PROPOSED

PENNSYLVANIA STATEWIDE PROGRAM-TO-PROGRAM ARTICULATION AGREEMENT IN PHYSICAL OCEANOGRAPHY

Overview

In accordance with Act 50 of 2009, institutions participating in Pennsylvania's statewide college credit transfer system agree to the following policies governing the transfer of credits from a participating associate-degree granting institution into a participating four-year college or university. This agreement specifically ensures that a student who successfully completes an Associate of Arts (AA) or Associate of Science (AS) degree in the field of Physical Oceanography can transfer the full degree into a parallel Physical Oceanography bachelor degree program at a participating four-year institution.

Full junior-standing at the bachelor degree institution will be granted to a student who successfully completes an associate degree provided that:

- The associate degree includes, at minimum, 37 credits of major specific competencies as identified in this Agreement.
- The associate degree includes completion of 30 credits of foundation-level coursework from the Transfer Credit Framework (see Appendix B), including all required Framework courses listed in this agreement.
- The student earns the stated minimum grade in courses covering all required major competencies and in required Transfer Credit Framework courses.
- The student earns a minimum grade point average of 2.0 or better in the associate degree.

See Appendix A: Minimum Associate Degree Requirements for Transfer under the Statewide Program-To-Program Articulation Agreement in Physical Oceanography. Minimum grades for competencies are described in Appendix A.

It is therefore understood that students meeting these requirements will be considered by both the associate degree granting institution and the receiving bachelor degree granting institution to possess the knowledge, skills and abilities necessary for entry as a junior into a parallel physical oceanography bachelor degree program.

As with many bachelor degree programs in physical sciences, much of the coursework in the first two years of study is comprised of prerequisite courses (e.g., chemistry, mathematics, and physics). Those prerequisite competencies comprise the bulk of this agreement. Those prerequisite competencies comprise the bulk of this agreement. Alignment between prerequisite competencies listed herein and those found within articulation agreements relating to those specific content areas is intentional.

In addition to the prerequisite competencies, it is typical for students pursing a bachelor degree in the field of Physical Oceanography to complete an introductory foundations course in oceanography that exposes the student to the breadth of required discipline-specific competencies in a Physical Oceanography curriculum. Corresponding competencies associated with such a course are also listed herein.

Required Major-Specific Content Areas

Under this Agreement, a fully-transferable associate degree in the field of Physical Oceanography must include at least 37 credits of coursework that includes competencies from the following content areas:

1. **Foundations of Oceanography – a minimum of 4 credits**
2. **Chemistry – a minimum of 8 credits**
3. **Mathematics – a minimum total of 15 credits**
    a. Calculus – a minimum of 12 credits
    b. Ordinary Differential Equations – a minimum of 3 credits
4. **Calculus-based Physics – a minimum of 10 credits**

Institutions may determine how the competencies identified in these content areas are met. For example, one institution may choose to embed the Calculus competencies in four 3-credit courses, while another institution teaches the same competencies in three 4-credit courses. How an institution incorporates the competencies into the associate degree does not affect the transferability of the degree under this Agreement in so long as all of the competencies are met.

1. Foundations in Oceanography – a minimum 4 credits

In addition to the prerequisite competencies, students pursing a bachelor degree in the field of Physical Oceanography must complete an introductory foundations course in oceanography that exposes the student to the breadth of required discipline-specific competencies in a Physical Oceanography curriculum.

Successful completion of comparable coursework at the Calculus 1 level (see bullet 3 below) will at the minimum yield competency in:

Lecture

- Describing the relationship between the oceans, land and atmosphere.
- Describing the concept of the earth system.
- Listing the relative sizes and distinguishing characteristics of the world's major ocean basins.
- Describing the formation of ocean basins and the general features of the ocean bottom.
- Describing the chemical properties of water; the hydrogen bond.
- Describing the concept of salinity and the principle of constant proportions.
- Describing the relationship between water's salinity, temperature and density.
- Describing the relationship between atmospheric circulation, climate belts and wind belts.
- Describing the ocean's major flow patterns and listing the names of the major ocean currents.
- Differentiating between surface ocean currents and deep ocean currents.
- Describing the dynamics of waves and tides.
- Explaining how ocean processes influence the shape of shorelines.
- Listing the major primary producers in the ocean ecosystem.
- Explaining how a simple and a more complex ocean ecosystem works.
- Discussing the role of the ocean in global climate change.

