Pennsylvania Department of Education
Transfer and Articulation Oversight Committee
Approved by TAOC on June 16, 2011
Amended April 11, 2012

# PENNSYLVANIA STATEWIDE PROGRAM-TO-PROGRAM ARTICULATION AGREEMENT IN PHYSICS

## 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 Physics or any AA or AS degree that incorporates the required competencies at a participating institution can transfer the full degree into a parallel bachelor degree program in Physics at a participating four-year institution.

In order for students to transfer the full associate degree into a parallel bachelor degree program at a participating four-year institution, all of the following criteria must be met:

- Successful completion of an associate degree that includes all of the required major competencies identified in this Agreement.
- Successful completion of 30 credits of foundation courses from the Transfer Credit Framework.

See Appendix A: Program-to-Program Articulation Model for Physics.

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

References to courses in all agreements designate competencies and are not to be construed as making a reference to a specific course at a specific institution. Course titles in the agreements are presented for guidance in advising students as to which coursework they should take even though the course at the student's college may not have the specific title mentioned in the agreement.[1]

## REQUIRED Major-Specific Content Areas

Under this Agreement, a fully-transferable associate degree in the field of Physics must include competencies from six primary content areas:

1. **Mechanics**
2. **Oscillations and Mechanical Waves**
3. **Thermodynamics**
4. **Electromagnetism**
5. **Optics**
6. **Modern Physics**

The content taught must be calculus-based and include laboratory work. See Appendix B: Competencies for Preparation in Physics.

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

[1] Adopted by TAOC and added to the agreement on April 11, 2012.

## REQUIRED Related Coursework

In addition to the major-specific content, a fully-transferable associate degree in the field of Physics must include competencies in two related areas outside of the discipline:

### 1. Calculus

Much of the required Physics content requires skills in mathematics. Therefore, it is essential that students acquire and develop these skills by taking Calculus. To meet this requirement, the student should take the Calculus courses required to satisfy the Calculus competencies listed in Appendix B of the Program–to-Program Articulation Agreement for Mathematics. This may require two or three courses. See Attachment 1.

### 2. General Chemistry

Physics content is complemented and reinforced in other sciences. It is expected that Physics majors are well versed in as much science as possible. For this reason, students must complete at least two sequential semesters of Chemistry as part of the associate degree.

## RECOMMENDED Related Coursework

Students transferring into a bachelor degree in Physics are strongly encouraged to complete one advanced mathematics course in Differential Equations prior to entering the bachelor degree program:

### 1. Differential Equations

Advanced coursework in Physics requires skills in working with differential equations. Therefore, it is recommended that students take a course in differential equations as part of their Associates degree program.

Coursework is Differential Equations is a recommendation only. Students are not required to complete the course as part of the major or the articulation Agreement, and therefore, will not be penalized for not completing the course prior to transferring into the parallel bachelor degree.

## Transfer Credit Framework

In accordance to Article XX-C of the Public School Code of 1949, the Commonwealth's statewide college credit transfer system includes an advising tool called the "Transfer Credit Framework." The Framework allows students to 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 six categories which include courses in English, public speaking, math, science, art, humanities, history and the behavioral and social sciences. To fully benefit from the Framework, students are advised to select a range of courses from all six categories as designated in the Transfer Credit Framework Policy noted in Appendix C.

Under this Agreement, students may select courses according to the criteria indicated for Framework Category 1, Category 2, Category 5 and Category 6.

In Framework Category 3, students may apply a maximum of 8 credits completed as part of the Required Outside of Discipline Coursework in Calculus.

Likewise, a maximum of 8 credits in General Chemistry, required coursework outside of the field of Physics, may be used to satisfy the requirements of Framework Category 4. 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.

## Table 1: Transfer Credit Framework Requirements for Physics Majors

| Framework Category | Framework Allows Students to Take… | Physics Majors Are REQUIRED to Take… |
|---|---|---|
| **Category 1** | 1 course (3-4 credits) | **1 course** to be selected by the student with the assistance of an advisor. |
| **Category 2** | 1 course (3-4 credits) | **1 course** to be selected by the student with the assistance of an advisor. |
| **Category 3** | 2 courses (6-8 credits) | **1. Calculus I**<br>**2. Calculus II** |
| **Category 4** | 2 courses (6-8 credits) | **1. General Chemistry I**<br>**2. General Chemistry II** |
| **Category 5** | 2 courses (6-8 credits) | **2 courses** to be selected by the student with the assistance of an advisor. |
| **Category 6** | 2 courses (6-8 credits) | **2 courses** to be selected by the student with the assistance of an advisor. |

