

APS DISTRICT HIGH SCHOOL SCIENCE CURRICULUM FRAMEWORK

Course Title: Engineering Robotics II Course Number: 446C3

Department: Science ADS Number: 17347113

Prerequisites: Completion of Electronics Engineering and Robotics I

Length of Course: One Year Credit/PRI Area: 1.50 per Sem/Practical Art/Elective Grade Level(s): 11 - 12

Important Notes:

The student who takes Electronics Engineering and Robotics II receives 1.5 credits per semester – elective electronics mathematics, elective preengineering science, and practical arts. A course that offers more than .5 per semester allows the student additional opportunities for in-depth study and application of the course content. The student is required to take a placement exam.

COURSE DESCRIPTION: Do you want an opportunity to develop and use the engineering skills from the first year course? Do you want a chance to develop an advanced robotics project that could be used with a résumé or for areas such as Science Fair? **This class does that – and more!** Activities include:

- Advanced circuit design applications
- Continued development of machining and tooling applications
- Basic welding
- Continued development of advanced 3-D modeling applications
- Design and fabrication of advanced radio and A. I.-based robot
- Integration of multiple microcontrollers into a “master-slave” relationship
- Application options for competitions, résumé, and Science fairs
- Second year studentjobs.

Literacy and technological skills are integrated throughout the curriculum.

References in parentheses following each performance standard align with the National Council of Teachers of Mathematics Standards (NCTM), the State of New Mexico Mathematics Standards (NM), the State of New Mexico Career Readiness Standards (CR), WorkKeys, the Albuquerque Public Schools Mathematics Standards (APS), and the APS Language Arts Standards (APS – LA).

STRATEGIES:

The “Illustrations” column in the *Program of Studies* provides exemplars of the performance standards, strategies, and best practices suggested by robotics teachers in the Albuquerque Public Schools (APS).

ASSESSMENTS:

Assessments may include: authentic and performance-based assessment, cooperative learning, teacher observations, checklists, tests and exams, formal and informal writing, small group and full class discussions, oral and multimedia presentations, projects, demonstrations, and portfolios. Assessments are based on appropriate rubrics.

SUGGESTED TEXTBOOKS AND INSTRUCTIONAL MATERIALS:

- *Foundations of Electronics: Circuits and Devices*, Meade, Delmar Publishers, Inc., 1994
- *Basic Mathematics for Electronics*, Cooke, Adams, Dell, Moore, Glencoe: McGraw-Hill, 1995
- Computers and computer software

SUGGESTED TITLES/AUTHORS WEB SITES:

- <http://www.nmroborave.com/> The New Mexico ROBO RAVE (Robots Are Very Educational) is a state robot competition.
- <http://www.werc.net/contest/> An environmental design contest including developing new technology to solve a real-world problem.
- <http://parallax.com> Digital circuit board kits, online activity manuals, software
NASA site. Cool robot of the week with archives of past robots

Approved by HSCA: May 5, 2005

STRAND I: SCIENTIFIC THINKING AND PRACTICE**CONTENT STANDARD:** The student understands the processes of scientific investigations and uses inquiry and scientific ways of observing, experimenting, predicting, and validating to think critically.

- BENCHMARKS:**
- A. The student uses accepted scientific methods to collect, analyze, and interpret data and observations and to design and conduct scientific investigations and communicate results.
 - B. The student understands that scientific processes produce scientific knowledge that is continually evaluated, validated, revised, or rejected.
 - C. The student uses mathematical concepts, principles, and expressions to analyze data, develop models, understand patterns and relationships, evaluate findings, and draw conclusions.

GRADE 11 - 12	PERFORMANCE STANDARDS	ILLUSTRATIONS
	<ol style="list-style-type: none"> 1. Describes the essential components of an investigation, including appropriate methodologies, proper equipment, and safety precautions (NM-I.I.I.1). 2. Designs and conducts scientific investigations that include (NM-I.I.I.2): <ul style="list-style-type: none"> • testable hypotheses • controls and variables • methods to collect, analyze, and interpret data • results that address hypotheses being investigated • predictions based on results • re-evaluation of hypotheses and additional experimentation as necessary • error analysis. 3. Uses appropriate technologies (e.g., computers, calculators, balances, microscopes) to collect, analyze, and communicate scientific data (NM-I.I.I.3). 	<p>NOTE: Illustrations include suggested activities for attaining each performance standard. A check for (✓) refers to a key feature to look for while assessing student performance.</p> <p>1 – 7, 12 – 16. The second year student properly and safely designs and fabricates various aspects and modules of a complex robotics project. He/She continues to adjust, modify and analyze the design features with regards to environmental variables. The dynamic fabrication utilizes specific tools and equipment while results and effects are documented, improved and reformulated. The second year student advances the first year indoor robot’s structural design by re-engineering the structural needs to navigate outdoors in rugged terrain.</p> <ul style="list-style-type: none"> ✓ proper safety techniques ✓ identification of independent/dependent variables and controls ✓ experimental design ✓ reasonable and testable engineering task ✓ selection and use of appropriate equipment ✓ explanation of fabrication and circuit analysis ✓ accurate mathematical calculations ✓ organization and analysis of data ✓ multiple trials to verify data ✓ defensible conclusion based on data ✓ critical thinking and insights ✓ use of technology ✓ effective communication skills ✓ writing conventions <p>3, 4. The second year student integrates multiple microcontrollers into a system. The first year student learns to use basic microcontroller functionality, while the second year student implements them using various programming</p>

