Texas CTE

Science, Technology, Engineering, and Mathematics (2010): Grade 11

Adopted 2010

Biotechnology

(1) The student explores biotechnology career opportunities. The student is expected to:

(A) determine interests and aptitudes through conversations with biotechnology professionals;

(B) identify career options in the field of biotechnology;

(C) identify reliable sources of career information;

(D) research interests, knowledge, educational level, abilities, and skills needed in a biotechnology-related occupation;

(E) seek a mentor in the biotechnology area;

(F) identify conventional and non-conventional career opportunities that match interests and aptitudes;

(G) research applications of biotechnology and biomaterials in the areas of medicine, the environment, and pharmaceutical, agricultural, and industrial settings; and

(H) use technology to research biotechnology topics, identify pertinent scientific articles, obtain articles of interest, and write a formal research paper in the format used by academic and professional journals and magazines.

(2) The student evaluates ethical and legal issues in biotechnology. The student is expected to:

(A) identify current ethical and legal issues;

(B) describe the history of biotechnology and related current issues;

(C) discuss legal and technology issues for at least two biotechnology related areas; and

(D) compare and contrast examples of objective and subjective scientific, economic, and political data and positions used to defend biotechnology views.

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The student examines federal, state, local, and industry regulations as applied to biotechnical processes through library research and Internet research. The student is expected to:

(A) identify local, state, and federal agencies responsible for regulating the biotechnology industry;

(B) identify professional organizations participating in the development of biotechnology policies;

(C) identify and define terms related to biotechnology regulations; and

(D) outline the methods and procedures used in biotechnology laboratories to follow and enforce local, state, and federal regulations, including those in the agricultural and health areas.

(4) The student demonstrates knowledge of the business climate for biotechnology industry sectors in the current market. The student is expected to:

(A) identify professional publications;

(B) identify the various biotechnology industry sectors; and

(C) investigate and report on career opportunities in the biotechnology industry sectors.

(5) The student researches and exhibits employability skills that support a career in the biotechnology industry. The student is expected to:

(A) demonstrate verbal, nonverbal, written, and electronic communication skills;

(B) demonstrate skills used to secure and maintain employment;

(C) demonstrate appropriate workplace etiquette; and

(D) display productive work habits and attitudes.

(6) The student investigates the origins of waste and examines the relationship of biotechnology to resource recovery. The student is expected to:

(A) investigate at least three end products from biotechnology manufacturing processes;

(B) investigate the effects of waste on environmental and biological life cycles;

(C) investigate the impacts of waste on the environment;

(D) analyze the results of manufacturing refuse;

(E) explain the negative impacts of waste with respect to the individual, society, and the global population;

(F) research solutions to biological waste with respect to commercial applications through investigation of various pollution waste treatments using natural organisms;

(G) investigate biotechnology as it relates to health and well-being; and

(H) cite evidence regarding regulations, patents and public policy, design development and testing, and safety.

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The student examines the relationship of biotechnology to the development of commercial products. The student is expected to:

(A) identify the ability to change or enhance genetic characteristics;

(B) identify applications of genetic engineering;

(C) identify applications of nanotechnology in biotechnology;

(D) identify applications of bioinformatics in biotechnology;

(E) identify the applications of biotechnology in medicine, forensics, and law enforcement; and

(F) research ethical considerations, laws, and regulations governing genetic engineering and nanotechnology.

Advanced Biotechnology

(1) The student, for at least 40% of instructional time, conducts laboratory and field investigations using safe, environmentally appropriate, and ethical practices. These investigations must involve actively obtaining and analyzing data with physical equipment, but may also involve experimentation in a simulated environment as well as field observations that extend beyond the classroom. The student is expected to:

(A) demonstrate safe practices during laboratory and field investigations, including chemical, electrical, and fire safety, and safe handling of live and preserved organisms;

(B) demonstrate an understanding of the use and conservation of resources and the proper disposal or recycling of materials;

(C) demonstrate appropriate safety procedures, guidelines, and chemical hygiene plan;

(D) maintain required safety training, including location and understanding of interpretation of material safety data sheets;

(E) comply with federal and state safety regulations as specified by Occupational Safety and Health Administration and other regulatory agencies as appropriate;

(F) identify and obey safety symbols and signs;

(G) maintain clean and well organized work areas;

(H) dispose of equipment, glassware, and biologics according to laboratory policies;

(I) recognize common laboratory hazards;

(J) observe procedures for the safe use of instruments, gas cylinders, and chemicals; and

(K) maintain safety and personal protection equipment.

(2) The student uses scientific methods and equipment during laboratory and field investigations. The student is expected to:

(A) know the definition of science and understand that it has limitations, as specified in subsection (b)(3) of this section;

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(B) know that scientific hypotheses are tentative and testable statements that must be capable of being supported or not supported by observational evidence. Hypotheses of durable explanatory power which have been tested over a wide variety of conditions are incorporated into theories;

(C) know that scientific theories are based on natural and physical phenomena and are capable of being tested by multiple independent researchers. Unlike hypotheses, scientific theories are well-established and highly-reliable explanations, but they may be subject to change as new areas of science and new technologies are developed;

(D) distinguish between scientific hypotheses and scientific theories;

(E) plan and implement investigative procedures, including asking questions, formulating testable hypotheses, and selecting, handling, and maintaining appropriate equipment and technology;

(F) collect data individually or collaboratively, make measurements with precision and accuracy, record values using appropriate units, and calculate statistically relevant quantities to describe data, including mean, median, and range;

(G) demonstrate the use of course apparatus, equipment, techniques, and procedures;

(H) organize, analyze, evaluate, build models, make inferences, and predict trends from data;

(I) perform calculations using dimensional analysis, significant digits, and scientific notation; and

(J) communicate valid conclusions using essential vocabulary and multiple modes of expression such as lab reports, labeled drawings, graphic organizers, journals, summaries, oral reports, and technology-based reports.

(3) The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to:

(A) in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student;

(B) communicate and apply scientific information extracted from various sources such as current events, news reports, published journal articles, and marketing materials;

(C) draw inferences based on data related to promotional materials for products and services;

(D) evaluate the impact of research and technology on scientific thought, society, and the environment;

(E) describe the connection between biotechnology and future careers; and

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(F) research and describe the history of biotechnology and contributions of scientists.

(4) The student explores the emerging field of biotechnology. The student is expected to:

(A) define biotechnology as related to new and emerging occupations;

(B) explore engineering and bioinformatics;

(C) create a timeline of historical biotechnology research and development; and

(D) research career opportunities in fields such as molecular, forensic, medical, regulatory, and agricultural biotechnology.

(5) The student analyzes bacterial, plant, and animal cell structures. The student is expected to:

(A) distinguish among bacterial, plant, and animal cells;

(B) describe the major structures in a bacterial cell and their functions such as pili, capsule, and flagella;

(C) describe the major structures in a plant cell and their functions such as cell wall and chloroplasts;

(D) describe the major structures in an animal cell and their functions such as nucleus, nucleolus, cell membrane, mitochondria, ribosomes, Golgi apparatus, chromatin, cytoplasm, and endoplasmic reticulum; and

(E) identify cells using the microscope.

(6) The student understands the role of genetics in the biotechnology industry. The student is expected to:

(A) explain terms related to molecular biology such as nucleic acids, nitrogen bases, amino acids, transcription, translation, polymerase, and protein synthesis;

(B) describe the structure of a nucleotide;

(C) identify the nitrogen bases of deoxyribonucleic acid and ribonucleic acid;

(D) explain how nucleotides join together to form a double-helical deoxyribonucleic acid molecule;

(E) describe the deoxyribonucleic acid and ribonucleic acid replication process;

(F) illustrate the process of protein synthesis;

(G) define genome and gene expression;

(H) evaluate the significance of ethics and regulations as it relates to gene expression; and

(I) summarize the role of genetics in the biotechnology industry.

(7) The student analyzes the importance of recombinant deoxyribonucleic acid technology and genetic engineering. The student is expected to:

(A) define recombinant deoxyribonucleic acid technology as it relates to the biotechnology industry;

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(B) explain how recombinant deoxyribonucleic acid technology is used to clone genes;

(C) explain the role of tissue cultures to genetic modification procedures;

(D) propagate plant cultures;

(E) maintain proper growing conditions for plant tissue cultures;

(F) explain the role of restriction enzymes and plasmid deoxyribonucleic acid;

(G) describe the vectors commonly used, including bacteriophage vectors;

(H) discuss the polymerase chain reaction and its application in recombinant deoxyribonucleic acid technology; and

(I) perform restriction digests.

(8) The student examines federal, state, local, and industry regulations as related to biotechnology. The student is expected to:

(A) discuss the relationship between the local, state, and federal agencies responsible for regulation of the biotechnology industry; and

(B) analyze policies and procedures used in the biotechnology industry such as animal research laboratories.

(9) The student performs standard biotechnology laboratory procedures. The student is expected to:

(A) operate laboratory equipment such as a microscope, thermocycler, hood, pH meter, stirrers, balance, mixers, autoclave, power supply, shakers, dry heat oven, incubators, and Bunsen burners;

(B) practice measuring volumes and weights to industry standards;

(C) analyze data and perform calculations and statistical analysis as it relates to biotechnology laboratory experiments;

(D) demonstrate and show proficiency in titration and pipetting techniques;

(E) identify microorganisms using staining methods such as the Gram stain, methylene-blue stain, and acid-fast staining;

(F) document laboratory results; and

(G) investigate how laboratory techniques vary in different industry sectors.