Laboratory

- Describing the locations of Earth's physiographic features, i.e., major mountain belts, mid-ocean rides, subduction zones, continental shelves, abyssal plains, etc.
- Describing ocean property plots, vertical profiles and sections.
- Describing ocean salinity and salinity units for major, minor and trace constituents.
- Describing marine sediment grain sizes and how to quantify the size distribution using screens.
- Measuring the characteristics of an ocean surface wave generated in a wave tank.
- Demonstrating basic marine navigation skills.
- Identifying and describing basic features of the more common phytoplankton and zooplankton.
- Applying and demonstrating Stokes' Law to sediment and /or plankton in the ocean.
- Applying the Reynolds number to particles in the ocean.
- Applying Sverdrup's critical depth analysis to model the timing and onset of the spring phytoplankton bloom.

2. Chemistry – a minimum 8 credits

A student should meet this requirement by successfully completing General Chemistry I and II for majors as part of the Transfer Credit Framework (see Appendix B). Successful completion of comparable coursework will at the minimum yield competency in:

- Presenting the scientific method.
- Classifying matter on the basis of physical and chemical properties.
- Classifying matter on the basis of physical and chemical changes.
- Listing the common SI units of measurement, the values of selected prefixes, and the use of dimensional analysis to interconvert units of measurement.
- The use of the rules for significant figures for calculation problems.

- Describing the structure of the atom in terms of subatomic particles; writing the isotopic symbol for any isotope of a given element or ion.
- Describing the basic features of the periodic table.
- Writing formulas of ionic or covalent compounds from their names and from their names writing their formulas.
- Writing and balancing a chemical reaction.
- Classifying reactions into various types such as combination, decomposition, single replacement, double replacement, oxidation-reduction, acid-base, precipitation and gas forming reactions.
- The use of the mole concept to calculate the molar mass, the number of moles from the mass of a sample, the number of atoms or molecules and molarity of solutions.
- Applying the mole concept to the determination of mass %, empirical and molecular formulas.
- Applying the mole concept to reaction stoichiometry calculations including limiting reagent and percent yield.
- The use of kinetic molecular theory to account for the properties of gases and the gas laws (Boyles, Charles, Avogadro, etc.).
- The use of gas laws to calculate the pressure, volume, temperature or number of moles from appropriate data.
- The use of the Ideal gas law to determine the density or molar mass of a gas and the stoichiometry of reactions involving gases.
- Calculating of the partial pressure or mole fractions from the appropriate data of gas mixtures.
- Explaining how the properties of real gases differ from an Ideal Gas.
- Explaining the role of heat in chemical reactions (Thermodynamic Laws).
- Performing calorimetric calculations and use enthalpy tables or Hess's Law to determine the heat of a reaction.
- Explaining the relationships between the properties of electromagnetic radiation with respect to wavelength, frequency, energy and spectral region and being able to calculate the energy, frequency or wavelength from appropriate data.
- Comparing and contrasting the Bohr and quantum theories of atomic structure and how they account for location of electrons in atoms and spectral lines.
- Explaining the characteristics of atomic orbitals and the quantum numbers associated with them.
- Writing the electronic configuration of atoms and ions.
- The use of the periodic table to predict the physical and chemical properties of elements, including atomic radii, ionization energy and electron affinity.
- Writing Lewis structures for neutral atoms, ions, ionic and covalent compounds.
- The use of Lewis structures and VSPER theory to predict electronic and molecular geometries.
- The use of the principle of electronegativity to describe the characteristics of polar covalent bonds.
- The use of polar and covalent bonds and VSEPR to determine the overall polarity of a molecule.
- The use of valence bond theory and molecular geometry to determine the hybridization of atoms.
- Comparing and contrasting valence bond, molecular orbital and metallic bonding theories and how each accounts for molecular structures and properties.
- Comparing the differences between the state of matter and the changes of state that occur.
- Describing the major types of intermolecular forces and use them to explain the properties of solids and liquids such as boiling point, melting point, surface tension and viscosity.
- Describing how intermolecular forces determine solubility of polar and nonpolar substances.
- Calculating the concentration of solutions in molarity, molality, normality, mole fraction, or percent by mass and be able to interconvert between them.
- Listing the colligative properties of solutions (freezing point depression, boiling point elevation, vapor pressure lowering and osmotic pressure) and performing calculations involving them.
- Determining rate laws and order of a reaction from experimental data using the initial rates or graphical methods.
- The use of collision theory to explain the concept of activation energy and the effect of temperature on reaction rates and use the Arrhenius equation to calculate the activation energy.
- The use of elementary steps to link the mechanism of a reaction to the rate law.
- Explaining how a catalyst affects a reaction.
- Stating and applying LeChatlelier's Principle to a reaction at equilibrium.

