  $k=0.693/T_{(1/2)}$ ; nuclear decay:  $A_f=A_0e^{kt}$ ].

✓ **3231.6.3** Explain dating methods using carbon-14 or uranium.

✓ **3231.6.4** Investigate the concept of half-life.

✓ **3231.6.5** Explain how particles behave like waves.

✓ **3231.6.6** Distinguish between coherent and incoherent light.

✓ **3231.6.7** Recognize how the quantum theory explains the photoelectric effect.

✓ **3231.6.8** Investigate the history and current events associated with nuclear and radioactive science.

✓ **3231.6.9** Identify the parts of an atom.

✓ **3231.6.10** Describe the properties and location of subatomic particles.

✓ **3231.6.11** Describe three forms of radioactivity.

✓ **3231.6.12** Distinguish between nuclear fission and nuclear fusion.

✓ **3231.6.13** Distinguish between the Bohr model and the quantum model of an atom.

✓ **3231.6.14** Explain the changes in atomic number or mass number for each form of radioactivity.

✓ **3231.6.15** Discuss transmutation and transuranium.

✓ **3231.6.16** Explain how particles behave like waves.

✓ **3231.6.17** Examine the properties of lasers.

✓ **3231.6.18** Recognize how the quantum theory explains the photoelectric effect.