Physics Pacing Guide

Physics should ground students in the five traditional areas of Physics (Newtonian mechanics, thermodynamics, optics, electricity and magnetism, and quantum mechanics) as well as the nature of science. It should provide the knowledge base needed for many college programs. Students should be expected to use higher-level mathematics and collect and analyze data. Instruction and assessment should include both appropriate technology and the safe use of laboratory equipment. Students should be engaged in hands-on laboratory experiences at least 20% of the instructional time.

First Nine Weeks

1. Enduring Understanding - Science is a systematic inquiry process where conclusions are derived from questions through appropriate and accurate investigative techniques.

1a. Essential Question - What steps do scientists use to investigate problems?

NS.16.P1	Describe why science is limited to natural explanations of how the world works
NS.16.P.2	Compare and contrast the criteria for the formation of *hypotheses, theories*, and *laws*
NS.16.P.3	Summarize the guidelines of science:
	*results are based on observations, evidence, and testing
	**hypotheses* must be testable
	*understandings and/or conclusions may change as new data are generated
	*empirical knowledge must have peer review and verification before acceptance

1b. Essential Question - What guidelines must be followed to design and conduct a scientific investigation?

NS.17.P.1	Develop the appropriate procedures using controls and variables (dependent and independent) in scientific experimentation
NS.18.P.1	Recognize that theories are scientific explanations that require empirical data, verification, and peer review
NS.17.P.2	Research and apply appropriate safety precautions (ADE Guidelines) when designing and/or conducting scientific investigations
NS.17.P.3	Identify sources of *bias* that could affect experimental outcome
NS.17.P.4	Gather and analyze data using appropriate summary statistics (e.g., percent yield, percent gain)
NS.17.P.5	Formulate valid conclusions without *bias*

1c. Essential Question - How can technology be appropriately used in solving and communicatig life science problems?

NS.19.P.1	Use appropriate equipment and technology as tools for solving problems (e.g., balances, scales, calculators, probes, glassware, burners, computer software and hardware)
NS.19.P.2	Manipulate scientific data using appropriate mathematical calculations, charts, tables, and graphs
NS.19.P.3	Utilize technology to communicate research findings

1d. Essential Question - What is the connection between pure science and science applied to the real world?

NS.20.P.1	Compare and contrast the connections between pure science and applied science as it relates to physics
NS.20.P.2	Give examples of scientific bias that affect outcomes of experimental results
NS.20.P.3	Discuss why scientists should work within ethical parameters
NS.20.P.4	Evaluate long-range plans concerning resource use and by-product disposal for environmental, economic, and political impact
NS.20.P.5	Explain how the cyclical relationship between science and technology results in reciprocal advancements in science and technology
NS.21.P.1	Research and evaluate science careers using the following criteria:
	*educational requirements
	*salary
	*availability of jobs
	*working conditions
NS.18.P.2	Research historical and current events in physics

2. Enduring Understanding - Motion in the universe can be predicted, calculated and understood through the use of mathematics.	
2a. Essential Question - What is the simplest motion that allows us to predict its behavior?	
MF.1.P.1	Compare and contrast *scalar* and *vector* quantities
MF.1.P2	Solve problems involving constant and average velocity
	$v = \frac{d}{t}$
	$v_{ave} = \frac{\Delta d}{\Delta t}$
MF.1.P.3	Apply kinematic equations to calculate distance, time, and velocity under conditions of constant acceleration
	$a = \frac{v}{t}$
	$a_{ave} = \frac{\Delta v}{\Delta t}$
	$\Delta x = \frac{1}{2}(v_i + v_f)\Delta t$
	$v_f = v_i + a\Delta t$
	$\Delta x = v_i \Delta t + \frac{1}{2} a(\Delta t)^2$
	$v_f^2 = v_i^2 + 2a\Delta x$
MF.1.P.4	Compare graphic representations of motion.
	d-t
	v-t
	a-t
MF.1.P.5	Calculate the components of a free falling object at various points in motion.
	$v_f^2 = v_i^2 + 2a\Delta y$
	Where a = gravity (g)
MF.1.P.6	Compare and contrast contact force (e.g., friction) and *field* forces (e.g., *gravitational* force)
MF.1.P.7	Draw free body diagrams of all forces acting on an object.
MF.1.P.8	Calculate the applied forces represented in a free body diagram
MF.1.P.9	Apply Newton's First law of Motion to show balanced and unbalanced forces.
MF.1.P.10	Apply Newton's Second law of Motion to solve motion problems that involve constant forces
	$F = ma$
MF.1.P.11	Apply Newton's Third Law of Motion to explain action-reaction pairs.
MF.1.P.12	Calculate frictional forces (i.e. kinetic and static):
	$\mu_k = \frac{F_k}{F_n}$
	$\mu_s = \frac{F_s}{F_n}$
MF.1.P.13	Calculate the magnitude of the force of friction:
	$F_f = \mu F_n$