(10) The student prepares solutions and reagents for the biotechnology laboratory. The student is expected to:

(A) practice aseptic technique;

(B) prepare, dispense, and monitor physical properties of stock reagents, buffers, media, and solutions;

(C) calculate and prepare a dilution series; and

(D) determine acceptability and optimum conditions of reagents for experimentation.

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(11) The student performs advanced biotechnology laboratory procedures. The student is expected to:

(A) explain the importance of media components to the outcome of cultures;

(B) isolate, maintain, and store pure cultures;

(C) prepare seed inoculum;

(D) perform plating techniques such as the Kirby-Bauer method;

(E) precipitate and solubilize proteins;

(F) isolate and interpret proteins using electrophoresis; and

(G) perform nucleic acid sequencing procedures.

(12) The student conducts quality-control analysis while performing biotechnology laboratory procedures. The student is expected to:

(A) perform validation testing on laboratory reagents and equipment; and

(B) analyze data and perform calculations and statistical analysis on results of quality-control samples such as trending of data.

(13) The student summarizes biotechnology laboratory procedures and their applications in the biotechnology industry. The student is expected to:

(A) identify the major sectors of the biotechnology industry;

(B) categorize the biotechnology laboratory procedures included in each sector; and

(C) compare the different applications used in biotechnology laboratory procedures of each sector.

Engineering Design and Presentation

(1) The student gains knowledge of and demonstrates the skills necessary for success in the workplace. The student is expected to:

(A) distinguish the differences between an engineering technician, engineering technologist, and engineer;

(B) identify employment and career opportunities;

(C) investigate and work toward industry certifications;

(D) demonstrate the principles of teamwork related to engineering and technology;

(E) identify and use appropriate work habits;

(F) demonstrate knowledge related to governmental regulations, including health and safety;

(G) discuss ethical issues related to engineering and technology and incorporate proper ethics in submitted projects;

(H) demonstrate respect for diversity in the workplace;

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(I) demonstrate appropriate actions and identify consequences relating to discrimination, harassment, and equality;

(J) demonstrate effective oral and written communication skills using a variety of software applications and media; and

(K) explore career preparation learning experiences, including, but not limited to, job shadowing, mentoring, and apprenticeship training.

(2) The student participates in team projects in various roles. The student is expected to:

(A) understand and discuss how teams function;

(B) use teamwork to solve problems; and

(C) serve as a team leader and a team member and demonstrate appropriate attitudes while participating in team projects.

(3) The student develops skills for managing a project. The student is expected to:

(A) use time-management techniques to develop and maintain work schedules and meet deadlines;

(B) complete work according to established criteria;

(C) participate in the organization and operation of a real or simulated engineering project; and

(D) develop a plan for production of an individual product.

(4) The student practices safe and proper work habits. The student is expected to:

(A) master relevant safety tests;

(B) follow safety guidelines as described in various manuals, instructions, and regulations;

(C) identify and classify hazardous materials and wastes according to Occupational Safety and Health Administration regulations;

(D) dispose of hazardous materials and wastes appropriately;

(E) perform maintenance on selected tools, equipment, and machines;

(F) handle and store tools and materials correctly; and

(G) describe the results of negligent or improper maintenance.

(5) The student applies the concepts of sketching and skills associated with computer-aided drafting and design. The student is expected to:

(A) sketch single- and multi-view projections;

(B) prepare orthographic and pictorial views;

(C) prepare auxiliary views;

(D) prepare section views;

(E) project points and construct lines to build geometric forms;

(F) construct true length of lines and true size of planes by the revolution method;

(G) draw developments using radial line, parallel line, and triangulation methods;

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(H) construct piercing points and intersection of planes using edge-view and cutting plane methods;

(I) prepare and revise annotated multi-dimensional production drawings in computer-aided drafting and design to industry standards; and

(J) demonstrate knowledge of effective file structure and management.

(6) The student uses engineering design methodologies. The student is expected to:

(A) understand and discuss principles of ideation;

(B) think critically, identify the system constraints, and make fact-based decisions;

(C) use rational thinking to develop or improve a product;

(D) apply decision-making strategies when developing solutions;

(E) use an engineering notebook to record prototypes, corrections, and/or mistakes in the design process; and

(F) use an engineering notebook to record the final design, construction, and manipulation of finished projects.

(7) The student applies concepts of engineering to specific problems. The student is expected to:

(A) use a variety of technologies to design components;

(B) use tools, laboratory equipment, and precision measuring instruments to develop prototypes;

(C) research applications of different types of computer-aided drafting and design software; and

(D) use multiple software applications for concept presentations.

(8) The student designs products using appropriate design processes and techniques. The student is expected to:

(A) interpret engineering drawings;

(B) identify areas where quality, reliability, and safety can be designed into a product;

(C) improve a product design to meet a specified need;

(D) produce engineering drawings to industry standards; and

(E) describe potential patents and the patenting process.

(9) The student builds a prototype using the appropriate tools, materials, and techniques. The student is expected to:

(A) identify and describe the steps needed to produce a prototype;

(B) identify and use appropriate tools, equipment, machines, and materials to produce the prototype; and

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(C) present the prototype using a variety of media.

Advanced Engineering Design and Presentation

(1) The student gains knowledge of and demonstrates the skills necessary for success in the workplace. The student is expected to:

(A) distinguish the differences between an engineering technician, engineering technologist, and engineer;

(B) identify employment and career opportunities;

(C) investigate and work toward industry certifications;

(D) demonstrate the principles of teamwork related to engineering and technology;

(E) identify and use appropriate work habits;

(F) demonstrate knowledge related to governmental regulations, including health and safety;

(G) discuss ethical issues related to engineering and technology and incorporate proper ethics in submitted projects;

(H) demonstrate respect for diversity in the workplace;

(I) demonstrate appropriate actions and identify consequences relating to discrimination, harassment, and equality;

(J) demonstrate effective oral and written communication skills using a variety of software applications and media; and

(K) explore career preparation learning experiences, including, but not limited to, job shadowing, mentoring, and apprenticeship training.

(2) The student participates in team projects in various roles. The student is expected to:

(A) understand and discuss how teams function;

(B) use teamwork to solve problems; and

(C) serve as a team leader and a team member and demonstrate appropriate attitudes while participating in team projects.

(3) The student develops skills for managing a project. The student is expected to:

(A) use time-management techniques to develop and maintain work schedules and meet deadlines;

(B) complete projects according to established criteria;

(C) participate in the organization and operation of a real or simulated engineering project; and

(D) develop a plan for production of an individual product.

(4) The student demonstrates principles of project documentation and work flow. The student is expected to:

(A) complete work orders and related documentation;

(B) identify factors affecting cost and strategies to minimize costs;

(C) prepare a project budget;

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(D) prepare a production schedule;

(E) identify intellectual property and other legal restrictions; and

(F) read and interpret technical drawings, manuals, and bulletins.

(5) The student applies the concepts and skills of computer-aided drafting and design software to perform the following tasks. The student is expected to:

(A) prepare drawings to American National Standards Institute and International Standards Organization graphic standards;

(B) customize software user interface by creating blocks, attributes, and symbol libraries;

(C) prepare advanced sectional views and isometrics;

(D) draw detailed parts, assembly diagrams, and sub-assembly diagrams;

(E) indicate tolerances and standard fittings using appropriate library functions;

(F) prepare highway plan and profile drawings, including utility locations;

(G) prepare functional block diagrams for project management and decision making;

(H) prepare functional wiring harness diagrams;

(I) prepare electronic schematics to industry standards, including logic diagrams;

(J) prepare advanced development drawings; and

(K) identify the functions of computer hardware devices.

(6) The student practices safe and proper work habits. The student is expected to:

(A) master relevant safety tests;

(B) follow safety guidelines as described in various manuals, instructions, and regulations;

(C) identify and classify hazardous materials and wastes according to Occupational Safety and Health Administration regulations;

(D) dispose of hazardous materials and wastes appropriately;

(E) perform maintenance on selected tools, equipment, and machines;

(F) handle and store tools and materials correctly; and

(G) describe the results of negligent or improper maintenance.

(7) The student uses engineering design methodologies. The student is expected to:

(A) understand and discuss principles of system ideation;

(B) think critically, identify the system constraints, and make fact-based decisions;

(C) use rational thinking to develop or improve a system;

(D) apply decision-making strategies when developing solutions;

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(E) identify quality-control issues in engineering design and production;

(F) describe perceptions of the quality of products and how they affect engineering decisions;

(G) use an engineering notebook to record prototypes, corrections, and/or mistakes in the design process; and

(H) use an engineering notebook to record the final design, construction, and manipulation of finished projects.

(8) The student applies concepts of engineering to specific problems. The student is expected to:

(A) use a variety of technologies to design systems;

(B) use tools, laboratory equipment, and precision measuring instruments to develop prototypes;

(C) research applications of different types of computer-aided drafting and design software; and

(D) use multiple software applications for concept presentations.