## Appendix A: Program-to-Program Articulation Model for Physics

| **REQUIRED – Major-Specific Content Areas** | **Transfer Criteria** |
|---|---|
| **Calculus-Based Physics** | 8 credits minimum |
| **REQUIRED – Coursework Outside of the Discipline** | **Transfer Criteria** |
| **General Chemistry** | • To meet this requirement, the student should take General Chemistry I and II. See Category 4 of the Transfer Credit Framework below. |
| **Calculus** | • To meet this requirement, the student should take the Calculus courses required to satisfy the Calculus competencies listed in Appendix B of the Program–to-Program Articulation Agreement for Mathematics. See Category 3 of the Transfer Credit Framework below. |
| **RECOMMENDED – Coursework Outside of the Discipline** | **Transfer Criteria** |
| **Differential Equations** | • Student will not be penalized for not taking the course prior to transferring. |
| **Transfer Credit Framework** | **Transfer Criteria** |
| **Category 1** | **1 course** to be selected by the student with the assistance of an advisor. |
| **Category 2** | **1 course** to be selected by the student with the assistance of an advisor. |
| **Category 3** | **1. Calculus I**<br>**2. Calculus II** |
| **Category 4** | **1. General Chemistry I**<br>**2. General Chemistry II** |
| **Category 5** | **2 courses** to be selected by the student with the assistance of an advisor. |
| **Category 6** | **2 courses** to be selected by the student with the assistance of an advisor. |

## Appendix B: Physics Competencies

Competencies listed with the superscripts "I" or "d" should include applications requiring **INTEGRATION - (I)** or **DIFFERENTIATION- (d).**

### 1. Units, Physical Quantities, and Vectors.

Students demonstrate competency in this area by identifying the physical quantities used in physics, recognizing and using the appropriate units associated with physical quantities, representing vectors in the appropriate notation, and performing mathematical operations on vectors. In particular, students should

1.1 Understand the distinction between scalar and vector quantities
1.2 Correctly use standard units when measuring or calculating physical quantities
1.3 Express vector quantities in terms of components and unit vectors
1.4 Add and subtract vector quantities and determine scalar and vector products
1.5 Determine the scalar and vector product of two vectors.

### 2. Linear Motion in One, Two, and Three Dimensions.

Students demonstrate competency in this area by applying the kinematics equations to determine the linear motion of a particle. In particular, students should be able to

2.1 Define displacement, velocity, and acceleration for linear motion of a particle in three dimensions.
2.2 Derive the kinematics 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.
2.3 Solve problems using the kinematics equation for a particle.
2.4 Determine velocity and acceleration as a function of time by differentiation of displacement and velocity.[d]

### 3. Newton's Laws of Motion and Application.

Students will demonstrate competency in this area by applying Newton's Laws of motion and gravity to the linear motion of a particle in three dimensions. In particular, students should be able to

3.1 Describe the difference between mass and weight.
3.2 Calculate the weight of a mass in a given gravitation field.
3.3 Apply Newton's Second Law in multiple dimensions.
3.4 Solve problems involving bodies in free fall.
3.5 Draw correct free-body diagrams for each body in a system.
3.6 Calculate kinetic and static friction forces and apply to Newton's Second Law problems.

### 4. Work, Kinetic Energy, and Energy Conservation.

Students demonstrate competency in this area by knowing and applying the concepts of work and energy to solids, liquids, and gases. In particular, students should be able to

4.1 Define and calculate the work performed on solids, liquids, and gasses
4.2 Derive the Work/Energy Theorem and apply it to the motion of solids and liquids
4.3 Define and calculate gravitational and elastic potential energy
4.4 Define and calculate kinetic energy.
4.5. Solve problems applying the Conservation of Energy Principle

### 5. Linear Momentum, Impulse, and Collisions and Conservation of Linear Momentum

Students will have demonstrated understanding of the concepts and problem-solving ability when they:

5.1 Solve problems relating impulse and change in momentum.
5.2 Solve problems by applying the principle of conservation of momentum.
5.3 Identify elastic and inelastic collisions.
5.4 Perform vector addition of momentum vectors
5.5 Calculate impulse by integrating force w.r.t. time.[I]

**6. Rotational Motion of Rigid Bodies and the Dynamics of Rotational Motion**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:

6.1 Apply rotational kinematics equations to solve problems.
6.2 Apply the relationship between linear and angular quantities to solve problems.
6.3 Calculate the moment of inertia of selected objects.[I]
6.4 Solve problems involving the rotation of a rigid body.
6.5 Solve problems relating torque, moment of inertia and angular momentum.
6.6 Solve problems involving rolling motion.
6.7 Compute torque as a vector product.

**7. Angular Momentum and the Conservation of Angular Momentum**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:

7.1 Explain the principle of conservation of angular momentum.
7.2 Solve problems utilizing the principle of conservation of angular momentum.
7.3 Solve problems relating torque and the rate of change of angular momentum.

**8. Static Equilibrium and Elasticity**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:
8.1 State the conditions for mechanical equilibrium.
8.2 Solve mechanical equilibrium in multiple dimensions by solving a system of equations.
8.3 Compute the center of gravity of an object and system of masses.[I]
8.4 Calculate Stress.
8.5 Solve problems using the relationship between stress, strain and the elastic modulus.

**9. Gravitation**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:

9.1 State the law of universal gravitation and utilize it in solving problems.
9.2 Use the law of gravitation to solve problems involving satellite motion.
9.3 Apply Kepler's Laws of Motion to solve problems involving satellites.
9.4 Calculate Gravitational potential energy of a system of masses.
9.5 Calculate the escape velocity.

**10. Fluid Mechanics**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:

10.1 Solve problems relating force, area and pressure.
10.2 Calculate the absolute pressure at a depth in a fluid.
10.3 Solve problems by applying Pascal's law.
10.4 Relate Bernoulli's equation to the concept of conservation of energy and solve related problems.
10.5 Apply Archimedes principle to problems involving weight, mass, and buoyancy.

