2022 Engineering

Program CIP: 14.0101—Engineering, General

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The Research and Curriculum Unit (RCU), located in Starkville, as part of Mississippi State University (MSU), was established to foster educational enhancements and innovations. In keeping with the land-grant mission of MSU, the RCU is dedicated to improving the quality of life for Mississippians. The RCU enhances intellectual and professional development of Mississippi students and educators while applying knowledge and educational research to the lives of the people of the state. The RCU works within the contexts of curriculum development and revision, research, assessment, professional development, and industrial training.

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Acknowledgments

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Standards

Standards and alignment crosswalks are referenced in the appendices. Depending on the curriculum, these crosswalks should identify alignment to the standards mentioned below, as well as possible related academic topics as required in the Subject Area Testing Program in Algebra I, Biology I, English II, and U.S. History from 1877, which could be integrated into the content of the units. Mississippi's CTE engineering curriculum is aligned to the following standards:

International Technology and Engineering Education Association (ITEEA)-Standards for Technological Literacy
The *International Technology and Engineering Educators Association* (ITEEA) is the professional organization for technology, innovation, design, and engineering educators. The mission is to promote technological and engineering literacy for all by supporting the teaching of technology and engineering and promoting the professionalism of those engaged in these pursuits. ITEEA strengthens the profession through leadership, professional development, membership services, publications, and classroom activities.
iteea.org/stel.aspx

International Society for Technology in Education Standards (ISTE)
Reprinted with permission from *ISTE Standards for Students* (2016). All rights reserved. Permission does not constitute an endorsement by ISTE.
iste.org

College- and Career-Readiness Standards
College- and career-readiness standards emphasize critical thinking, teamwork, and problem-solving skills. Students will learn the skills and abilities demanded by the workforce of today and the future. Mississippi adopted Mississippi College- and Career-Readiness Standards (MCCRS) to provide a consistent, clear understanding of what students are expected to learn and so teachers and parents know what they need to do to help them.
mdek12.org/oae/college-and-career-readiness-standards

Framework for 21st Century Learning
In defining 21st-century learning, the Partnership for 21st Century Skills has embraced key themes and skill areas that represent the essential knowledge for the 21st century: global awareness; financial, economic, business, and entrepreneurial literacy; civic literacy; health literacy; environmental literacy; learning and innovation skills; information, media, and technology skills; and life and career skills (21 *Framework Definitions*, 2019).
battelleforkids.org/networks/p21/frameworks-resources

Preface

Secondary CTE programs in Mississippi face many challenges resulting from sweeping educational reforms at the national and state levels. Schools and teachers are increasingly being held accountable for providing applied learning activities to every student in the classroom. This accountability is measured through increased requirements for mastery and attainment of competency as documented through both formative and summative assessments. This document provides information, tools, and solutions that will aid students, teachers, and schools in creating and implementing applied, interactive, and innovative lessons. Through best practices, alignment with national standards and certifications, community partnerships, and a hands-on, student-centered concept, educators will be able to truly engage students in meaningful and collaborative learning opportunities.

The courses in this document reflect the statutory requirements as found in Section 37-3-49, *Mississippi Code of 1972*, as amended (Section 37-3-46). In addition, this curriculum reflects guidelines imposed by federal and state mandates (Laws, 1988, Ch. 487, §14; Laws, 1991, Ch. 423, §1; Laws, 1992, Ch. 519, §4 eff. from and after July 1, 1992; Strengthening Career and Technical Education for the 21st Century Act, 2019 [Perkins V]; and Every Student Succeeds Act, 2015).

Mississippi Teacher Professional Resources

The following are resources for Mississippi teachers:

Curriculum, Assessment, Professional Learning
: Program resources can be found at the RCU's website, rcu.msstate.edu.

Learning Management System: An Online Resource
: Learning management system information can be found at the RCU's website, under Professional Learning.

Should you need additional instructions, call the RCU at 662.325.2510.

Executive Summary

Pathway Description

Engineering is a program in pre-engineering, robotics, and automated manufacturing for high school students. The purpose of the program is to provide pupils with expanded knowledge of the use of critical thinking, analysis, problem solving, and technological skills and to enable them to apply knowledge in a technological context. Hands-on experiences related to the application of engineering concepts in the workplace are central to all portions of this course. Students will develop academic, 21st century, and human relations skills and competencies that accompany technical skills for job success to help foster lifelong learning. Students who complete the program will be better prepared to enter and succeed in the engineering and STEM-related workforce or programs offered by Mississippi community and junior colleges, as well as institutions of higher education.

College, Career, and Certifications

Most engineering bachelor's degree programs involve a concentration of study in an engineering specialty along with courses in both mathematics and the physical and life sciences. Many programs also include courses in general engineering. A design course, sometimes accompanied by a computer or laboratory class or both, is part of the curriculum of most programs. General courses not directly related to engineering, such as those in the social sciences or humanities, are also often required.

In addition to the standard bachelor's engineering degree, many colleges offer two-year or four-year degree programs in engineering technology (ET). These programs, which usually include various hands-on laboratory classes that focus on current issues in the application of engineering principles, prepare students for practical design and production work, rather than for jobs that require more theoretical and scientific knowledge. Graduates of four-year technology programs may get jobs like those obtained by graduates with a bachelor's degree in engineering. Engineering technology graduates, however, are not qualified to register as professional engineers under the same terms as graduates with degrees in engineering.

Some employers regard technology program graduates as having skills between those of a technician and an engineer. A two-year study by the National Academy of Engineering (2016) found that despite a high (and increasing) demand for ET graduates in many fields, there "appears to be little awareness of ET as a field of study or a category of employment." This curriculum attempts to shed some light on these areas as the number of modern, high-tech, and well-paying ET jobs continues to increase in Mississippi, the United States, and internationally.

Although most engineering jobs require a degree, some entry level/base positions that support professionals in engineering and STEM fields require only certifications. One industry certification example (emphasized in this course) signifies skills in using 3D drafting software and can benefit students applying for jobs in the field. These certifications are applicable in both college and careers. Interested students are encouraged to sharpen and expand upon the skills learned in this course in pursuit of a widely recognized certification. Specific 3D drafting certificates depend on the industry sector or company, but the two most valued certifications for high school students at this point are:

- The Certified SolidWorks Associate - Academic (CSWA - Academic)
- AutoDesk Certified User certificate in AutoDesk Inventor (offered by Certiport)

Grade Level and Class Size Recommendations
It is recommended that students enter this program as a 10th grader. Exceptions to this are a district-level decision based on class size, enrollment numbers, student maturity and CTE delivery method. This is a hands-on, lab- or shop-based course. Therefore, a maximum of 15 students is recommended per class.

Student Prerequisites
For students to experience success in the program, the following student prerequisites are suggested:

1. C or higher in English (the previous year)
2. C or higher in high school-level math (last course taken, or the instructor can specify the level of math instruction needed)
3. Instructor approval and TABE reading score (eighth grade or higher)

or

1. TABE reading and math score (eighth grade or higher)
2. Instructor approval

or

1. Instructor approval

Assessment
The latest assessment blueprint for the curriculum can be found at rcu.msstate.edu/curriculum/curriculumdownload.

Applied Academic Credit
The latest academic credit information can be found at mdek12.org/ese/approved-course-for-the-secondary-schools.

Teacher Licensure
The latest teacher licensure information can be found at mdek12.org/oel/apply-for-an-educator-license.

Professional Learning
If you have specific questions about the content of any of the training sessions provided, please contact the RCU at 662.325.2510.

Course Outlines

Option 1—Four 1-Carnegie Unit Courses

This curriculum consists of four 1-credit courses that should be completed in the following sequence:

1. **Engineering Fundamentals—Course Code: 994002**
2. **Engineering Applications—Course Code: 994003**
3. **Engineering Design—Course Code: 994004**
4. **Engineering Systems—Course Code: 994005**

Course Description: Engineering Fundamentals
Engineering Fundamentals introduces students to the engineering career field, ethics, safety, the engineering design process, and Computer-Aided Design (CAD). Utilizing a team-based, hands-on, minds-on approach to foster reasoning, students will progress from completing teacher-led guided activities to more challenging student-led open-ended projects and problems that will require planning, organization, communication, team building, and technical writing skills.

Course Description: Engineering Applications
Engineering Applications will allow students the opportunity to move beyond showing to creating as they implement their CAD designs and see their ideas become a reality, generating excitement and a deeper understanding of the engineering design process. Students will explore additive manufacturing, subtractive manufacturing, robotics, and apply concepts learned in the classroom at local, regional, state, and/or national competition.

Course Description: Engineering Design
Engineering Design will allow students the opportunity to complete a capstone project where students will solve an open-ended student-led problem. As students work through the capstone project, they will review basic CAD concepts and build upon their knowledge to design and test models and predict how they will behave under various loads and conditions.

Course Description: Engineering Systems
Engineering Systems is a course that will allow students the opportunity to move beyond the basic physical and operational concepts of robotics to programming. Students will also explore robotics resources such as electrical, fluid, and thermal systems as they build an autonomous and a user-controlled robot to solve a competitive manufacturing challenge.

Engineering Fundamentals—Course Code: 994002

Unit	Unit Title	Hours
1	Orientation and Student Organizations	10
2	Ethics and Safety	15
3	Engineering Design Process and Technical Writing	40
4	Computer-Aided Design and Drafting	75
Total		**140**

Engineering Applications—Course Code: 994003

Unit	Unit Title	Hours
5	Modern Manufacturing Systems	45
6	Introduction to Mechanical Systems and Robotics	95
Total		**140**

Engineering Design—Course Code: 994004

Unit	Unit Title	Hours
7	Safety Review	10
8	Capstone	65
9	Advanced Computer-Aided Design	65
Total		**140**

Engineering Systems—Course Code: 994005

Unit	Unit Title	Hours
10	Advanced Robotics	90
11	Introduction to Electrical Systems	25
12	Introduction to Fluid Power Systems	15
13	Introduction to Thermal Systems	10
Total		**140**

Option 2—Two 2-Carnegie Unit Courses

This curriculum consists of two 2-credit courses that should be completed in the following sequence:

1. **Engineering I—Course Code: 994000**
2. **Engineering II—Course Code: 994001**

Course Description: Engineering I
Engineering I teaches students about student organizations and introduces them to the engineering design process along with ethical and safe practice standards. Concepts of 3D sketching and modeling by hand and with CAD software are introduced within the context of engineering design and prototype development. Robotics concepts in engineering are covered with understanding catalyzed by student competitions. This course also focuses on several fields of engineering and engineering technology specialization to include technical writing and analysis.

Course Description: Engineering II
Engineering II is a comprehensive course that focuses on advanced CAD modeling and simulations. Additionally, it is a course that teaches students advanced robotics concepts. The capstone unit will allow students to learn valuable workforce readiness skills in the field of engineering, which will be demonstrated with all other parts of the course. Electrical, fluid, and thermal systems are covered in detail due to their relevance to real-world applications and industry.

Engineering I—Course Code: 994000

Unit	Unit Title	Hours
1	Orientation and Student Organizations	10
2	Ethics and Safety	15
3	Engineering Design Process and Technical Writing	40
4	Computer-Aided Design and Drafting	75
5	Modern Manufacturing Systems	45
6	Introduction to Mechanical Systems and Robotics	95
Total		**280**

Engineering II—Course Code: 994001

Unit	Unit Title	Hours
7	Safety Review	10
8	Capstone	70
9	Advanced Computer-Aided Design	65
10	Advanced Robotics	85
11	Introduction to Electrical Systems	25
12	Introduction to Fluid Power Systems	15
13	Introduction to Thermal Systems	10
Total		**280**

Career Pathway Outlook

Overview

Engineers and Engineering Technology (ET) professionals apply principles of science, mathematics, and technology to develop economical solutions for society. Whether it is working on scientific discoveries or commercial applications, engineering employees are expected to pursue continuing education as technology evolves. Engineering professionals are typically required to obtain a bachelor's degree, though several other ET options with variable course and degree requirements are offered. Licensing requirements for engineers usually include a professional degree and at least 3–4 years of practical work experience, but ET careers may involve a professional degree, industry certifications, training, and/or practical work experience. The 2018-2028 occupational employment projections and wage estimates for Mississippi were used to determine where large employment needs would be in the population over a 10-year period. The research also includes information from industry publications, the Mississippi Department of Education, institutions of higher learning, and community and junior colleges regarding articulation agreements and degree requirements. The pathways were affirmed through existing Mississippi curriculum blueprints and the expectations provided in industry interviews.

Needs of the Future Workforce

Data for this synopsis were compiled from the Mississippi Department of Employment Security (2021). Employment opportunities in Mississippi representative of various engineering occupations are listed below.

Table 1.1: Current and Projected Occupation Report (State of Mississippi)

Occupations (Alphabetical)	Employment		Projected Growth 2018-2028		Average Wage 2021	
	Current (2018)	Projected (2028)	Number	Percent	Hourly	Annual
Aerospace Engineers	100	100	0	0%	$47.07	$97,890
Chemical Engineers	250	260	10	4%	$52.15	$108,480
Civil Engineers	1,590	1,670	80	5%	$42.84	$89,120
Civil Engineering Technicians	1,060	1,090	30	2.8%	$18.72	$39,940
Electrical and Electronic Engineering Technicians	1,040	1,060	20	1.9%	$33.80	$70,300
Electrical Engineers	1,120	1,140	20	1.8%	$47.14	$98,050
Industrial Engineers	1,870	2,050	180	9.6%	$39.97	$83,140
Mechanical Engineers	1,130	1,200	70	6.2%	$40.61	$84,460
Mechanical Engineering Technicians	330	350	20	6.1%	$29.39	$61,130
Surveyors	390	420	30	7.7%	$25.28	$52,590

Source: Mississippi Department of Employment Security; www.mdes.ms.gov (accessed August 2021).

Perkins V Requirements and Academic Infusion

The engineering curriculum meets Perkins V requirements of introducing students to and preparing them for high-skill, high-wage occupations in engineering fields. It also offers students a program of study, including secondary, postsecondary, and institutions of higher learning courses, that will further prepare them for engineering careers. Additionally, this curriculum is integrated with academic college- and career-readiness standards. Lastly, it focuses on ongoing and meaningful professional development for teachers as well as relationships with industry.

Transition to Postsecondary Education

The latest articulation information for secondary to postsecondary can be found at the Mississippi Community College Board website, mccb.edu.

Best Practices

Innovative Instructional Technologies
Classrooms should be equipped with tools that will teach today's digital learners through applicable and modern practices. The engineering educator's goal should be to include teaching strategies that incorporate current technology. To make use of the latest online communication tools—wikis, blogs, podcasts, and social media platforms, for example—the classroom teacher is encouraged to use a learning management system that introduces students to education in an online environment and places more of the responsibility of learning on the student.