2b. Essential Question - How does motion along two axis differ from our simplest motion?	
MF.2.P.1	Calculate the resultant vector of a moving object
MF.2.P.2	Resolve two-dimensional *vectors* into their *components:*
	$d_x = d\cos\theta$
	$d_y = d\sin\theta$
MF.2.P.3	Calculate the *magnitude* and direction of a *vector* from its *components:*
	$d^2 = x^2 + y^2$
	$\tan^{-1}\theta = \frac{x}{y}$
MF.2.P.4	Solve two-dimensional problems using balanced forces:
	$W = \mathrm{T}\sin\theta$
	$W = weight; \mathrm{T} = tension$
MF.2.P.5	Solve two-dimensional problems using the Pythagorean Theorem or the quadratic formula:
	$a^2 + b^2 = c^2$
	$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$
MF.2.P.6	Describe the path of a projectile as a *parabola*
MF.2.P.7	Apply *kinematic* equations to solve problems involving projectile motion of an object launched at an angle:
	$v_x = v_i \cos\theta =$ constant
	$\Delta x = v_i(\cos\theta)\Delta t$
	$v_{y,f} = v_i(\sin\theta) - g\Delta t$
	$v_{y,f}^2 = v_i^2(\sin\theta)^2 - 2g\Delta y$
	$\Delta y = v_i(\sin\theta)\Delta t - \frac{1}{2}g(\Delta t)^2$
MF.2.P.8	Apply *kinematic* equations to solve problems involving projectile motion of an object launched with initial horizontal velocity
	$v_{y,f} = -g\Delta t$ $\quad$ $v_x = v_{x.i} =$
	$\therefore v_{y,f}^2 = -2g\Delta y$ $\quad$ $\therefore \Delta x = v_x\Delta t$
	$\therefore \Delta y = -\frac{1}{2}g(\Delta t)^2$
MF.2.P.9	Calculate *rotational motion* with a constant force directed toward the center:
	$F_c = \frac{mv^2}{r}$
MF.2.P.10	Solve problems in circular motion by using *centripetal acceleration*:
	$a_c = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$
2c. Essential Question - How does circular motion differ from standard motion?	
MF.3.P.1	Relate radians to degrees:
	$\Delta\theta = \frac{\Delta s}{r}$
	Where Δ*s = arc length; r = radius*
MF.3.P.2	Calculate the *magnitude* of *torque* on an object:
	$\tau = Fd(\sin\theta)$
	Where $\tau = torque$
MF.3.P.3	Calculate angular speed and *angular acceleration:*
	$\omega_{ave} = \frac{\Delta\theta}{\Delta t}$
	$\alpha = \frac{\Delta\omega}{\Delta t}$

MF.3.P.4	Solve problems using *kinematic* equations for angular motion: $\omega_f = \omega_i + \alpha\Delta t$ $\Delta\theta = \omega_i \Delta t + \frac{1}{2}\alpha(\Delta t)^2$ $\omega_f^2 = \omega_i^2 + 2\alpha(\Delta\theta)$ $\Delta\theta = \frac{1}{2}(\omega_i + \omega_f)\Delta t$
MF.3.P.5	Solve problems involving *tangential speed:* $v_t = r\omega$
MF.3.P.6	Solve problems involving *tangential acceleration:* $a_t = r\alpha$
MF.3.P.7	Calculate *centripetal acceleration:* $a_c = \frac{v_t^2}{r}$ $a_c = r\omega^2$
MF.3.P.8	Apply Newton's universal law of gravitation to find the gravitational force between two masses: $F_g = G\frac{m_1 m_2}{r^2}$ Where $G = 6.673 \times 10^{-11} \frac{N \cdot m^2}{kg^2}$

$$F_g = G\frac{m_1 m_2}{r^2} \qquad G = 6.673\times10^{-11}\frac{N\cdot m^2}{kg^2}$$