- Calculating the value of an equilibrium constant from experimental data and use equilibrium constants to predict quantities of all species at equilibrium.
- Stating and applying the Arrenhius, Bronsted-Lowry and Lewis acid-base theories to acid-base reactions.
- Performing equilibrium calculations for pH, Ka and buffer systems.
- Explaining the concept of solubility product constant, complex ion equilibrium, the common ion effect and write the Ksp and Keq expressions.
- Calculating the molar solubility of a species and determining if a precipitate will form.
- Discussing the fundamental laws of thermodynamics, free energy and entropy.
- Performing thermodynamics calculations to predict the spontaneity of a chemical reaction and its equilibrium constant.
- Discussing and applying the principles of electrochemistry including writing and balancing redox reactions.
- Calculating cell potentials.
- Calculating free energy and equilibrium constants from cell potentials.
- Applying the above-mentioned competencies in a collaborative laboratory environment.

3. Mathematics – a minimum total of 15 credits as defined in the three subcategories areas below

a. Calculus – a minimum of 12 credits

A student should partially meet this requirement by successfully completing Calculus I as part of the Transfer Credit Framework (see Appendix B).

Completion of additional coursework will at the minimum yield competency in:

- Finding the area of a region bounded by the graphs of given equations.
- Determining the volume of a solid of revolution by the disc and washer methods or by the shell method.
- Finding the length of a plane curve.
- Determining the area of the surface of revolution.
- Calculating various physical quantities such as amount of work done by a variable force over an interval, moments, centers of mass, centroids, fluid pressure and fluid force.
- Calculating the average value of a function and use the Mean-Value Theorem for Integrals
- Finding derivatives of functions involving the natural logarithmic function.
- Integrating rational functions whose antiderivatives are natural logarithmic functions.
- Finding the derivative of an inverse function.
- Differentiating and integrating natural exponential functions.
- Differentiating and integrating exponential functions that have bases other than *e*.
- Solving growth and decay problems.
- Differentiating inverse trigonometric, hyperbolic, and inverse hyperbolic functions.
- Integrating functions yielding inverse trigonometric, hyperbolic or inverse hyperbolic functions.
- Integrating by parts.
- Integrating powers of trigonometric functions.
- Integrating using trigonometric substitution.
- Integrating using partial fraction decomposition.
- Integrating using tables.
- Evaluating improper integrals.
- Identifying the parts (e.g., center, vertices, foci, axes, asymptotes, eccentricity, etc.) of a conic section, and graphing it.
- Finding the equation of a conic section (circle, parabola, ellipse, hyperbola) given sufficient information about its parts.
- Graphing a curve given by a set of parametric equations.
- Finding a set of parametric equations to represent a curve.
- Finding the slope of a tangent line to a curve given by a set of parametric equations.
- Finding the arc length of a curve given by a set of parametric equations.
- Transforming equations from polar coordinates to rectangular coordinates and vice-versa.