(9) The student designs systems using appropriate design processes and techniques. The student is expected to:

(A) interpret engineering drawings;

(B) identify areas where quality, reliability, and safety can be designed into a system;

(C) improve a system design to meet a specified need, including properties of materials selected;

(D) produce engineering drawings to industry standards; and

(E) describe potential patents and the patenting process.

(10) The student builds a prototype using the appropriate tools, materials, and techniques. The student is expected to:

(A) identify and describe the steps needed to produce a prototype;

(B) identify and use appropriate tools, equipment, machines, and materials to produce the prototype; and

(C) present the prototype using a variety of media.

Engineering Mathematics

(1) The student uses mathematically based hydraulics concepts to measure and find pump output, understand pressure versus cylinder force, and understand flow rate verses cylinder speed. The student is expected to:

(A) explain how flow rate can be measured in gallons per minute and liters per minute;

(B) calculate and record data using actual flow rates from a flow meter chart;

(C) calculate, measure, and illustrate the force output and speed of an extending and retracting cylinder; and

(D) determine and depict the stroke time of a cylinder in gallons per minute.

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(2) The student uses mathematical concepts of structure design to define and describe statics, acquire data, apply concepts of moments and bending stress, and apply concepts of truss design and analysis. The student is expected to:

(A) calculate a resultant force;

(B) apply the concept of equilibrium to force calculations;

(C) calculate a force using a free-body diagram;

(D) develop an application of strain gauges that determines mathematically and experimentally the force on a structural element;

(E) calculate the magnitude of force applied to a rotational system;

(F) apply the moment equilibrium equation to force calculations;

(G) calculate, measure, and illustrate a bending moment on a beam;

(H) determine and depict the bending stress in a beam;

(I) calculate forces in truss using a six-step problem-solving method;

(J) apply modulus of elasticity to the deflection of beams;

(K) calculate a beam deflection for a given load;

(L) determine and depict the critical load for buckling using Euler's formula; and

(M) design and apply factors of safety to column and beam design.

(3) The student understands the properties of trigonometry in spatial applications. The student is expected to:

(A) apply trigonometric ratios, including sine, cosine, and tangent, to spatial problems; and

(B) determine the distance and height of remote objects using trigonometry.

(4) The student understands the concepts of design processes with multi-view computer-aided drafting and design drawings for facilities layouts, precision part design, process design, computer-aided manufacturing for lathe, and injection mold design. The student is expected to:

(A) determine a dimension of an object given a scaled drawing having no dimensions;

(B) compare and contrast the function of production time and production rate;

(C) calculate, analyze, and apply the proper cycle time and machines required to meet a specified production rate;

(D) demonstrate the calculation and application of output shaft speed and torque in a gear train;

(E) create a method to determine the direction of a gear train's output shaft;

(F) design a spur gear train given speed and torque requirements;

(G) calculate and apply the proper spacing between the centers of gears in a gear train to a specified tolerance;

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(H) apply positional tolerances to assembled parts;

(I) predict the production cost of a product given process information and a bill of materials;

(J) apply the correct spindle speed for a computer-aided manufacturing device by calculation;

(K) apply the correct feed rate for a computer-aided manufacturing device by using calculation;

(L) calculate the pressure drop in an injection mold system;

(M) design a gate size in an injection mold system using the gate width and depth formulas;

(N) determine the size of a mold; and

(O) create size runners for a multi-cavity mold.

(5) The student calculates electronic quantities and uses electrical measuring instruments to experimentally test their calculations. The student is expected to:

(A) apply common electronic formulas to solve problems;

(B) use engineering notation to properly describe calculated and measured values;

(C) compare and contrast the mathematical differences between a direct current and alternating current;

(D) show the effect of an inductor in an alternating current circuit and give an application;

(E) show the effect of a capacitor in an alternating current circuit and give an application;

(F) create a resistive capacitive timing circuit in a time-delay circuit;

(G) calculate the output voltage and current load of a transformer;

(H) calculate the effective alternating current voltage root mean square given the peak alternating current voltage and the peak alternating current voltage given the root mean square value; and

(I) calculate the cost of operating an electric motor.

(6) The student applies mathematical principles of pneumatic pressure and flow to explain pressure versus cylinder force, apply and manipulate pneumatic speed control circuits, and describe maintenance of pneumatic equipment, centrifugal pump operation and characteristics, data acquisition systems, pump power, and pump system design. The student is expected to:

(A) calculate the force output of a cylinder in retraction and extension;

(B) demonstrate how gage pressure and absolute pressure are different;

(C) consider and analyze Boyle's Law to explain its significance;

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(D) convert air volumes at pressures to free air volumes;

(E) analyze dew point and relative humidity to explain their importance;

(F) explain the importance of the two units of pump flow rate measurement;

(G) convert between mass and volumetric flow rate;

(H) convert between units of head and pressure;

(I) explain the importance of total dynamic head in terms of suction and discharge head;

(J) demonstrate the measurement of the total head of a centrifugal pump;

(K) calculate friction head loss in a given pipe length using head loss tables and charts;

(L) calculate total suction lift, total suction head, total discharge head, and the total dynamic head of a system for a given flow rate;

(M) analyze and explain the importance of sensitivity in relation to pumps;

(N) use a data acquisition system to measure and mathematically analyze pressure drop characteristics in a pipe;

(O) analyze a flat plate orifice flow meter for operation and demonstrate an application;

(P) use a data acquisition system to measure and analyze mathematically data from a flat plate orifice flow meter;

(Q) calculate hydraulic power;

(R) explain the importance of brake horsepower and centrifugal pump efficiency;

(S) calculate centrifugal pump brake horsepower given pump efficiency and hydraulic power;

(T) calculate the effect of impeller diameter on the flow rate of a centrifugal pump and pump head;

(U) predict the effect of impeller diameter on a pump head capacity curve;

(V) calculate the effect of impeller speed on the flow rate of a centrifugal pump and pump head;

(W) calculate net positive suction head available and required result to explain its importance; and

(X) analyze the proper size of a centrifugal pump for a given application.

(7) The student applies mathematical principles of manufacturing processes in lathe operations and computer numerical control mill programming and calculates speeds and feeds for machining tools, including special cutting tools. The student is expected to:

(A) calculate the diameter of a tap drill given the thread specifications for a given application;

(B) analyze and set the point reference zero and the tool offsets in a computer numerical control mill;

(C) calculate spindle speeds for various machine tools; and

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(D) calculate and select the proper feed rate for machine tool operations.

(8) The student applies mathematical principles of material engineering, including tensile strength analysis, data acquisition systems, compression testing and analysis, shear and hardness testing and analysis, and design evaluation. The student is expected to:

(A) calculate stress, strain, and elongation using the modulus of elasticity for a material or model with a given set of data;

(B) analyze and explain the importance of sensitivity in relation to material engineering;

(C) analyze the operation of a data acquisition formula;

(D) mathematically analyze a part for stress and strain under a compression load;

(E) calculate shear stress for a material with a given set of data;

(F) use the Brinell hardness number to determine the ultimate tensile strength of a material;

(G) design and apply factors of safety to material engineering; and

(H) create material testing conditions for a model using equipment such as a polariscope.

(9) The student applies mathematical principles for mechanical drives, including levers, linkages, cams, turnbuckles, pulley systems, gear drives, key fasteners, v-belt drives, and chain drives. The student is expected to:

(A) calculate the weight of an object for a given mass;

(B) analyze and calculate torque for a given application using the proper units of measurement;

(C) calculate the magnitude of force applied to a rotational system;

(D) calculate the mechanical advantage of first-, second-, and third-class levers;

(E) compare and contrast the advantages and disadvantages of the three classes of levers for different applications;

(F) calculate and analyze the coefficient of friction in its proper units of measurement;

(G) analyze and calculate mechanical advantage for simple machines using proper units of measurement;

(H) calculate the mechanical advantage of gear drive systems;

(I) compare and contrast at least two methods of loading a mechanical drive system;

(J) calculate rotary mechanical power applied to an application;

(K) analyze the mechanical efficiency of a given application;

(L) demonstrate various examples of pitch and analyze its proper application;

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(M) calculate the shaft speed and torque of a belt drive and chain drive system; and

(N) calculate sprocket ratio and analyze importance to various applications.

(10) The student applies mathematical principles of quality assurance, including using precision measurement tools, statistical process control, control chart operation, analysis of quality assurance control charts, geometric dimensioning and tolerancing, and location, orientation, and form tolerances. The student is expected to:

(A) evaluate the readings of dial calipers and micrometers to make precise measurements;

(B) use at least three measures of central tendency to analyze the quality of a product;

(C) use a manually constructed histogram to analyze a given a set of data;

(D) construct and use a mean value and range chart to determine if a process remains constant over a specified range of time;

(E) examine the maximum and minimum limits of a dimension given its tolerance; and

(F) use position tolerance to calculate the location of a hole.

(11) The student applies mathematical principles of robotics and computer programming of robotic mechanisms in point-to-point assembly, calculating working envelope and computer system conversions. The student is expected to:

(A) create a pallet load configuration and program a robot to execute the operation;

(B) calculate the working envelope of a robotic arm; and

(C) convert between the hexadecimal, binary, and decimal number systems.