**11. Oscillatory Motion and Mechanical Waves**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:

11.1 Calculate the frequency, angular frequency and period for a mass-spring system.
11.2 Calculate the frequency, angular frequency and period for a pendulum.
11.3 Solve problems relating frequency, angular frequency and period.
11.4. Find 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.[d]
11.5 Calculate the energy of a simple harmonic oscillator.
11.6 Use conservation of energy to calculate displacement and/or velocity of a simple harmonic oscillator.

**12. Superposition, Standing Waves, Sound**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:

12.1 Calculate the speed of a wave in different media.
12.2 Identify and calculate amplitude, wave number, angular frequency, speed and acceleration in the expression for displacement as a function of time and position.
12.3 Calculate resonance frequency.
12.4 Show that a particular displacement function satisfies the wave equation.[d]
12.6 Calculate the rate at which energy is transported by waves in a string.
12.7 Calculate the speed of sound in various media.
12.8 Identify and calculate amplitude, wave number, angular frequency, speed in the expression for pressure as a function of time and position.
12.9 Calculate the shift in frequency due to the Doppler Effect.
12.10 Calculate the decibel level for a given intensity level and vice versa.
12.11 Calculate the resulting wave function due to the superposition of two waves.
12.12 Determine relationship between length of open and closed end pipes and their resonant frequencies.

**13. Temperature and the Kinetic Theory of Gases**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:

13.1 Convert between Celsius, Fahrenheit, Kelvin and Rankine units.
13.2 Calculate the number of molecules of a given mass using the molar or molecular mass.
13.2 Calculate the average translational kinetic energy of a monatomic gas at a given temperature.
13.3 Calculate the root mean square speed of a monatomic gas at a given temperature.
13.4 Solve problems using the ideal gas law.
13.5 Calculate work done by a gas during constant volume, constant pressure and constant temperature processes.
13.5 Solve problems involving thermal expansion.

**14. Heat and the First Law of Thermodynamics**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:

14.1 Solve problems involving specific heat capacity including method of mixtures.
14.2 Solve problems involving constant pressure and constant volume specific heat for gases.
14.2 Calculate the amount of heat required to change phase.
14.3 Explain the first law of thermodynamics.
14.4 Apply the first law of thermodynamics to adiabatic, isothermal and constant volume processes.
14.5 Solve problems involving heat transfer by conduction.
14.6 Solve problems involving heat transfer by radiation.

**15. The Second Law of Thermodynamics**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:

15.1 Explain the Second Law of Thermodynamics.
15.2 Calculate the efficiency of a heat engine.
15.3 Calculate the efficiency of a Carnot engine.
15.4 Describe entropy.
15.5 Calculate the change in entropy for a system.

**16. Electric Charge, Electric Field, and Gauss's Law**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:

16.1 Solve problems using Coulomb's Law.
16.2 Solve problems relating electric force and electric field.
16.3 Calculate the electric filed vector for a system of point charges and uniformly distributed charges.[l]

16.4 Draw electric field lines.
16.5 Calculate electric flux. [I]
16.6 Apply Gauss' Law to find the electric field due to a distribution of charge.[I]
16.7 Explain the four properties of a conductor in electrostatic equilibrium resulting from Gauss' Law.

**17. Electric Potential**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:

17.1 Calculate the Electric Potential difference between two points when given and electric field.[I]
17.2 Calculate the value of electric potential for a distribution of charges.[I]
17.3 Solve problems relating change in electric potential energy and change in electric potential.
17.4 Calculate the electric potential energy for a system of charges.
17.5 Determine the electric field by taking the partial derivatives of the electric potential.[d]

**18. Capacitance and Dielectrics**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:

18.1 Solve problems relating potential difference, charge and capacitance.
18.2 Calculate the capacitance of a parallel plate, cylindrical and spherical capacitors.
18.3 Find the equivalent capacitance of capacitors in parallel and series.
18.4 Calculate the energy stored in a capacitor.
18.5 Solve capacitance problems which include the effect of dielectric materials.

**19. Current, Resistance, and Direct-Current Circuits**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:

19.1 Determine current by taking the derivative of charge w.r.t. time.[d]
19.2 Solve problems by applying Ohm's Law.
19.3 Solve problems relating resistance, resistivity, length and cross-sectional area.
19.4 Calculate the effect of temperature on resistivity and resistance.
19.5 Solve problems relating power, current, potential and resistance.
19.6 Find the equivalent resistance of resistors in parallel and series.
19.7 Solve electric circuit problems by applying Kirchoff's laws.
19.8 Solve for values of current, charge or potential for charging and discharging an RC circuit.

**20. Magnetic Field and Sources of the Magnetic Field**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:

20.1 Determine the magnetic force on a moving charge by finding the cross product of velocity and magnetic field multiplied by the charge.
20.2 Solve problems involving the speed of a charge through a velocity selector.
20.3 Calculate the force on a current carrying wire due to a magnetic field.
20.4 Calculate the torque on a current carrying loop of wire in a magnetic field.
20.5 Solve problems by applying the Biot-Savart Law.[I]
20.6 Calculate the magnetic force between two current carrying wires.
20.7 Use Ampere's Law to determine magnetic field due to a current in various configurations.
20.8 Calculate magnetic flux by using Gauss' law in magnetism.
20.9 Explain the source of magnetism in matter.