Differentiated Instruction
Students learn in a variety of ways, and numerous factors—students' background, emotional health, and circumstances, for example—create unique learners. By providing various teaching and assessment strategies, students with various learning preferences can have more opportunities to succeed.

CTE Student Organizations
Teachers should investigate opportunities to sponsor a student organization. There are several here in Mississippi that will foster the types of learning expected from the engineering curriculum. Technology Student Association (TSA) and Skills USA are examples of student organizations with many outlets for Engineering. Student organizations provide participants and members with growth opportunities and competitive events. They also open the doors to the world of industry careers and scholarship opportunities.

Cooperative Learning
Cooperative learning can help students understand topics when independent learning cannot. Therefore, you will see several opportunities in the engineering curriculum for group work. To function in today's workforce, students need to be able to work collaboratively with others and solve problems without excessive conflict. The engineering curriculum provides opportunities for students to work together and help each other complete complex tasks. There are many field experiences within the engineering curriculum that will allow and encourage collaboration with professionals currently in the engineering field.

Work-Based Learning
Work-based learning is an extension of understanding competencies taught in the Engineering classroom. This curriculum is designed in a way that necessitates active involvement by the students in the community around them and the global environment. These real-world connections and applications link all types of students to knowledge, skills, and professional dispositions. Work-based learning should encompass ongoing and increasingly more complex involvement with local companies and industry professionals. Thus, supervised collaboration and immersion into the industry around the students are keys to students' success, knowledge, and skills development.

Professional Organizations

Teachers are encouraged to charter one student organization (SkillsUSA or TSA), which are listed immediately below:

SkillsUSA
skillsusa.org

Technology Student Association
tsaweb.org

Using This Document

Competencies and Suggested Objectives
A competency represents a general concept or performance that students are expected to master as a requirement for satisfactorily completing a unit. Students are expected to receive instruction on all competencies. The suggested objectives represent the enabling and supporting knowledge and performances that will indicate mastery of the competency at the course level. Teachers are welcome to teach the competencies in other ways than the listed objectives if it allows for mastery of the competencies. Teachers are also allowed to teach the units and competencies in the order that they prefer, as long as they teach necessary material allotted for that specific course or credit they are teaching at the time.

Teacher Resources
Teacher resources for this curriculum may be found in multiple places. Many program areas have teacher resource documents that accompany the curriculum and can be downloaded from the same site as the curriculum. The teacher resource document contains references, lesson ideas, websites, teaching and assessment strategies, scenarios, skills to master, and other resources divided by unit. This document could be updated periodically by RCU staff. Please check the entire document, including the entries for each unit, regularly for new information. If you have something you would like to add or have a question about the document, call or email the RCU's instructional design specialist for your program. The teacher resource document can be downloaded at rcu.msstate.edu/curriculum/curriculumdownload.aspx. All teachers should request to be added to the Canvas Resource Guide for their course. This is where all resources will be housed in the future if they are not already. To be added to the guide, send a Help Desk ticket to the RCU by emailing helpdesk@rcu.msstate.edu.

Perkins V Quality Indicators and Enrichment Material
Some of the units may include an enrichment section at the end. If the Engineering program is currently using the Mississippi Career Planning and Assessment System (MS-CPAS) as a measure of accountability, the enrichment section of material will not be tested. If this is the case, it is suggested to use the enrichment material when needed or desired by the teacher and if time allows in the class. This material will greatly enhance the learning experiences for students. If, however, the engineering program is using a national certification, work-based learning, or other measure of accountability that aligns with Perkins V as a quality indicator, this material could very well be tested on that quality indicator. It is the responsibility of the teacher to ensure all competencies for the selected quality indicator are covered throughout the year.

Unit 1: Orientation and Student Organizations

Competencies and Suggested Objectives
1. Identify course expectations, school policies, student organizations, and program policies related to this course. DOK1 a. Identify school rules, policy, and procedures. b. Identify and establish classroom guidelines and procedures. c. Review course standards and affiliated national standards.
2. Relate student organization elements to the National Society of Professional Engineers.DOK2 a. Describe the importance of effective communication skills. • Demonstrate verbal and nonverbal communication skills. • Apply appropriate speaking listening skills to class and work-related situations. b. Apply leadership skills to class and work-related situations. • Define leadership • Discuss the attributes of a leader • Identify the roles a leader can assume c. Utilize teambuilding skills in class and work-related situations. • Define teambuilding • Discuss the attributes of a team • Identify the roles included in a team d. Discuss the various competitions offered through a program area student organization. • Describe each of the competitions and the skills needed to accomplish the tasks e. Perform the tasks needed to complete an assigned requirement for a competition.
3. Explore educational and occupational opportunities in the field of engineering, specifically those within the state of Mississippi. DOK2 a. Explore careers in a variety of engineering fields, including but not limited to: • Mechanical engineering • Civil engineering • Electrical engineering • Computer engineering • Chemical engineering b. Research and report on emerging technologies in the field of engineering.

Unit 2: Ethics and Safety

Competencies and Suggested Objectives
1. Utilize proper safety procedures in a laboratory setting. DOK1 a. Identify, describe, and demonstrate the importance of safety and the proper use of lab equipment. b. Describe safe operating procedures for the equipment utilized in the course. c. Adhere to applicable Occupational Safety and Health Administration (OSHA) 10-Hour General Industry Guidelines and Material Safety Data Sheet (MSDS) in the laboratory setting d. Demonstrate understanding of Lockout/Tagout procedures. e. Complete lab safety assessment with 100% mastery prior to accessing and operating laboratory equipment.
2. Recognize the importance of ethical teamwork in the field of engineering. DOK1 a. Using the National Society of Professional Engineers (NSPE) Code of Ethics, engage in arguments from workplace scenarios addressing safe and ethical practices including considerations of environmental (sustainability), social, and personal impacts. b. Apply the NSPE Code of Ethics to current or future technological advancements for potential ethical implications c. Relate student organization central tenets to the NSPE.
Enrichment
1. Research various emerging technologies to include impacts on society and changing technological cultures.

Unit 3: Engineering Design Process and Technical Writing

Competencies and Suggested Objectives
1. Implement the National Aeronautics and Space Administration (NASA) Beginning Engineering, Science, and Technology (BEST) engineering design process. DOK 2 a. Apply the engineering design process in the development of a student project. b. Conduct a student-to-student peer review of a project.
2. Apply the standards of technical writing to the student project using industry standards. DOK4 a. Apply industry standards for technical writing for engineers (e.g., Google technical writing standards for engineers, or similar). b. Discuss the differences in technical writing along various fields or audiences. (e.g., executives, technical scientific report, etc.)
3. Investigate and apply elements of technical writing to produce documents that include clarity, conciseness, accessibility, audience recognition, and accuracy. DOK4 a. Analyze and interpret an existing technical document from an authoritative source to assess relevant information pertaining to a specific real-world project. b. Create a technical document from a class project that employs multiple formats (verbally, graphically, textually, and/or mathematically); include cost analysis, data collection, communication, marketing, and presentation elements.

Unit 4: Computer-Aided Design and Drafting

Competencies and Suggested Objectives
1. Explain the purpose of technical drawing and freehand technical sketches. DOK1 a. Research and evaluate appropriate techniques for technical drawing and freehand technical sketches.
2. Identify and demonstrate proper use of measurement tools. DOK2 a. Select and use appropriate tools or instruments to collect qualitative and quantitative data and record and represent that data in an appropriate form to include: • Calipers • Engineering scales • Micrometers • Protractors • Rulers
3. Create an appropriately scaled technical drawing. DOK4 a. Apply mathematical concepts and/or processes (such as ratio, rate, percent, basic operations, and simple algebra) to engineering questions and problems related to measurement. b. Convert fractions to decimals and decimals to fractions to test and compare proposed solutions to an engineering design problem to include: • 1/16 • 1/8 • 1/4 • 1/2 c. Hand draw a 2D technical drawing within the following views: • Orthographic views • Isometric views • Section view d. Create a 3D object from a 2D technical drawing.

4. Use CAD software to create 3D models. DOK4
   a. Create a part using CAD software.
   b. Identify and demonstrate appropriate application of the following CAD software concepts:
      - Axis
      - Boss
      - Center lines
      - Chamfer
      - Constraints
      - Construction lines
      - Cut
      - Dimension lines
      - Extrude
      - Fillet
      - Hole
      - Invisible and visible lines
      - Loft
      - Mates
      - Origin
      - Pattern
      - Plane
      - Revolve
      - Rib
      - Section lines
      - Shell
      - Sweep

5. Use CAD software to create 2D drawings and 3D assemblies. DOK4
   a. Create an assembly using CAD software.
   b. Create a detailed drawing using CAD software.
   c. Integrate a CAD drawing into technical documents.
   d. Analyze real world engineering drawings to distinguish between the need for orthographic and isometric drawing views.

Unit 5: Modern Manufacturing Systems

Competencies and Suggested Objectives
1. Use additive machining methods to create objects that serve a specific purpose. DOK3 a. Research and analyze the components of various types of 3D printers and their operation to include: • Electronic beam melting • Fused deposition modeling • Selective laser sintering b. Create a part using a 3D printer that serves a specific purpose. c. Explore the role of additive machining in industry and emerging technologies.
2. Use subtractive machining methods to create objects that serve a specific purpose. DOK3 a. Research and analyze the components of various types of subtractive machines and their operation (e.g., CNC, plasma cutter, water jet, laser engraver/cutter, etc.) b. Use a subtractive machining method to create a part for a specific purpose. c. Explore the role of subtractive machining in industry and emerging technologies.

Unit 6: Introduction to Mechanical Systems and Robotics

Competencies and Suggested Objectives
1. Introduce physical and operational concepts related to robotics or similar mechanical devices. DOK1 a. Introduce a competition utilizing robotics or similar mechanical devices (e.g., Sea Perch, Vex, First, Best, Lego, Skills, TSA, etc.). b. Build a robot or a similar mechanical device utilizing various physical and operational elements including but not limited to: • Actuators • Autonomous versus user control • Drive train/mechanism • Electronic controls • Manipulators and end effectors • Motors/servos • Power supply • Programming languages • Sensors
2. Explore physics or physical concepts as they relate to robotics or similar mechanical devices. DOK2 a. Design and conduct experiments to generate evidence of the relationships between distance, velocity, and acceleration through motion. b. Interpret motion graphs to explain or describe phenomena contained within them. c. Construct an explanation of observed relationships between variables by applying Newton's Laws of Motion to various real-world scenarios; include F=ma. d. Ask questions to generate hypotheses based on empirical evidence and observations to apply principles of physics involved in gears and gear trains. e. Evaluate various models to calculate gear ratios and use the results to justify use of specific ratios in real-world or laboratory scenarios. f. Recognize fundamentals of: • Angular velocity • Motors • Rotational dynamics • Torque g. Compare, integrate, and evaluate the following concepts related to robotics: • Actual mechanical advantage • Efficiency • Energy • Ideal mechanical advantage • Power • Work h. Recognize the fundamentals of degrees of freedom as it relates to robotic arms.

3. Explore concepts associated with computer programming as it relates to robotics. DOK2
   a. Recognize the fundamentals of computer programming in real-world applications to include:
      - Comments
      - Flow charts
      - Pseudocode
      - Appropriate use of variable names
   b. Demonstrate proper use of programming techniques in multiple settings to include:
      - Conditional statements
      - Constants
      - Loops
      - Variables
   c. Differentiate between analog and digital sensors.
   d. Differentiate between open and closed loop control.
   e. Use appropriate programming concepts to autonomously control an end effector.

4. Engage in one or more student competitions that include elements from this unit according to the student organization and/or competition guidelines. DOK4

Unit 7: Safety Review

Competencies and Suggested Objectives
1. Identify and/or review course expectations, school policies, and program policies related to this course. DOK1 a. Identify school rules, policy, and procedures. b. Identify and establish classroom guidelines and procedures. c. Review course standards and affiliated national standards.
2. Review and utilize proper safety procedures in a laboratory setting. DOK2 a. Identify, describe, and demonstrate the importance of safety and the proper use of lab equipment. b. Describe safe operating procedures for the equipment utilized in the course. c. Adhere to applicable MSDS and OSHA 10-Hour General Industry Guidelines in the laboratory setting. d. Demonstrate understanding of Lockout/Tagout procedures. e. Complete lab safety assessment with 100% mastery prior to accessing and operating laboratory equipment.

Unit 8: Capstone

It is important to understand that the Capstone is not to be completed as an isolated unit, but rather an ongoing project that will address, teach, and utilize the other competencies in this course.

Competencies and Suggested Objectives
1. Using digital and/or traditional fabrication methods, apply the engineering design process to solve a student-selected, instructor approved, industry/community relevant problem (individual, small group, or large group). DOK4 a. Research a problem that can be developed into an appropriate and manageable project. b. Create a project proposal that must be approved by the instructor before starting the project. c. Use a highly iterative design process including freehand sketching/drawing and/or a CAD program to design, test, or simulate, and assemble models for the project. d. Apply numerical calculations whenever appropriate to aide in development of the solution. e. Utilize graphs, charts, and tables to analyze and display the data. f. Follow technical writing guides to convey project data and results. g. Using appropriate tools and materials, create a physical or digital product or prototype while considering sustainability, trade-offs, (e.g., safety, cost, reliability, aesthetics, maintenance) and manufacturability. h. Develop the project in a way that can easily be shared with others so that they can retrace steps and build on successes. i. Demonstrate effective interpersonal communication skills in a team or professional setting.
2. Create a project management schedule to track progress and ensure completion. DOK4 a. Discuss and utilize various project management tools (e.g., Gantt chart, software applications, etc.) b. Plan for and conduct mid-project check-ins.
3. Present and justify a final proposal/product to an authentic audience. DOK4 a. Produce professional quality technical documents with the following elements (Based on NASA BEST Engineering Design Process): • Problem definition • Brainstorming documentation • Project plan and specifications • Project design and methods • Project results • Conclusion and future work b. Using appropriate technology and professional manner, present project elements to an authentic audience (industry, and/or community stakeholders). c. Collect the following work materials in a portfolio to demonstrate proper use of the design process to include: • Project goals

- Pertinent research findings
- Sketches
- CAD drawings
- Prototypes (images or renderings of prototypes)
- Working diagrams
- Product specifications and analysis
- Testing methodology and results
- Technical writing samples

4. Exhibit or present the project in a public setting (e.g., maker fair, school fair, school board meeting, community STEM/STEAM night, or online). DOK 3

Suggested Capstone Ideas

1. Augment the capstone project by crossing curricular boundaries, integrating one or more maker-style domains: DOK4
    - Architecture
    - Composites
    - Construction
    - Deconstruction and repair or repurposing/tinkering
    - Energy/electricity (e.g., alternative energy)
    - Flight
    - Farming/gardening/food production
    - Food and culinary arts
    - Launching/propulsion (rockets and projectiles)
    - Light and circuits (e.g., LED and electroluminescent wire)
    - Materials and their life cycles (i.e., material origins, uses, recycling, reuse, repurpose—cradle-to-cradle or cradle-to-grave)
    - Mechanics, motors, and switches (including robotics)
    - Musical instruments and/or music production
    - Papercraft/cardboard construction
    - Programming, microcontrollers, soft circuits/wearables, and sound circuits
    - Sensors and robots (e.g., sensing and interactions)
    - Smart home technologies and IoT
    - Textiles
    - Vehicles/transportation (e.g., bicycles)
    - Water
    - Woodworking/carpentry and metal fabrication
2. Work collaboratively with an engineer to solve a real-world industry problem or apply the engineering process to an issue in your community. DOK4
    a. Work under the guidance of the engineering instructor and the sponsoring engineer.
    b. Observe and record the engineers' work environment, tasks, and procedures.