Electronics

(1) The student demonstrates the skills necessary for success in the workplace. The student is expected to:

(A) identify employment and career opportunities, including differences between an engineering technician, engineering technologist, and engineer;

(B) investigate and work toward industry certifications;

(C) demonstrate the principles of teamwork related to engineering and technology;

(D) identify and use appropriate work habits;

(E) identify governmental regulations for health and safety in the workplace related to electronics;

(F) discuss ethical issues related to electronics;

(G) demonstrate respect for diversity in the workplace;

(H) demonstrate appropriate actions and identify consequences relating to discrimination, harassment, and equality;

(I) demonstrate effective oral and written communication skills using a variety of software applications and media; and

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(J) explore career preparation learning experiences, including, but not limited to, job shadowing, mentoring, and apprenticeship training.

(2) The student participates in team projects in various roles. The student is expected to:

(A) apply principles of effective teamwork;

(B) solve problems as part of a team;

(C) demonstrate proper attitudes as a team leader; and

(D) demonstrate proper attitudes as a team member.

(3) The student develops skills for managing a project. The student is expected to:

(A) use time-management techniques to develop and maintain work schedules and meet deadlines;

(B) complete work according to established criteria;

(C) participate in the organization and operation of a real or simulated engineering project; and

(D) develop a plan for production of an individual product.

(4) The student practices safe and proper work habits. The student is expected to:

(A) master relevant safety tests;

(B) follow safety guidelines as described in various manuals, instructions, and regulations;

(C) identify and classify hazardous materials and wastes according to Occupational Safety and Health Administration regulations and industry standards;

(D) dispose of hazardous materials and wastes appropriately;

(E) perform maintenance on selected tools, equipment, and machines;

(F) handle and store tools and materials correctly; and

(G) describe the results of negligent or improper maintenance.

(5) The student implements the concepts and skills that form the technical knowledge of electronics using project-based assessments. The student is expected to:

(A) apply Ohm's law, Kirchoff's laws, and power laws;

(B) demonstrate an understanding of magnetism and induction as they relate to electronic circuits;

(C) demonstrate knowledge of the fundamentals of electronics theory;

(D) perform electrical-electronic troubleshooting assignments; and

(E) develop knowledge of voltage regulation devices.

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The student applies the concepts and skills to simulated and actual work situations. The student is expected to:

(A) measure and calculate resistance, current, voltage, and power in series, parallel, and complex circuits;

(B) apply electronic theory to generators, electric motors, and transformers;

(C) design analog and digital circuits using common components; and

(D) demonstrate knowledge of common devices in optoelectronics.

(7) The student uses engineering design methodologies. The student is expected to:

(A) understand and discuss principles of ideation;

(B) think critically, identify the system constraints, and make fact-based decisions;

(C) use rational thinking to develop or improve a product;

(D) apply decision-making strategies when developing solutions;

(E) use an engineering notebook to record prototypes, corrections, and mistakes in the design process; and

(F) use an engineering notebook to record the final design, construction, and manipulation of finished projects.

(8) The student learns the function and application of the tools, equipment, and materials used in electronics through project-based assignments. The student is expected to:

(A) safely use tools and laboratory equipment to construct and repair circuits;

(B) use precision measuring instruments to analyze circuits and prototypes;

(C) describe and perform measurements using oscilloscopes; and

(D) use multiple software applications to simulate circuit behavior and present concepts.

(9) The student designs products using appropriate design processes and techniques. The student is expected to:

(A) interpret industry standard circuit schematics;

(B) identify areas where quality, reliability, and safety can be designed into a product;

(C) improve a product design to meet a specified need;

(D) produce schematics to industry standards;

(E) describe potential patents and the patenting process;

(F) use a variety of technologies to design components; and

(G) explore new technologies that may affect electronics.

(10) The student builds a prototype using the appropriate tools, materials, and techniques. The student is expected to:

(A) identify and describe the steps needed to produce a prototype;

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(B) identify and use appropriate tools, equipment, machines, and materials to produce the prototype; and

(C) present the prototype using a variety of media.

Advanced Electronics

(1) The student demonstrates the technical skills necessary for success in the workplace. The student is expected to:

(A) identify employment and career opportunities, including differences between an engineering technician, engineering technologist, and engineer;

(B) investigate and prepare for industry certifications;

(C) demonstrate the principles of teamwork related to engineering and technology;

(D) identify and use appropriate work habits;

(E) demonstrate knowledge related to governmental regulations, including health and safety;

(F) discuss ethical issues related to engineering and technology and incorporate proper ethics in submitted projects;

(G) demonstrate respect for diversity in the workplace;

(H) demonstrate appropriate actions and identify consequences relating to discrimination, harassment, and equality;

(I) demonstrate effective oral and written communication skills using a variety of software applications and media; and

(J) explore career preparation learning experiences, including, but not limited to, job shadowing, mentoring, and apprenticeship training.

(2) The student participates in team projects in various roles. The student is expected to:

(A) understand and discuss how teams function;

(B) use teamwork to solve problems;

(C) serve as a team leader while demonstrating appropriate attitudes; and

(D) serve as a team member while demonstrating appropriate attitudes.

(3) The student develops skills for managing a project. The student is expected to:

(A) use time-management techniques to develop and maintain work schedules to meet specific project objectives;

(B) complete work according to established criteria;

(C) participate in the organization and operation of a real or simulated engineering project; and

(D) develop a plan for production of an individual product.

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The student demonstrates principles of project documentation and work flow. The student is expected to:

(A) complete work orders and related documentation;

(B) identify factors affecting cost and strategies to minimize costs;

(C) prepare a project budget;

(D) prepare a production schedule;

(E) identify intellectual property and other legal restrictions; and

(F) read and interpret technical drawings, manuals, and bulletins.

(5) The student practices safe and proper work habits. The student is expected to:

(A) master relevant safety tests;

(B) follow safety guidelines as described in various manuals, instructions, and regulations;

(C) recognize the classification of hazardous materials and wastes;

(D) dispose of hazardous materials and wastes appropriately;

(E) perform maintenance on selected tools, equipment, and machines;

(F) handle and store tools and materials correctly; and

(G) describe the results of negligent or improper maintenance.

(6) The student implements the concepts and skills that form advanced knowledge of electronics using project-based rubrics. The student is expected to:

(A) apply Ohm's law, Kirchoff's laws, and power laws to advanced circuit theory;

(B) demonstrate advanced knowledge of the theory of direct current, alternating current, digital circuits, and semi-conductor circuits such as Thevenin and Norton's theorems;

(C) perform advanced electrical-electronic troubleshooting assignments;

(D) apply knowledge of voltage regulation devices;

(E) apply knowledge of the design and use of diodes, transistors, and analog components with integrated circuits;

(F) implement knowledge of solid-state components and devices such as a power supply design;

(G) demonstrate knowledge of the similarities and differences in optoelectronic devices;

(H) implement knowledge of transmission theory;

(I) implement knowledge of microprocessor applications;

(J) apply electronic theory to generators, electric motors, power supplies, electronic amplifiers, electronic oscillators, communication circuits, and systems; and

(K) complete advanced electrical-electronic troubleshooting assignments to industry standards.

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The student uses engineering design methodologies. The student is expected to:

(A) understand and discuss principles of ideation;

(B) think critically, identify the system constraints, and make fact-based decisions;

(C) use rational thinking to develop or improve a product;

(D) apply decision-making strategies when developing solutions;

(E) identify quality-control issues in engineering design and production;

(F) describe perceptions of the quality of products and how they affect engineering decisions;

(G) use an engineering notebook to record prototypes, corrections, and mistakes in the design process; and

(H) use an engineering notebook to record the final design, construction, and manipulation of finished projects.

(8) The student learns the function and application of the tools, equipment, and materials used in electronics through specific project-based assessments. The student is expected to:

(A) safely use tools and laboratory equipment to construct and repair circuits;

(B) use precision measuring instruments to analyze circuits and prototypes;

(C) describe and perform measurement techniques with analog, digital, and storage oscilloscopes;

(D) use multiple software applications to simulate circuit behavior and present concepts; and

(E) identify and describe the functions of computer hardware devices.

(9) The student designs products using appropriate design processes and techniques. The student is expected to:

(A) interpret advanced industry standard schematics;

(B) identify areas where quality, reliability, and safety can be designed into a product;

(C) improve a product design to meet a specified need;

(D) produce advanced schematics to industry standards;

(E) discuss the process of obtaining a patent;

(F) use a variety of technologies to design components such as computer simulation software; and

(G) explore innovative technologies that may affect electronics.

(10) The student builds a simulated or physical prototype using the appropriate tools, materials, and techniques. The student is expected to:

(A) identify and describe the steps needed to produce a prototype;

(B) identify and use appropriate tools, equipment, machines, and materials to produce the prototype; and

(C) present the prototype using a variety of media to a panel.

