Engineering
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Embedded Math Credit Crosswalk

The Engineering program has been recognized by the Arizona State Board of Career and Technical Education (CTE) as being eligible for consideration by local governing boards to grant 1 credit of 4th-year high school math. This document is the result of a committee analysis completed in May 2023.

Engineering Standards	AZ Math Standards	Reasoning/Rationale
STANDARD 1.0 INVESTIGATE THE FIELD OF ENGINEERING TO ADDRESS THE NEEDS OF A GLOBAL SOCIETY		
1.1 Define the disciplines of engineering (types of engineers) (i.e., chemical, civil, electrical, mechanical, agricultural, industrial, aeronautical, software, biomedical, etc.)		
1.2 Recognize that engineers solve a wide range of problems involving innovation, cost reduction, and more efficient/effective processes		
1.3 Describe the specialties/areas of training that may lead to jobs/careers (i.e., transportation, construction, research and development, analytical design, disaster management, waste management, environmental, automation and robotics, etc.)		
1.4 Explore emerging fields in engineering and challenges to future work and future life [i.e., drones, electric cars, autonomous cars, AI, IoT, Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), Additive Manufacturing (AM), Smart City design, Automation, Machine Learning (ML), M2M (Machine-to-Machine), H2M (Human-to-Machines), etc.]		
1.5 Analyze the societal, environmental, legal, and ethical responsibilities of engineers (e.g., Engineering Code of Ethics, economic, political, sustainability, and community health and safety)		

1.6 Determine the skills and education required to enter engineering careers (i.e., aptitude for math and science; complex problem-solving, critical thinking and decision-making; interpreting plans, schematics, and blueprints; communication skills to influence and convey facts with specificity, etc.)		
Engineering Standards	**AZ Math Standards**	**Reasoning/Rationale**
STANDARD 2.0 CREATE ENGINEERING SOLUTIONS BY APPLYING A STRUCTURED PROBLEM-SOLVING/DECISION MAKING PROCESS		
2.1 Identify the problem		
2.2 Develop a problem statement based on facts, research, and experience		
2.3 Explore possible issues or options to the problem		
2.4 Select the best solution within the constraints and criteria	**A1.A-CED.A.3** Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or non-viable options in a modeling context. **A2.F-IF.B.4** For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. Include problem-solving opportunities utilizing a real-world context. Key features include: intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior; and periodicity. Functions include linear, quadratic, exponential, polynomial, logarithmic, rational, sine, cosine, tangent, square root, cube root and piecewise-defined functions.	Collect data including quality control statistics Evaluate mean-median-mode (std deviation) Project(s): Solar oven - systems optimized using inequalities and a system of two equations
2.5 Develop a prototype or model to test the selected solution	**A1.A-CED.A.3** Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and	Modeling - modifying plan to find different solutions

	interpret solutions as viable or non-viable options in a modeling context. **QR.CR.3** Identify, create, and use appropriate models for bivariate data sets (i.e. linear, exponential) to estimate solutions for contextual questions, identify patterns and identify how changing parameters affect the models.	Problem-solving requires recalculations Prototype data - testing unknowns with equations and expressions
2.6 Implement the solution		
2.7 Evaluate the solution, and revise or repeat if necessary (i.e., Are there other solutions, better solutions, or cheaper solutions? etc.)	**A1.S-ID.A.2** Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets. **QR.CR.3** Identify, create, and use appropriate models for bivariate data sets (i.e. linear, exponential) to estimate solutions for contextual questions, identify patterns and identify how changing parameters affect the models.	Graphing data compared to quality control statistics
2.8 Document and report all results	**A2.F-IF.B.4** For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. Include problem-solving opportunities utilizing a real-world context. Key features include: intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior; and periodicity. Functions include linear, quadratic, exponential, polynomial, logarithmic, rational, sine, cosine, tangent, square root, cube root and piecewise-defined functions.	Explain and interpret graph data