Unit 9: Advanced Computer-Aided Design

Competencies and Suggested Objectives
1. Review and create 3D models within CAD software. (See previous CAD unit.) DOK4
2. Review 2D drawings and 3D assemblies. (See previous CAD unit.) DOK2
3. Use CAD analysis tools to manipulate variables and collect data to formulate decisions about prototypes or design solutions. DOK3 a. Determine physical properties of a CAD model including: • Center of gravity • Mass • Volume b. Use CAD simulations to calculate the following for a model: • Displacements • Factor of safety • Strains • Stresses c. Redesign a model based on data collected from CAD analysis.
4. Demonstrate proficiency in CAD software simulations. DOK3 a. Use animation to analyze an assembly for: • Collision • Moti • Rotation b. Use flow simulations to evaluate fluid dynamics around an object. c. Conduct an analysis of a CAD assembly, draw conclusions about the system, and critique the conclusions based on the adequacy of the model.
5. Incorporate sustainable methodologies. DOK3 a. Explore CAD sustainability tools and tutorials to include materials, manufacturing, and environmental impact. b. Reevaluate previous designs using sustainable methodologies.

Unit 10: Advanced Robotics

Competencies and Suggested Objectives

1. Create an autonomous or manual control robotics system that solves a competitive challenge with student teams. DOK 4
   a. Develop and/or use a complex model that allows for manipulation and testing of a proposed process or system using advanced programming languages and concepts to include:
      - Digital inputs and outputs
      - Analog inputs and outputs
      - Remote control vs. autonomous
      - Timers
      - Servos
      - Encoders
      - Thresholds
      - Contact and non-contact sensors
      - Subroutines, loops, and counters
      - Switch cases
      - While loops
      - If … else statements
      - Variables
      - Global variables
2. Use the engineering design process to solve real-world manufacturing challenges with robotics. DOK3
   a. Employ the engineering design process to develop an autonomous system that solves or simulates a real-world challenge using conveyors and mechanical drives while utilizing the following:
      - Programming languages
      - Manipulators
      - Sensory feedback
      - Subroutines

Enrichment

1. Ask questions to determine the relationships between Programmable Logic Controllers (PLCs) and autonomous robotics systems to include:
      - AND logic
      - Examining input/output relationships
      - Latching and unlatching outputs
      - NOT logic
      - OR logic

- PLC monitoring tools
- Project: controlling a sorting system
- Timer on delay and timer off delay
- Writing and simulating a basic ladder diagram

2. Explore practical applications of kinematic pairs, cam and follower, and linkages.

Unit 11: Introduction to Electrical Systems

Competencies and Suggested Objectives
1. Examine electrical systems in engineering. DOK1 a. Safely demonstrate the law of electrical charges b. Magnetism and electricity c. Compare and contrast the electrical components and their uses/purposes • Conductors • Insulators • Semiconductors • Resistors • Capacitor • Potentiometer d. Develop, revise, or use a model based on evidence to predict the relationships between alternating and direct current circuits.
2. Examine principles of electrical circuits. DOK1 a. Using the Institute of Electrical and Electronics Engineers (IEEE STD 315-1975, reaffirmed1993) standards, identify standard schematic symbols for: • A/C source • Ammeter • Battery (D/C) • Bulb (lamp) • Capacitor • Circuit ground (power ground – common) • Conductor (connected and unconnected) • Diode • Fixed resistor • Light emitting diode • Motor • N.O. pushbutton switch • Potentiometer • Transformer • Voltmeter b. Develop schematics to explain the parts in 2a that make up simple electrical circuits (i.e., series and parallel circuits). c. Introduce Ohm's Law and formulate an application with it.

3. Construct both series and parallel circuits from the schematics and prove Ohm's law and Watt's law. [DOK3]
   a. Apply appropriate safety practices and precautions to multi-meter use in various applications including OSHA standard familiarity related to electrical systems.
   b. Demonstrate proper meter setup for specified measurements.
   c. Build series and parallel circuit to prove Ohm's law.
   d. Apply Ohm's law to solve for circuit parameters of voltage, current, and resistance.
   e. Apply Watt's Law to solve for circuit parameters of voltage, current, and power.

Unit 12: Introduction to Fluid Power Systems

Competencies and Suggested Objectives
1. Examine fluid power systems in engineering. DOK1 a. Examine how Pascal's laws are applied in fluid systems b. Explain what the measurement unit psi is describing c. Calculate force output when given incoming pressure and piston diameter (F = PA) d. Use mathematical representations to explain absolute pressure and gauge pressure. e. Identify and use tables, graphs, or digital tools to select a proper hydraulic or pneumatic component for a certain task.
2. Discuss the components of a typical fluid system. DOK1 a. Identify and describe the following cylinder types and associated elements: • Single-acting type • Double-acting type • Control valves • Filters • Hoses • Hydraulic fluid • Pumps • Tanks
3. Investigate industrial applications to communicate differences between pneumatic and hydraulic devices and functions. DOK3 a. Identify and discuss applications of fluid power within the industry. b. Demonstrate the force ratio multiplier advantage of hydraulic system using a student fabricated device.

Unit 13: Introduction to Thermal Systems

Competencies and Suggested Objectives
1. Investigate the principles of thermodynamics. DOK1 a. Explain the following concepts: • Heat • Temperature • Entropy • Specific heat b. Describe the following three modes of heat transfer: • Conduction • Convection • Radiation c. Describe the four laws of thermodynamics and understand the applications of each law. • Zeroth • First • Second • Third d. Use mathematical concepts to solve real world problems involving specific heat and heat capacity.
Enrichment: Student projects (possible Capstone project ideas)
1. Apply the laws of thermodynamics to analyses of heat engines and refrigerators and develop a presentation to showcase the project. 2. Develop, revise, and/or use a model based on evidence to demonstrate thermal conductivity of materials and develop a presentation to showcase the project. 3. Design an energy efficient home using modes of heat transfer and laws of thermodynamics and develop a presentation to showcase the project.

Student Competency Profile for Engineering

Student's Name: _____

This record is intended to serve as a method of noting student achievement of the competencies in each unit. It can be duplicated for each student, and it can serve as a cumulative record of competencies achieved in the course.

In the blank before each competency, place the date on which the student mastered the competency.

Unit 1: Orientation and Student Organizations		
	1.	Identify course expectations, school policies, student organizations, and program policies related to this course.
	2.	Relate student organization elements to the National Society of Professional Engineers.
	3.	Explore educational and occupational opportunities in the field of engineering, specifically those within the state of Mississippi.
Unit 2: Ethics and Safety		
	1.	Utilize proper safety procedures in a laboratory setting.
	2.	Recognize the importance of ethical teamwork in the field of engineering.
Unit 3: Engineering Design Process and Technical Writing		
	1.	Implement the National Aeronautics and Space Administration (NASA) Beginning Engineering, Science, and Technology (BEST) engineering design process.
	2.	Apply the standards of technical writing to the student project using industry standards.
	3.	Investigate and apply elements of technical writing to produce documents that include clarity, conciseness, accessibility, audience recognition, and accuracy.
Unit 4: Computer-Aided Design and Drafting		
	1.	Explain the purpose of technical drawing and freehand technical sketches.
	2.	Identify and demonstrate proper use of measurement tools.
	3.	Create an appropriately scaled technical drawing.
	4.	Use CAD software to create 3D models.
	5.	Use CAD software to create 2D drawings and 3D assemblies.
Unit 5: Modern Manufacturing Systems		
	1.	Use additive machining methods to create objects that serve a specific purpose.
	2.	Use subtractive machining methods to create objects that serve a specific purpose.

Unit 6: Introduction to Mechanical Systems and Robotics		
	1.	Introduce physical and operational concepts related to robotics or similar mechanical devices.
	2.	Explore physics or physical concepts as they relate to robotics or similar mechanical devices.
	3.	Explore concepts associated with computer programming as it relates to robotics.
	4.	Engage in one or more student competitions that include elements from this unit according to the student organization and/or competition guidelines.
Unit 7: Safety Review		
	1.	Identify and/or review course expectations, school policies, and program policies related to this course.
	2.	Review and utilize proper safety procedures in a laboratory setting.
Unit 8: Capstone		
	1.	Using digital and/or traditional fabrication methods, apply the engineering design process to solve a student-selected, instructor approved, industry/community relevant problem (individual, small group, or large group).
	2.	Create a project management schedule to track progress and ensure completion.
	3.	Present and justify a final proposal/product to an authentic audience.
	4.	Exhibit or present the project in a public setting (e.g., maker fair, school fair, school board meeting, community STEM/STEAM night, or online).
Unit 9: Advanced Computer-Aided Design		
	1.	Review and create 3D models within CAD software.
	2.	Review 2D drawings and 3D assemblies.
	3.	Use CAD analysis tools to manipulate variables and collect data to formulate decisions about prototypes or design solutions.
	4.	Demonstrate proficiency in CAD software simulations.
	5.	Incorporate sustainable methodologies.
Unit 10: Advanced Robotics		
	1.	Create an autonomous or manual control robotics system that solves a competitive challenge with student teams.
	2.	Use the engineering design process to solve real-world manufacturing challenges with robotics.
Unit 11: Introduction to Electrical Systems		
	1.	Examine electrical systems in engineering.
	2.	Examine principles of electrical circuits.
	3.	Construct both series and parallel circuits from the schematics and prove Ohm's law and Watt's law.

Unit 12: Introduction to Fluid Power Systems		
	1.	Examine fluid power systems in engineering.
	2.	Discuss components of a typical fluid system.
	3.	Investigate industrial applications to communicate differences between pneumatic and hydraulic devices and functions.
Unit 13: Introduction to Thermal Systems		
	1.	Investigate the principles of thermodynamics.

Appendix A: National Standards

	Units	1	2	3	4	5	6	7	8	9	10	11	12	13
Standards														
STL-1		x				x	x		x		x	x	x	x
STL-2		x	x				x		x		x	x	x	x
STL-3		x	x			x	x		x		x	x	x	x
STL-4		x			x				x				x	
STL-5							x		x	x			x	x
STL-6		x	x				x	x	x				x	x
STL-7		x						x	x					
STL-8		x				x	x		x	x	x			x
STL-9		x	x	x	x	x	x	x	x	x	x	x	x	x
STL-10			x	x	x	x	x	x	x	x	x		x	x
STL-11				x	x	x	x	x	x	x	x	x		
STL-12		x					x		x	x	x		x	x
STL-13		x			x		x		x				x	x
STL-14		x						x	x					
STL-15			x						x				x	
STL-16		x	x					x	x		x	x	x	
STL-17									x	x	x			x
STL-18							x		x					
STL-19						x	x		x					
STL-20						x	x		x	x				

International Technology and Engineering Education Association (ITEEA)-Standards for Technological Literacy

STL1 Students will develop an understanding of the characteristics and scope of technology.
STL2 Students will develop an understanding of the core concepts of technology.
STL3 Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.
STL4 Students will develop an understanding of the cultural, social, economic, and political effects of technology.
STL5 Students will develop an understanding of the effects of technology on the environment.
STL6 Students will develop an understanding of the role of society in the development of and use of technology.
STL7 Students will develop an understanding of the influence of technology on history.
STL8 Students will develop an understanding of the attributes of design.
STL9 Students will develop an understanding of engineering design.
STL10 Students will develop an understanding of the role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving.

STL11 Students will develop the abilities to apply the design process.
STL12 Students will develop the abilities to use and maintain technological products and systems.
STL13 Students will develop the abilities to assess the impact of products and systems.
STL14 Students will develop an understanding of and be able to select and use medical technologies.
STL15 Students will develop an understanding of and be able to select and use agricultural and related biotechnologies.
STL16 Students will develop an understanding of and be able to select and use energy and power technologies.
STL17 Students will develop an understanding of and be able to select and use information and communication technologies.
STL18 Students will develop an understanding of and be able to select and use transportation technologies.
STL19 Students will develop an understanding of and be able to select and use manufacturing technologies.
STL20 Students will develop an understanding of and be able to select and use construction technologies.

Appendix B: MS-CCR Physical Science Standards

	Unit	1	2	3	4	5	6	7	8	9	10	11	12	13
Standard														
PHS.1.1														
PHS.1.2														
PHS.1.3														
PHS.1.4					x	x	x		x	x	x	x	x	x
PHS.1.5									x					
PHS.1.6										x				
PHS.2.1														
PHS.3.1														
PHS.3.2														
PHS.3.3														
PHS.3.4														
PHS.3.5														
PHS.4.1														x
PHS.4.2														
PHS.4.3														
PHS.4.4														
PHS.4.5														
PHS.4.6														
PHS.5.1							x		x		x			
PHS.5.2							x		x		x			
PHS.5.3							x		x		x			
PHS.5.4							x		x		x			
PHS.5.5							x		x		x			
PHS.5.6				x			x		x		x			
PHS.5.7							x		x		x			
PHS.5.8							x		x		x			
PHS.6.1														
PHS.6.2														
PHS.6.3														
PHS.6.4*														
PHS.6.5														
PHS.6.6														
PHS.6.7*														
PHS.6.8*														
PHS.7.1							x		x	x				
PHS.7.2							x		x	x				
PHS.7.3							x		x	x				
PHS.7.4							x		x	x				
PHS.8.1														x

PHS.8.2														x
PHS.8.3														x
PHS.8.4*														x
PHS.9.1												x		
PHS.9.2							x				x	x		
PHS.9.3*												x		
PHS.9.4				x								x		

* Indicates enrichment

2018 Mississippi College and Career Readiness Standards – Physical Science

PHS.1 Students will demonstrate an understanding of the nature of matter.

PHS.1.1 Use contextual evidence to describe particle theory of matter. Examine the particle properties of solids, liquids, and gases.

PHS.1.2 Use scientific research to generate models to compare physical and chemical properties of elements, compounds, and mixtures.