- Sketching common polar graphs.
- Determining the slope of a tangent line to a polar graph.
- Finding the area of a region bounded by a polar graph and the arc length of a polar graph.
- Writing a vector in component form or as a linear combination of standard unit vectors.
- Graphing a given a vector, unitizing it, and finding its magnitude and direction.
- Adding, subtracting, and forming scalar multiples of vectors.
- Calculating the dot (scalar) product of two vectors and using the dot product to find the angle between two vectors, the direction cosines of a vector, and the projection of one vector onto another.
- Calculating the cross product of two vectors and the triple scalar product of three vectors.
- Finding equations of lines and planes in 3-space, given sufficient data.
- Identifying and sketching planes, cylinders, and quadric surfaces, given their equations.
- Converting between rectangular, cylindrical and spherical coordinates.
- Extending the concepts of limit, continuity, differentiation, and integration to vector-valued functions.
- Graphing vector-valued functions.
- Differentiating a displacement (position) vector to find the velocity and acceleration vectors and the speed at a point.
- The use of vector-valued functions to analyze projectile motion.
- Finding a unit tangent, a unit normal, and the tangential and normal components of acceleration for a given vector-valued function,
- Finding the arc length and the curvature of a space curve described by a vector-valued function.
- Finding the first-order partial derivatives of functions.
- Finding higher order partial derivatives.
- The use of the chain rule for partial derivatives.
- Calculating the total differential.
- Finding the directional derivative.
- Finding the equation of the tangent plane to a surface at a given point.
- Finding the gradient of a function.
- Maximizing or minimizing functions of two independent variables.
- Applying Lagrange Multipliers to maximum – minimum problems.
- Evaluating double integrals.
- Evaluating double integrals by use of polar coordinates.
- Evaluating triple integrals.
- Evaluating triple integrals by use of cylindrical coordinates.
- Evaluating triple integrals by use of spherical coordinates.
- Finding areas by use of double integration.
- Locating the center of gravity and centroid of a solid.
- Finding volumes by use of multiple integrals.
- Evaluating triple integrals to solve applied problems.
- Finding surface area.
- Evaluating surface integrals.
- Evaluating line integrals.
- Finding work done in a vector field.
- Determining the path-independent line integrals.
- The use of Green's Theorem to compute line integrals or double integrals.
- The use of the Divergence Theorem to compute surface integrals or triple integrals.
- The use of Stokes' Theorem to compute line integrals or surface integrals.
- Determining whether a sequence converges or diverges.
- Finding the limit of convergent sequences.
- Determining whether a given geometric series or p-series converges or diverges.
- Finding closed expressions for the sum of terms of an infinite geometric and telescoping series.
- Testing for convergence or divergence of an infinite series of non-negative terms using, (a) direct comparison and limit comparison tests, (b) the integral test, (c) the ratio test, (d) the root test.
- Testing for absolute convergence and conditional convergence of alternating series.
- Expressing functions as power series.
- Finding the interval of convergence for power series.
- Writing Maclaurin series expansions.
- Writing Taylor series expansions.

- Computing using series expansions.
- Differentiating and integrating power series.
- The use of the Remainder Term in Taylor's Theorem to perform error estimates

b. Differential Equations – a minimum of 3 credits

Completion of comparable coursework will at the minimum yield competency in:

- Classifying differential equations as ordinary and partial; classifying ordinary differential equations (ODEs) by linearity and by order.
- Understanding the concept of solutions and verify solutions by substitution.
- Explaining the difference of the general solutions of ODEs and the solutions to initial value problems (IVPs).
- Understanding the concepts of direction fields associated with first order ODEs and integral curves.
- Sketching the direction fields and some typical integral curves for such ODEs.
- Recognizing various types of first order ODEs and find their general solutions by elementary integration.
- Finding the solution of an IVP of such equations by determining the appropriate constant. Such equations should include linear first order and separable ODEs, Bernoulli equations, homogeneous equations, and exact equations.
- Identifying simple integral factors for certain non-exact equations.
- Developing a sense of solving an ODE using appropriate substitutions.
- Determining if a first order linear IVP has a unique solution and the interval of existence.
- Understanding the result on existence/uniqueness/interval of existence of solutions of an IVP of a general first order ODE.
- Recognizing the differences between linear and nonlinear ODEs.
- Setting up and solving IVPs for various applied problems such as those involving exponential growth/decay, mixing, and mechanics/physics.
- Understanding the logistic model in population dynamics.
- Understanding stability properties of equilibrium solutions of first order autonomous equations and determine their stability properties using linear stability criteria.
- Explaining the principle of superposition and the relation between the general solutions of a second order linear homogeneous ODE and the corresponding nonhomogeneous one.
- Understanding the basic theory of second order linear homogeneous ODEs: linear dependence and independence, the Wronskian, the fundamental set of solutions; Abel's theorem and its consequences.
- Finding the general solutions of second order linear homogeneous ODEs with constant coefficient using the characteristic equations.
- Explaining and using the technique of reduction of order to find the general solution of a linear homogeneous ODE if a nontrivial solution is known.
- Explaining and applying the method of undetermined coefficients to appropriate second order linear nonhomogeneous ODEs to find particular solutions and the general solutions.
- Explaining and applying the method of variation of parameters to find a particular solution of a second order linear nonhomogeneous ODE if the general solution of the corresponding homogeneous equation is known.
- Solving appropriate applied problems related to mechanical or electric oscillations.
- Explaining the terms: free oscillations, forcing, damping, resonance, etc.
- Finding the solution to an IVP for any second order linear ODEs from the general solution.
- Determining whether a given point is an ordinary point, a regular singular point, or an irregular singular point for any given second order linear homogeneous ODE.
- Finding the two linearly independent series solutions, or at least the first several terms in each near an ordinary point.
- Determining the minimum radius of convergence of these series solutions from the coefficients of the ODE.
- Recognizing Euler ODEs and find their general solutions.
- Finding the series solutions or at least the first several terms of two linearly independent series solutions of a second order ODE near a regular singular point by Frobenius method under appropriate condition on the exponents of singularity.