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Robotics and Automation

(1) The student demonstrates the skills necessary for success in the workplace. The student is expected to:

(A) distinguish the differences between an engineering technician, engineering technologist, and engineer;

(B) identify employment and career opportunities;

(C) investigate and work toward industry certifications;

(D) demonstrate the principles of teamwork related to engineering and technology;

(E) identify and use appropriate work habits;

(F) demonstrate knowledge related to governmental regulations, including health and safety;

(G) discuss ethical issues related to engineering and technology and incorporate proper ethics in submitted projects;

(H) demonstrate respect for diversity in the workplace;

(I) demonstrate appropriate actions and identify consequences relating to discrimination, harassment, and equality;

(J) demonstrate effective oral and written communication skills using a variety of software applications and media; and

(K) explore career preparation learning experiences, including, but not limited to, job shadowing, mentoring, and apprenticeship training.

(2) The student participates in team projects in various roles. The student is expected to:

(A) understand and discuss how teams function;

(B) use teamwork to solve problems; and

(C) serve as a team leader and a team member and demonstrate appropriate attitudes while serving in those roles.

(3) The student develops skills for managing a project. The student is expected to:

(A) use time-management techniques to develop and maintain work schedules and meet deadlines;

(B) complete work according to established criteria;

(C) participate in the organization and operation of a real or simulated engineering project; and

(D) develop a plan for production of an individual product.

(4) The student practices safe and proper work habits. The student is expected to:

(A) master relevant safety tests;

(B) follow safety guidelines as described in various manuals, instructions, and regulations;

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(C) identify and classify hazardous materials and wastes according to Occupational Safety and Health Administration regulations;

(D) dispose of hazardous materials and wastes appropriately;

(E) perform maintenance on selected tools, equipment, and machines;

(F) handle and store tools and materials correctly; and

(G) describe the results of negligent or improper maintenance.

(5) The student develops the ability to use and maintain technological products, processes, and systems. The student is expected to:

(A) demonstrate the use of computers to manipulate a robotic or automated system and associated subsystems;

(B) troubleshoot and maintain systems and subsystems to ensure safe and proper function and precision operation;

(C) demonstrate knowledge of process control factors; and

(D) demonstrate knowledge of motors, gears, and gear trains used in the robotic or automated systems.

(6) The student develops an understanding of the advanced concepts of physics, robotics, and automation. The student is expected to:

(A) demonstrate knowledge of rotational dynamics, weight, friction, and traction factors required for the operation of robotic and automated systems;

(B) demonstrate knowledge of torque and power factors used in the operation of robotic systems;

(C) demonstrate knowledge of feedback control loops to provide information; and

(D) demonstrate knowledge of different types of sensors used in robotic or automated systems and their operations.

(7) The student develops an understanding of the characteristics and scope of manipulators and end effectors required for a robotic or automated system to function. The student is expected to:

(A) demonstrate knowledge of robotic or automated system arm construction;

(B) understand and discuss the relationship of torque, gear ratio, and weight of payload in a robotic or automated system operation; and

(C) demonstrate knowledge of end effectors and their use in linkages and the gearing of a robotic or automated system.

(8) The student uses engineering design methodologies. The student is expected to:

(A) understand and discuss principles of ideation;

(B) think critically, identify the system constraints, and make fact-based decisions;

(C) use rational thinking to develop or improve a product;

(D) apply decision-making strategies when developing solutions;

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(E) identify quality-control issues in engineering design and production;

(F) describe perceptions of the quality of products and how they affect engineering decisions;

(G) use an engineering notebook to record prototypes, corrections, and or mistakes in the design process; and

(H) use an engineering notebook to record the final design, construction, and manipulation of finished projects.

(9) The student learns the function and application of the tools, equipment, and materials used in robotic and automated systems through specific project-based assessments. The student is expected to:

(A) safely use tools and laboratory equipment to construct and repair systems;

(B) use precision measuring instruments to analyze systems and prototypes; and

(C) use multiple software applications to simulate robot behavior and present concepts.

(10) The student designs products using appropriate design processes and techniques. The student is expected to:

(A) interpret industry standard system schematics;

(B) identify areas where quality, reliability, and safety can be designed into a product;

(C) improve a product design to meet a specified need;

(D) understand use of sensors in a robotic or automated system;

(E) produce system schematics to industry standards;

(F) evaluate design solutions using conceptual, physical, and mathematical models at various times during the design process to check for proper functionality and to note areas where improvements are needed;

(G) implement a system to identify and track all components of the robotic or automated system and all elements involved with the operation, construction, and manipulative functions; and

(H) describe potential patents and the patenting process.

(11) The student builds a prototype using the appropriate tools, materials, and techniques. The student is expected to:

(A) identify and describe the steps needed to produce a prototype;

(B) identify and use appropriate tools, equipment, machines, and materials to produce the prototype;

(C) implement sensors in a robotic or automated system;

(D) construct a robotic or automated system to perform specified operations using the design process;

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(E) test and evaluate the design in relation to pre-established requirements such as criteria and constraints and refine as needed;

(F) refine the design of a robotic or automated system to ensure quality, efficiency, and manufacturability of the final product; and

(G) present the prototype using a variety of media.

Principles of Technology

(1) The student, for at least 40% of instructional time, conducts laboratory and field investigations using safe, environmentally appropriate, and ethical practices. These investigations must involve actively obtaining and analyzing data with physical equipment, but may also involve experimentation in a simulated environment as well as field observations that extend beyond the classroom. The student is expected to:

(A) demonstrate safe practices during laboratory and field investigations; and

(B) demonstrate an understanding of the use and conservation of resources and the proper disposal or recycling of materials.

(2) The student uses a systematic approach to answer scientific laboratory and field investigative questions. The student is expected to:

(A) know the definition of science and understand that it has limitations, as specified in subsection (b)(2) of this section;

(B) know that scientific hypotheses are tentative and testable statements that must be capable of being supported or not supported by observational evidence. Hypotheses of durable explanatory power that have been tested over a wide variety of conditions are incorporated into theories;

(C) know that scientific theories are based on natural and physical phenomena and are capable of being tested by multiple independent researchers. Unlike hypotheses, scientific theories are well-established and highly-reliable explanations, but may be subject to change as new areas of science and new technologies are developed;

(D) distinguish between scientific hypotheses and scientific theories;

(E) design and implement investigative procedures, including making observations, asking well-defined questions, formulating testable hypotheses, identifying variables, selecting appropriate equipment and technology, and evaluating numerical answers for reasonableness;

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(F) demonstrate the use of course apparatus, equipment, techniques, and procedures, including multimeters (current, voltage, resistance), triple beam balances, batteries, clamps, dynamics demonstration equipment, collision apparatus, data acquisition probes, discharge tubes with power supply (H, He, Ne, Ar), hand-held visual spectroscopes, hot plates, slotted and hooked lab masses, bar magnets, horseshoe magnets, plane mirrors, convex lenses, pendulum support, power supply, ring clamps, ring stands, stopwatches, trajectory apparatus, tuning forks, carbon paper, graph paper, magnetic compasses, polarized film, prisms, protractors, resistors, friction blocks, mini lamps (bulbs) and sockets, electrostatics kits, 90-degree rod clamps, metric rulers, spring scales, knife blade switches, Celsius thermometers, meter sticks, scientific calculators, graphing technology, computers, cathode ray tubes with horseshoe magnets, ballistic carts or equivalent, resonance tubes, spools of nylon thread or string, containers of iron filings, rolls of white craft paper, copper wire, Periodic Table, electromagnetic spectrum charts, slinky springs, wave motion ropes, and laser pointers;

(G) use a wide variety of additional course apparatus, equipment, techniques, materials, and procedures as appropriate such as ripple tank with wave generator, wave motion rope, micrometer, caliper, radiation monitor, computer, ballistic pendulum, electroscope, inclined plane, optics bench, optics kit, pulley with table clamp, resonance tube, ring stand screen, four-inch ring, stroboscope, graduated cylinders, and ticker timer;

(H) make measurements with accuracy and precision and record data using scientific notation and International System (SI) units;

(I) identify and quantify causes and effects of uncertainties in measured data;

(J) organize and evaluate data and make inferences from data, including the use of tables, charts, and graphs;

(K) communicate valid conclusions supported by the data through various methods such as lab reports, labeled drawings, graphic organizers, journals, summaries, oral reports, and technology-based reports; and

(L) express and manipulate relationships among physical variables quantitatively, including the use of graphs, charts, and equations.

(3) The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to:

(A) in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student;

(B) communicate and apply scientific information extracted from various sources such as current events, news reports, published journal articles, and marketing materials;

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(C) draw inferences based on data related to promotional materials for products and services;

(D) explain the impacts of the scientific contributions of a variety of historical and contemporary scientists on scientific thought and society;

(E) research and describe the connections between physics and future careers; and

(F) express and interpret relationships symbolically in accordance with accepted theories to make predictions and solve problems mathematically, including problems requiring proportional reasoning and graphical vector addition.