PHS.1.3 Conduct an investigation to determine the identity of unknown substances by comparing properties to known substances.

PHS.1.4 Design and conduct investigations to explore techniques in measurements of mass, volume, length, and temperature.

PHS.1.5 Design and conduct an investigation using graphical analysis (e.g., line graph) to determine the density of liquids and/or solids.

PHS.1.6 Use mathematical and computational analysis to solve density problems. Manipulate the density formula to determine density, volume, or mass or use dimensional analysis to solve problems.

PHS.2 Students will demonstrate an understanding of both modern and historical theories of atomic structure.

PHS.2.1 Research and develop models (e.g., 3-D models, online simulations, or ball and stick) to investigate both modern and historical theories of atomic structure. Compare models and contributions of Dalton, Thomson, Rutherford, Bohr, and of modern atomic theory.

PHS.3 Students will analyze the organization of the periodic table of elements to predict atomic interactions.

PHS.3.1 Use contextual evidence to determine the organization of the periodic table, including metals, metalloids, and nonmetals; symbols; atomic number; atomic mass; chemical families/groups; and periods/series.

PHS.3.2 Using the periodic table and scientific methods, investigate the formation of compounds through ionic and covalent bonding.

PHS.3.3 Using naming conventions for binary compounds, write the compound name from the formula, and write balanced formulas from the name (e.g., carbon dioxide - CO2, sodium chloride - NaCl, iron III oxide- Fe2O3, and calcium bromide - CaBr2).

PHS.3.4 Use naming conventions to name common acids and common compounds used in classroom labs (e.g., sodium bicarbonate (baking soda), NaHCO3; hydrochloric acid, HCl; sulfuric acid, H2SO4 ; acetic acid (vinegar), HC2H3O2; and nitric acid, HNO3).

PHS.3.5 Use mathematical and computational analysis to determine the atomic mass of binary compounds.

PHS.4 Students will analyze changes in matter and the relationship of these changes to the law

	of conservation of matter and energy.
PHS.4.1	Design and conduct experiments to investigate physical and chemical changes of various household products (e.g., rusting, sour milk, crushing, grinding, tearing, boiling, and freezing) and reactions of common chemicals that produce color changes or gases.
PHS.4.2	Design and conduct investigations to produce evidence that mass is conserved in chemical reactions (e.g., vinegar and baking soda in a Ziploc© bag).
PHS.4.3	Apply the concept of conservation of matter to balancing simple chemical equations.
PHS.4.4	Use mathematical and computational analysis to examine evidence that mass is conserved in chemical reactions using simple stoichiometry problems (1:1 mole ratio) or atomic masses to demonstrate the conservation of mass with a balanced equation.
PHS.4.5	Research nuclear reactions and their uses in the modern world, exploring concepts such as fusion, fission, stars as reactors, nuclear energy, and chain reactions.
PHS.4.6	Analyze and debate the advantages and disadvantages of nuclear reactions as energy sources.
PHS.5	Students will analyze the scientific principles of motion, force, and work.
PHS.5.1	Research the scientific contributions of Newton and use models to communicate Newton's principles.
PHS.5.2	Design and conduct an investigation to study the motion of an object using properties such as displacement, time of motion, velocity, and acceleration.
PHS.5.3	Collect, organize, and interpret graphical data using correct metric units to determine the average speed of an object.
PHS.5.4	Use mathematical and computational analyses to show the relationships among force, mass, and acceleration (i.e., Newton's second law).
PHS.5.5	Design and construct an investigation using probe systems and/or online simulations to observe relationships between force, mass, and acceleration (F=ma).
PHS.5.6	Use an engineering design process and mathematical analysis to design and construct models to demonstrate the law of conservation of momentum (e.g., roller coasters, bicycle helmets, bumper systems).
PHS.5.7	Use mathematical and computational representations to create graphs and formulas that describe the relationships between force, work, and energy (i.e., W=Fd, KE=½ mv2, PE=mgh, W=KE).
PHS.5.8	Research the efficiency of everyday machines, and debate ways to improve their economic impact on society (e.g., electrical appliances, transportation vehicles).
PHS.6	Students will explore the characteristics of waves.
PHS.6.1	Use models to analyze and describe examples of mechanical waves' properties (e.g., wavelength, frequency, speed, amplitude, rarefaction, and compression).
PHS.6.2	Analyze examples and evidence of transverse and longitudinal waves found in nature (e.g., earthquakes, ocean waves, and sound waves).
PHS.6.3	Generate wave models to explore energy transference.
PHS.6.4	Enrichment: Use an engineering design process to design and build a musical instrument to demonstrate the influence of resonance on music.*
PHS.6.5	Design and conduct experiments to investigate technological applications of sound (e.g., medical uses, music, acoustics, Doppler effects, and influences of mathematical theory on music).
PHS.6.6	Research real-world applications to create models or visible representations of the electromagnetic spectrum, including visible light, infrared radiation, and ultraviolet radiation.
PHS.6.7	Enrichment: Use an engineering design process to design and construct an apparatus that forms images to project on a screen or magnify images using lenses and/or mirrors. *

PHS.6.8	Enrichment: Debate the particle/wave behavior of light.
PHS.7	Students will examine different forms of energy and energy transformations.
PHS.7.1	Using digital resources, explore forms of energy (e.g., potential and kinetic energy, mechanical, chemical, electrical, thermal, radiant, and nuclear energy).
PHS.7.2	Use scientific investigations to explore the transformation of energy from one type to another (e.g., potential to kinetic energy, and mechanical, chemical, electrical, thermal, radiant, and nuclear energy interactions).
PHS.7.3	Using mathematical and computational analysis, calculate potential and kinetic energy based on given data. Use equations such as PE=mgh and KE=½ mv2.
PHS.7.4	Conduct investigations to provide evidence of the conservation of energy as energy is converted from one form of energy to another (e.g., wind to electric, chemical to thermal, mechanical to thermal, and potential to kinetic).
PHS.8	Students will demonstrate an understanding of temperature scales, heat, and thermal energy transfer.
PHS.8.1	Compare and contrast temperature scales by converting between Celsius, Fahrenheit, and Kelvin.
PHS.8.2	Apply particle theory to phase change and analyze freezing point, melting point, boiling point, vaporization, and condensation of different substances.
PHS.8.3	Relate thermal energy transfer to real world applications of conduction (e.g., quenching metals), convection (e.g., movement of air masses/weather/plate tectonics), and radiation (e.g., electromagnetic).
PHS.8.4	Enrichment: Use an engineering design process to construct a simulation of heat energy transfer between systems. Calculate the calories/joules of energy generated by burning food products. Communicate conclusions based on evidence from the simulation. *
PHS.9	Students will explore basic principles of magnetism and electricity (e.g., static electricity, current electricity, and circuits).
PHS.9.1	Use digital resources and online simulations to investigate the basic principles of electricity, including static electricity, current electricity, and circuits. Use digital resources (e.g., online simulations) to build a model showing the relationship between magnetic fields and electric currents.
PHS.9.2	Distinguish between magnets, motors, and generators, and evaluate modern industrial uses of each.
PHS.9.3	Enrichment: Use an engineering design process to construct a working electric motor to perform a task. Communicate the design process and comparisons of task performance efficiencies. *
PHS.9.4	Use an engineering design process to construct and test conductors, semiconductors, and insulators using various materials to optimize efficiency.*

2018 Engineering (Core)

Mississippi Department of Education

Program CIP: 14.0101-Engineering, General

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The Research and Curriculum Unit (RCU), located in Starkville, MS, as part of Mississippi State University, was established to foster educational enhancements and innovations. In keeping with the land grant mission of Mississippi State University, the RCU is dedicated to improving the quality of life for Mississippians. The RCU enhances intellectual and professional development of Mississippi students and educators while applying knowledge and educational research to the lives of the people of the state. The RCU works within the contexts of curriculum development and revision, research, assessment, professional development, and industrial training.

Table of Contents

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~~Melissa Luckett, Project Coordinator for the Research and Curriculum Unit at Mississippi State University~~

Standards

Standards are superscripted in each unit and are referenced in the appendices. Standards in the *Engineering Curriculum Framework and Supporting Materials* are based on the following:

International Technology and Engineering Educators Association (ITEEA) Standards

The International Technology and Engineering Educators Association (ITEEA) is the professional organization for technology, innovation, design, and engineering educators. The standards referenced in this curriculum are reprinted with permission from the International Technology Education Association, Copyright © 2007, .

The Mississippi Engineering Curriculum Framework is aligned to the 2007 ITEEA Standards for Technological Literacy. An alignment crosswalk can be viewed in the appendix of this document.

College and Career-Ready Standards

The College and Career-Ready Standards emphasize critical thinking, teamwork and problem-solving skills. Students will learn the skills and abilities demanded by the workforce of today and the future. Mississippi adopted Mississippi College- and Career-Ready Standards (MCCRS) because they provide a consistent, clear understanding of what students are expected to learn so that teachers and parents know what they need to do to help them. Reprinted from http://www.mde.k12.ms.us/MCCRS

The Mississippi Engineering Curriculum Framework is aligned to the College and Career Readiness Standards for Mathematics and English Language Arts. An alignment crosswalk can be viewed in the appendix of this document.

Mississippi 2018 College and Career Readiness Standards for Science — Physics

Physics, **a one-credit course,** provides opportunities for students to develop and communicate an understanding of matter and energy through lab-based activities, integrated STEM activities, mathematical expressions, and concept exploration. Concepts covered in this course include kinematics, dynamics, energy, mechanical and electromagnetic waves, and electricity. Laboratory activities, uses of technology, effective communication of results, and research of contemporary scientific theories through various methods are integral components of this course. Science as inquiry is an integral part of the framework, placing emphasis on developing the ability to ask questions, observe, experiment, measure, problem solve, gather data, and communicate findings. Inquiry is not an isolated unit of instruction and must be embedded throughout the content strands.

The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world to increase the depth of understanding

based on evidence, logic, and innovation. These concepts are expected to appear throughout the course. As a laboratory-based course, students are expected to utilize the science and engineering practices to design and conduct investigations using appropriate equipment, measurement (SI units), and safety procedures. Students should also design data tables and draw conclusions using mathematical computations and/or graphical analysis. It is recommended that students actively engage in inquiry activities, laboratory experiences, and scientific research (projects) for a minimum of 30% of class time.

The Mississippi Engineering Curriculum Framework is aligned to the Physics course in the 2018 Mississippi College and Career Readiness Standards for Science. An alignment crosswalk can be viewed in the appendix of this document.

International Society for Technology in Education Standards (ISTE)

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The Mississippi Engineering Curriculum Framework is aligned to ISTE's National Educational Technology Standards for Students. An alignment crosswalk can be viewed in the appendix of this document.

21st Century Skills and Information and Communication Technologies Literacy Standards

In defining 21st-century learning, the Partnership for 21st Century Skills (P21) has embraced five content and skill areas that represent the essential knowledge for the 21st century: global awareness; civic engagement; financial, economic, and business literacy; learning skills that encompass problem-solving, critical-thinking, and self-directional skills; and Information and Communication Technology (ICT) literacy.

The Mississippi Engineering Curriculum Framework is aligned to P21's Framework for 21st Century Learning. An alignment crosswalk can be viewed in the appendix of this document.

Technology and Engineering Literacy Framework for the 2014 National Assessment of Educational Progress (NAEP)

"…The 2014 NAEP Technology and Engineering Framework is a statement about what should be expected of students in terms of their knowledge and skills with technology, written to be the basis for an assessment of technology and engineering literacy appropriate for all students. It opens the door to seeing what our K-12 students know about technology and engineering, in the same way that NAEP already assesses their knowledge and capabilities in reading, mathematics, science, and other subjects."

https://www.nagb.org/publications/frameworks/technology/2014-technology-framework.html. Accessed April 26, 2017.

The Mississippi Engineering Curriculum Framework is aligned to 12th grade assessment targets within the National Assessment for Educational Progress' Technology and Engineering Literacy Framework for 2014. An alignment crosswalk can be viewed in the appendix of this document.

Preface

Secondary Career and Technical Education programs in Mississippi are faced with many challenges and opportunities resulting from ongoing educational reforms at the national and state levels. School districts, administrators, and teachers are increasingly being held accountable for providing appropriate and relevant learning activities to every student in the classroom. This accountability is measured through increased requirements for mastery and attainment of competency as documented through both formative and summative assessments. There are also rising calls for more hands-on, applied techniques related to the real world, developing 21st Century skills essential to success in college and career. CTE is well positioned to meet these needs.

The courses in this document reflect the statutory requirements as found in Section 37-3-49, Mississippi Code of 1972, as amended (Section 37-3-46). In addition, this curriculum reflects guidelines imposed by federal and state mandates (Laws, 1988, ch. 487, §14; Laws, 1991, ch. 423, §1; Laws, 1992, ch. 519, §4 eff. from and after July 1, 1992; Carl D. Perkins Vocational Education Act IV, 2007; and Every Student Succeeds Act 2015.)

Mississippi Teacher Professional Resources

The following are resources for Mississippi teachers.

Curriculum, Assessment, Professional Learning, and other program resources can be found at The Research and Curriculum Unit's website: http://www.rcu.msstate.edu

Learning Management System: An online resource
Learning Management System information can be found at the RCU's website, under Professional Learning.

Should you need additional instructions, please call 662.325.2510.

Executive Summary

Pathway Description

Engineering and Mechatronics is a program in pre-engineering, robotics, and automated manufacturing for high school students. The purpose of the program is to provide pupils with expanded knowledge of the use of critical thinking, analysis, problem solving, and technological skills and to enable them to apply knowledge in a technological context. Hands-on experiences related to the application of engineering concepts in the workplace are central to all portions of this course. Students will develop academic, 21st century, and human relations skills and competencies that accompany technical skills for job success to help foster lifelong learning. Students who complete the program will be better prepared to enter and succeed in the engineering and STEM-related workforce or programs offered by Mississippi community and junior colleges, as well as institutions of higher education.

College, Career, and Certifications

Most engineering bachelor's degree programs involve a concentration of study in an engineering specialty along with courses in both mathematics and the physical and life sciences. Many programs also include courses in general engineering. A design course, sometimes accompanied by a computer or laboratory class or both, is part of the curriculum of most programs. General courses not directly related to engineering, such as those in the social sciences or humanities, are also often required.

In addition to the standard bachelor's engineering degree, many colleges offer 2-year or 4-year degree programs in engineering technology (ET). These programs, which usually include various hands-on laboratory classes that focus on current issues in the application of engineering principles, prepare students for practical design and production work, rather than for jobs that require more theoretical and scientific knowledge. Graduates of 4-year technology programs may get jobs similar to those obtained by graduates with a bachelor's degree in engineering. Engineering technology graduates, however, are not qualified to register as professional engineers under the same terms as graduates with degrees in engineering. Some employers regard technology program graduates as having skills between those of a technician and an engineer. A two-year study by the National Academy of Engineering (2016) found that despite a high (and increasing) demand for ET graduates in many fields, there "appears to be little awareness of ET as a field of study or a category of employment." This curriculum attempts to shed some light on these areas as the number of clean, modern, high-tech, and well-paying ET jobs continues to increase in Mississippi, the United States, and internationally.