- Understanding the definition of the Laplace transform, calculate the Laplace transforms of simple functions, and determining whether the Laplace transform of a given function exists.
- The use of tables and general properties (linearity, derivative, translation) of Laplace transform to find the Laplace transform or the inverse Laplace transform of a given function.
- The use of Laplace transforms to solve a nonhomogeneous second-order IVP, where the forcing function could be discontinuous (expressed in terms of unit step functions), or periodic, or involving impulse functions.
- Understanding the unit impulse function, its Laplace transform and applications in the context of ODEs.
- Defining the convolution of two functions, calculate it, and understand the convolution theorem.

4. Physics – a minimum of 10 credits

Completion of comparable coursework at the minimum will at the minimum yield competency in:

(a: At the Calculus I level from the Transfer Credit Framework (see Appendix B))

- Distinguishing between scalar and vector quantities.
- The use of standard units when measuring or calculating physical quantities.
- Expressing vector quantities in terms of components and unit vectors.
- Adding and subtracting vector quantities and determining scalar and vector products.
- Determining the scalar and vector product of two vectors.
- Defining displacement, velocity, and acceleration for linear motion of a particle in three dimensions.
- Deriving the kinematic equations for the linear motion of a particle in terms of its displacement, velocity, and acceleration for the cases of constant and non-constant linear acceleration.
- Solving problems using the kinematics equation for a particle.
- Determining velocity and acceleration as a function of time by differentiation of displacement and velocity.
- Describing the difference between mass and weight.
- Calculating the weight of a mass in a given gravitation field.
- Applying Newton's Second Law in multiple dimensions.
- Solving problems involving bodies in free fall.
- Drawing correct free-body diagrams for each body in a system.
- Calculating kinetic and static friction forces and applying those to Newton's Second Law problems.
- Defining and calculating the work performed on solids, liquids, and gasses.
- Deriving the Work/Energy Theorem and applying it to the motion of solids and liquids.
- Defining and calculating gravitational and elastic potential energy.
- Defining and calculating kinetic energy.
- Solving problems applying the Conservation of Energy Principle.
- Solving problems relating impulse and change in momentum.
- Solving problems by applying the principle of conservation of momentum.
- Identifying elastic and inelastic collisions.
- Performing vector addition of momentum vectors.
- Calculate impulse by integrating force with respect to time.
- Applying rotational kinematics equations to solve problems.
- Applying the relationship between linear and angular quantities to solve problems.
- Calculating the moment of inertia of selected objects.
- Solving problems involving the rotation of a rigid body.
- Solving problems relating torque, moment of inertia and angular momentum.
- Solving problems involving rolling motion.
- Computing torque as a vector product.
- Explaining the principle of conservation of angular momentum.
- Solving problems utilizing the principle of conservation of angular momentum.
- Solving problems relating torque and the rate of change of angular momentum.
- Stating the conditions for mechanical equilibrium.
- Solving mechanical equilibrium in multiple dimensions by solving a system of equations.
- Computing the center of gravity of an object and system of masses.
- Calculating stress.