(4) The student uses the scientific process to investigate physical concepts. The student is expected to:

(A) understand that scientific hypotheses are tentative and testable statements that must be capable of being supported by observational evidence;

(B) understand that scientific theories are based on natural and physical phenomena and are capable of being tested by multiple independent researchers;

(C) design and implement investigative procedures;

(D) demonstrate the appropriate use and care of laboratory equipment;

(E) demonstrate accurate measurement techniques using precision instruments;

(F) record data using scientific notation and International System (SI) of units;

(G) identify and quantify causes and effects of uncertainties in measured data;

(H) organize and evaluate data, including the use of tables, charts, and graphs;

(I) communicate conclusions supported through various methods such as laboratory reports, labeled drawings, graphic organizers, journals, summaries, oral reports, or technology-based reports; and

(J) record, express, and manipulate data using graphs, charts, and equations.

(5) The student demonstrates appropriate safety techniques in the field and laboratory environments. The student is expected to:

(A) master relevant safety procedures;

(B) follow safety guidelines as described in various manuals, instructions, and regulations;

(C) identify and classify hazardous materials and wastes; and

(D) make prudent choices in the conservation and use of resources and the disposal of hazardous materials and wastes appropriately.

(6) The student uses critical-thinking, scientific-reasoning, and problem-solving skills. The student is expected to:

(A) analyze and evaluate scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing;

(B) communicate and apply scientific information;

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(C) explain the societal impacts of scientific contributions; and

(D) research and describe the connections between technologies and future career opportunities.

(7) The student describes and applies the laws governing motion in a variety of situations. The student is expected to:

(A) generate and interpret relevant equations using graphs and charts for one- and two-dimensional motion, including:<ol type="i">
using and describing one-dimensional equations for displacement, distance, speed, velocity, average velocity, acceleration, and average acceleration;
using and describing two-dimensional equations for projectile and circular motion; and
using and describing vector forces and resolution;

(B) describe and calculate the effects of forces on objects, including law of inertia and impulse and conservation of momentum;

(C) develop and interpret free-body force diagrams; and

(D) identify and describe motion relative to different frames of reference.

(8) The student describes the nature of forces in the physical world. The student is expected to:

(A) research and describe the historical development of the concepts of gravitational, electromagnetic, weak nuclear, and strong nuclear forces;

(B) describe and calculate the magnitude of gravitational forces between two objects;

(C) describe and calculate the magnitude of electrical forces;

(D) describe the nature and identify everyday examples of magnetic forces and fields;

(E) describe the nature and identify everyday examples of electromagnetic forces and fields;

(F) characterize materials as conductors or insulators based on their electrical properties;

(G) design and construct both series and parallel circuits and calculate current, potential difference, resistance, and power of various circuits;

(H) investigate and describe the relationship between electric and magnetic fields in applications such as generators, motors, and transformers; and

(I) describe technological applications of the strong and weak nuclear forces in nature.

(9) The student describes and applies the laws of the conservation of energy and momentum. The student is expected to:

(A) describe the transformational process between work, potential energy, and kinetic energy (work-energy theorem);

(B) use examples to analyze and calculate the relationships among work, kinetic energy, and potential energy;

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(C) describe and calculate the mechanical energy of, the power generated within, the impulse applied to, and the momentum of a physical system; and

(D) describe and apply the laws of conservation of energy and conservation of momentum.

(10) The student analyzes the concept of thermal energy. The student is expected to:

(A) describe how the macroscopic properties of a thermodynamic system such as temperature, specific heat, and pressure are related to the molecular level of matter, including kinetic or potential energy of atoms;

(B) contrast and give examples of different processes of thermal energy transfer, including conduction, convection, and radiation; and

(C) analyze and explain technological examples such as solar and wind energy that illustrate the laws of thermodynamics, including the law of conservation of energy and the law of entropy.

(11) The student analyzes the properties of wave motion and optics. The student is expected to:

(A) examine and describe oscillatory motion and wave propagation in various types of media;

(B) investigate and analyze characteristics of waves, including velocity, frequency, amplitude, and wavelength;

(C) investigate and calculate the relationship between wavespeed, frequency, and wavelength;

(D) compare and contrast the characteristics and behaviors of transverse waves, including electromagnetic waves and the electromagnetic spectrum, and longitudinal waves, including sound waves;

(E) investigate behaviors of waves, including reflection, refraction, diffraction, interference, resonance, and the Doppler effect;

(F) describe and predict image formation as a consequence of reflection from a plane mirror and refraction through a thin convex lens; and

(G) describe the role of wave characteristics and behaviors in medical and industrial technology applications.

(12) The student analyzes the concepts of atomic, nuclear, and quantum phenomena. The student is expected to:

(A) describe the photoelectric effect and the dual nature of light;

(B) compare and explain emission spectra produced by various atoms;

(C) describe the significance of mass-energy equivalence and apply it in explanations of phenomena such as nuclear stability, fission, and fusion;

(D) describe the role of mass-energy equivalence for areas such as nuclear stability, fission, and fusion; and

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(E) explore technology applications of atomic, nuclear, and quantum phenomena such as nanotechnology, radiation therapy, diagnostic imaging, and nuclear power.

Scientific Research and Design

(1) The student, for at least 40% of instructional time, conducts laboratory and field investigations using safe, environmentally appropriate, and ethical practices. These investigations must involve actively obtaining and analyzing data with physical equipment, but may also involve experimentation in a simulated environment as well as field observations that extend beyond the classroom. The student is expected to:

(A) demonstrate safe practices during laboratory and field investigations; and

(B) demonstrate an understanding of the use and conservation of resources and the proper disposal or recycling of materials.

(2) The student uses a systematic approach to answer scientific laboratory and field investigative questions. The student is expected to:

(A) know the definition of science and understand that it has limitations, as specified in subsection (b)(1) of this section;

(B) know that scientific hypotheses are tentative and testable statements that must be capable of being supported or not supported by observational evidence. Hypotheses of durable explanatory power which have been tested over a wide variety of conditions are incorporated into theories;

(C) know that scientific theories are based on natural and physical phenomena and are capable of being tested by multiple independent researchers. Unlike hypotheses, scientific theories are well-established and highly-reliable explanations, but may be subject to change as new areas of science and new technologies are developed;

(D) distinguish between scientific hypotheses and scientific theories;

(E) design and implement investigative procedures, including making observations, asking well-defined questions, formulating testable hypotheses, identifying variables, selecting appropriate equipment and technology, and evaluating numerical answers for reasonableness;

(F) collect and organize qualitative and quantitative data and make measurements with accuracy and precision using tools such as calculators, spreadsheet software, data-collecting probes, computers, standard laboratory glassware, microscopes, various prepared slides, stereoscopes, metric rulers, electronic balances, gel electrophoresis apparatuses, micropipettors, hand lenses, Celsius thermometers, hot plates, lab notebooks or journals, timing devices, cameras, and meter sticks;

(G) analyze, evaluate, make inferences, and predict trends from data;

(H) identify and quantify causes and effects of uncertainties in measured data;

(I) organize and evaluate data and make inferences from data, including the use of tables, charts, and graphs; and

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(J) communicate valid conclusions supported by the data through various methods such as lab reports, labeled drawings, graphic organizers, journals, summaries, oral reports, and technology-based reports.

(3) The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to:

(A) in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student;

(B) communicate and apply scientific information extracted from various sources such as current events, news reports, published journal articles, and marketing materials;

(C) draw inferences based on data related to promotional materials for products and services;

(D) explain the impacts of the scientific contributions of a variety of historical and contemporary scientists on scientific thought and society;

(E) research and describe the connections between science and future careers; and

(F) express and interpret relationships symbolically in accordance with accepted theories to make predictions and solve problems mathematically, including problems requiring proportional reasoning and graphical vector addition.

(4) The student formulates hypotheses to guide experimentation and data collection. The student is expected to:

(A) perform background research with respect to an investigative problem; and

(B) examine hypotheses generated to guide a research process by evaluating the merits and feasibility of the hypotheses.

(5) The student analyzes published research. The student is expected to:

(A) identify the scientific methodology used by a researcher;

(B) examine a prescribed research design and identify dependent and independent variables;

(C) evaluate a prescribed research design to determine the purpose for each of the procedures performed; and

(D) compare the relationship of the hypothesis to the conclusion.

(6) The student develops and implements investigative designs. The student is expected to:

(A) interact and collaborate with scientific researchers and/or other members of the scientific community to complete a research project;

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(B) identify and manipulate relevant variables within research situations;

(C) use a control in an experimental process; and

(D) design procedures to test hypotheses.

(7) The student collects, organizes, and evaluates qualitative and quantitative data obtained through experimentation. The student is expected to:

(A) record observations and events as they occur within an investigation;

(B) acquire, manipulate, and analyze data using equipment and technology;

(C) construct data tables to organize information collected in an experiment; and

(D) evaluate data using statistical methods to recognize patterns, trends, and proportional relationships.

(8) The student knows how to synthesize valid conclusions from qualitative and quantitative data. The student is expected to:

(A) synthesize conclusions supported by research data;

(B) consider and communicate alternative explanations for observations and results; and

(C) identify limitations within the research process and provide recommendations for additional research.

(9) The student communicates conclusions clearly and concisely to an audience of professionals. The student is expected to:

(A) construct charts, tables, and graphs in facilitating data analysis and in communicating experimental results clearly and effectively using technology; and

(B) suggest alternative explanations from observations or trends evident within the data or from prompts provided by a review panel.