Although most engineering jobs require a degree, some entry level/base positions that support professionals in engineering and STEM fields require only certifications. One industry certification example (emphasized in this course) signifies skills in using 3D drafting software and can benefit students applying for jobs in the field. These certifications are applicable in both college and careers. Interested students are encouraged to sharpen and expand upon the skills learned in this course in pursuit of a widely recognized certification. Specific 3D drafting

certificates depend on the industry sector or company, but the two most valued certifications for high school students at this point are:

- The Certified SolidWorks Associate - Academic (CSWA - Academic)
- AutoDesk Certified User certificate in AutoDesk Inventor (offered by Certiport)

Assessment

The latest assessment blueprint for the curriculum can be found at http://www.rcu.msstate.edu/Curriculum/CurriculumDownload.aspx

Student Prerequisites

In order for students to experience success in the Engineering program, the following prerequisites are suggested:

1. A grade of C or Higher in Pre-Algebra
   and/or
2. TABE Math Computation and TABE Math Applied Score (eighth grade or higher)
   and/or
3. Instructor Approval

Academic Alignment

The *Engineering Curriculum Framework* is aligned to the Physics course content in the Mississippi 2018 College and Career Readiness Standards for Science. The Office of Accreditation has approved the recommendation effective the 2012-2013 school year. The Institutions of Higher Learning the student attends will decide if the equivalent credit can be awarded as a science. * Credits recognized for high school graduation by a school district are different from credits/courses recognized for college acceptance.*

Applied Academic Credit

The latest academic credit information can be found at http://www.mde.k12.ms.us/ACCRED/AAS.
Once there, click the "Mississippi Public School Accountability Standards Year" tab.
Review the appendices for graduation options and superscript information regarding specific programs receiving academic credit.

Licensure Requirements

The most current teacher licensure information can be found at http://www.mde.k12.ms.us/educator-licensure.

Professional Learning

If you have specific questions about the content of any of training sessions provided, please contact the Research and Curriculum Unit at 662.325.2510 and ask for a professional learning specialist.

Course Outlines

Option 1 – Four One-Carnegie-Unit Courses

This curriculum consists of four one-credit courses, which should be completed in the following sequence:

1. Engineering and Mechatronics Fundamentals – Course Code: 994002
2. Engineering and Mechatronics Industry Skills – Course Code: 994003

Credits 3 and 4 are found in the 2nd year curriculum document.

Course Description: Engineering and Mechatronics Fundamentals

Engineering Fundamentals teaches students the history of engineering and the careers associated with the field. Students will learn the foundations and fundamentals of engineering and materials, as well as the engineering design process and the steps one follows for successful design planning. Additionally, students are introduced to the advanced concepts of 3D sketching and modeling with CAD software. Safe and ethical practices are introduced in this unit and both are expected to be applied throughout all parts of the course.

Course Description: Engineering and Mechatronics Industry Skills

Engineering Industry Skills introduces students to professional practice concepts in engineering. It also focuses on several fields of engineering specialization and engineering technology. CAD is emphasized alongside technical writing and analysis.

Engineering and Mechatronics Fundamentals – Course Code: 994002

Unit	Unit Name	Hours
1	Orientation and Student Organizations	10
2	Ethics and Safety	10
3	Engineering Design Process	15
4	Computer-Aided Design and Drafting I	80
Total		115

Engineering and Mechatronics Industry Skills – Course Code: 994003

Unit	Unit Name	Hours
5	Introduction to Mechanical Systems and Robotics	90
6	Computer-Aided Design and Drafting II	25
7	Engineering Careers and Technical Writing	25
Total		140

Option 2 – Two (2) Two-Carnegie-Unit Courses

This curriculum consists of two (2) two-credit courses, which should be completed in the following sequence:

1. Engineering and Mechatronics I – Course Code: 994000
2. Credit 2 is found in the 2nd year curriculum document.

Course Description: Engineering and Mechatronics I

Engineering I teaches students about student organizations and introduces them to the engineering design process along with ethical and safe practice standards. Concepts of 3D sketching and modeling by hand and with CAD software are introduced within the context of engineering design and prototype development. Robotics concepts in engineering are covered with understanding catalyzed by student competitions. This course also focuses on several fields of engineering and engineering technology specialization to include technical writing and analysis.

Engineering and Mechatronics I – Course Code: 994000

Unit	Unit Name	Hours
1	Orientation and Student Organizations	10
2	Ethics and Safety	10
3	Engineering Design Process	15
4	Computer Aided Design and Drafting I	80
5	Introduction to Mechanical Systems and Robotics	90
6	Computer Aided Design and Drafting II	25
7	Engineering Careers and Technical Writing	25
Total		255

Research Synopsis

Introduction

Engineers and ET professionals apply principles of science, mathematics, and technology to develop economical solutions for society. Whether it is working on scientific discoveries or commercial applications, engineering employees are expected to pursue continuing education as technology evolves. Engineering professionals are typically required to obtain a bachelor's degree, though several other Engineering Technology (ET) options with variable course and degree requirements are offered. Licensing requirements for engineers usually include a professional degree and at least 3–4 years of practical work experience, but ET careers may involve a professional degree, industry certifications, training, and/or practical work experience. The 2010-2020 occupational employment projections and wage estimates for Mississippi were used to determine where large employment needs would be in the population over a 10-year period. The research also includes information from industry publications, the Mississippi Department of Education, institutions of higher learning, and community and junior colleges regarding articulation agreements and degree requirements. The pathways were affirmed through existing Mississippi curriculum blueprints and the expectations provided in industry interviews.

Needs of the Future Workforce in Mississippi

Data for this synopsis were compiled from the Mississippi Department of Employment Security (2017). Employment opportunities in Mississippi representative of various engineering occupations are listed below.

Table 1.1: Current and Projected Occupation Report (State of Mississippi)

Occupations (Grouped)	Employment		Projected Growth 2012-2022		Average Wage 2017	
	Current (2012)	Projected (2022)	Number	Percent	Hourly	Annual
Chemical Engineering						
Biological Technicians	110	140	30	27.3	$17.93	$37,300
Biomedical Engineers	20	30	10	50.0	$44.79	$93,160
Chemical Engineers	110	120	10	9.1	$48.30	$100,470
Chemical Technicians	330	350	20	6.1	$21.74	$45,220
Materials Engineers	130	150	20	15.4	$45.56	$94,760
Medical and Clinical Laboratory Technicians	1,590	1,680	90	5.7	$17.03	$35,420
Medical and Clinical Laboratory Technologists	1,740	1,850	110	6.3	$27.19	$56,560
Petroleum Engineers	210	230	20	9.5	$44.79	$93,160
Civil Engineering						
Architectural and Engineering Managers	980	1,010	30	3.1	$56.90	$118,360
Civil Engineering Technicians	3,050	3,070	20	0.7	$17.59	$36,580

Civil Engineers	2,230	2,320	90	4.0	$40.73	$84,730
Environmental Engineering Technicians	100	110	10	10.0	$17.82	$37,070
Geological and Petroleum Technicians	100	110	10	10.0	$28.36	$58,990
Surveying and Mapping Technicians	470	480	10	2.1	$19.43	$40,420
Computer and Electrical Engineering						
Broadcast Technicians	210	220	10	4.8	$17.34	$36,080
Computer and Information Research Scientists	80	90	10	12.5	$45.16	$93,940
Computer Engineers and Information System Managers	1,180	1,320	140	11.9	$44.79	$93,160
Electrical and Electronics Engineering Technicians	760	770	10	1.3	$27.33	$56,850
Electrical Engineers	670	690	20	3.0	$46.00	$95,690
Mechanical Engineering						
Electro-Mechanical Technicians	10	10	0	0	$26.98	$56,120
Industrial Engineering Technicians	380	390	10	2.6	$25.16	$52,330
Mechanical Engineering Technicians	240	230	-10	-4.2	$21.74	$45,230
Mechanical Engineers	820	860	40	4.9	$42.82	$89,060

Source: Mississippi Department of Employment Security; www.mdes.ms.gov (accessed June 2017).

Perkins IV Requirements

The Engineering curriculum meets Perkins IV requirements of high-skill, high-wage, and/or high-demand occupations by introducing students to and preparing students for occupations. It also offers students a program of study including secondary, postsecondary, and Institutes of Higher Learning (IHL) courses that will prepare them for occupations in these fields. Additionally, the Engineering curriculum is integrated with the College and Career Readiness Standards (CCRS) and focuses on ongoing and meaningful professional development for teachers as well as relationships with industry.

Curriculum

The following national standards were referenced for this curriculum:

- International Technology and Engineering Education Association (ITEEA) Standards for Technological Literacy
- 21st Century Skills and Information and Communication Technologies Literacy Standards
- Mississippi College and Career Readiness Standards (CCSS) for math, English language arts, and science (Physics)

- ISTE's National Educational Technology Standards (NETS-S) for Students
- National Assessment of Educational Progress (NAEP) Technology and Engineering Literacy Framework
- The National Research Council's *A Framework for K-12 Science Education*

2016 Massachusetts Science and Technology/Engineering Curriculum Framework

A new engineering task force consisting of industry professionals, community college instructors, IHLs, and Career and Technical Education (CTE) educators used current research and curriculum models to reformulate Mississippi's new Engineering curriculum. Mechatronics elements are integrated in this course, but a more specific pathway will be paired with this course in the near future, providing a year two course with an even greater work ready focus.

Best Practices

Innovative Instructional Technologies

Recognizing today's digital learners and the increasing role of technology in industry, the classroom should be equipped with flexible tools that reflect the needs of the student and industry alike. The Engineering curriculum includes content that incorporates current technology. Each classroom should incorporate one teacher desktop or laptop as well as student computers in a networked environment. Each classroom is suggested to be equipped with the best, most current educational technology possible, thus facilitating customized and efficient interactions between students and teachers during class. Project-based instruction infusing technology is an essential approach to grow autonomous, 21st century learners. Teachers are encouraged to investigate Dr. Ruben Puentedura's SAMR (Substitution, Augmentation, Modification, Redefinition) Model to better understand how to infuse technology into lessons. In addition, teachers should make use of the latest online communication tools such as online file sharing, wikis, blogs, vlogs, and podcasts. They are also encouraged to teach using an online Learning Management System (LMS) such as Canvas, which allows for increased student access, interaction, lesson customization, and assessment and grading automation. Finally, students are encouraged to engage in Maker Ed's Open Portfolio Project to document skill mastery for workforce or college entry.

Differentiated Instruction

While some research suggests that students learn in different ways, certain approaches appeal to a wider array of learners and should be considered by more educators. Research suggests that applied, hands-on methods tied to solving real-world problems are more impactful, leading to deeper understanding, more connections to existing knowledge, and greater independence as a learner and problem solver. Combining possible learning styles or preferences, personality types, and other conditions such as student background, emotional health, and home/support circumstances, shows that a very unique learner profile emerges for every student. To meet more students where they are with an appropriate level of rigor, the Engineering curriculum is written to include a variety of performance objectives, which allow students to perform an array of hands-on activities or solve problems by selecting projects. By encouraging various teaching and assessment strategies, students with different learning profiles are more likely to experience success in the classroom, lab, college, and career.

Career and Technical Education Student Organizations

At least two student organizations are relevant for this curriculum. Teachers are encouraged to charter one of these organizations if one is not already available to students. The suggested organizations for this course are Technology Student Association (TSA) or SkillsUSA, which both feature appropriate projects and/or outputs for Engineering. The point is not necessarily the student organization itself, but the spirit and associated soft skills that develop over an extended period through a nationally recognized outlet. Contact information for these organizations and supplemental applications/outputs are listed under "Student Organizations and Student Competitions" sections of this document. In addition to an ongoing and proactive charter in one of these organizations, teachers are encouraged to engage in at least one student competition depending on what is most appropriate and relevant for the students. In many cases these student organizations will provide a student competition outlet.

Articulation

The latest articulation information for Secondary to Postsecondary can be found at the Mississippi Community College Board (MCCB) website http://www.mccb.edu/

Conclusion

Based on information presented above, Mississippi's updated Engineering curriculum will provide many opportunities for students to develop workforce skills. Applied approaches such as projects, robotics competitions, and hands-on activities will continue to be central to the course, but the method of application will now be open to more possibilities to include solar cars, submersible vehicles, and various robotics platforms. Anticipated project approaches could include unmanned aerial systems or virtual reality. These will help to prepare students for the applied, hands-on skills essential to their success in the workforce. The curriculum document will be updated regularly to reflect changing technologies, pedagogical methods, and the needs of the engineering and engineering technology workforce.

Student Organizations

Teachers are encouraged for charter one student organization (SkillsUSA or TSA), which are listed immediately below:

SkillsUSA
14001 SkillsUSA Way
Leesburg, VA 20176
703.777.8810
http://www.skillsusa.org/

Technology Student Association
1914 Association Drive
Reston, VA 20191-1540
888.860.9010
http://www.tsaweb.org/

Student Competitions

Teachers are encouraged to charter one student organization (above) and at least one of the following student competitions (student org charter and competition may occur in tandem):

BEST Robotics
P.O. Box 1024
Georgetown, TX 78627
http://bestinc.org

FIRST Robotics (FIRST Tech Challenge or FIRST Robotics Competition)
200 Bedford Street
Manchester, NH 03101
https://www.firstinspires.org

MATE (Marine Advanced Technology Education)
Monterey Peninsula College
980 Fremont Street
Monterey, CA 93940
https://www.marinetech.org

SeaPerch National Challenge
2700 Quincy Street, Suite 400
Arlington, VA 22206
http://www.seaperch.org/index

Solar Car Challenge
3505 Cassidy Drive
Plano, TX 75023
http://www.solarcarchallenge.org/challenge/

Transportation and Civil Engineering (TRAC™) Bridge Challenge
Mississippi Department of Transportation (MDOT)
401 Northwest Street
Jackson, MS 38829
http://mdot.ms.gov/stemeducation/site/programs/trac.html

VEX Robotics Competition (through TSA, REC, or both)
1519 Interstate 30 West
Greenville, TX 75402
https://www.vexrobotics.com

Using This Document

Suggested Time on Task

This section indicates an estimated number of clock hours of instruction that should be required to teach the competencies and objectives of the unit. A minimum of 140 hours of instruction is required for each Carnegie unit credit. The curriculum framework should account for approximately 75–80% of the time in the course.