**21. Faraday's Law, Magnetic Induction, and Inductance**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:

21.1 Calculate induced emf using Faraday's law.[d]
21.2 Calculate motional emf and solve related problems.

21.3 Use Lenz's law to determine the direction of induced emf.
21.4 Apply Faraday's law to solve problems involving motors and generators.[d]
21.5 Calculate induced emf due to a time-varying current in a circuit.[d]
21.6 Calculate the inductance for a solenoid.
21.7 Solve for values of current and potential when closing an LC circuit with a potential source and then after removing the potential source.
21.8 Calculate the energy stored in an inductor.
21.9 Calculate the value of mutual inductance for two current carrying coils.
21.10 Solve problems involving induced emf due to mutual inductance.
21.11 Calculate the natural frequency for an LC circuit.
21.12 Calculate the natural frequency for an RLC circuit.

**22. Alternating-Current Circuits**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:

22.1 Calculate the root-mean-square values for current and potential for n AC circuit.
22.2 Calculate inductive and capacitive reactance and impedance.
22.3 Determine the phase angle between the current and potential in an AC circuit.
22.4 Calculate the average power for an AC circuit.
22.5 Explain the term band width and calculate the quality factor for an AC circuit.
22.6 Solve problems involving step-up and step-down transformers.

**23. Maxwell's Equations and Electromagnetic Waves**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:

23.1 Explain and calculate displacement current due to a changing electric flux.
23.2 Modify Ampere's Law to include the effect of the displacement current.
23.3 List Maxwell's equations.
23.4 Solve problems by relating the strength of the electric field to the strength of the magnetic field in an electromagnetic wave.
23.5 Determine the Poynting vector by using the cross product of the electric and magnetic fields.
23.6 Calculate the intensity of an electromagnetic wave.
23.7 Calculate the momentum and energy of an electromagnetic wave.
23.8 Order the types of electromagnetic waves from low frequency tom high frequency.

**24. The Nature and Propagation of Light and the Laws of Geometric Optics**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:

24.1 Apply the law of reflection.
24.2 Apply Snell's Law of refraction.
24.3. Solve problems relating the speed of light in a medium to its index of refraction.
24.4 Explain Huygens' principle.
24.5 Calculate the angle of dispersion for refraction involving electromagnetic waves of different frequency.
24.6 Calculate the critical angle of incidence for a medium.
24.7 Solve problems involving image distance, image height, object distance, object height, magnification and focal length of spherical mirrors and lenses.

**25. Physical Optics, Interference, Diffraction, and Polarization**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:

25.1 Describe how Young's double slit experiment bright and dark regions by constructive and destructive interference.
25.2 Solve Young's double slit problems for position of dark bands, bright bands, wavelength and slit separation.
25.3 Calculate the intensity of light for a given position in a Young's double slit experiment.

25.4 Solve problems involving the change of phase due to reflection including thin-film interference and non-reflective coatings.
25.5 Explain how a Fraunhofer diffraction pattern is created using Huygens' principle.
25.6 Solve Fraunhofer diffaction problems for position of dark bands, bright bands, wavelength and slit width.
25.7 Calculate the intensity of light for a given position in a Fraunhofer diffraction pattern.
25.8 Calculate the resolution for a slit and circular aperture.
25.9 Solve diffraction grating problems for position of dark bands, bright bands, wavelength and slit separation.
25.10 Solve problems using Bragg's law.
25.11 Calculate the intensity of light after passing through polarizing lenses.
25.12. Solve problems using Brewster's law.

**26. Relativity**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:

26.1 Calculate time dilation, length contraction, relativistic linear momentum and relativistic energy for speeds near the speed of light.
26.2 Solve problems involving the relativistic Doppler effect.
26.3 Solve problems using the Lorentz Transformation equations for position and velocity.
26.4 Solve problems involving the total energy of a relativistic particle.

**27. Wave-Particle Duality and Quantum Physics**
Students will have demonstrated understanding of the concepts and problem-solving ability when they:

27.1 Apply Wien's displacement law.
27.2 Explain how quantum theory predicts the intensity as a function of wavelength distribution for radiation.
27.3 Calculate the energy of an electromagnetic wave of given frequency.
27.4 Explain the photoelectric effect.
27.5 Solve problems involving cutoff frequency, wavelength, stopping voltage, maximum electron kinetic energy and work function in relation to the photoelectric effect.
27.6 Calculate the Compton shift for an X-ray/electron interaction.
27.7 Calculate the De Broglie wavelength.
27.8 Explain how particles behave as waves and how waves behave as particles.
27.9 Calculate minimum uncertainty using the Heisenberg uncertainty principle.

