DRAFT

STATEWIDE PROGRAM-TO-PROGRAM ARTICULATION IN

PHYSICS

In Pennsylvania, Statewide Program-to-Program Articulation is intended to provide students with a seamless pathway from an Associate of Arts or Associate of Science degree into a bachelor degree in a similar field of study without loss of academic progress or credit.

A committee of faculty and personnel from the colleges and universities that participate in the Commonwealth's college credit transfer system has developed the following DRAFT articulation agreement and are requesting members of the participating institutions provide them with feedback before finalizing the agreement May 20, 2011.

SUBMITTING COMMENTS
Comments must be submitted using the electronic form available on the Pennsylvania Transfer and Articulation Center website located at www.PAcollegetransfer.com.

Before submitting feedback, individuals are advised to visit the PA TRAC website to gain a better understanding of the purpose of statewide articulation and the process being used to develop this agreement.

DEADLINE
Comments on this DRAFT articulation agreement may be submitted online **starting April 20 and ending midnight on May 8, 2011**.

QUESTIONS?
Questions concerning this DRAFT articulation agreement should be submitted as a comment using the online form mentioned above.

Questions concerning the statewide articulation process and college credit transfer system in Pennsylvania may be emailed to the Pennsylvania Department of Education at ra-patrac@state.pde.us.

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 at least 30 credits of foundation courses from the Transfer Credit Framework.
- A minimum grade of C or better (equivalent of a 2.0 GPA on a 4.0 scale) in all major-specific competencies.

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.

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.

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.

Students are required to earn a minimum grade of C (equivalent of a 2.0 GPA on a 4.0 scale) or better in courses addressing the required competencies specified in each content area.

See Appendix B: Competencies for Preparation in Physics.

REQUIRED Related Coursework

In addition to the major-specific content, a fully-transferable associate degree in the field of Physics must include competencies 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.

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

Under Act 114 of 2006, the Commonwealth's statewide college credit transfer system includes an advising tool called the "Transfer Credit Framework". The Framework 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. See Appendix C: Transfer Credit Framework.

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.

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 (2 courses) completed as part of the Required Outside of Discipline Coursework in Calculus.

Likewise, a maximum of 8 credits (2 courses) 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 Requires 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** **2. Calculus II**
Category 4	2 courses (6-8 credits)	**1. General Chemistry I** **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)	• Minimum grade of C (equivalent 2.0 GPA on a 4.0 scale) or better in courses addressing the required competencies in this Agreement for Physics.
REQUIRED – Coursework Outside of the Discipline	**Transfer Criteria**
1. General Chemistry I **2. General Chemistry II**	• Students may use both courses to meet the requirements of Category 3 of the Transfer Credit Framework. • Minimum grade of C (equivalent 2.0 GPA on a 4.0 scale) or better.
Calculus	• Minimum grade of C (equivalent 2.0 GPA on a 4.0 scale) or better in courses addressing the required Calculus competencies from Appendix B of the Program-to-Program Articulation Agreement for Mathematics.
RECOMMENDED – Coursework Outside of the Discipline	**Transfer Criteria**
Differential Equations	• Minimum grade of C (equivalent 2.0 GPA on a 4.0 scale) or better. • 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** **2. Calculus II**
Category 4	**1. General Chemistry I** **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.[I]
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:

25.1 Apply the law of reflection.
25.2 Apply Snell's Law of refraction.
25.3. Solve problems relating the speed of light in a medium to its index of refraction.
25.4 Explain Huygens' principle.
25.5 Calculate the angle of dispersion for refraction involving electromagnetic waves of different frequency.
25.6 Calculate the critical angle of incidence for a medium.
25.7 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
					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)
					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 2nd 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