- Solving problems using the relationship between stress, strain and the elastic modulus.
- Stating the law of universal gravitation and utilize it in solving problems.
- The use of the law of gravitation to solve problems involving satellite motion.
- Applying Kepler's Laws of Motion to solve problems involving satellites.
- Calculating gravitational potential energy of a system of masses.
- Calculating the escape velocity.
- Solving problems relating force, area and pressure.
- Calculating the absolute pressure at a depth in a fluid.
- Solving problems by applying Pascal's law.
- Relating Bernoulli's equation to the concept of conservation of energy and solve related problems.
- Applying Archimedes principle to problems involving weight, mass, and buoyancy.
- Calculating the frequency, angular frequency and period for a mass-spring system.
- Calculating the frequency, angular frequency and period for a pendulum.
- Solving problems relating frequency, angular frequency and period.
- Finding velocity and acceleration as a function of time by finding the derivative of displacement as a function of time for a sine and cosine wave.
- Calculating the energy of a simple harmonic oscillator.
- The use of conservation of energy to calculate displacement and/or velocity of a simple harmonic oscillator.
- Calculating the speed of a wave in different media.
- Identifying and calculating amplitude, wave number, angular frequency, speed and acceleration in the expression for displacement as a function of time and position.
- Calculating resonance frequency.
- Showing that a particular displacement function satisfies the wave equation.
- Calculating the rate at which energy is transported by waves in a string.
- Calculating the speed of sound in various media.
- Identifying and calculating amplitude, wave number, angular frequency, speed in the expression for pressure as a function of time and position.
- Calculating the shift in frequency due to the Doppler Effect.
- Calculating the decibel level for a given intensity level and vice versa.
- Calculating the resulting wave function due to the superposition of two waves.
- Determining relationship between length of open and closed end pipes and their resonant frequencies.
- Converting between Celsius, Fahrenheit, Kelvin and Rankine units.
- Calculating the number of molecules of a given mass using the molar or molecular mass.
- Calculating the average translational kinetic energy of a monatomic gas at a given temperature.
- Calculating the root mean square speed of a monatomic gas at a given temperature.
- Solving problems using the ideal gas law.
- Calculating work done by a gas during constant volume, constant pressure and constant temperature processes.
- Solving problems involving thermal expansion.
- Solving problems involving specific heat capacity including method of mixtures.
- Solving problems involving constant pressure and constant volume specific heat for gases.
- Calculating the amount of heat required to change phase.
- Explaining the first law of thermodynamics.
- Applying the first law of thermodynamics to adiabatic, isothermal and constant volume processes.
- Solving problems involving heat transfer by conduction.
- Solving problems involving heat transfer by radiation.
- Explaining the Second Law of Thermodynamics.
- Calculating the efficiency of a heat engine.
- Calculating the efficiency of a Carnot engine.
- Describing entropy.
- Calculating the change in entropy for a system.
- Applying the above-mentioned competencies in a collaborative laboratory environment.

(b: At the post Calculus I level)

- Solving problems using Coulomb's Law.

- Solving problems relating electric force and electric field.
- Calculating the electric filed vector for a system of point charges and uniformly distributed charges.
- Drawing electric field lines.
- Calculating electric flux.
- Applying Gauss' Law to find the electric field due to a distribution of charge.
- Explaining the four properties of a conductor in electrostatic equilibrium resulting from Gauss' Law.
- Calculating the Electric Potential difference between two points when given and electric field.
- Calculating the value of electric potential for a distribution of charges.
- Solving problems relating change in electric potential energy and change in electric potential.
- Calculating the electric potential energy for a system of charges.
- Determining the electric field by taking the partial derivatives of the electric potential.
- Solving problems relating potential difference, charge and capacitance.
- Calculating the capacitance of a parallel plate, cylindrical and spherical capacitors.
- Finding the equivalent capacitance of capacitors in parallel and series.
- Calculating the energy stored in a capacitor.
- Solving capacitance problems which include the effect of dielectric materials.
- Determining current by taking the derivative of charge with respect to time.
- Solving problems by applying Ohm's Law.
- Solving problems relating resistance, resistivity, length and cross-sectional area.
- Calculating the effect of temperature on resistivity and resistance.
- Solving problems relating power, current, potential and resistance.
- Finding the equivalent resistance of resistors in parallel and series.
- Solving electric circuit problems by applying Kirchhoff's laws.
- Solving for values of current, charge or potential for charging and discharging an RC circuit.
- Determining the magnetic force on a moving charge by finding the cross product of velocity and magnetic field multiplied by the charge.
- Solving problems involving the speed of a charge through a velocity selector.
- Calculating the force on a current carrying wire due to a magnetic field.
- Calculating the torque on a current carrying loop of wire in a magnetic field.
- Solving problems by applying the Biot-Savart Law.
- Calculating the magnetic force between two current carrying wires.
- The use of Ampere's Law to determine magnetic field due to a current in various configurations.
- Calculating magnetic flux by using Gauss' law in magnetism.
- Explaining the source of magnetism in matter.
- Calculating induced emf using Faraday's law.
- Calculating motional emf and solve related problems.
- The use of Lenz's law to determine the direction of induced emf.
- Applying Faraday's law to solve problems involving motors and generators.
- Calculating induced emf due to a time-varying current in a circuit.
- Calculating the inductance for a solenoid.
- Solving for values of current and potential when closing an LC circuit with a potential source and then after
- Removing the potential source.
- Calculating the energy stored in an inductor.
- Calculating the value of mutual inductance for two current carrying coils.
- Solving problems involving induced emf due to mutual inductance.
- Calculating the natural frequency for an LC circuit.
- Calculating the natural frequency for an RLC circuit.
- Calculating the root-mean-square values for current and potential for n AC circuit.
- Calculating inductive and capacitive reactance and impedance.
- Determining the phase angle between the current and potential in an AC circuit.
- Calculating the average power for an AC circuit.
- Explaining the term band width and calculate the quality factor for an AC circuit.
- Solving problems involving step-up and step-down transformers.
- Explaining and calculate displacement current due to a changing electric flux.
- Modifying Ampere's Law to include the effect of the displacement current.
- Listing Maxwell's equations.