**28. Atomic Physics, Molecules, Solids**
Students should:

28.1 Have an understanding of the solution of the Schroedinger equation for the hydrogen atom and its implications.
28.2 Understand the mathematical techniques of solution and how they give rise to the quantum numbers defining the state of the electron.
28.3 Be able to appreciate the nature of the wave function and what it can be used to compute.
28.4 Have an appreciation for the Copenhagen interpretation of quantum mechanics.
28.5 Understand the quantum mechanical view of molecular bonding.
28.6 Understand qualitatively the wave functions and energy levels for atoms more complex than hydrogen, including the relevance to the periodic table of elements.
28.7 Understand the Pauli Exclusion Principle and its impact on electron configurations.
28.8 Understand the details of the spin-orbit effect, and the Zeeman effect.
28.9 Understand the processes of radiation absorption, scattering, and stimulated emission.
28.10 Understand the quantum theory of conduction in solids, band theory, and semiconductor theory.

**29. Nuclear Physics**
Students should:

29.1 Understand the structure of the atomic nucleus and the basic nature of the nuclear force.

29.2 Understand the processes of fission and fusion and how to compute the energetics of such processes.
29.3 Understand the binding energy curve for atomic nuclei and its relation to the fission/fusion processes.
29.4 Understand radioactive decay processes and the concept of half-life.
29.5 Understand the basics of particle detection and its relevance to measuring radioactive decay products.
29.6 Be able to quantify radiation levels in terms of appropriate units of measurement.

**30. Particle Physics and Cosmology**
Students should:

30.1 Have a firm grasp of the type of particles that form the building blocks of nature and how they are classified.
30.2 Understand the implications of particle physics interactions and how it relates to the early universe and questions about our origin.
30.3 Understand the basic interactions of the elementary particles.
30.4 Understand how the conservation laws govern particle reactions or decay of unstable particles.

**31. Laboratory Competencies**
The courses which develop the competencies listed above should be accompanied by laboratory experience which reinforces the concepts and gives the student experience in collecting and analyzing data.

This lab component should develop the student’s ability to:

31.1 Collect data from a variety of manual and electronic instruments typically found in a university physics lab.
31.2 Report collected data with the proper use of significant digits, tables and graphs.
31.3 Write a clear, concise and complete objective, procedure and discussion of results including error analysis and consideration of the reasonableness of the results.

## Appendix C: Transfer Credit Framework

Students who successfully complete courses from the categories below may transfer those credits toward the graduation requirements of nearly any major offered by the participating institutions. Please be aware that certain majors may have specific requirements prescribed by external agencies. Students should work with an advisor to select appropriate courses as they relate to the major.

| Category 1 (3-4 credits total) | Category 2 (3-4 credits total) | 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 |
| | | | | Human Growth & Development | Introduction to Literature (may also be known as Introduction to Poetry, Interpreting Literature, Reading Literature, Theses in Literature, Topics in Literature, Current Themes in Literature) |
| | | | | Child Psychology | Survey of American Literature |
| | | | | | Literature of the Western World |
| | | | | | World Literature |
| | | | | | American Literature |
| | | | | | Survey of English Literature |
| | | | | | Introduction to Theatre |

## Attachment 1: Calculus Competencies from the Program-to-Program Articulation in Mathematics (Approved November 2010)

**Competency 1**: Utilize the concept of limit.
**Behavioral Objectives**: In order to attain this competency, the student should be able to:
1.1 determine limits using a table of values or graph.
1.2 evaluate limits of polynomial, rational, and trigonometric functions by direct substitution.
1.3 where substitution yields an indeterminate form, find limits by cancellation and rationalization techniques or by the use of identities.
1.4 use L'Hopital's Rule to find limits of indeterminate forms.
1.5 evaluate limits using the Squeeze Theorem.
1.6 use limit theorems involving sums, differences, products, and quotients of functions.
1.7 indicate whether a function is continuous or discontinuous; if discontinuous, give all points of discontinuity.
1.8 determine limits at infinity.

**Competency 2**: Differentiate functions.
**Behavioral Objectives**: In order to attain this competency, the student should be able to:
2.1 define and interpret the derivative of a function.
2.2 compute derivatives of functions using the definition.
2.3 obtain the derivatives of sums, products, quotients, and powers of polynomial, trigonometric, and transcendental functions using the general formulas for differentiation.
2.4 use the chain rule to differentiate the composition of functions.
2.5 find differentials.
2.6 differentiate implicitly.
2.7 find higher order derivatives.
2.8 evaluate derivatives.

**Competency 3**: Use differential calculus to sketch curves and to solve applied problems.
**Behavioral Objectives**: In order to attain this competency, the student should be able to:
3.1 find the intervals on which a function is increasing or decreasing and the intervals on which a function is concave upward or concave downward.
3.2 determine relative minima, relative maxima, and points of inflection, if any, and sketch the graph of a function.
3.3 find the equations of lines tangent and normal to a curve at a given point.
3.4 find the point(s) on a curve where the tangent line has a given slope.
3.5 use differentials to approximate values of non-linear functions.
3.6 approximate a solution for an equation using Newton's Method.
3.7 given a position function, calculate the velocity and acceleration of a particle and analyze its motion.
3.8 apply Rolle's Theorem and the Mean Value Theorem to a function.
3.9 solve applied related rate problems.
3.10 solve applied maximum-minimum problems.
3.11 apply the Extreme Value Theorem to a function.