Second Nine Weeks	
2d. Essential Question - What relationship exists between work and energy?	
MF.4.P.1	Calculate net work done by a constant net force: $W_{net} = F_{net} d \cos\theta$ Where $W_{net} = work$
MF.4.P.2	Solve problems relating kinetic energy and potential energy to the *work-energy theorem:* $W_{net} = \Delta KE$
MF.4.P.3	Solve problems through the application of conservation of mechanical energy: $ME_i = ME_f$ $\frac{1}{2}mv_i^2 + mgh_i = \frac{1}{2}mv_f^2 + mgh_f$
MF.4.P.4	Relate the concepts of time and *energy* to power
MF.4.P.5	Prove the relationship of time, *energy* and power through problem solving: $P = \frac{W}{\Delta t}$ $P = Fv$ Where P = power; W = work; F = force; V = velocity; T = time
2e. Essential Question - What is significant about the conservation of momentum?	
MF.5.P.1	Describe changes in momentum in terms of force and time
MF.5.P.2	Solve problems using the impulse-momentum theorem: $F\Delta t = \Delta p$ or $F\Delta t = mv_f - mv_i$ Where Δp = change in momentum; $F\Delta t$ = impulse
MF.5.P.3	Compare total momentum of two objects before and after they interact: $m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$
MF.5.P.4	Solve problems for perfectly inelastic and elastic *collisions* : $m_1 v_{1i} + m_2 v_{2i} = (m_1 + m_2) v_f'$ $m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$ Where v_f is the final velocity
2f. Essential Question - What constitutes a fluid and how can we predict its behavior?	
MF.6.P.1	Calibrate the applied buoyant force to determine if the object will sink or float: $F_B = F_{g(displaced fluid)} = m_f g$
MF.6.P.2	Apply Pascal's principle to an enclosed *fluid* system $P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$ Where P = pressure
MF.6.P.3	Apply Bernoulli's equation to solve *fluid* -flow problems: $p + \frac{1}{2}\rho v^2 + \rho g h = constant$ Where ρ = density
MF.6.P.4	Use the ideal gas law to predict the properties of an ideal gas under different conditions **PHYSICS** / **CHEMISTRY** $PV = Nk_B T$ / $PV = nRT$ N = number of gas particles / n = number of moles (1mole =6.022x1023 particles) k_b = Boltzmann's constant (1.38x10^{-23} J/k) / R = Molar gas constant (8.31 J/mole K) T = temperature / T = temperature

T

Third Nine Weeks	
3. Enduring Understanding - Heat, temperature and energy within a system is a function of the Kinetic Theory of Matter.	
3a. Essential Question - What is thermal energy and how does it effect matter?	
HT.7.P.1	Perform *specific heat capacity* calculations: $C_p = \frac{Q}{m\Delta T}$
HT.7.P.2	Perform calculations involving *latent heat:* $Q = mL$
HT.7.P.3	Interpret the various sections of a heating curve diagram
HT.7.P.4	Calculate heat energy of the different phase changes of a substance: $Q = mC_p\Delta T$; $Q = mL_f$; $Q = mL_v$; Where L_f = Latent heat of fusion; L_v = Latent heat of vaporization
3b. Essential Question -What relationship exists between heat and energy?	
HT.8.P.1	Describe how the first law of thermodynamics is a statement of *energy* conversion
HT.8.P.2	Calculate heat, work, and the change in internal *energy* by applying the first law of thermodynamics: $\Delta U = Q - W$; Where ΔU = change in system's internal energy
HT.8.P.3	Calculate the efficiency of a heat engine by using the second law of thermodynamics: $Eff = \frac{W_{net}}{Q_h} = \frac{Q_h - Q_c}{Q_h} = 1 - Q_c$; Where Q_h = energy added as heat; Q_c = energy removed as heat
HT.8.P.4	Distinguish between *entropy* changes within systems and the *entropy* change for the universe as a whole
4. Enduring Understanding - Natural forces cause repetitive or harmonic motion exemplified in waves and simple harmonic motion (SHM).	
4a. Essential Question - How do force and acceleration effect the repetitive motions of waves and simple harmonic motion?	
WO.9.P.1	Explain how force, velocity, and *acceleration* change as an object vibrates with *simple harmonic motion*
WO.9.P.2	Calculate the spring force using Hooke's law: $F_{elastic} = -kx$; Where $-k$ = *spring constant*
WO.9.P.3	Calculate the *period* and frequency of an object vibrating with a *simple harmonic motion:* $T = 2\pi\sqrt{\frac{L}{g}}$; $f = \frac{1}{T}$; Where T = period
WO.9.P.4	Differentiate between *pulse* and *periodic waves*
WO.9.P.4	Relate *energy* and *amplitude*
4b. Essential Question - How do different media effect waves?	
WO.10.P.1	Calculate the frequency and wavelength of electromagnetic radiation
WO.10.P.2	Apply the law of reflection for flat mirrors: $\theta_{in} = \theta_{out}$
WO.10.P.3	Describe the *image* s formed by flat mirrors
WO.10.P.4	Calculate distances and *focal lengths* for curved mirrors: $\frac{1}{p} + \frac{1}{q} = \frac{2}{R}$; Where p = object distance; q = image distance; R = radius of curvature
WO.10.P.5	Draw ray diagrams to find the *image* distance and *magnification* for curved mirrors
WO.10.P.6	Solve problems using Snell's law: $n_i(\sin\theta_i) = n_r(\sin\theta_r)$