GRADE 11 - 12	PERFORMANCE STANDARDS	ILLUSTRATIONS
	<p>4. Conveys results of investigations using scientific concepts, methodologies, and expressions, including (NM-I.I.I.4):</p> <ul style="list-style-type: none"> • scientific language and symbols • diagrams, charts, and other data displays • mathematical expressions and processes (e.g., mean, median, slope, proportionality) • clear, logical, and concise communication • reasoned arguments <p>5. Understands how scientific theories are used to explain and predict natural phenomena (e.g., plate tectonics, ocean currents, structure of atom) (NM-I.I.I.5).</p> <p>6. Understands how scientific processes produce valid, reliable results, including (NM-I.I.II.1):</p> <ul style="list-style-type: none"> • consistency of explanations with data and observations • openness to peer review • full disclosure and examination of assumptions • testability of hypotheses • repeatability of experiments and reproducibility of results <p>7. Uses scientific reasoning and valid logic to recognize (NM-I.I.II.2):</p> <ul style="list-style-type: none"> • faulty logic • cause and effect • the difference between observation and unsubstantiated inferences and conclusions • potential bias <p>8. Understands how new data and observations can result in new scientific knowledge (NM-I.I.II.3).</p> <p>9. Critically analyzes an accepted explanation by reviewing current scientific knowledge (NM-I.I.II.4).</p> <p>10. Examines investigations of current interest in science (e.g., superconductivity, molecular machines, age of the universe) (NM-I.I.II.5).</p> <p>11. Examines the scientific processes and logic used in investigations of past events (e.g., using data from crime scenes, fossils), investigations</p>	<p>languages according to design intent and often utilizes more than one to accomplish various tasks. He/She programs (e.g., C, Assembly) a microcontroller to gather environmental data and to make decisions related to the structural capabilities of the second year fabricated design.</p> <ul style="list-style-type: none"> ✓ appropriate assembly and integration of circuitry ✓ desired output attained ✓ effective programming (e.g., steps) <p>8 - 11. The second year student researches, reports and experiments with new improvements and changes in technology with respect to technology currently being used in the classroom (e.g., transistors, microcontrollers, SMT). The second year student often finds that newer technology better addresses problems that he/she is engaged with. His/Her research and discoveries are then presented to the class in order to compare the past achievements with current applications with incoming advances. The research includes:</p> <ul style="list-style-type: none"> • technological accessibility • historical timeline • societal advancements • technological improvements and design • impact on science and integration

GRADE 11 - 12	PERFORMANCE STANDARDS	ILLUSTRATIONS
	<p>that can be planned in advance but are only done once (e.g., expensive or time consuming experiments such as medical clinical trials), and investigations of phenomena that can be repeated easily and frequently (NM-I.I.II.6).</p> <p>12. Creates multiple displays of data to analyze and explain the relationships in scientific investigations (NM-I.I.III.1).</p> <p>13. Uses mathematical models to describe, explain, and predict natural phenomena (NM-I.I.III.2).</p> <p>14. Uses technologies (e.g., calculators, computer spreadsheets and databases, graphing software, simulations, modeling) to quantify relationships in scientific hypotheses (NM-I.I.III.3; CR – 3A).</p> <p>15. Identifies and applies measurement techniques and considers possible effects of measurement errors (NM-I.I.III.4).</p> <p>16. Uses mathematics to express and establish scientific relationships (e.g., scientific notation, vectors, dimensional analysis) (NM-I.I.III.5).</p>	<ul style="list-style-type: none"> ✓ thorough research ✓ all required components ✓ effective presentation <p>The second year student uses 3-D modeling software to design, document, and present investigations and developed research with regards to an embedded and systemic robotic system (e.g., project design software, circuit simulation software).</p> <ul style="list-style-type: none"> ✓ thorough research ✓ effective presentation ✓ writing conventions ✓ technology applications <p>13 – 16. First year students experiment with established sensors by changing parameters and environmental variables in order to explore a sensors capability. The second year student characterizes an environmental variables and conditions and specifically designs the sensor circuitry by using the information from each component’s datasheet, oftentimes, acquiring data from the sensor circuitry and inputting it into Excel to plot graphs of it’s range. Regression and curve fitting can be used to formulate possible functions that describe and predict the sensor in different environments. Each newly derived sensor has its own characteristics documented and is then individually implemented and provided to the first year students.</p> <ul style="list-style-type: none"> ✓ accurate measurements of resistance and voltage drops ✓ analysis and measurement of environmental variables ✓ analysis of sources of error ✓ accurate computations of current ✓ safety procedures

STRAND II: THE CONTENT OF PHYSICAL SCIENCE**CONTENT STANDARD:** The student understands the structure and properties of matter, the characteristics of energy, and the interactions between matter and energy.**BENCHMARKS:** A. The student understands the properties, underlying structure, and reactions of matter.
B. The student understands the transformation and transmission of energy and how energy and matter interact.