**Competency 4**: Integrate functions by approximation and by use of antiderivatives.
**Behavioral Objectives**: In order to attain this competency, the student should be able to:
4.1 define the indefinite and definite integral of a function.
4.2 find antiderivatives by using the power rule and substitution.
4.3 integrate algebraic and trigonometric functions.
4.4 determine the constant of integration given sufficient conditions.
4.5 use the Fundamental Theorem of Calculus to evaluate definite integrals.
4.6 approximate an integral by the Trapezoidal Rule or Simpson's Rule.
4.7 use the $2^{nd}$ Fundamental Theorem of Integral Calculus
4.8 express the limit of a Riemann sum as a definite integral.

**Competency 5**: Use integral calculus to determine area and to solve applied problems.
**Behavioral Objectives**: In order to attain this competency, the student should be able to:
5.1 find the area of a region bounded by the graphs of given equations.
5.2 determine the volume of a solid of revolution by the disc and washer methods or by the shell method.
5.3 find the length of a plane curve.
5.4 determine the area of the surface of revolution.
5.5 calculate 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.
5.6 calculate the average value of a function and use the Mean-Value Theorem for Integrals

**Competency 6**: Differentiate and integrate using transcendental functions.
**Behavioral Objectives**: In order to attain this competency, the student should be able to:
6.1 find derivatives of functions involving the natural logarithmic function.
6.2 integrate rational functions whose antiderivatives are natural logarithmic functions.
6.3 find the derivative of an inverse function.
6.4 differentiate and integrate natural exponential functions.
6.5 differentiate and integrate exponential functions that have bases other than *e*.
6.6 solve growth and decay problems.
6.7 differentiate inverse trigonometric, hyperbolic, and inverse hyperbolic functions.
6.8 integrate functions yielding inverse trigonometric, hyperbolic or inverse hyperbolic functions.

**Competency 7**: Integrate functions using special methods.
**Behavioral Objectives**: In order to attain this competency, the student should be able to:
7.1 integrate by parts.
7.2 integrate powers of trigonometric functions.
7.3 integrate using trigonometric substitution.
7.4 integrate using partial fraction decomposition.
7.5 integrate using tables.
7.6 evaluate improper integrals.

**Competency 8**: Relate the functional and geometric properties of conic sections, curves given in parametric form, and polar curves.
**Behavioral Objectives:** In order to attain this competency, the student should be able to:
8.1 given the equation of a conic section, identify its parts (e.g., center, vertices, foci, axes, asymptotes, eccentricity, etc.) and graph it.
8.2 find the equation of a conic section (circle, parabola, ellipse, hyperbola) given sufficient information about its parts.
8.3 graph a curve given by a set of parametric equations.
8.4 find a set of parametric equations to represent a curve.
8.5 find the slope of a tangent line to a curve given by a set of parametric equations
8.6 find the arc length of a curve given by a set of parametric equations.
8.7 transform equations from polar coordinates to rectangular coordinates and vice-versa.
8.8 sketch common polar graphs.
8.9 determine the slope of a tangent line to a polar graph.
8.10 find the area of a region bounded by a polar graph and the arc length of a polar graph.

**Competency 9:** Use vectors to solve 2-space and 3-space geometrical problems.
**Behavioral Objectives:** In order to attain this competency, the student should be able to:
9.1 write a vector in component form or as a linear combination of standard unit vectors.
9.2 graph a given a vector, unitize it, and find its magnitude and direction.
9.3 add, subtract, and form scalar multiples of vectors.
9.4 calculate the dot (scalar) product of two vectors and use the dot product to find the angle between two vectors, the direction cosines of a vector, and the projection of one vector onto another.
9.5 calculate the cross product of two vectors and the triple scalar product of three vectors.

9.6 find equations of lines and planes in 3-space, given sufficient data.
9.7 identify and sketch planes, cylinders, and quadric surfaces, given their equations.
9.8 Convert between rectangular, cylindrical and spherical coordinates.

**Competency 10:** Use vector-valued functions to describe motion in space.
**Behavioral Objectives:** In order to attain this competency, the student should be able to:
10.1 extend the concepts of limit, continuity, differentiation, and integration to vector-valued functions.
10.2 graph vector-valued functions.
10.3 differentiate a displacement (position) vector to find the velocity and acceleration vectors and the speed at a point.
10.4 use vector-valued functions to analyze projectile motion.
10.5 for a given vector-valued function, find a unit tangent, a unit normal, and the tangential and normal components of acceleration.
10.6 find the arc length and the curvature of a space curve described by a vector-valued function.

**Competency 11:** Find partial derivatives of functions of two or more variables.
**Behavioral Objectives:** In order to attain this competency, the student should be able to:
11.1 find the first-order partial derivatives of functions.
11.2 find higher order partial derivatives.
11.3 use the chain rule for partial derivatives.
11.4 calculate the total differential

**Competency 12:** Use partial differentiation to solve applied problems.
**Behavioral Objectives:** In order to attain this competency, the student should be able to:
12.1 find the directional derivative.
12.2 find the equation of the tangent plane to a surface at a given point.
12.3 find the gradient of a function.
12.4 maximize or minimize functions of two independent variables.
12.5 apply Lagrange Multipliers to maximum – minimum problems.