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STANDARD 3.0 APPLY MATHEMATICAL LAWS AND PRINCIPLES RELEVANT TO ENGINEERING TECHNOLOGY		
3.1 Use basic mathematical functions and tools (i.e., Google Sheets, Excel, graphing calculator, etc.)	**QR.NR.3** Understand and compare magnitudes of numbers utilizing real-world context. Understand the importance and impact of unit selection. **A1.F-BF.A.1** Write a function that describes a relationship between two quantities. Determine an explicit expression, a recursive process, or steps for calculation from real-world context. Focus on linear, quadratic, exponential and piecewise-defined functions (limited to absolute value and step).	Calculating units Students first learn how to perform calculations and then learn software tools Create software simulations (excel) to code/create functions Note: Mathematical models applied are explained in projects used in Standard 3
3.2 Use data collection and analysis to display data and verify its accuracy	**QR.SPR.4** Represent center, shape, and spread of two or more data sets. Reason, communicate, and compare data sets in context. **QR.SPR.2** Analyze statistical information and identify limitations, strengths, or lack of information in studies including data collection methods (e.g. sampling, experimental, observational) and possible sources of bias. Identify errors or misuses of statistics to justify particular conclusions.	Prototype analysis using scatter plots and histograms
3.3 Display data graphically using diagrams and working drawings	**A1.A-CED.A.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. **A2.F-IF.C.7** Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. Functions include linear, quadratic, exponential, polynomial, logarithmic, rational, sine, cosine, tangent, square root, cube root and piecewise-defined functions.	Use Ohm's law relationship graphing V=IR students **Project(s):** Rocket Launch - analyzation of data trends by graphing mass compared to distance/height traveled and center of gravity location to distance/height traveled Motorized Gutter Boats - top speed and elapsed time calculated Measure the voltage and resistance relationship in an inverse relationship graph using a modeling equation to derive the relationship Cardboard boat project - volume, depth, and surface area

3.4 Use statistical measures of a central tendency (mean, median, and mode) as needed in the structured problem-solving process	**A2.S-ID.A.4** Use the mean and standard deviation of a data set to fit it to a normal curve, and use properties of the normal distribution and to estimate population percentages. Recognize that there are data sets for which such a procedure is not appropriate. Use calculators, spreadsheets, or tables to estimate areas under the normal curve.	Calculate standard deviation and tolerances Project(s): 3D design unit puzzle pieces with wooden cubes
3.5 Use mathematical models including algebraic, geometric, trigonometric, and calculus relationships to solve, analyze, and design solutions	**A2.F-BF.B.4** Find inverse functions. a. Understand that an inverse function can be obtained by expressing the dependent variable of one function as the independent variable of another, recognizing that functions *f* and g are inverse functions if and only if *f(x) = y* and *g(y) = x* for all values of *x* in the domain of *f* and all values of *y* in the domain of *g*. b. Understand that if a function contains a point (*a,b*), then the graph of the inverse relation of the function contains the point (b*,a*). c. Interpret the meaning of and relationship between a function and its inverse utilizing real-world context. **A2.F-IF.B.6** Calculate and interpret the average rate of change of a continuous function (presented symbolically or as a table) on a closed interval. Estimate the rate of change from a graph. Include problem-solving opportunities utilizing real-world context. Functions include linear, quadratic, exponential, polynomial, logarithmic, rational, sine, cosine, tangent, square root, cube root and piecewise-defined functions. **A2.F-IF.C.7** Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. Functions include linear, quadratic, exponential, polynomial, logarithmic, rational, sine, cosine, tangent, square root, cube root and piecewise-defined functions. **A2.A-REI.C.7** Solve a system consisting of a linear equation and	**Algebra in Engineering** -Create the algebraic equation to determine buoyancy (cargo mass), calculate percent of error tested and explain results. Project: Cardboard Boat -Calculate the speed of a robot based on the RPM of the motor and the gear ratio. Convert RPM (circular distance) to a linear distance using the circumference of a wheel. Project: Robot Combination of parallel and series circuits to determine all values given with only few variables. Project: Arduinos -Determine system of equations and Inequalities, quadratic, and nonlinear functions. Project: Solar Ovens **Geometry in Engineering** -Determine the volume of cylinder and cone. Project: Cardboard Boats project -Determine the relationship of sine cosine of a complementary angle. Project: Robot (gears) -Design an image with circle and arcs using degrees and radians. Area of the sector-coding unit of geometrical shapes. Project: 3D Image -Create a rocket cone of by folding a cylinder shape. Project: Origami **Trigonometry in Engineering** - Calculate the height of a rocket from a known distance and angle. Project: Rockets