Engineering Design and Problem Solving

(1) The student, for at least 40% of instructional time, conducts engineering field and laboratory activities using safe, environmentally appropriate, and ethical practices. The student is expected to:

(A) demonstrate safe practices during engineering field and laboratory activities; and

(B) make informed choices in the use and conservation of resources, recycling of materials, and the safe and legal disposal of materials.

(2) The student applies knowledge of science and mathematics and the tools of technology to solve engineering design problems. The student is expected to:

(A) apply scientific processes and concepts outlined in the Texas Essential Knowledge and Skills (TEKS) for Biology, Chemistry, or Physics relevant to engineering design problems;

(B) apply concepts, procedures, and functions outlined in the TEKS for Algebra I, Geometry, and Algebra II relevant to engineering design problems;

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(C) select appropriate mathematical models to develop solutions to engineering design problems;

(D) integrate advanced mathematics and science skills as necessary to develop solutions to engineering design problems;

(E) judge the reasonableness of mathematical models and solutions;

(F) investigate and apply relevant chemical, mechanical, biological, electrical, and physical properties of materials to engineering design problems;

(G) identify the inputs, processes, outputs, control, and feedback associated with open and closed systems;

(H) describe the difference between open-loop and closed-loop control systems;

(I) make measurements and specify tolerances with minimum necessary accuracy and precision;

(J) use appropriate measurement systems, including customary and International System (SI) of units; and

(K) use conversions between measurement systems to solve real-world problems.

(3) The student communicates through written documents, presentations, and graphic representations using the tools and techniques of professional engineers. The student is expected to:

(A) communicate visually by sketching and creating technical drawings using established engineering graphic tools, techniques, and standards;

(B) read and comprehend technical documents, including specifications and procedures;

(C) prepare written documents such as memorandums, emails, design proposals, procedural directions, letters, and technical reports using the formatting and terminology conventions of technical documentation;

(D) organize information for visual display and analysis using appropriate formats for various audiences, including, but not limited to, graphs and tables;

(E) evaluate the quality and relevance of sources and cite appropriately; and

(F) defend a design solution in a presentation.

(4) The student recognizes the history, development, and practices of the engineering professions. The student is expected to:

(A) identify and describe career options, working conditions, earnings, and educational requirements of various engineering disciplines such as those listed by the Texas Board of Professional Engineers;

(B) recognize that engineers are guided by established codes emphasizing high ethical standards;

(C) explore the differences, similarities, and interactions among engineers, scientists, and mathematicians;

(D) describe how technology has evolved in the field of engineering and consider how it will continue to be a useful tool in solving engineering problems;

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(E) discuss the history and importance of engineering innovation on the United States economy and quality of life; and

(F) describe the importance of patents and the protection of intellectual property rights.

(5) The student creates justifiable solutions to open-ended problems using engineering design practices and processes. The student is expected to:

(A) identify and define an engineering problem;

(B) formulate goals, objectives, and requirements to solve an engineering problem;

(C) determine the design parameters associated with an engineering problem such as materials, personnel, resources, funding, manufacturability, feasibility, and time;

(D) establish and evaluate constraints pertaining to a problem, including, but not limited to, health, safety, social, environmental, ethical, political, regulatory, and legal;

(E) identify or create alternative solutions to a problem using a variety of techniques such as brainstorming, reverse engineering, and researching engineered and natural solutions;

(F) test and evaluate proposed solutions using methods such as models, prototypes, mock-ups, simulations, critical design review, statistical analysis, or experiments;

(G) apply structured techniques to select and justify a preferred solution to a problem such as a decision tree, design matrix, or cost-benefit analysis;

(H) predict performance, failure modes, and reliability of a design solution; and

(I) prepare a project report that clearly documents the designs, decisions, and activities during each phase of the engineering design process.

(6) The student manages an engineering design project. The student is expected to:

(A) participate in the design and implementation of a real or simulated engineering project;

(B) develop a plan and timeline for completion of a project;

(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members;

(D) compare and contrast the roles of a team leader and other team responsibilities;

(E) identify and manage the resources needed to complete a project;

(F) use a budget to determine effective strategies to meet cost constraints;

(G) create a risk assessment for an engineering design project;

(H) analyze and critique the results of an engineering design project; and

(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments.

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Scientific processes. The student, for at least 40% of instructional time, conducts laboratory and field investigations using safe, environmentally appropriate, and ethical practices. The student is expected to:

(A) demonstrate safe practices during laboratory and field investigations; and

(B) demonstrate an understanding of the use and conservation of resources and the proper disposal or recycling of materials.

(2) Scientific processes. The student uses scientific methods and equipment during laboratory and field investigations. The student is expected to:

(A) know the definition of science and understand that it has limitations, as specified in subsection (b)(2) of this section;

(B) know that hypotheses are tentative and testable statements that must be capable of being supported or not supported by observational evidence. Hypotheses of durable explanatory power which have been tested over a wide variety of conditions are incorporated into theories;

(C) know scientific theories are based on natural and physical phenomena and are capable of being tested by multiple independent researchers. Unlike hypotheses, scientific theories are well-established and highly-reliable explanations, but they may be subject to change as new areas of science and new technologies are developed;

(D) distinguish between scientific hypotheses and scientific theories;

(E) plan and implement descriptive, comparative, and experimental investigations, including asking questions, formulating testable hypotheses, and selecting equipment and technology;

(F) collect and organize qualitative and quantitative data and make measurements with accuracy and precision using tools such as spreadsheet software, data-collecting probes, computers, standard laboratory glassware, microscopes, various prepared slides, animal restraints, stereoscopes, electronic balances, micropipettors, hand lenses, surgical and imagining equipment, thermometers, hot plates, lab notebooks or journals, timing devices, Petri dishes, lab incubators, dissection equipment, and models, diagrams, or samples of biological specimens or structures;

(G) analyze, evaluate, make inferences, and predict trends from data; and

(H) communicate valid conclusions supported by the data through methods such as lab reports, labeled drawings, graphic organizers, journals, summaries, oral reports, and technology-based reports.

(3) Scientific processes. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to:

(A) in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student;

(B) communicate and apply scientific information extracted from various sources such as current events, news reports, published journal articles, and marketing materials;

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(C) draw inferences based on data related to promotional materials for products and services;

(D) evaluate the impact of scientific research on society and the environment;

(E) evaluate models according to their limitations in representing objects or events; and

(F) research and describe the history of veterinary medicine and contributions of scientists in that field.

(4) Principles of engineering. The student investigates engineering-related fields and career opportunities. The student is expected to:

(A) evaluate models according to their limitations in representing objects or events;

(B) differentiate between engineering and engineering technology;

(C) identify the job opportunities available in engineering and engineering technology;

(D) identify and differentiate among different engineering disciplines; and

(E) demonstrate appropriate oral, written, and visual forms of technical communication.

(5) Design problems. The student demonstrates an understanding of design problems and works individually and as a member of a team to solve design problems. The student is expected to:

(A) solve design problems individually and in a team;

(B) create solutions to existing problems using a design process;

(C) use a design brief to identify problem specifications and establish project constraints;

(D) use communication to achieve a desired goal within a team; and

(E) work as a member of a team to conduct research to develop a knowledge base, stimulate creative ideas, and make informed decisions.

(6) Energy and power. The student understands mechanisms, including simple and compound machines, and performs calculations related to mechanical advantage, drive ratios, work, and power. The student is expected to:

(A) explain how components, including gears, sprockets, pulley systems, and simple machines, make up mechanisms;

(B) distinguish between the six simple machines and their attributes and components;

(C) measure forces and distances related to a mechanism;

(D) calculate work and power in mechanical systems;

(E) determine efficiency in mechanical systems; and

(F) calculate mechanical advantage and drive ratios of mechanisms.

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(7) Energy and power. The student understands energy sources, energy conversion, and circuits and performs calculations related to work and power. The student is expected to:

(A) identify and categorize energy sources as nonrenewable, renewable, or inexhaustible;

(B) define and calculate work and power;

(C) calculate power in a system that converts energy from electrical to mechanical; and

(D) define voltage, current, and resistance and calculate each using Ohm's law.

(8) Energy and power. The student understands system energy requirements and how energy sources can be combined to convert energy into useful forms. The student calculates material conductivity, resistance, and energy transfer. The student is expected to:

(A) explain the purpose of energy management;

(B) evaluate system energy requirements in order to select the proper energy source;

(C) explain how multiple energy sources can be combined to convert energy into useful forms;

(D) describe how hydrogen fuel cells create electricity and heat and how solar cells create electricity;

(E) explain how thermal energy is transferred via convection, conduction, and radiation and complete calculations for conduction, R-values, and radiation; and

(F) calculate resistance, energy transfer, and material conductivity.

(9) Materials and structures. The student understands the interaction of forces acting on a body and performs calculations related to structural design. The student is expected to:

(A) illustrate and calculate all forces acting upon a given body;

(B) locate the centroid of structural members mathematically;

(C) calculate moment of inertia of structural members;

(D) define and calculate static equilibrium;

(E) differentiate between scalar and vector quantities;

(F) identify magnitude, direction, and sense of a vector;

(G) calculate the X and Y components given a vector;

(H) calculate moment forces given a specified axis;

(I) calculate unknown forces using equations of equilibrium; and

(J) calculate external and internal forces in a statically determinate truss using translational and rotational equilibrium equations.