GRADE 11 - 12	PERFORMANCE STANDARDS	ILLUSTRATIONS
	<p>Chemical Reactions</p> <ol style="list-style-type: none"> Understands types of chemical reactions (e.g., synthesis, decomposition, combustion, redox, neutralization) and identifies them as exothermic or endothermic (NM-II.I.I.13). Describes how the rate of chemical reactions depends on many factors that include temperature, concentration, and the presence of catalysts (NM-II.I.I.15). <p>Energy Transformation and Transfer</p> <ol style="list-style-type: none"> Identifies different forms of energy, including kinetic, gravitational (i.e., potential), chemical, thermal, nuclear, and electromagnetic (NM-II.I.II.1). Explains how thermal energy (i.e., heat) consists of the random motion and vibrations of atoms and molecules and is measured by temperature (NM-II.I.II.2). Understands that energy can change from one form to another (e.g., changes in kinetic and potential energy in a gravitational field, heats of reaction, hydroelectric dams) and knows that energy is conserved in these changes (NM-II.I.II.3). Understands that the ability of energy to do something useful (work) tends to decrease (and never increases) as energy is converted from one form to another (NM-II.I.II.5). 	<ol style="list-style-type: none"> The second year student implements and advances the process observed in Engineering Robotics I involving the etching of a circuit board, including the proper making, handling, storage and disposal of the created acid as described in the MSDS. He/She discusses and recognizes hazards, byproducts and proper disposal techniques. <ul style="list-style-type: none"> ✓ safety procedures ✓ accurate description of steps ✓ application of proper mixing procedures ✓ correct identification of reactions and reaction types (i.e., endothermic/exothermic) ✓ clear explanation and understanding of chemical factors involving mixtures ✓ application of proper disposal methods The second year robotic student expands and designs circuitry that requires more power and energy to drive complicated systems. The student must account for chemical processes in batteries, heat generated from the high power usages in devices in the circuit and the flyback diode requirements for electromagnetic fields and their affect on integrated circuits. <ul style="list-style-type: none"> ✓ recognition of limits of these energy transfer technologies ✓ accurately account for the energy in a system (i.e., conservation of energy using power) ✓ accurate identification of energy transformations

GRADE 11 - 12	PERFORMANCE STANDARDS	ILLUSTRATIONS
	<p>Interactions of Energy and Matter</p> <p>7. Understands that electromagnetic waves carry energy that can be transferred when they interact with matter (NM-II.I.II.7).</p> <p>8. Describes the characteristics of electromagnetic waves (e.g., visible light, radio, microwave, X-ray, ultraviolet, gamma) and other waves (e.g., sound, seismic waves, water waves) (NM-II.I.II.8).</p> <p>Forces</p> <p>9. Explains how electric currents cause magnetism and how changing magnetic fields produce electricity (e.g., electric motors, generators) (NM-II.I.III.5).</p> <p>10. Represents the magnitude and direction of forces by vector diagrams (NM-II.I.III.6).</p> <p>11. Knows that when one object exerts a force on a second object, the second object exerts a force of equal magnitude and in the opposite direction on the first object (i.e., Newton's Third Law) (NM-II.I.III.7).</p> <p>Motion</p> <p>12. Applies Newton's Laws to describe and analyze the behavior of moving objects, including:</p> <ul style="list-style-type: none"> • displacement, velocity, and acceleration of a moving object <p>Newton's Second Law, $F = ma$ (NM-II.I.III.8).</p>	<p>7, 8. The second year student designs the circuitry and writes the software for implementing radio modems (as opposed to the first year student who just implements a radio system). Radio modems use various radio frequencies to communicate with the operator and between different robots. The student uses an oscilloscope to identify and describe orally or written the properties and characteristics of the radio signal.</p> <ul style="list-style-type: none"> ✓ workable circuit ✓ accurate identification of bipolar voltages and digital signals ✓ troubleshooting skills <p>9. The second year student regularly integrates various relays into his/her robot circuitry. He/She describes and diagrams the magnetic flux lines for the induced magnetic field once the relay is engaged in activity.</p> <ul style="list-style-type: none"> ✓ proper use of safety equipment ✓ workable circuit ✓ accurate identification ✓ troubleshooting skills <p>10. The second year students designs and develops unique drive train systems that exert various forces on the existing robot. Drive train systems that are modeled in software have machined parts, gears and pulleys that exert tangential forces, normal forces, and various other force vectors that must all be accounted for in order for efficiency.</p> <ul style="list-style-type: none"> ✓ accurate diagram <p>11, 12. The second year student designs outdoor, mobile robots around Newton's Laws for velocity, acceleration and displacement. He/She begins design around establishing average traveling velocity of robot as well as weight constraints and establishes force calculations in order to decide on battery requirements.</p> <ul style="list-style-type: none"> ✓ safety procedures ✓ accurate measurements of time and distance ✓ analysis of sources of error ✓ accurate computations of speed and acceleration (e.g., equations of motion) and description of forces

STRAND III: MATHEMATICAL PRINCIPLES AND APPLICATIONS

CONTENT STANDARD: The student demonstrates understanding of mathematical principles through meaningful mathematical experiences.

BENCHMARK: The student applies mathematical procedures to measure, solve, and graph a variety of equations related in real-world situations.