Competencies and Suggested Objectives

A competency represents a general concept that students are expected to master as a requirement for completion of a unit. Students will be expected to demonstrate mastery of all competencies. Suggested objectives represent constituent components that comprise competencies. Satisfactory student performance (as set by the district and the MS CSPAS2) related to objectives will accumulate to indicate mastery of the competency, unit, and overall course.

Unit 1: Orientation and Student Organizations

Competencies and Suggested Objectives
1. Identify course expectations, school policies, student organizations, and program policies related to this course. a. Identify school rules, policy, and procedures b. Identify and establish classroom guidelines and procedures c. Review course standards and affiliated national standards
2. Relate student organization elements to the National Society of Professional Engineers to include: a. Describe the importance of effective communication skills • Demonstrate verbal and nonverbal communication skills • Apply appropriate speaking listening skills to class and work related situations b. Apply leadership skills to class and work related situations • Define leadership • Discuss the attributes of a leader • Identify the roles a leader can assume c. Utilize teambuilding skills in class and work related situations • Define teambuilding • Discuss the attributes of a team • Identify the roles included in a team d. Discuss the various competitions offered through a program area student organization • Describe each of the competitions and the skills needed to accomplish the tasks • Perform the tasks needed to complete an assigned requirement for a competition

FCI = full course integration
CR = career readiness practice
National and state standard alignments for Unit 1: ITEEA, NAEP, P21, MS CCRS-ELA, ISTE NETS-S,

Unit 2: Ethics and Safety

Competencies and Suggested Objectives
1. Utilize proper safety procedures in a laboratory setting. a. Identify, describe, and demonstrate the importance of safety and the proper use of lab equipment b. Describe safe operating procedures for the equipment utilized in the course c. Adhere to applicable Occupational Safety and Health Administration (OSHA) 10-Hour General Industry Guidelines and Material Safety Data Sheet (MSDS) in the laboratory setting d. Demonstrate understanding of Lockout/Tagout procedures e. Complete lab safety assessment with 100% mastery prior to accessing and operating laboratory equipment
2. Recognize the importance of ethical teamwork in the field of engineering. a. Using the National Society of Professional Engineers (NSPE) Code of Ethics, engage in arguments from workplace scenarios addressing safe and ethical practices including considerations of environmental (sustainability), social, and personal impacts b. Apply the NSPE Code of Ethics to current or future technological advancements for potential ethical implications c. Relate student organization central tenets to the NSPE
Enrichment: Research various emerging technologies to include impacts on society and changing technological cultures.

FCI = full course integration
CR = career readiness practice
National and state standard alignments for Unit 2: ITEEA, NAEP, P21, MS CCRS-ELA, ISTE NETS-S

Unit 3: Engineering Design Process

Competencies and Suggested Objectives
1. Implement the National Aeronautics and Space Administration (NASA) Beginning Engineering, Science, and Technology (BEST) engineering design process. PHY.3.11, PHY.5.6 a. Apply the continuous improvement model of the engineering design process to improve an existing product; include tradeoff (sustainability and efficiency) concepts frequently used in industry b. Apply the engineering design process in the development of a student project
Enrichment: Use the engineering design process to develop an innovative prototype to address an authentic problem. Strengthen models through a peer review process.

FCI = full course integration
CR = career readiness practice
National and state standard alignments for Unit 3: ITEEA, NAEP, P21, MS CCRS-ELA, MS CCRS-Math, ISTE NETS-S, MS CCRS-Physics

Unit 4: Computer Aided Design and Drafting I

Competencies and Suggested Objectives
1. Explain the purpose of technical drawing and freehand technical sketches. a. Research and evaluate appropriate techniques for technical drawing and freehand technical sketches
2. Identify and demonstrate proper use of measurement tools. a. Select and use appropriate tools or instruments to collect qualitative and quantitative data and record and represent that data in an appropriate form to include: • Calipers • Engineering scales • Micrometers • Protractors • Rulers
3. Create an appropriately scaled technical drawing. a. Apply mathematical concepts and/or processes (such as ratio, rate, percent, basic operations, and simple algebra) to engineering questions and problems related to measurement b. Convert fractions to decimals and decimals to fractions in order to test and compare proposed solutions to an engineering design problem to include: • 1/16 • 1/8 • ¼ • ½
4. Use Computer Aided Design and Drafting (CADD or CAD) software to create 3D models. a. Create a part using CAD software b. Identify and demonstrate appropriate application of the following CAD software concepts: • Axis • Boss • Center lines • Chamfer • Constraints • Construction lines • Cut • Dimension lines • Extrude • Fillet • Hole • Invisible and visible lines • Loft

- ~~Mates~~
- ~~Origin~~
- ~~Pattern~~
- ~~Plane~~
- ~~Revolve~~
- ~~Rib~~
- ~~Section Lines~~
- ~~Shell~~
- ~~Sweep~~

~~FCI = full course integration~~
~~SP = comprise essential elements of student portfolios~~
~~CR = career readiness practice~~
~~IC = tied to industry certification~~
~~National and state standard alignments for Unit 4: ITEEA, NAEP, P21, MS CCRS-ELA, MS CCRS-Math, ISTE NETS-S, MS CCRS-Physics~~

Unit 5: Introduction to Mechanical Systems and Robotics

Competencies and Suggested Objectives
1. Explore concepts related to physical and operational concepts of robotics. a. Collect, organize and interpret the following critical physical and operational elements as they pertain to robotics using tables, graphs, flow charts, and/or digital tools to include connections and patterns: • Actuators • Autonomous versus user control • Drive train/mechanism • Electronic controls • Manipulators and end effectors • Motors/servos • Power supply • Programming languages • Sensors
2. Explore physics or physical concepts as they relate to robotics (mechanisms and simple machines to create working robots). PHY.1.1, PHY.1.2, PHY.1.5, PHY.1.6, PHY.1.7, PHY.1.8, PHY.2.1, PHY.2.2, PHY.2.3, PHY.2.4, PHY.2.5, PHY.2.6, PHY.2.7, PHY.2.8, PHY.2.9, PHY.2.10, PHY.3.1, PHY.3.2, PHY.3.3, PHY.3.5, PHY.3.8, PHY.3.9, PHY.3.10, PHY.3.11, PHY.5.7, PHY.5.8 a. Design and conduct experiments to generate evidence of the relationships between distance, velocity, and acceleration through motion b. Interpret motion graphs in order to explain or describe phenomena contained within them c. Construct an explanation of observed relationships between variables by applying Newton's Laws of Motion to various real world scenarios; include F=ma d. Ask questions to generate hypotheses based on empirical evidence and observations to apply principles of physics involved in gears and gear trains e. Evaluate various models in order to calculate gear ratios and use the results to justify use of specific ratios in real-world or laboratory scenarios f. Recognize fundamentals of: • Angular velocity • Motors • Rotational dynamics • Torque g. Compare, integrate, and evaluate the following concepts related to robotics: • Actual mechanical advantage • Efficiency • Energy • Ideal mechanical advantage • Power • Work h. Recognize the fundamentals of degrees of freedom as it relates to robotic arms

3. Explore concepts associated with computer programming as it relates to robotics.
   a. Recognize the fundamentals of computer programming in real-world applications to include:
      - Comments
      - Flow charts
      - Pseudocode
      - Appropriate use of variable names
   b. Demonstrate proper use of programming techniques in multiple settings to include:
      - Conditional statements
      - Constants
      - Loops
      - Variables
   c. Differentiate between analog and digital sensors
   d. Differentiate between open and closed loop control
   e. Use appropriate programming concepts to autonomously control an end effector

4. Engage in one or more student competitions that include elements from competencies 1–3 above according to student organization and/or competition sections in the introduction of this document

SP = comprise essential elements of student portfolios
National and state standard alignments for Unit 5: ITEEA, NAEP, P21, MS CCRS-ELA, MS CCRS-Math, ISTE NETS-S, MS CCRS-Physics

Unit 6: Computer Aided Design and Drafting II

Competencies and Suggested Objectives
1. Use Computer-Aided Design and Drafting (CAD) software to create 2D drawings and 3D assemblies. PHY.1.1, PHY.1.2, PHY.1.3, PHY.1.4, PHY.1.5, PHY.1.6, PHY.2.1, PHY.2.4, PHY.2.5, PHY.2.6, PHY.2.7, PHY.3.1 a. Create an assembly using CAD software b. Create a detailed drawing using CAD software c. Integrate a CAD drawing into technical documents d. Analyze real world engineering drawings to distinguish between the need for orthographic and isometric drawing views

SP = comprise essential elements of student portfolios
IC = tied to industry certification
National and state standard alignments for Unit 6: ITEEA, NAEP, P21, MS CCRS-ELA, ISTE NETS-S, MS CCRS-Physics

Unit 7: Engineering Careers and Technical Writing

Competencies and Suggested Objectives
1. Explore educational and occupational opportunities in the field of mechanical engineering. a. Explore careers related to this particular area of engineering to include engineering and engineering technology fields such as: • Electromechanical engineering • Industrial system technology • Manufacturing engineering technology • Mechanical engineering technology • Advanced Manufacturing/Electro-Mechanical/Mechatronics Technician • Precision manufacturing and machining technology b. Employ the engineering design process with a mechanical engineering problem, taking into consideration ethical, environmental, social, and personal impacts c. Research and report on achievements of mechanical engineering in modern history to include well-known figures from Mississippi
2. Explore educational and occupational opportunities in the field of civil engineering. a. Explore careers related to this particular area to include engineering and engineering technology fields such as: • Architectural engineering technology • Civil engineering technology • Construction engineering technology • Geological engineering • Environmental engineering technology • Ocean engineering • Surveying and geomatics technology b. Employ the engineering design process with a civil engineering problem, taking into consideration ethical, environmental, social, and personal impacts c. Explore specific applications of Civil Engineering with licensed practitioners onsite or through class visits
3. Explore educational and occupational opportunities in the field of electrical/computer Engineering. a. Explore careers related to this particular area to include engineering and engineering technology fields such as: • Audio engineering • Computer engineering technology • Electronics engineering technology • Engineering technology management • Telecommunications engineering b. Employ the engineering design process with an electrical and computer engineering problem, taking into consideration ethical, environmental, social, and personal impacts c. Use digital/multimedia formats to present findings related to electrical and computer engineering to include current events and future technologies

4. Explore educational and occupational opportunities in the field of chemical engineering. a. Explore careers related to this particular area to include engineering and engineering technology fields such as: • Biomedical engineering • Chemical engineering technology • Composites engineering technology • Petroleum engineering • Polymer science engineering b. Employ the engineering design process with a chemical engineering problem, taking into consideration ethical, environmental, social, and personal impacts c. Choose a chemically engineered product and trace it back to its research and development stages, laboratories, funding sources, and engineers
5. Investigate and apply elements of technical writing to produce documents that include clarity, conciseness, accessibility, audience recognition, and accuracy. a. Analyze and interpret an existing technical document from an authoritative source to assess relevant information pertaining to a specific real-world project from one of the career fields mentioned above b. Create a technical document from a class project that employs multiple formats (verbally, graphically, textually, and/or mathematically); include cost analysis, data collection, communication, marketing, and presentation elements
Enrichment: Research career opportunities that are emerging as a result of evolving technologies. Enrichment: Develop a technical document detailing an innovative prototype to address an authentic problem.

CR = career readiness practice
National and state standard alignments for Unit 7: ITEEA, NAEP, P21, MS CCRS-ELA, ISTE NETS-S

Student Competency Checklist

Student Name: _____

This record is intended to serve as a method of noting student achievement of the competencies in each unit. It can be duplicated for each student, and it can serve as a cumulative record of competencies achieved in the course.

In the blank before each competency, place the date on which the student mastered the competency.

Unit 1: Orientation and Student Organizations		
	1.	Identify course expectations, school policies, student organizations, and program policies related to this course.
	2.	Relate student organization elements to the National Society of Professional Engineers.
Unit 2: Ethics and Safety		
	1.	Utilize proper safety procedures in a laboratory setting.
	2.	Recognize the importance of ethical teamwork in the field of engineering.
Unit 3: Engineering Design Process		
	1.	Implement the National Aeronautics and Space Administration (NASA) Beginning Engineering, Science, and Technology (BEST) engineering design process.
Unit 4. Computer Aided Design and Drafting I		
	1.	Explain the purpose of technical drawing and freehand technical sketches.
	2.	Identify and demonstrate proper use of measurement tools.
	3.	Create an appropriately scaled technical drawing.
	4.	Use Computer Aided Design and Drafting (CADD or CAD) software to create 3D models.
Unit 5: Introduction to Mechanical Systems and Robotics		
	1.	Explore concepts related to physical and operational concepts of robotics.
	2.	Explore physics or physical concepts they relate to robotics (mechanisms and simple machines to create working robots).
	3.	Explore concepts associated with computer programming as it relates to robotics.
Unit 6: Computer Aided Design and Drafting II		
	1.	Use Computer Aided Design and Drafting (CAD) software to create 2D drawings and 3D assemblies.
Unit 7: Engineering Careers and Technical Writing		
	1.	Explore educational and occupational opportunities in the field of mechanical engineering.

	~~2.~~	~~Explore educational and occupational opportunities in the field of civil engineering.~~
	~~3.~~	~~Explore educational and occupational opportunities in the field of electrical/computer engineering.~~
	~~4.~~	~~Explore educational and occupational opportunities in the field of chemical engineering.~~
	~~5.~~	~~Investigate and apply elements of technical writing to produce documents that include clarity, conciseness, accessibility, audience recognition, and accuracy.~~

Appendix A: National Standards

International Technology and Engineering Education Association (ITEEA) – Standards for Technological Literacy

	Units	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7
Standards for Technological Literacy								
STL1		x	x			x	x	
STL2		x	x			x	x	
STL3			x	x	x			x
STL4		x	x	x				
STL5				x	x			x
STL6		x	x	x	x			x
STL7			x					
STL8			x			x	x	
STL9			x			x	x	
STL10		x	x	x	x	x	x	x
STL11			x			x	x	
STL12							x	
STL13				x	x			x
STL14								
STL15								x
STL16								x
STL17						x	x	
STL18								
STL19				x	x			
STL20					x			

International Technology and Engineering Education Association (ITEEA) – Standards for Technological Literacy

STL1 Students will develop an understanding of the characteristics and scope of technology.
STL2 Students will develop an understanding of the core concepts of technology.
STL3 Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.
STL4 Students will develop an understanding of the cultural, social, economic, and political effects of technology.
STL5 Students will develop an understanding of the effects of technology on the environment.
STL6 Students will develop an understanding of the role of society in the development of and use of technology.