- Solving problems by relating the strength of the electric field to the strength of the magnetic field in an electromagnetic wave.
- Determining the Poynting vector by using the cross product of the electric and magnetic fields.
- Calculating the intensity of an electromagnetic wave.
- Calculating the momentum and energy of an electromagnetic wave.
- Ordering the types of electromagnetic waves from low frequency tom high frequency.
- Applying the law of reflection.
- Applying Snell's Law of refraction.
- Solving problems relating the speed of light in a medium to its index of refraction.
- Explaining Huygens' principle.
- Calculating the angle of dispersion for refraction involving electromagnetic waves of different frequency.
- Calculating the critical angle of incidence for a medium.
- Solving problems involving image distance, image height, object distance, object height, magnification and focal length of spherical mirrors and lenses.
- Describing how Young's double slit experiment produce bright and dark regions by constructive and destructive interference.
- Solving Young's double slit problems for position of dark bands, bright bands, wavelength and slit separation.
- Calculating the intensity of light for a given position in a Young's double slit experiment.
- Solving problems involving the change of phase due to reflection including thin-film interference and nonreflective coatings.
- Explaining how a Fraunhofer diffraction pattern is created using Huygens' principle.
- Solving Fraunhofer diffraction problems for position of dark bands, bright bands, wavelength and slit width.
- Calculating the intensity of light for a given position in a Fraunhofer diffraction pattern.
- Calculating the resolution for a slit and circular aperture.
- Solving diffraction grating problems for position of dark bands, bright bands, wavelength and slit separation.
- Solving problems using Bragg's law.
- Calculating the intensity of light after passing through polarizing lenses.
- Solving problems using Brewster's law.
- Applying the above-mentioned competencies in a collaborative laboratory environment.

Transfer Credit Framework

Under Act 114 of 2006, the Commonwealth's statewide college credit transfer system includes an advising tool called the "Transfer Credit Framework". The Framework (see Appendix B) allows students to seamlessly transfer up to 30 credits of foundation courses from one participating college or university to another and have those courses count toward graduation.

The Framework consists of a menu of 49 courses that fall within six broad categories: English, public speaking, math, science, fine arts and humanities, and the behavioral and social sciences. To fully benefit from the Framework, students are advised to select a range of courses according to the criteria for each category.

Students transferring under this Agreement are advised to take specific Framework courses in Category 3 and Category 4 to meet the major-specific competency requirements outlined above and to ensure adequate preparation for entry into the major as a junior. See Table 1.

Students are advised to work with an advisor to select courses related to their associate degree program, transfer major and personal interests. Contact should be made with an advisor at the expected four-year institution as soon as possible to ensure that the four-year institution's general education requirements are appropriately woven into the student's associate degree curriculum.

Table 1: Transfer Credit Framework Requirements

Transfer Credit Framework	Framework Requirement	Student Transferring Under This Agreement are REQUIRED TO TAKE…
Category 1	1 course (3-4 credits)	1. One course to be selected by the student with the assistance of an advisor.
Category 2	1 course (3-4 credits)	1. One course to be selected by the student with the assistance of an advisor.
Category 3	2 courses (6-8 credits)	1. Calculus 1 2. One post Calculus 1 course
Category 4	2 courses (6-8 credits)	1. General Chemistry I for majors 2. General Chemistry II for majors
Category 5	2 courses (6-8 credits)	1. One course to be selected by the student with the assistance of an advisor. 2. One course to be selected by the student with the assistance of an advisor.
Category 6	2 courses (6-8 credits)	1. One course to be selected by the student with the assistance of an advisor. 2. One course to be selected by the student with the assistance of an advisor.