GRADE 11 - 12	PERFORMANCE STANDARDS	ILLUSTRATIONS
	<ol style="list-style-type: none">1. Applies the “rule of four” (i.e., represents mathematics graphically, symbolically, verbally, numerically) (APS – all of Strand I).2. Prepares mathematically for future careers (APS – I. 14).3. Uses reasoning and problem-solving strategies to solve new problems [APS – I.3; NM – IIA (5-7)].4. Makes connections among mathematical concepts (APS – I.12; NM – IA.6).5. Recognizes when to use previously learned strategies to solve new problems (APS – I.2; NM – IC.1, IID.2).	<p>1 - 5. The second year student models robotic parts in 3-D modeling software. Mathematical analysis allows the student to design parts that have centroids, various densities given design materials, graphical aspects for assembling parts, volume constraints, and numerical calculations.</p> <ul style="list-style-type: none">✓ use of technology✓ determination of volume, area and surface area✓ real-life design and mathematical analysis✓ problem-solving strategies✓ accurate calculations✓ communication of ideas✓ teamwork, collaboration <p>The second year student captures data from RS232 serial ports and, using Excel, plots out the data fields in order to analyze linear and exponential relationships between motors and speed control based on analog input values.</p> <ul style="list-style-type: none">✓ use of technology✓ real-life connections✓ problem-solving strategies✓ teamwork, collaboration✓ accurate calculations✓ communication of ideas <p style="text-align: center;">OR</p> <p>The second year student responds to the following scenario:</p> <p>The strength of a radio signal received from a transmitter varies inversely with the square of the distance from the transmitter. Derive the particular equation expressing strength in terms of distance if the strength is 1000 units at a distance of 2 km. Predict the strength 10 km from the transmitter. Explain why when you drive past a transmitting station, the signal from the station can sometimes be heard on the car radio even though the radio is tuned to another station.</p>

GRADE 11 - 12	PERFORMANCE STANDARDS	ILLUSTRATIONS
	<p>6. Identifies how seemingly different mathematical situations may be essentially the same (e.g., The intersection of two lines is the same as the solution to a system of linear equations.) (APS – I.13; NM – IA.7, IA.10).</p> <p>7. Develops a logical sequence of arguments leading to a valid conclusion or solution to a problem (APS – 1.7).</p> <p>8. Performs operations, converts to standard notation, and applies in appropriate context numbers in scientific notation (APS – II.2E; NM – IA.7).</p>	<ul style="list-style-type: none"> ✓ accuracy ✓ connections ✓ effective communication ✓ problem-solving strategies <p style="text-align: center;">OR</p> <p>The amount of force you must exert on a wrench handle to loosen a rusty bolt depends on how long the wrench handle is. Suppose that for a particular bolt, a wrench 7 in. long would require a force of 270 lbs., and a wrench 21 in. long would require 90 lbs. How does force vary with length? Write the general equation. What are the units of the proportionality constant (torque)?</p> <ul style="list-style-type: none"> ✓ reasoning ✓ connections ✓ strategies ✓ documentation of work ✓ clear communication <p>6, 7. The second year student uses a 3-D design diagram to visually solve a problem and, later, a more complex problem, in order to eventually machine the very part in question. As an example, the second year student designs a bushing that must have drive shaft tolerances of less than .005”, be slotted correctly for a gear that is mounted on it and aligns correctly to the drive train frame.</p> <ul style="list-style-type: none"> ✓ visual representation ✓ accuracy ✓ reasonableness ✓ required tolerances ✓ problem-solving strategies <p>8, 10, 13. The second year student works with and manages numbers that correspond to a programming environment and a machining environment. The programming environment requires values that refer to the number line and have specific sizes based on use while the machining environment works in thousands of an inch and often requires metric conversions along the way.</p> <ol style="list-style-type: none"> a) Use of various precision of integers and non-integers in computer programming. b) Machining devices and parts that have tolerances of $\pm .010$”. c) Express in decimal form 2.03×10^{-3}. <ul style="list-style-type: none"> ✓ accuracy ✓ comprehension

GRADE 11 - 12	PERFORMANCE STANDARDS	ILLUSTRATIONS
	<p>9. Uses estimation as a first step in calculations (APS – II.10E).</p> <p>10. Develops a deeper understanding of very large and very small numbers and various representations of them (APS – II.1E).</p> <p>11. Applies ratios, proportions, and percents in more complex mathematical situations (APS – II.8E; NM – IA.7, ID.2).</p> <p>12. Demonstrates number sense in solving problems with units and precision (APS – III.8E).</p> <p>13. Performs calculations and conversions with metric units and uses appropriate tools and instruments.</p> <p>14. Judges the effects of such operations as multiplication, division, and computing powers and roots on the magnitudes of quantities (APS – II.9E).</p> <p>15. Translates a real-life problem into an expression, equation, inequality, or matrix as a first step in working towards a solution (APS – V.11E; NM – IC.9).</p> <p>16. Solves linear equations in one variable (NM – IC.4).</p> <p>17. Explains the meaning of and uses common algebraic symbols (APS – V.7E).</p>	<p>9, 12, 14. The second year student observes, records and translates motor speed and direction requirements. Using the observations, the student designs a matrix that identifies motion requirements and then derives equations and inequalities that can be programmed into the microcontroller.</p> <ul style="list-style-type: none"> ✓ individual participation ✓ real-life examples ✓ reasonableness ✓ accuracy of estimations <p>11. The student solves a variety of problems of this nature: a) One hundred pounds of force are applied over five square inches of area. What is the pressure? Justify work. b) Ten volts are applied across a resistor in 3mA of current. If the voltage were increased to 15 volts, what would be the resulting current? Justify work.</p> <ul style="list-style-type: none"> ✓ accuracy ✓ understanding of ratios, proportions, and percents ✓ documentation of work <p>15, 19. The second year student sets up and solves a system of equations to find the current in and voltage drop devices in a given AC circuit:</p> <ul style="list-style-type: none"> ✓ correct equations ✓ solutions (e.g., accuracy) ✓ documentation of work <p>16, 20. The student solves and graphs a variety of quadratic relations and systems such as $-16y^2 = -9x^2 + 144$ and documents work.</p> <ul style="list-style-type: none"> ✓ accuracy (e.g., calculations, graphs) ✓ justification of work <p>17, 21. The second year student uses and implements mathematical symbols, units and abbreviations and applies them in his/her design work and presentations.</p> <ul style="list-style-type: none"> ✓ relevant example ✓ clear explanation <p style="text-align: center;">OR</p>