WO.10.P.7	Calculate the *index of refraction* through various media using the following equation: $n = \frac{c}{v}$ Where n = index of refraction; c = speed of light in vacuum; v = speed of light in medium
WO.10.P.8	Use a ray diagram to find the position of an *image* produced by a lens
WO.10.P.9	Solve problems using the thin-lens equation: $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$ Where q = image distance; p = object distance; f = focal length
WO.10.P.10	Calculate the *magnification* of lenses: $M = \frac{h'}{h} = -\frac{q}{p}$ Where M = magnification; h' = image height; h = object height; q = image distance; p = object distance

Fourth Nine Weeks	
5. Enduring Understanding - Electric forces create fields, transfer energy and do work.	
5a. Essential Question - What is the relationship between an electric force and the field it generates?	
EM.11.P.1	Calculate *electric force* using Coulomb's law: $F = k_c(\frac{q_1 \times q_2}{r^2})$ Where k_c = Coulomb's constant $8.99 \times 10^9 N \bullet \frac{m^2}{c^2}$
EM.11.P.2	Calculate *electric field* strength: $E = \frac{F_{electric}}{q_0}$
EM.11.P.3	Draw and interpret *electric field* lines
EM.12.P.1	Calculate electrical potential *energy*: $PE_{electric} = -qEd$
EM.12.P.2	Compute the electric potential for various charge distributions: $\Delta V = \frac{\Delta PE_{electric}}{q}$
EM.12.P.3	Calculate the *capacitance* of various devices: $C = \frac{Q}{\Delta V}$
EM.12.P.4	Construct a *circuit* to produce a pre-determined value of an Ohm's law variable
5b. Essential Question - What is the relationship between magnetism and electric current?	
EM.13.P.1	Determine the strength of a *magnetic field*
EM.13.P.2	Use the *first right-hand rule* to find the direction of the force on the charge moving through a *magnetic field*
EM.13.P.3	Determine the *magnitude* and direction of the force on a *current*-carrying wire in a *magnetic field*
EM.13.P.4	Describe how the change in the number of *magnetic field* lines through a *circuit* loop affects the *magnitude* and direction of the induced *current*
EM.13.P.5	Calculate the induced electromagnetic field (*emf*) and *current* using Faraday's law of *induction:* $emf = -N\frac{\Delta[AB(\cos\theta)]}{\Delta t}$ Where N = number of loops in the circuit
6. Enduring Understanding - The structure of atoms explains the stability and decay of specific atoms.	
6a. Essential Question - What binds the nuclsue and holds it in a stable form?	
NP.13.P.1	Calculate the binding *energy* of various nuclei
NP.15.P.2	Predict the products of nuclear decay
NP15.P.3	Calculate the decay constant and the *half-life* of a radioactive substance
NP.14.P.1	Calculate *energy* quanta using Planck's equation: $E = hf$
NP.14.P.2	Calculate the de Broglie wavelength of matter: $\lambda = \frac{h}{p} = \frac{h}{mv}$
NP.14.P.3	Distinguish between classical ideas of measurement and Heisenberg's *uncertainty principle*
NP.14.P.4	Research emerging theories in physics, such as string theory