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(10) Materials and structures. The student understands material properties and the importance of choosing appropriate materials for design. The student is expected to:

(A) conduct investigative non-destructive material property tests on selected common household products;

(B) calculate the weight, volume, mass, density, and surface area of selected common household products; and

(C) identify the manufacturing processes used to create selected common household products.

(11) Materials and structures. The student uses material testing to determine a product's function and performance. The student is expected to:

(A) use a design process and mathematical formulas to solve and document design problems;

(B) obtain measurements of material samples;

(C) use material testing to determine a product's reliability, safety, and predictability in function;

(D) identify and calculate test sample material properties using a stress-strain curve; and

(E) identify and calculate sample material properties such as elastic range, proportional limit, modulus of elasticity, elastic limit, resilience, yield point, plastic deformation, ultimate strength, failure, and ductility using stress-strain data points.

(12) Control systems. The student understands that control systems are designed to provide consentient process control and reliability and uses computer software to create flowcharts and control system operating programs. The student is expected to:

(A) create detailed flowcharts using a computer software application;

(B) create control system operating programs using computer software;

(C) create system control programs that use flowchart logic;

(D) select appropriate inputs and output devices based on the need of a technological system; and

(E) judge between open- and closed-loop systems in order to select the most appropriate system for a given technological problem.

(13) Materials and structures. The student demonstrates an understanding of fluid power systems and calculates values in a variety of systems. The student is expected to:

(A) identify and explain basic components and functions of fluid power devices;

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(B) differentiate between pneumatic and hydraulic systems and between hydrodynamic and hydrostatic systems;

(C) use Pascal's Law to calculate values in a fluid power system;

(D) distinguish between pressure and absolute pressure and between temperature and absolute temperature;

(E) calculate values in a pneumatic system using the perfect gas laws; and

(F) calculate flow rate, flow velocity, and mechanical advantage in a hydraulic system.

(14) Statistics and kinematics. The student demonstrates an understanding of statistics and kinematics and applies both to engineering design problems. The student is expected to:

(A) calculate the theoretical probability that an event will occur;

(B) calculate the experimental frequency distribution of an event occurring;

(C) apply the Bernoulli process to events that only have two distinct possible outcomes;

(D) apply AND, OR, and NOT logic to probability;

(E) apply Bayes's theorem to calculate the probability of multiple events occurring;

(F) calculate the central tendency of a data array, including mean, median, and mode;

(G) calculate data variation, including range, standard deviation, and variance;

(H) create a histogram to illustrate frequency distribution;

(I) calculate distance, displacement, speed, velocity, and acceleration from data;

(J) calculate acceleration due to gravity given data from a free-fall device;

(K) calculate the X and Y components of a projectile motion; and

(L) determine the angle needed to launch a projectile a specific range given the projectile's initial velocity.

Digital Electronics

(1) The student uses mathematical processes to acquire and demonstrate mathematical understanding. The student is expected to:

(A) apply mathematics to problems arising in everyday life, society, and the workplace;

(B) use a problem-solving model that incorporates analyzing given information, formulating a plan or strategy, determining a solution, justifying the solution, and evaluating the problem-solving process and the reasonableness of the solution;

(C) select tools, including real objects, manipulatives, paper and pencil, and technology as appropriate, and techniques, including mental math, estimation, and number sense as appropriate, to solve problems;

(D) communicate mathematical ideas, reasoning, and their implications using multiple representations, including symbols, diagrams, graphs, and language as appropriate;

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(E) create and use representations to organize, record, and communicate mathematical ideas;

(F) analyze mathematical relationships to connect and communicate mathematical ideas; and

(G) display, explain, and justify mathematical ideas and arguments using precise mathematical language in written or oral communication.

(2) The student explores the fundamentals of analog and digital electronics. The student uses appropriate notation and understands the logic of circuit design and logic gates. The student is expected to:

(A) use scientific notation, engineering notation, and Systems International (SI) notation to conveniently write very large or very small numbers frequently encountered when working with electronics;

(B) describe the process of soldering and how it is used in the assembly of electronic components;

(C) explain the different waveforms and distinctive characteristics of analog and digital signals;

(D) identify the voltage levels of analog and digital signals;

(E) determine whether a material is a conductor, an insulator, or a semiconductor based on its atomic structure;

(F) analyze the three fundamental concepts of voltage, current, and resistance;

(G) define circuit design software and explain its purpose;

(H) identify the fundamental building block of sequential logic;

(I) identify the components of a manufacturer's datasheet, including a logic gate's general description, connection diagram, and function table;

(J) categorize integrated circuits by their underlying circuitry, scale of integration, and packaging style;

(K) describe the advantages and disadvantages of the various sub-families of transistor-transistor logic (TTL) gates;

(L) explain that a logic gate is depicted by its schematic symbol, logic expression, and truth table;

(M) evaluate the different functions of input and output values of combinational and sequential logic;

(N) explain combinational logic designs implemented with AND gates, OR gates, and INVERTER gates; and

(O) identify the fundamental building block of sequential logic.

(3) The student understands and uses multiple forms of AND-OR-Invert (AOI) logic. The student is expected to:

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(A) develop an understanding of the binary number system and its relationship to the decimal number system as an essential component in the combinational logic design process;

(B) translate a set of design specifications into a truth table to describe the behavior of a combinational logic design by listing all possible input combinations and the desired output for each;

(C) derive logic expressions from a given truth table;

(D) demonstrate logic expressions in sum-of-products (SOP) form and products-of-sum (POS) form;

(E) explain how all logic expressions, whether simplified or not, can be implemented using AND gates, OR gates, and Inverter gates; and

(F) apply a formal design process to translate a set of design specifications into a functional combinational logic circuit.

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(4) The student understands, explains, and applies NAND and NOR Logic and understands the benefits of using universal gates. The student is expected to:

(A) apply the Karnaugh Mapping graphical technique to simplify logic expressions containing two, three, and four variables;

(B) define a "don't care" condition and explain its significance;

(C) explain why NAND and NOR gates are considered universal gates;

(D) demonstrate implementation of a combinational logic expression using only NAND gates or only NOR gates;

(E) discuss the formal design process used for translating a set of design specifications into a functional combinational logic circuit implemented with NAND or NOR gates; and

(F) explain why combinational logic designs implemented with NAND gates or NOR gates will typically require fewer integrated circuits (IC) than AOI equivalent implementations.

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(5) The student understands combinational logic systems, including seven-segment displays, Exclusive OR and Exclusive NOR gates, and multiplexer/de-multiplexer pairs. The student understands the relative value of various logic approaches. The student is expected to:

(A) use seven-segment displays used to display the digits 0-9 as well as some alpha characters;

(B) identify the two varieties of seven-segment displays;

(C) describe the formal design process used for translating a set of design specifications into a functional combinational logic circuit;

(D) develop an understanding of the hexadecimal and octal number systems and their relationships to the decimal number system;

(E) explain the primary intended purpose of Exclusive OR (XOR) and Exclusive NOR (XNOR) gates;

(F) describe how to accomplish the addition of two binary numbers of any bit length;

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(G) explain when multiplexer/de-multiplexer pairs are most frequently used;

(H) explain the purpose of using de-multiplexers in electronic displays that use multiple seven-segment displays;

(I) identify the most commonly used method for handling negative numbers in digital electronics;

(J) discuss the use of programmable logic devices and explain designs for which they are best suited; and

(K) compare and contrast circuits implemented with programmable logic devices with circuits implemented with discrete logic.

(6) The student understands and describes multiple types of sequential logic and various uses of sequential logic. The student is expected to:

(A) explain the capabilities of flip-flop and transparent latch logic devices;

(B) discuss synchronous and asynchronous inputs of flip-flops and transparent latches;

(C) explore the use of flip-flops, including designing single event detection circuits, data synchronizers, shift registers, and frequency dividers;

(D) explain how asynchronous counters are characterized and how they can be implemented;

(E) explore the use of the asynchronous counter method to implement up counters, down counters, and modulus counters;

(F) explain how synchronous counters are characterized and how they can be implemented;

(G) explore the use of the synchronous counter method to implement up counters, down counters, and modulus counters;

(H) describe a state machine;

(I) identify common everyday devices that state machines are used to control such as elevator doors, traffic lights, and combinational or electronic locks; and

(J) discuss various ways state machines can be implemented.

(7) The student explores microcontrollers, specifically their usefulness in real-world applications. The student is expected to:

(A) understand the use of flowcharts as graphical organizers by technicians, computer programmers, engineers, and other professionals and the benefits of various flowcharting techniques;

(B) develop an understanding of basic programming skills, including variable declaration, loops, and debugging;

(C) identify everyday products that use microcontrollers such as robots, garage door openers, traffic lights, and home thermostats;

(D) describe a servo motor;

(E) explore the way microcontrollers sense and respond to outside stimuli;

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(F) explain why digital devices are only relevant if they can interact with the real world;

(G) explain the importance of digital control devices, including microcontrollers in controlling mechanical systems; and

(H) understand that realistic problem solving with a control system requires the ability to interface analog inputs and outputs with a digital device.