GRADE 11 - 12	PERFORMANCE STANDARDS	ILLUSTRATIONS
	<p>18. Manipulates variables in formulas (NM – IA.13).</p> <p>19. Creates and solves equations in two or three variables in a variety of ways (e.g., with and without technology) (APS – V.5L; NM – IC.4, IC.5).</p> <p>20. Graphs linear equations (APS – V.12E; NM – IC.4).</p> <p>21. Applies the law of exponents with integers to perform operations on expressions (APS – V.14E; NM – IC.11).</p> <p>22. Identifies the amplitude, period, phase shift, and vertical shift of a graph of a trigonometric function from its equations (APS – V.7L; NM – VB.FS).</p> <p>23. Graphs more complex trig functions using knowledge of period, phase shift, vertical shift, and amplitude (APS – V.6L; NM – VB.FS).</p> <p>24. Works with everyday problems and applications including integration with other subject areas studied at the same grade level (APS – V.7L, V.8L; NM – VB.FS).</p> <p>25. Solves trigonometric equations by analytical and graphical methods (APS – III.8L; NM – VB. F. S.).</p>	<p>The student describes, orally or in drawings, the timing diagram for RC time constants as they relate to the triggering of a specific system.</p> <p>18. The second year student regularly attempts to model real-world data using certain kinds of variation functions. The functions generally have proportionality constants that have to be determined through analytical and graphical methods.</p> <ul style="list-style-type: none"> ✓ correct manipulation of variables <p>22. The student properly identifies the various features (e.g., amplitude, period, phase shift and vertical shift) from a generated frequency on an Oscilloscope and then recreates the trigonometric function.</p> <ul style="list-style-type: none"> ✓ graphical representations ✓ correct manipulation of variables ✓ accuracy ✓ connections <p>23 - 24. The student is given the following scenario to respond to: The AC supplied to your house is created by an alternating electrical potential which has a frequency of 60 cycles per second. Suppose that the peak voltage is 180V and that the voltage leads the current by .003 seconds. Write an equation expressing voltage in terms of time. Simulate this condition on the Oscilloscope using the Signal Generator.</p> <ul style="list-style-type: none"> ✓ all required components ✓ accuracy ✓ connections <p>23, 29. The student sketches the graphs of trigonometric functions using radians and notes the domain, range, x-intercepts, y-intercepts, and asymptotes of each. He/She uses a graphing calculator to verify figures.</p> <ul style="list-style-type: none"> ✓ graphical representations ✓ identification of required elements ✓ accuracy <p>25. Second year students find the exact value of the expression, $\sin(\tan^{-1} 5/12)$.</p>

GRADE 11 - 12	PERFORMANCE STANDARDS	ILLUSTRATIONS
	<p>26. Changes from degree to radian measure and radian to degree measure (APS – II.11E; NM – IID.5, NM – VB. F. S.).</p> <p>27. Uses trigonometry to find areas of triangles (NM – VB).</p> <p>28. Masters the unit circle (NM – VB).</p> <p>29. Graphs trigonometric functions using radian measure and their domains and ranges (NM – VB).</p>	<ul style="list-style-type: none"> ✓ accuracy <p>26. The student converts a variety of problems (e.g., $7\pi/5$ to degrees or 150° to radians) from degree to radian measure and conversely.</p> <ul style="list-style-type: none"> ✓ manipulation of formulas ✓ accuracy <p>27. The student finds the centroid of various triangles, discovering with trigonometry that this unique point creates three triangles all with the same area. This use of centroid and area is expanded upon with other polygons using geometry, trigonometry, and 3-D modeling software.</p> <ul style="list-style-type: none"> ✓ trigonometrical applications ✓ multiple representations ✓ accuracy <p>28. The student writes a paragraph describing the entire Unit Circle in the form of a table using right triangle relationships. With this information, the student describes the relationship between Phasor Diagrams and various sine waves that are out-of-phase. Prior to the assignment, the class develops a rubric for grading the paragraph.</p> <ul style="list-style-type: none"> ✓ relatedness between points ✓ relationship between the functions ✓ accuracy ✓ effective communication ✓ adherence to criteria <p>Most of the illustrations in this strand deal with applying problem-solving techniques and strategies to new situations.</p>

STRAND IV: SAFETY**CONTENT STANDARD:** The student exhibits the safe use of equipment and shop practices.**BENCHMARK:** The student develops and demonstrates proficiency in shop safety and practice in completion of required activities.