	a quadratic equation in two variables algebraically and graphically. *For example, find the points of intersection between the line y =-3x and the circle $x^2 + y^2 = 3$.* **G.G-SRT.C.7** Explain and use the relationship between the sine and cosine of complementary angles. **G.G-SRT.C.8** Use trigonometric ratios (including inverse trigonometric ratios) and the Pythagorean Theorem to find unknown measurements in right triangles utilizing real-world context. **G.G-C.B.5** Derive using similarity the fact that the length of the arc intercepted by an angle is proportional to the radius, and define the radian measure of the angle as the constant of proportionality; derive the formula for the area of a sector. Convert between degrees and radians. **G.G-GPE.B.7** Use coordinates to compute perimeters of polygons and areas of triangles and rectangles. **RFR.AF.1** Interpret parameters of a function defined by an expression in the context of the situation. **RFR.AF.2** Sketch the graph of a function that models a relationship between two quantities, identifying key features. **RFR.AF.3** Interpret key features of graphs and tables for a function that models a relationship between two quantities in terms of the quantities. **RFR.ETT.**1 Model real-world situations involving trigonometry. **RFR.ETT.2** Apply the Law of Sines and Law of Cosines to solve problems. **RV.EV.1** Recognize vector quantities as having both magnitude and direction. **RV.EV.2** Represent vector quantities by directed line segments, and use appropriate symbols for vectors and their magnitudes.	- Examine vector forces, use transversal lines to determine the angle of the ramp to that of the robot. Calculate torque required to go up the ramp with determining the friction coefficient. Project: Robot Projects with Vectors: - Gliders - Robot Gear train challenge - Cardboard Boats - Trebuchets - CO2 Cars - Solar oven - Rockets - Coding 3D images - Origami (modeling with Geometry) **Precalculus in Engineering** - Determining parabolic trajectory of rocket and parachute. Project: Rocket (launches with parachutes) -Calculate actual gain from reflectors. Project: Solar oven

	RV.EV.4 Solve problems involving velocity and other quantities that can be represented by vectors. **QR.CR.2** Compare, reason and communicate about proportional and non-proportional models utilizing real-world contexts.	
3.6 Generate manually and electronically mathematical solutions and evaluate their validity	**Same Math Standards as 3.5**	
3.7 Use English and Metric systems of measurement	**A2-N-Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays, include utilizing real-world context. **G.N-Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities utilizing real-world context. **QR.NR.3** Understand and compare magnitudes of numbers utilizing real-world context. Understand the importance and impact of unit selection.	Conversions are performed: -Multi-step problems to solve using conversion calculations -Bridge measurements given in IPS and then converted to Metric -3D printing designed in IPS and converted to Metric -Vex Robotics motor torque calculations are done in metric and students measure in IPS -Solar Oven conversions from IPS to metric or even cm/mm to meters -Electrical unit Watts to Kilowatts -Barge project IPS to metric system -Fluid Dynamics -Linear Kinematics, CO2 Car Project -Torque Wrench Calculations -Water Distribution -Calculate predicted distance travel and determine percentage of error, Mouse Trap Car Project
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STANDARD 4.0 APPLY SCIENTIFIC LAWS AND PRINCIPLES RELEVANT TO ENGINEERING TECHNOLOGY		
4.1 Use the relationship among energy, work, and power to solve a variety of problems involving mechanical, fluid, electrical, and thermal systems	**Same Math Standards as 3.5**	
4.2 Use Newton's Laws of Motion to analyze static and dynamic systems with and without the presence of external forces	**Same Math Standards as 3.5 and 3.7**	Nonlinear systems are solved algebraically and graphed **Projects:** -Bridge Design -Mouse Trap -CO2 Car
4.3 Use the laws of conservation of energy, charge, and momentum to solve a variety of problems	**Same Math Standards as 3.5**	