Appendix A: Minimum Associate Degree Requirements for Transfer under the Statewide Program-To-Program Articulation Agreement in Physical Oceanography

Required Major-Specific Content Areas	Minimum Credits	Transfer Criteria
Foundations in Oceanography	4 credits	• Minimum grade of C- or better (equivalent of a 1.7 GPA on a 4.0 scale) in coursework addressing the required competencies for this area.
Chemistry	8 credits	• This requirement may be satisfied by successfully completing General Chemistry I and II for majors in Category 4 of the Transfer Credit Framework. See below. • Minimum grade of C- or better (equivalent of a 1.7 GPA on a 4.0 scale) in General Chemistry 1 for majors coursework.
Mathematics: Calculus	12 credits	• Part of this requirement may be satisfied by successfully completing Calculus I in Category 3 of the Transfer Credit Framework. See below • Minimum grade of C- or better (equivalent of a 1.7 GPA on a 4.0 scale) in Calculus 1 coursework.
Mathematics: Ordinary Differential Equations	3 credits	
Physics	10 credits	• Minimum grade of C- (equivalent of a 1.7 GPA on a 4.0 scale) in Calculus-based Physics 1 coursework.
TOTAL Major CREDITS	**Minimum 36 credits**	
Transfer Credit Framework	**Framework Requirement**	**Student Transferring Under This Agreement are REQUIRED TO TAKE…**
Category 1	1 course	1. One course to be selected by the student with the assistance of an advisor (3 credits)
Category 2	1 course	1. One course to be selected by the student with the assistance of an advisor. (3 credits)
Category 3	No more than 2 courses	1. Calculus 1 (See above) 2. Post Calculus 1
Category 4	No more than 2 courses	1. General Chemistry I for majors (See above) 2. General Chemistry II for majors (See above)
Category 5	No more than 2 courses	1. One course to be selected by the student with the assistance of an advisor. (3 credits) 2. One course to be selected by the student with the assistance of an advisor. (3 credits)
Category 6	No more than 2 courses	1. One course to be selected by the student with the assistance of an advisor. (3 credits) 2. One course to be selected by the student with the assistance of an advisor. (3 credits)
TOTAL Framework CREDITS	**Minimum 18 credits**	

APPENDIX B: Transfer Credit Framework

Students who successfully complete courses from the approved categories below can have their credits transferred and counted towards graduation at any of the participating PA TRAC colleges and universities. Please be aware that certain majors may have specific requirements prescribed by external agencies. It is the student's responsibility to work with an advisor to select appropriate courses as they relate to the major.

Category 1 (3-4 credits)	**Category 2 (3-4 credits)**	**Category 3 (min. 3-4 credits; max. 6-8 credits)**	**Category 4 Must include lab (min. 3-4 credits; max. 6-8 credits)**	**Category 5 (min. 3-4 credits; max. 6-8 credits)**	**Category 6 (min. 3-4 credits; max. 6-8 credits)**
English Composition	Public Speaking	Foundations of Mathematics	General Chemistry I (majors & non-majors courses)	General Psychology	Introduction to Music
		College Algebra	General Chemistry II (majors & non-majors courses)	Introduction to Sociology	Introduction to Philosophy
		Elementary Statistics	General Biology I (majors & non-majors courses)	American National Government	Elementary Spanish I
		Precalculus	General Biology II (majors & non-majors courses)	Educational Psychology	Elementary Spanish II
		Calculus I	General Physics I (non-calculus)	History of Western Civilization II	Painting I
			General Physics II (non-calculus)	Principles of Macroeconomics	Elementary French I
			Anatomy & Physiology I	Principles of Microeconomics	Elementary French II
			Anatomy & Physiology II	U.S. History I	Drawing I
			Introduction to Astronomy	U.S. History II	Ethics
				History of Western Civilization I	Introduction to Art
				Contemporary Social Problems	German I
				Introduction to Anthropology	German II
					Introduction to Literature (may also known as Introduction to Poetry, Interpreting Literature, Reading Literature, Theses in Literature, Topics in Literature, Current Themes in Literature)
					Survey of American Literature
					Literature of the Western World
					World Literature
					American Literature
					Survey of English Literature
					Introduction to Theatre