GRADE 11 - 12	PERFORMANCE STANDARDS	ILLUSTRATIONS
	<ol style="list-style-type: none"> 1. Integrates safe tool and machine usage and passes a certification test at a 100% level (CR – 1E, 4D). 2. Demonstrates proficiency in the safe manipulation of tools (CR – 4D). 3. Demonstrates individual responsibilities and personal traits of safe work habits (CR – 4A, 4C, 4D). 4. Employs the use and care of appropriate personal protective equipment (CR – 4C, 4D; WorkKeys). 5. Exhibits proper material handling (e.g., oversized material, lifting, chemicals, electrical hazards (WorkKeys; CR - 4E). 6. Practices fire prevention and fire safety procedures (CR - 4D). 7. Demonstrates responsive behavior related to safety issues (CR – 4A, 4D, 4E). 8. Operates safely in a machine shop and welding environment (CR – 4D). 9. Develops skills used in metal machining processes, which includes measuring, lathe work, mill work, grinding, and shaping (CR – 1E, 3C, 3D). 	<ol style="list-style-type: none"> 1. The second year student continues to demonstrate proficiency on each machine by reviewing general safety requirements with 100% accuracy. Areas to be tested and reinforced are safety glasses, lathing, milling, use of general tools, and sheet metal. After reassessment, the second year student continues to master tested skills under teacher supervision. Test results are kept on file for liability purposes. <ul style="list-style-type: none"> ✓ safety practices ✓ test mastery 2 – 5, 8 - 13. The second year student demonstrates safe and proper material handling noting any MSDS requirements during the construction of a project that has been approved by the instructor. <ul style="list-style-type: none"> ✓ safety practices ✓ correct use of tools ✓ appropriate behavior 6, 7. The second year student reviews, examines, properly marks and verifies locations of all fire extinguishers, first-aid kits, fire blankets and emergency exits. <ul style="list-style-type: none"> ✓ correct identification of locations and exits ✓ safety practices

GRADE 11 - 12	PERFORMANCE STANDARDS	ILLUSTRATIONS
	<p>10. Performs basic setup of all machines and equipment used in the shop (CR – 1E, 3C, 3D).</p> <p>11. Incorporates machine combination in all projects (WorkKeys).</p> <p>12. Applies other related technological machines not found in the classroom (CR – 3A).</p> <p>13. Applies working knowledge and procedures in sheet metal operations, welding techniques, and metal fabrication techniques (CR – 1E).</p>	

STRAND V: CAREER READINESS

CONTENT STANDARD: The student develops skills necessary for responsible and ethical workplace behaviors, for effective teamwork, for attainment of project goals, and for marketable skills for future careers.

- BENCHMARKS:**
- A. The student develops effective interpersonal leadership, and team skills.
 - B. The student effectively produces a quality product.
 - C. The student develops and demonstrates the technological knowledge and skills required for future careers.

GRADE 11 - 12	PERFORMANCE STANDARDS	ILLUSTRATIONS
	<p>Personal Skills</p> <ol style="list-style-type: none"> 1. Integrates positive behavior, conduct, and social manners (e.g., Character Counts pillars) (CR - 4A). 2. Analyzes and applies appropriate safety standards (CR - 4E). 3. Works cooperatively with others from diverse backgrounds to accomplish goals (CR - 4B, 5C). 4. Identifies and utilizes individual interests, aptitudes, and skills with the group to accomplish goals (CR - 2B, 5A). 5. Demonstrates leadership within a group through effective communication, ability to motivate team members, and effective delegation of responsibilities (CR - 5D). 6. Problem solves and thinks critically (CR – 5C, 5E). <p>Production of Quality Product</p> <ol style="list-style-type: none"> 7. Identifies goals, required resources, prioritizes activities, and evaluates progress toward achievement of goals within a specified timeline (CR - 2A). 8. Prepares a budget, records costs, and makes adjustments within a specific maximum amount (CR - 2C). 9. Reassesses individual and group skills and makes adjustments in the delegation of responsibilities for efficient progress toward attainable goals (CR - 2B). 10. Demonstrates a high level of effort, patience, and perseverance toward goal attainment (CR - 4C). 	<p>1 – 11. The second year student picks a partner and chooses a final project that either enters a formal competition or the Science Fair. The project generally involves a mentor that helps answer or address certain unexpected problems. The project is formally developed, designed and documented and reflects many of the same aspects that the first year project did except that the magnitude of the effort and the depth of the exploration are more defined and requires more sophistication. Aspects to be included/considered are:</p> <ul style="list-style-type: none"> • DC/AC circuitry • digital circuitry • student developed sensors • motors • microcontrollers • usefulness <ul style="list-style-type: none"> ✓ positive behavior and conduct ✓ safety practices ✓ cooperation ✓ delegation of responsibilities ✓ skills assessments ✓ leadership qualities ✓ goal setting with reevaluation if necessary ✓ budgeting and cost accounts ✓ effort and perseverance ✓ demonstration of electronics knowledge ✓ usefulness of product ✓ adherence to timelines ✓ clearly written presentation ✓ effective oral presentation ✓ effective visuals <p style="text-align: center;">OR</p>

GRADE 11 - 12	PERFORMANCE STANDARDS	ILLUSTRATIONS
	<p>11. Problem solves and thinks critically (CR – 5C, 5E).</p> <p>Technological Knowledge and Skills</p> <p>12. Demonstrates marketable skills for entry into a post secondary education training program leading to career fields of interest (CR - 1E, 3D).</p> <p>13. Explains how technology is used in electronic technology, electrical engineering, or other science and engineering fields (CR - 3A).</p> <p>14. Demonstrates knowledge of advanced technological systems/computer operations to design, develop, and maintain engineering products (CR - 3B, 3C).</p> <p>15. Develops awareness of advances in metal-working equipment and the importance of the industry in society (CR – 1B, 3C, 3D, 4E).</p>	<p>The second year student project (with instructor approval) completes various levels of competency. These levels involve 3-D modeling, machining and fabrication of the parts, originality of circuitry and utilizing the appropriate materials.</p> <ul style="list-style-type: none"> ✓ completion of project ✓ quality of project ✓ safety practices ✓ correct use of materials and instruments <p>12 – 15. Many of the second year students are available to work with post-secondary institutions. A variety of organizations (e.g., The University of New Mexico, SNL, Honeywell) continue to express interest in hiring these particular students due to their background, exposure and experience.</p> <ul style="list-style-type: none"> ✓ pertinent information (e.g., education, training) ✓ effective communication ✓ appropriate behavior

STRAND VI: SCIENCE AND SOCIETY**CONTENT STANDARD:** The student understands how scientific discoveries, inventions, practices, and knowledge influence, and are influenced by, individuals and societies.**BENCHMARK:** The student examines and analyzes how scientific discoveries and their applications affect the world, and explains how societies influence scientific investigations and applications.