STL7 Students will develop an understanding of the influence of technology on history.
STL8 Students will develop an understanding of the attributes of design.
STL9 Students will develop an understanding of engineering design.
STL10 Students will develop an understanding of the role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving.
STL11 Students will develop the abilities to apply the design process.
STL12 Students will develop the abilities to use and maintain technological products and systems.
STL13 Students will develop the abilities to assess the impact of products and systems.
STL14 Students will develop an understanding of and be able to select and use medical technologies.
STL15 Students will develop an understanding of and be able to select and use agricultural and related biotechnologies.
STL16 Students will develop an understanding of and be able to select and use energy and power technologies.
STL17 Students will develop an understanding of and be able to select and use information and communication technologies.
STL18 Students will develop an understanding of and be able to select and use transportation technologies.
STL19 Students will develop an understanding of and be able to select and use manufacturing technologies.
STL20 Students will develop an understanding of and be able to select and use construction technologies.

National Assessment of Educational Progress (NAEP) Technology and Engineering Literacy Framework

NAEP Standard	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7
T.12.1		X	X				X
T.12.2		X	X				X
T.12.3		X	X				X
T.12.4		X	X				X
T.12.5			X				X
T.12.6			X				X
T.12.7			X				X
T.12.8			X				X
T.12.9			X				X
T.12.10			X				X
T.12.11			X				X
T.12.12			X				X
T.12.13			X				X
T.12.14			X				X
T.12.15			X				X
D.12.1		X	X			X	X
D.12.2		X	X			X	X
D.12.3		X	X			X	X
D.12.4			X			X	X
D.12.5			X			X	X
D.12.6			X			X	X
D.12.7			X			X	X
D.12.8			X			X	X
D.12.9			X			X	X
D.12.10			X			X	X
D.12.11			X			X	X
D.12.12			X			X	X
D.12.13			X			X	X
D.12.14			X			X	X
D.12.15			X			X	X
D.12.16			X			X	X
D.12.17			X			X	X
D.12.18			X			X	X
D.12.19			X			X	X
I.12.1	X	X	X	X	X	X	X
I.12.2	X	X	X	X	X	X	X
I.12.3	X	X	X	X	X	X	X
I.12.4		X	X	X	X	X	X
I.12.5		X	X	X	X	X	X
I.12.6		X	X	X	X	X	X
I.12.7		X	X	X	X	X	X
I.12.8		X	X	X	X	X	X
I.12.9		X	X	X	X	X	X
I.12.10	X	X	X	X	X	X	X
I.12.11	X	X	X	X	X	X	X
I.12.12		X	X	X	X	X	X
I.12.13		X	X	X	X	X	X

Students know that:

T.12.1: The decision to develop a new technology is influenced by societal opinions and demands. These driving forces differ from culture to culture.

T.12.2: Changes caused by the introduction and use of a new technology can range from gradual to rapid and from subtle to obvious and can change over time. These changes may vary from society to society as a result of differences in a society's economy, politics, and culture.

Students are able to:

T.12.3: Choose an appropriate technology to help solve a given societal problem, and justify the selection based on an analysis of criteria and constraints, available resources, likely trade-offs, and relevant environmental and cultural concerns.

T.12.4: Analyze cultural, social, economic, or political changes (separately or together) that may be triggered by the transfer of a specific technology from one society to another. Include both anticipated and unanticipated effects.

Students know that:

T.12.5: Many technologies have been designed to have a positive impact on the environment and to monitor environmental change over time to provide evidence for making informed decisions.

T.12.6: Development and modification of any technological system needs to take into account how the operation of the system will affect natural resources and ecosystems.

Students are able to:

T.12.7: Identify a complex global environmental issue, develop a systematic plan of investigation, and propose an innovative sustainable solution.

Students know that:

T.12.8: Information technology allows access to vast quantities of data, expertise, and knowledge through a wide array of devices and formats to answer questions, solve problems, and inform the decision-making process.

T.12.9: Information technologies such as artificial intelligence, image enhancement and analysis, and sophisticated computer modeling and simulation, create new types of information that may have profound effects on society. These new types of information must be evaluated carefully.

T.12.10: The development of communication technologies that enable people to access vast quantities of information and publish their ideas globally has implications for governments, organizations, and individuals.

Students are able to:

T.12.11: Give examples to illustrate the effects on society of the recording, distribution, and access to information and knowledge that have occurred in history, and discuss the effects of those revolutions on societal change.

Students know that:

T.12.12: Decisions made about the use of a technology may have intended and unintended consequences, and these consequences may be different for different groups of people and may change over time. Decisions about the use of a technology should consider different points of view.

T.12.13: Disparities in the technologies available to different groups of people have consequences for public health and prosperity, but deciding whether to introduce a new technology should consider local resources and the role of culture in acceptance of the new technology.

Students are able to:

T.12.14: Analyze responsibilities of different individuals and groups, ranging from citizens and entrepreneurs to political and government officials, with respect to a controversial technological issue.

T.12.15: Demonstrate the responsible and ethical use of information and communication technologies by distinguishing between kinds of information that should and should not be publicly shared and describing the consequences of a poor decision.

Students know that:

D.12.1: Advances in science have been applied by engineers to design new products, processes, and systems, while improvements in technology have enabled breakthroughs in scientific knowledge.

D.12.2: Engineers use science, mathematics, and other disciplines to improve technology, while scientists use tools devised by engineers to advance knowledge in their disciplines. This interaction has deepened over the past century.

D.12.3: The evolution of tools, materials, and processes has played an essential role in the development and advancement of civilization, from the establishment of cities and industrial societies to today's global trade and commerce networks.

Students are able to:

D.12.4: Take into account trade-offs among several factors when selecting a material for a given application.

D.12.5: Design a new tool to accomplish a task more efficiently.

Students know that:

D.12.6: Engineering design is a complicated process in which creative steps are embedded in content knowledge and research on the challenge. Decisions on trade-offs involve systematic comparisons of all costs and benefits, and final steps may involve redesigning for optimization.

D.12.7: Specifications involve criteria, which may be weighted in various ways, and constraints, which can include natural laws and available technologies. Evaluation is a process for determining how well a solution meets the requirements.

Students are able to:

D.12.8: Meet a sophisticated design challenge by identifying criteria and constraints, predicting how these will affect the solution, researching and generating ideas, and using trade-offs to balance competing values in selecting the best solution.

D.12.9: Construct and test several models to see if they meet the requirements of a problem. Combine features to achieve the best solution.

D.12.10: Communicate the entire design process from problem definition to evaluation of the final design, taking into account relevant criteria and constraints, including aesthetic and ethical considerations as well as purely logical decisions.

Students know that:

D.12.11: The stability of a system depends on all of its components and how they are connected, with more complicated systems tending to require more energy and to be more vulnerable to error and failure. Negative feedback loops tend to increase the stability and efficiency of systems.

D.12.12: Technological systems are embedded within larger technological, social, natural, and environmental systems.

Students are able to:

D.12.13: Examine a system to predict how it will perform with a given set of inputs in a given situation and how performance will change if the components or interactions of the system are changed.

D.12.14: Redesign a complex machine by modifying or rearranging its subsystems in order to optimize its efficiency.

D.12.15: Construct and test a manufacturing system composed of several machines to accomplish a given goal. Redesign the system to optimize its efficiency.

Students know that:

D.12.16: Products and structures of various kinds can be redesigned to eliminate frequent malfunctions and reduce the need for regular maintenance.

Students are able to:

D.12.17: Analyze a system malfunction using logical reasoning (such as a fault tree) and appropriate diagnostic tools and instruments. Devise strategies and recommend tools for fixing the problem.

D.12.18: Analyze a complicated system to identify ways that it might fail in the future. Identify the most likely failure points and recommend safeguards to avoid future failures.

D.12.19: Taking into account costs and current trends in technology, identify how long a product should be maintained and repaired and how it might be redesigned to lessen negative environmental impacts.

Students know that:

I.12.1: Effective collaboration requires careful selection of team members, monitoring of progress, strategies for reaching agreement when there are opposing points of view, and iterative improvement of collaborative processes. Information and communication technologies can be used to record and share different viewpoints and to collect and tabulate the views of groups of people.

Students are able to:

I.12.2: Work through a simulation of a collaborative process. Negotiate team roles and resources, draw upon the expertise and strengths of other team members and remote experts, monitor progress toward goals, and reflect on and refine team processes for achieving goals.

I.12.3: Synthesize input from multiple sources to communicate ideas to a variety of audiences using various media, genres, and formats.

Students know that:

I.12.4: Advanced search techniques can be used with digital and network tools and media resources to locate information and to check the credibility and expertise of sources.

Students are able to:

I.12.5: Select digital and network tools and media resources to gather information and data on a practical task, and justify choices based on the tools' efficiency and effectiveness for a given purpose.

I.12.6: Search media and digital resources on a community or world issue and evaluate the timeliness and accuracy of the information as well as the credibility of the source.

Students are able to:

I.12.7: Use digital tools and resources to identify a complicated global issue and develop a systematic plan of investigation. Present findings in terms of pros and cons of two or more innovative sustainable solutions.

I.12.8: Use digital tools to collect, analyze, and display data in order to design and conduct complicated investigations in various subject areas. Explain rationale for the design and justify conclusions based on observed patterns in the data.

I.12.9: Having conducted a simulation of a system using a digital model, draw conclusions about the system, or propose possible solutions to a problem or ways to reach a goal based on outcomes of the simulation. Critique the conclusions based on the adequacy of the model.

~~**Students know that:**~~

~~**I.12.10:** Legal requirements governing the use of copyrighted information and ethical guidelines for appropriate citations are intended to protect intellectual property.~~

~~**Students are able to:**~~

~~**I.12.11:** Identify or provide examples of responsible and ethical behavior that follow the letter and spirit of current laws concerning personal and commercial uses of copyrighted material as well as accepted ethical practices when using verbatim quotes, images, or ideas generated by others.~~

~~**Students know that:**~~

~~**I.12.12:** A variety of digital tools exist for a given purpose. The tools differ in features, capacities, operating modes, and style. Knowledge about many different ICT tools is helpful in selecting the best tool for a given task.~~

~~**Students are able to:**~~

~~**I.12.13:** Demonstrate the capability to use a variety of digital tools to accomplish a task or develop a solution for a practical problem. Justify the choice of tools, explain why other tools were not used based on specific features of the tools, and summarize the results.~~

Appendix B: 21st Century Skills

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7
21st Century Standards							
CS1	x						x
CS2			x				x
CS3					x		
CS4							
CS5		x	x		x		x
CS6			x	x	x	x	x
CS7	x	x	x	x	x	x	x
CS8	x	x	x	x	x	x	x
CS9	x	x	x	x	x	x	x
CS10				x	x	x	x
CS11		x	x	x	x	x	x
CS12				x	x	x	
CS13		x	x	x	x	x	x
CS14		x			x	x	
CS15		x	x	x	x	x	x
CS16		x	x		x	x	

CSS1 21st Century Themes

CS1 Global Awareness

1. Using 21st century skills to understand and address global issues
2. Learning from and working collaboratively with individuals representing diverse cultures, religions, and lifestyles in a spirit of mutual respect and open dialogue in personal, work, and community contexts
3. Understanding other nations and cultures, including the use of non-English languages

CS2 Financial, Economic, Business, and Entrepreneurial Literacy

1. Knowing how to make appropriate personal economic choices
2. Understanding the role of the economy in society
3. Using entrepreneurial skills to enhance workplace productivity and career options

CS3 Civic Literacy

1. Participating effectively in civic life through knowing how to stay informed and understanding governmental processes
2. Exercising the rights and obligations of citizenship at local, state, national, and global levels
3. Understanding the local and global implications of civic decisions

CS4 Health Literacy

1. Obtaining, interpreting, and understanding basic health information and services and using such information and services in ways that enhance health
2. Understanding preventive physical and mental health measures, including proper diet, nutrition, exercise, risk avoidance, and stress reduction
3. Using available information to make appropriate health-related decisions

4. Establishing and monitoring personal and family health goals
5. Understanding national and international public health and safety issues

CS5 Environmental Literacy

1. Demonstrate knowledge and understanding of the environment and the circumstances and conditions affecting it, particularly as relates to air, climate, land, food, energy, water, and ecosystems.
2. Demonstrate knowledge and understanding of society's impact on the natural world (e.g., population growth, population development, resource consumption rate, etc.).
3. Investigate and analyze environmental issues, and make accurate conclusions about effective solutions.
4. Take individual and collective action toward addressing environmental challenges (e.g., participating in global actions, designing solutions that inspire action on environmental issues).

CSS2 Learning and Innovation Skills

CS6 Creativity and Innovation

1. Think Creatively
2. Work Creatively with Others
3. Implement Innovations

CS7 Critical Thinking and Problem Solving

1. Reason Effectively
2. Use Systems Thinking
3. Make Judgments and Decisions
4. Solve Problems

CS8 Communication and Collaboration

1. Communicate Clearly
2. Collaborate with Others

CSS3 Information, Media and Technology Skills

CS9 Information Literacy

1. Access and Evaluate Information
2. Use and Manage Information

CS10 Media Literacy

1. Analyze Media
2. Create Media Products

CS11 ICT Literacy

1. Apply Technology Effectively

CSS4 Life and Career Skills

CS12 Flexibility and Adaptability

1. Adapt to change
2. Be Flexible

CS13 Initiative and Self-Direction

1. Manage Goals and Time
2. Work Independently

3. Be Self-directed Learners

CS14 Social and Cross-Cultural Skills

1. Interact Effectively with others
2. Work Effectively in Diverse Teams

CS15 Productivity and Accountability

1. Manage Projects
2. Produce Results

CS16 Leadership and Responsibility

1. Guide and Lead Others

Appendix C: College and Career Readiness Standards

College and Career Readiness Standards for English Language Arts

	Unit 1	Unit 2	Unit 3	Unit4	Unit 5	Unit 6	Unit 7
Standards							
RL.11.1	x	x					x
RL.11.2	x	x					x
RL.11.4	x	x					
RI.11.1	x	x	x				x
RI.11.2	x	x	x				x
RI.11.3	x	x	x				x
RI.11.4	x	x	x		x		x
RI.11.7	x						x
W.11.1		x	x				x
W.11.2			x				x
W.11.3							x
W.11.4							x
W.11.6							x
W.11.7			x				x
W11.8							
W.11.9							
W.11.10							x
SL.11.1		x	x		x		x
SL.11.2		x					x
SL.11.4							x
SL.11.5							x
SL.11.6							
L.11.1							x
L.11.2							x
L.11.3							x
L.11.4	x	x	x	x	x	x	x
L.11.5	x	x	x	x	x	x	x
L.11.6	x	x	x	x	x	x	x

RH.11.1		x					x
RH.11.2		x					x
RH.11.3		x					x
RH.11.4	x	x	x	x	x	x	x
RH.11.5	x	x	x	x	x	x	x
RH.11.6		x					x
RH.11.7							x
RH.11.8							x
RH.11.9							x
RST.11.1	x	x	x	x	x	x	x
RST.11.2	x	x	x	x	x	x	x
RST.11.3	x	x	x	x	x	x	x
RST.11.4	x	x	x	x	x	x	x
RST.11.5	x	x	x	x	x	x	x
RST.11.6	x	x	x	x	x	x	x
RST.11.7	x	x	x	x	x	x	x
RST.11.8	x	x	x	x	x	x	x
RST.11.9	x	x	x	x	x	x	x
RST.11.10	x	x	x	x	x	x	x
WHST.11.1							x
WHST.11.2							x
WHST.11.4							x
WHST.11.5							x
WHST.11.6							x
WHST.11.7					x		x
WHST.11.8							x
WHST.11.9							x
WHST.11.10	x	x	x	x	x	x	x

Reading Standards for Literature (11-12)
College and Career Readiness Anchor Standards for *Reading Literature*
Key Ideas and Details

RL.11.1. Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text, including determining where the text leaves

matters uncertain.