**Competency 13:** Evaluate multiple integrals.
**Behavioral Objectives:** In order to attain this competency, the student should be able to:
13.1 evaluate double integrals.
13.2 evaluate double integrals by use of polar coordinates.
13.3 evaluate triple integrals.
13.4 evaluate triple integrals by use of cylindrical coordinates.
13.5 evaluate triple integrals by use of spherical coordinates.

**Competency 14:** Use multiple integrals to solve applied problems.
**Behavioral Objectives:** In order to attain this competency, the student should be able to:
14.1 find areas by use of double integration.
14.2 locate the center of gravity and centroid of a solid.
14.3 find volumes by use of multiple integrals.
14.4 evaluate triple integrals to solve applied problems.
14.5 find surface area.

**Competency 15:** Use techniques of vector analysis.
**Behavioral Objectives:** In order to attain this competency, the student should be able to:
15.1 evaluate surface integrals.
15.2 evaluate line integrals.
15.3 find work done in a vector field.
15.4 determine the path-independent line integrals.
15.5 use Green's Theorem to compute line integrals or double integrals.
15.6 use the Divergence Theorem to compute surface integrals or triple integrals.

15.7 use Stokes' Theorem to compute line integrals or surface integrals.

**Competency 16:** Test infinite series for convergence or divergence.
**Behavioral Objectives:** In order to attain this competency, the student should be able to:
16.1 determine whether a sequence converges or diverges.
16.2 find the limit of convergent sequences.
16.3 determine whether a given geometric series or p-series converges or diverges.
16.4 find closed expressions for the sum of terms of an infinite geometric and telescoping series.
16.5 test 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.
16.6 test for absolute convergence and conditional convergence of alternating series.
16.7 express functions as power series.
16.8 find the interval of convergence for power series.
16.9 write Maclaurin series expansions.
16.10 write Taylor series expansions.
16.11 compute using series expansions.
16.12 differentiate and integrate power series.
16.13 use the Remainder Term in Taylor’s Theorem to perform error estimates.

## ADDENDUM
## GENERAL STATEWIDE PROGRAM-TO-PROGRAM ARTICULATION in PENNSYLVANIA
***(Revised April 11, 2012)***

WHEREAS, the General Assembly of the Commonwealth of Pennsylvania enacted Act 114 of 2006, which added to the Public School Code of 1949, Article XX-C entitled "Transfers of Credits Between Institutions of Higher Education" (referred to in this Agreement as the "Statewide Transfer System");

WHEREAS, Act 114 of 2006 requires all community colleges in Pennsylvania and Pennsylvania State System of Higher Education (PASSHE) universities to participate in the Statewide Transfer System;

WHEREAS, Act 114 of 2006 permits independent and state-related institutions of higher education in Pennsylvania, as each is defined in Article XX-C, to elect to participate in the Statewide Transfer System;

WHEREAS, the General Assembly of the Commonwealth of Pennsylvania enacted Act 50 of 2009, which requires institutions participating in the Statewide Transfer System to accept the transfer of Associate of Arts and Associate Science degrees into parallel baccalaureate programs and recognize all competencies attained within the associate degree program;

WHEREAS, Act 50 of 2009 defines an Associate of Arts (AA) or Associate of Science (AS) degree containing a minimum of 60 college-level credits and designed primarily for transfer to a baccalaureate institution;

WHEREAS, Act 50 of 2009 requires the Transfer Articulation Oversight Committee (TAOC), as established in section 2004-C of the Public School Code of 1949, to identify Associate of Arts and Associate of Science degree programs for transfer with full junior standing into parallel baccalaureate degrees annually; and,

WHEREAS, Act 50 of 2009 requires members of the Transfer Articulation Oversight Committee established in section 2004-C of the Public School Code of 1949, to identify modifications that may be required in existing associate or baccalaureate degrees to satisfy external accreditation or licensure requirement;

All Institutions participating in the Statewide Transfer System enter into this Articulation Agreement and mutually agree as follows:

1. The statewide program-to-program articulation agreement ensures that students who complete an AA or AS degree from a participating institution will have their coursework and credits transfer into a parallel baccalaureate program with full junior standing and without the need for course-by-course equivalency.

2. Students are subject to the admissions and transfer credit policies of the participating institutions. The admissions and transfer credit policies for all of the institutions participating in Pennsylvania's college credit transfer system can be found at www.PAcollegetransfer.com.

3. The AA or AS degree must include a minimum of 60 college-level credits designed and acceptable for transfer, not including developmental or remedial courses or career, technical or applied courses.

4. The transfer of coursework with a grade less than a C (2.0 on a 4.0 scale) in the AA or AS will be consistent with the policies of native students at the participating college or university.

5. Students and institutional personnel will be able to find out which institutions offer articulated programs by accessing a searchable database located at www.PAcollegetransfer.com. PDE will maintain this database through program information provided to TAOC by the individual participating institutions.

6. References to courses in all agreements designate competencies and are not to be construed as making a reference to a specific course at a specific institution. Course titles in the agreements are presented for guidance in advising students

as to which coursework they should take even though the course at the student's college may not have the specific title mentioned in the agreement.[2]

7. **Responsibilities of Associate Degree Institutions**
   a. The AA or AS degree leading to a parallel bachelor degree will include the minimum number of credits and competencies of major-specific coursework as defined by the Agreement.

   b. Any remaining AA or AS degree requirements will be accepted from arts and sciences electives designed and acceptable for transfer, not including developmental, remedial, career, technical or applied courses.

   c. By awarding the AA or AS, the Associate Degree Institution is validating that the student has met the competency requirements outlined in the Agreement.