GRADE 11 - 12	PERFORMANCE STANDARDS	ILLUSTRATIONS
	<ol style="list-style-type: none"> 1. Knows how science enables technology but also constrains it, and recognizes the difference between real technology and science fiction (e.g., rockets vs. antigravity machines; nuclear reactors vs. perpetual-motion machines; medical X-rays vs. Star-Trek tricorders) (NM – III.I.1.1). 2. Understands how advances in technology enable further advances in science (e.g., microscopes and cellular structure; telescopes and understanding of the universe) (NM – III.I.1.2). 3. Evaluates the influences of technology on society (e.g., communications, petroleum, transportation, nuclear energy, computers, medicine, genetic engineering) including both desired and undesired effects, and including some historical examples (e.g., the wheel, the plow, the printing press, the lightning rod (NM – III.I.1.3). 4. Understands the scientific foundations of common technologies (e.g., kitchen appliances, radio, television, aircraft, rockets, computers, medical X-rays, selective breeding, fertilizers and pesticides, agricultural equipment) (NM – III.I.1.4). 5. Analyzes the impact of digital technologies on the availability, creation, and dissemination of information (NM – III.I.1.6). 6. Describes how scientific knowledge helps decision makers with local, national, and global challenges [e.g., Waste Isolation Pilot Project (WIPP), mining, drought, population growth, alternative energy, climate change] (NM – III.I.1.9). 7. Knows that societal factors can promote or constrain scientific discovery (NM – III.I.1.11). 	1 – 8. See Strand I, the illustration for performance standards #8 – #11.

GRADE 11 - 12	PERFORMANCE STANDARDS	ILLUSTRATIONS
	<p>8. Identifies how science has produced knowledge that is relevant to individual health and material prosperity (NM – III.I.I.15).</p> <p>9. Understands that scientists have characteristics in common with other individuals (e.g., employment and career needs, curiosity, desire to perform public service, greed, preconceptions and biases, temptation to be unethical, core values including honesty and openness) (NM – III.I.I.18).</p> <p>10. Knows that science plays a role in many different kinds of careers and activities (e.g., public service, volunteers, public office holders, researchers, teachers, doctors, nurses, technicians, farmers, ranchers) (NM – III.I.I.19).</p>	<p>9, 10. See Strand V.</p>

STRAND VII: DESIGN/PLAN/LAYOUT/ASSEMBLY**CONTENT STANDARD:** The student interprets and implements proper procedures and problem-solving techniques related to proper completion of projects.**BENCHMARK:** The student successfully completes a project applying proper design, plan, layout, and assembly techniques and procedures.

GRADE 11 - 12	PERFORMANCE STANDARDS	ILLUSTRATIONS
	<ol style="list-style-type: none"> 1. Assembles parts and machine-designed pieces for a completed project (CR-1D). 2. Applies geometric and trigonometric concepts (e.g., triangles, Pythagorean Theorem) (WorkKeys). 3. Applies and identifies precision measurement tools (e.g., micrometers larger than 1 inch (WorkKeys). 4. Uses scales in drawings, both decimal inch and metrics (WorkKeys). 5. Converts units within a measuring system (e.g., feet to inches, meters to centimeters) (WorkKeys). 6. Draws a project to the dimensions (CR – 1D). 7. Applies layout to actual material within acceptable tolerances (WorkKeys; CR – 1D). 8. Employs efficient use of materials (CR – 1D, 2C). 9. Prepares and follows materials list for course projects (CR – 2A, 2C). 10. Assembles robot using machining/tooling process (WorkKeys; CR – 1D). 11. Demonstrates proper use of fasteners (e.g., nuts, bolts, rivets) (WorkKeys; CR – 1D). 12. Creates a tolerance shoulder, diameter length (CR – 1D). 13. Applies principles of design, with consideration of materials and 	<p>1 - 15. Using applicable operational and technical documents, the student lays out (applying geometric and trigonometric concepts) and cuts materials by choosing correct methods to make a project within acceptable tolerances. He/She properly identifies and applies precision measuring tools and maintains tolerances necessary for proper machining.</p> <ul style="list-style-type: none"> ✓ acceptable tolerances ✓ accuracy ✓ application of layout techniques ✓ functionality <p>4 - 9. The second year student successfully designs a robotics project that uses the appropriate scale for measurement, accurately models the amount of material having to convert various units within a measuring system, the type of material, and the weight of the material. Looking up current market value, the student estimates the cost of the project.</p> <ul style="list-style-type: none"> ✓ completion of project ✓ accurate dimensions ✓ accurate cost calculations ✓ efficiency ✓ functionality <p>10 - 15. Using the computer generated design, technical documentation, and the accurately fabricated parts, the student builds an advanced robotic design that meets the pre-established tolerances and quality control standards.</p>

GRADE 11 - 12	PERFORMANCE STANDARDS	ILLUSTRATIONS
	<p>processes to prepare specifications and plans (CR – 1E, 3C, 3D, 4E, 5F).</p> <p>14. Builds an advanced project to meet given tolerances and quality control standards (CR – 1E, 3C, 3D, 5F).</p>	

STRAND VIII: MACHINING AND TOOLING**CONTENT STANDARD:** The student understands the proper use and application of a variety of tools and processing machines.**BENCHMARK:** The student demonstrates proper use and maintenances of hand, power, and machine tools and metal processing machines (e.g., welding, foundry).