involving mechanical, fluid, electrical, and thermal systems		
4.4 Analyze relevant properties of materials used in engineering projects [i.e., chemical, environmental, mechanical (tension, compression, torque), electrical, physical, etc.]	**Same Math Standards as 3.5**	Material properties, unit conversions, and multi-step problems **Projects:** -Solar Oven -Bridge Design
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STANDARD 5.0 APPLY TECHNOLOGY AND TOOLS TO ENGINEERING SOLUTIONS		
5.1 Explain the concepts of precision, accuracy, and tolerance as they relate to measurement tools (i.e., micrometers, dial indicator, digital calipers, etc.)	**Same Math Standards as 3.5**	Measure and run statistical analysis to determine acceptable tolerances, concepts of precision and accuracy are also discussed. Determine Tolerances margin of error, then use a mathematical model to determine accurate measurements in the CAD software to create a precision print. Projects: -Puzzle Cube
5.2 Use measurement devices such as calipers, oscilloscopes, and digital multimeters to gather data for analysis		Measure a variety of resistors to determine their **tolerances** using a digital multimeter. A2.N-Q.A.3?
5.3 Verify the calibration status of measurement tools (i.e., quality control, test, and retest, etc.)		Quality control
5.4 Use software tools to solve, model, analyze, and/or design solutions to engineering problems (i.e., SOLIDWORKS, AutoCAD, On-shape, Fusion360, Google Sheets, Excel, etc.)	**Same Math Standards as 3.5**	
5.5 Identify hazards, risks, and incidents related to tools and equipment		
5.6 Practice safe use of tools, machines, equipment, and materials (i.e., OSHA, SDS sheets, PPE, etc.)		
5.7 Review fabrication methods to create potential solutions to engineering problems (e.g., 3D printing, injection molding, woodworking, and welding)	**Same Math Standards as 3.5**	Puzzle Cubes project

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STANDARD 6.0 APPLY COMMUNICATION SKILLS TO ENGINEERING PROJECTS		
6.1 Apply technical writing skills and use visual aids to present critical information in reports (i.e., results/outcomes, conclusions, future work recommendations, etc.)	**Same Math Standards as 3.5**	Within all technical reports, students explain how equations were derived and used within each of their projects
6.2 Utilize the three stages of oral presentation (e.g., planning, practicing, and presenting)	**Same Math Standards as 3.5**	Within all presentations, students explain how equations were derived and used within each of their projects
6.3 Apply communication skills, including listening skills, with project teams, project managers, clientele, and/or contractors		
6.4 Explain the importance of multiculturalism in creative and professional decision-making (e.g., better decisions based on different views, perspectives, ideas, and proposals; fosters critical thinking, analysis, and collaboration)		
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STANDARD 7.0 APPLY PROJECT MANAGEMENT TOOLS AND TECHNIQUES TO ENGINEERING SOLUTIONS		
7.1 Determine the tools, materials, manpower, and money allocation required to manage the project		
7.2 Utilize time-management techniques (e.g., prioritizing and planning, creating goals, scheduling, advocating, and taking action)		
7.3 Organize and maintain work using project management tools (e.g., Gantt Chart, AGILE, Kanban, Waterfall model, dashboards, task lists, project reports, and time sheets)		
7.4 Schedule daily/weekly meetings to check status of the project and to deal with any constraints and obstacles to the project		
7.5 Document and present project results/outcomes as appropriate		

7.6 6 Analyze the project from various perspectives (i.e., sustainability, political, economic, health and safety perspectives, etc.)		