8. **Responsibilities of Bachelor Degree Institutions**
   a. The Bachelor Degree Institution will recognize all competencies attained within the AA or AS degree and accept a transfer student who has earned the associate degree with full junior standing into a parallel baccalaureate degree program.

   b. All decisions made with respect to the transfer process shall be based on the principle of equivalence of expectations and requirements for native and transfer students.

   c. A transfer student's admission into the parallel baccalaureate degree will be subject to the Bachelor Degree Institution's specific requirements for admission to that major and be consistent with such requirements for native students.

9. **Agreement Revision and Assessment**
   a. Once a statewide program-to-program articulation agreement has been approved by TAOC, no amendments to the agreement can be offered by any party within the initial six (6) months of the agreement. After that time, a TAOC member with a proposed amendment to an approved agreement should submit the change to PDE.

      Amendments that are offered as clarifying or technical but do not alter the substantive portions or intent of the agreement must be forwarded to TAOC. TAOC representatives will have at least thirty (30) days to review, comment and approve or deny the proposed amendments.

      Amendments that seek to alter the substantive nature or intent of the agreement in any part must be forwarded to the appropriate PAC for review and consideration. The PAC will then make a recommendation to the TAOC, and TAOC shall approve or deny the proposed amendments.[3]

   b. PDE and TAOC will exercise responsibility for monitoring the effectiveness of the Agreement and its implementation.

   c. PDE shall collect data annually from the participating institutions that will enable the Department and TAOC to assess the effectiveness of the implementation of the Agreement in fostering a seamless transfer process and the academic success of transfer students at the senior institutions.

10. **Transfer Appeal Process**
   a. In accordance with Pennsylvania's Statewide Transfer System, each Bachelor Degree Institution shall have a procedure through which a transfer student can appeal a decision that he/she believes is not consistent with this Agreement.

   b. The Transfer Appeal Process shall be published, at minimum, in the institution's catalog and posted to the Commonwealth's official website of the Statewide Transfer System, www.PAcollegetransfer.com.

[2] Adopted by TAOC and added to the agreement on April 11, 2012.
[3] Approved by TAOC and added to agreement on August 18, 2011.

**11. Institutional Resolution of Disputes**

a. In the event that an Associate Degree Institution considers the decision of a Bachelor Degree Institution to be inconsistent with this Agreement, the Associate Degree Institution shall consult directly with the Bachelor Degree Institution and attempt to resolve the matter.

b. If the institutions are unable to resolve the issue, the Associate Degree Institution may submit their concern to PDE for consideration by the TAOC Dispute Resolution Committee. The Dispute Resolution Subcommittee will act according to the policies and procedures developed by TAOC as part of the Statewide Transfer System. The determination made by the Dispute Resolution Subcommittee will be binding upon the parties.

12. **Implementation Date and Applicability**

Having fulfilled the requirements outlined in the Program-to-Program Articulation Agreement, students transferring with an AA or AS degree from a participating institution will be considered by the receiving baccalaureate degree institution to have received adequate preparation in the field of study at the foundation level and therefore eligible to transfer as a junior into advanced major coursework.

Participating institutions will enact the Agreement in accordance to the timeline outlined by the TAOC, but no later Fall 2013.[4]

Continuation of the agreement remains in effect until such time as all cooperating institutions of the Statewide Transfer System formally approve any revisions.

## GLOSSARY OF TERMS

**Articulation:** The aligning of curriculum between institutions of higher education to ensure the efficient and effective movement of students among those institutions.

**Associate of Arts (AA) and Associate of Science (AS) Degree:** A degree consisting of at least 60 college-level credits and designed for transfer into a baccalaureate degree program.

**Foundation Coursework:** Courses at a level of comprehension usually associated with freshman and sophomore students and typically offered during the first half of a baccalaureate degree program. Such coursework typically does not have course prerequisites.

**Native Student:** A student who entered a given college or university without first matriculating at another college.

**Parallel Baccalaureate Degree:** A bachelor degree program in a comparable field of study and with similar foundation-level major-specific competencies as an associate degree program.

**Receiving Institution:** The college or university where a transfer student plans to enroll and to apply previously earned credit toward a degree program.

**Transfer Credit:** The credit granted by a college or university for college-level courses or other academic work completed at another institution.

**Transfer Student:** A student who enters a participating college or university after earning college-level credit at another college or university.

**Transfer:** The process by which a student moves from one postsecondary institution to another. Also refers to the mechanics of credit, course and curriculum exchange between institutions.

[4] Agreements approved by TAOC prior to August 31, 2011 must be implemented by the institutions by Fall 2012. Agreements approved by TAOC after August 31, 2011 but before May 1, 2012 must be implemented by the institutions by Fall 2013.

**Advanced Coursework:** Courses with advanced depth of content knowledge in the field of study and carry the expectation of more complex competencies identified in the expected student learning outcomes is referred to as advanced coursework. These courses often have prerequisites and are usually beyond the "Introduction to…" or "Foundation of…" level.