GRADE 11 - 12	PERFORMANCE STANDARDS	ILLUSTRATIONS
	<ol style="list-style-type: none"> 1. Selects and uses the appropriate hand/hand-held power tools that are used in creating robotic projects (WorkKeys; CR – 1D). 2. Selects the appropriate tool to complete a project (WorkKeys; CR – 1D). 3. Applies machine usage to a project (WorkKeys). 4. Gives examples of industry-specific tooling (equipment) used in metal manufacturing processes (WorkKeys). 5. Recognizes other related technological machines not found in the classroom (CR – 3A). 6. Gains introductory working knowledge and procedures in sheet metal operations, welding techniques, and metal fabrication techniques (CR – 1E). 	<ol style="list-style-type: none"> 1 - 3. The second year student uses and maintains a variety of tools during the design project. The tools were introduced in the first course and are now a daily part of the shop experience. <ul style="list-style-type: none"> ✓ accurate identification of tools and functions ✓ proper handling ✓ appropriate selection 3. The second year student consistently and safely chucks up, faces, turns, parts and drills material in the lathe. <ul style="list-style-type: none"> ✓ correct assembly processes 3, 4, 6. The second year student demonstrates a particular procedure to the instructor and then with proper supervision, demonstrates it to the first year students. <ul style="list-style-type: none"> ✓ finish, size, and tolerances ✓ uniform appearance ✓ correct tool usage ✓ use of a combination of tools 5. Through videos and other supplements, the student gains exposure to other technological tools and equipment not found in the classroom and/or school shop. The student participates in class discussion relating what was seen in the videos to possible future practices. <ul style="list-style-type: none"> ✓ active participation in discussions ✓ insights ✓ effective communication <p>Option: The student writes about what was seen in the videos emphasizing how he/she might use those technological tools in the future.</p>

STRAND IX: LITERACY**CONTENT STANDARD:** The student communicates robotic/engineering principles through reading, writing, and speaking opportunities.**BENCHMARK:** The student demonstrates proficiency in reading comprehension, specialized vocabulary, and a variety of writing and speaking requirements.

GRADE 11 - 12	PERFORMANCE STANDARDS	ILLUSTRATIONS
	<p>The standards addressed in this strand align with the APS 11th grade Language Arts standards.</p> <ol style="list-style-type: none"> 1. Accurately interprets information presented in a technical format (e.g., charts, diagrams, tables) (APS – LA I.7). 2. Uses critical analysis to gain meaning and synthesize ideas (APS – LA II.5). 3. Reads blueprints and understands basic welding symbols (CR – 3C, 3D). 4. Demonstrates increased competence and fluency in using the writing process to create a final product (APS – LA III.1). 5. Demonstrates increased competence and fluency in using a variety of technology (APS – LA III.3). 6. Demonstrates increased competence and fluency in using writing conventions (i.e., grammar, spelling, punctuation, capitalization) (APS – LA III.4). 7. Participates in group discussions and/or presentations to the class (APS – LA IV.2). 8. Listens to and analyzes mathematical content (APS – LA V.1). 	<p>Although the following examples are representative of the indicated performance standards, the student integrates the literacy strategies consistently by reading the text and numerous word problems, taking notes, participating in class discussions, communicating orally or in a written format, and through research. The student is presented with multiple opportunities which are demonstrated in some way in every strand.</p> <ol style="list-style-type: none"> 1 – 3. Because a student may be new to the shop environment or have not yet passed the safety tests to work on machines, the student fills out worksheets using the textbook for guidance in answering questions or completing drawings and outlines. <ul style="list-style-type: none"> ✓ interpretation of information ✓ synthesis ✓ process skills See also Strand VII, the 1st illustration. 4, 6. See Strand II, the 3rd illustration; Strand III, the illustration for performance standard #28; and Strand VIII, the 3rd illustration. 5, 13. See Strand II; Strand III, the 1st illustration; Strand IV – Safety; Strand V – Career Readiness; and Strand VI – Science and Society. 7. Almost any of the illustrations where the student presents orally to a group meets this standard. Specifically, see Strand II, the 1st and 3rd illustrations; Strand III, the illustration for performance standards #17, #21; and Strand VIII, the 3rd illustration. 8, 9. Most of the illustrations in Strand III deal with problem solving and mathematical analysis.

GRADE 11 - 12	PERFORMANCE STANDARDS	ILLUSTRATIONS
	<p>9. Analyzes the work of others for consistency of facts, ideas, clarity, and conciseness (APS – LA V.7).</p> <p>10. Conducts research; collects data from in-depth field studies (APS – LA VI.1).</p> <p>11. Obtains and sends information electronically to support advanced research (APS – LA VI.2).</p> <p>12. Synthesizes and organizes information from a variety of sources to inform and persuade an audience (APS – LA VI.9).</p> <p>13. Uses a variety of media and technology to research and explain insights to an audience (APS – LA VI.10).</p> <p>14. Develops presentations by using clear research questions and creative research strategies (e.g., field studies, experiments) (APS – LA VI.11).</p>	<p>10 – 14. See Strand I, the illustration for performance standards #8 – #11 and Strand III, the 1st illustration.</p>