RL.11.2. Determine two or more themes or central ideas of a text and analyze their development over the course of the text, including how they interact and build on one another to produce a complex account; provide an objective summary of the text.

RL.11.3. Analyze the impact of the author's choices regarding how to develop and relate elements of a story or drama (e.g., where a story is set, how the action is ordered, how the characters are introduced and developed).

Craft and Structure

RL.11.4. Determine the meaning of words and phrases as they are used in the text, including figurative and connotative meanings; analyze the impact of specific word choices on meaning and tone, including words with multiple meanings or language that is particularly fresh, engaging, or beautiful. (Include Shakespeare as well as other authors.)

RL.11.5. Analyze how an author's choices concerning how to structure specific parts of a text (e.g., the choice of where to begin or end a story, the choice to provide a comedic or tragic resolution) contribute to its overall structure and meaning as well as its aesthetic impact.

RL.11.6. Analyze a case in which grasping point of view requires distinguishing what is directly stated in a text from what is really meant (e.g., satire, sarcasm, irony, or understatement).

Integration of Knowledge and Ideas

RL.11.7. Analyze multiple interpretations of a story, drama, or poem (e.g., recorded or live production of a play or recorded novel or poetry), evaluating how each version interprets the source text. (Include at least one play by Shakespeare and one play by an American dramatist.)

RL.11.8. (Not applicable to literature)

RL.11.9. Demonstrate knowledge of eighteenth-, nineteenth- and early-twentieth-century foundational works of American literature, including how two or more texts from the same period treat similar themes or topics.

Range of Reading and Level of Text Complexity

RL.11.10. By the end of grade 11, read and comprehend literature, including stories, dramas, and poems, in the grades 11–CCR text complexity band proficiently, with scaffolding as needed at the high end of the range.
By the end of grade 12, read and comprehend literature, including stories, dramas, and poems, at the high end of the grades 11–CCR text complexity band independently and proficiently.

Reading Standards for Informational Text (11-12)
College and Career Readiness Anchor Standards for *Informational Text*

Key Ideas and Details

RI.11.1. Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text, including determining where the text leaves matters uncertain.

RI.11.2. Determine two or more central ideas of a text and analyze their development over the course of the text, including how they interact and build on one another to provide a complex analysis; provide an objective summary of the text.

RI.11.3. Analyze a complex set of ideas or sequence of events and explain how specific individuals, ideas, or events interact and develop over the course of the text.

Craft and Structure

RI.11.4. Determine the meaning of words and phrases as they are used in a text, including figurative, connotative, and technical meanings; analyze how an author uses and refines the meaning of a key term or terms over the course of a text (e.g., how Madison defines faction in Federalist No. 10).

RI.11.5. Analyze and evaluate the effectiveness of the structure an author uses in his or her exposition or argument, including whether the structure makes points clear, convincing, and engaging.

RI.11.6. Determine an author's point of view or purpose in a text in which the rhetoric is particularly effective, analyzing how style and content contribute to the power, persuasiveness, or beauty of the text.

Integration of Knowledge and Ideas

RI.11.7. Integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a question or solve a problem.

RI.11.8. Delineate and evaluate the reasoning in seminal U.S. texts, including the application of constitutional principles and use of legal reasoning (e.g., in U.S. Supreme Court majority opinions and dissents) and the premises, purposes, and arguments in works of public advocacy (e.g., The Federalist, presidential addresses).

RI.11.9. Analyze seventeenth-, eighteenth-, and nineteenth-century foundational U.S. documents of historical and literary significance (including The Declaration of Independence, the Preamble to the Constitution, the Bill of Rights, and Lincoln's Second Inaugural Address) for their themes, purposes, and rhetorical features.

Range of Reading and Level of Text Complexity

RI.11.10. By the end of grade 11, read and comprehend literary nonfiction in the grades 11–CCR text complexity band proficiently, with scaffolding as needed at the high end of the range.

By the end of grade 12, read and comprehend literary nonfiction at the high end of the grades 11–CCR text complexity band independently and proficiently.
College and Career Readiness Anchor Standards for *Writing*

Text Types and Purposes

W.11.1. Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

a. Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences claim(s), counterclaims, reasons, and evidence.

b. Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant evidence for each while pointing out the strengths and limitations of both in a manner that anticipates the audience's knowledge level, concerns, values, and possible biases.

c. Use words, phrases, and clauses as well as varied syntax to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims.

d. Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

e. Provide a concluding statement or section that follows from and supports the argument presented.

W.11.2. Write informative/explanatory texts to examine and convey complex ideas, concepts, and information clearly and accurately through the effective selection, organization, and analysis of content.

a. Introduce a topic; organize complex ideas, concepts, and information so that each new element builds on that which precedes it to create a unified whole; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

b. Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

c. Use appropriate and varied transitions and syntax to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts.

d. Use precise language, domain-specific vocabulary, and techniques such as metaphor, simile, and analogy to manage the complexity of the topic.

e. Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

f. Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).

W.11.3. Write narratives to develop real or imagined experiences or events using effective technique, well-chosen details, and well-structured event sequences.

a. Engage and orient the reader by setting out a problem, situation, or observation and its significance, establishing one or multiple point(s) of view, and introducing a narrator and/or characters; create a smooth progression of experiences or events.

b. Use narrative techniques, such as dialogue, pacing, description, reflection, and multiple plot lines, to develop experiences, events, and/or characters

c. Use a variety of techniques to sequence events so that they build on one another to create a coherent whole and build toward a particular tone and outcome (e.g., a sense of mystery, suspense, growth, or resolution).

d. Use precise words and phrases, telling details, and sensory language to convey a vivid picture

of the experiences, events, setting, and/or characters.

e. Provide a conclusion that follows from and reflects on what is experienced, observed, or resolved over the course of the narrative.

Production and Distribution of Writing

W.11.4. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)

W.11.5. Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (Editing for conventions should demonstrate command of Language standards 1–3 up to and including grades 11–12 on page 54.)

W.11.6. Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.

Research to Build and Present Knowledge

W.11.7. Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

W.11.8. Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.

W.11.9. Draw evidence from literary or informational texts to support analysis, reflection, and research.

a. Apply grades 11–12 Reading standards to literature (e.g., "Demonstrate knowledge of eighteenth-, nineteenth- and early-twentieth-century foundational works of American literature, including how two or more texts from the same period treat similar themes or topics").

b. Apply grades 11–12 Reading standards to literary nonfiction (e.g., "Delineate and evaluate the reasoning in seminal U.S. texts, including the application of constitutional principles and use of legal reasoning [e.g., in U.S. Supreme Court Case majority opinions and dissents] and the premises, purposes, and arguments in works of public advocacy [e.g., The Federalist, presidential addresses]").

Range of Writing

W.11.10. Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

College and Career Readiness Anchor Standards for *Speaking and Listening*

Comprehension and Collaboration

SL.11.1. Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 11–12 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

a. Come to discussions prepared, having read and researched material under study; explicitly draw on that preparation by referring to evidence from texts and other research on the topic or issue to stimulate a thoughtful, well-reasoned exchange of ideas.

b. Work with peers to promote civil, democratic discussions and decision-making, set clear goals and deadlines, and establish individual roles as needed.

c. Propel conversations by posing and responding to questions that probe reasoning and evidence; ensure a hearing for a full range of positions on a topic or issue; clarify, verify, or challenge ideas and conclusions; and promote divergent and creative perspectives.

d. Respond thoughtfully to diverse perspectives; synthesize comments, claims, and evidence made on all sides of an issue; resolve contradictions when possible; and determine what additional information or research is required to deepen the investigation or complete the task.

SL.11.2. Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data.

SL.11.3. Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric, assessing the stance, premises, links among ideas, word choice, points of emphasis, and tone used.

Presentation of Knowledge and Ideas

SL.11.4. Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks.

SL.11.5. Make strategic use of digital media (e.g., textual, graphical, audio, visual, and

interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

SL.11.6. Adapt speech to a variety of contexts and tasks, demonstrating a command of formal English when indicated or appropriate. (See grades 11–12 Language standards 1 and 3 on page 54 for specific expectations.)

College and Career Readiness Anchor Standards for *Language*

Conventions of Standard English

L.11.1. Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

a. Apply the understanding that usage is a matter of convention, can change over time, and is sometimes contested.

b. Resolve issues of complex or contested usage, consulting references (e.g., Merriam-Webster's Dictionary of English Usage, Garner's Modern American Usage) as needed.

L.11.2. Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

a. Observe hyphenation conventions.

b. Spell correctly.

Knowledge of Language

L.11.3. Apply knowledge of language to understand how language functions in different contexts, to make effective choices for meaning or style, and to comprehend more fully when reading or listening.

a. Vary syntax for effect, consulting references (e.g., Tufte's Artful Sentences) for guidance as needed; apply an understanding of syntax to the study of complex texts when reading.

Vocabulary Acquisition and Use

L.11.4. Determine or clarify the meaning of unknown and multiple-meaning words and phrases based on grades 11–12 reading and content, choosing flexibly from a range of strategies.

a. Use context (e.g., the overall meaning of a sentence, paragraph, or text; a word's position or function in a sentence) as a clue to the meaning of a word or phrase.

b. Identify and correctly use patterns of word changes that indicate different meanings or parts of speech (e.g., conceive, conception, conceivable).

c. Consult general and specialized reference materials (e.g., dictionaries, glossaries, thesauruses), both print and digital, to find the pronunciation of a word or determine or clarify its precise meaning, its part of speech, its etymology, or its standard usage.

d. Verify the preliminary determination of the meaning of a word or phrase (e.g., by checking the inferred meaning in context or in a dictionary).

L.11.5. Demonstrate understanding of figurative language, word relationships, and nuances in word meanings.

a. Interpret figures of speech (e.g., hyperbole, paradox) in context and analyze their role in the text.

b. Analyze nuances in the meaning of words with similar denotations.

L.11.6. Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

Reading Standards for Literacy in History/Social Studies (11-12)

Key Ideas and Details

RH.11.1 Cite specific textual evidence to support analysis of primary and secondary sources, connecting insights gained from specific details to an understanding of the text as a whole.

RH.11.2. Determine the central ideas or information of a primary or secondary source; provide an accurate summary that makes clear the relationships among the key details and ideas

RH.11.3. Evaluate various explanations for actions or events and determine which explanation best accords with textual evidence, acknowledging where the text leaves matters uncertain

Craft and Structure

RH.11.4. Determine the meaning of words and phrases as they are used in a text, including analyzing how an author uses and refines the meaning of a key term over the course of a text (e.g., how Madison defines faction in Federalist No. 10).

RH.11.5. Analyze in detail how a complex primary source is structured, including how key sentences, paragraphs, and larger portions of the text contribute to the whole.

RH.11.6. Evaluate authors' differing points of view on the same historical event or issue by assessing the authors' claims, reasoning, and evidence.

Integration of Knowledge and Ideas

RH.11.7. Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, as well as in words) in order to address a question or solve a problem.

RH.11.8. Evaluate an author's premises, claims, and evidence by corroborating or challenging them with other information.

RH.11.9. Integrate information from diverse sources, both primary and secondary, into a coherent understanding of an idea or event, noting discrepancies among sources.

Range of Reading and Level of Text Complexity

RH.11.10. By the end of grade 12, read and comprehend history/social studies texts in the grades 11–CCR text complexity band independently and proficiently.

Reading Standards for Literacy in Science and Technical Subjects (11-12)

Key Ideas and Details

RST.11.1. Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

RST.11.2. Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

RST.11.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

Craft and Structure

RST.11.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11–12 texts and topics.

RST.11.5. Analyze how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas.

RST.11.6. Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, identifying important issues that remain unresolved.

Integration of Knowledge and Ideas

RST.11.7. Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

RST.11.8. Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

RST.11.9. Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

Range of Reading and Level of Text Complexity

RST.11.10. By the end of grade 12, read and comprehend science/technical texts in the grades 11–CCR text complexity band independently and proficiently.

Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects (11-12)

Text Types and Purposes

WHST.11.1. Write arguments focused on discipline-specific content.

a. Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence.

b. Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form that anticipates the audience's knowledge level, concerns, values, and possible biases.

c. Use words, phrases, and clauses as well as varied syntax to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims.

d. Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

e. Provide a concluding statement or section that follows from or supports the argument presented.

ST.11.2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
a. Introduce a topic and organize complex ideas, concepts, and information so that each new

element builds on that which precedes it to create a unified whole; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

b. Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

c. Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts.

d. Use precise language, domain-specific vocabulary and techniques such as metaphor, simile, and analogy to manage the complexity of the topic; convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers.

e. Provide a concluding statement or section that follows from and supports the information or explanation provided (e.g., articulating implications or the significance of the topic).

WHST.11.3. (Not applicable as a separate requirement)

Production and Distribution of Writing

WHST.11.4. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

WHST.11.5. Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.

WHST.11.6. Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.

Research to Build and Present Knowledge

WHST.11.7. Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

WHST.11.8. Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.

WHST.11.9. Draw evidence from informational texts to support analysis, reflection, and research.

Range of Writing

WHST.11.10. Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

College and Career Readiness Standards for Mathematics

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7
N-Q.1.			X	X	X		
N-Q.2.			X	X	X		
N-Q.3.			X	X	X		
N-VM.1			X	X	X		
N-VM.2			X	X	X		
N-VM.3			X	X	X		
N-VM.4.a			X	X	X		
N-VM.4.b			X	X	X		
N-VM.4.c			X	X	X		
N-VM.5.a			X	X	X		
N-VM.5.b			X	X	X		
A-SSE.1			X	X	X		
A-SSE.1.a			X	X	X		
A-SSE.1.b			X	X	X		
A-SSE.2			X	X	X		
A-CED.1					X		
A-CED.2					X		
A-CED.4			X	X	X		
A-REI.1			X	X	X		
A-REI.10			X	X	X		
A-REI.11			X	X	X		
F-IF.1			X	X	X		
F-IF.6			X	X	X		
F-BF.1					X		
F-BF.1.c					X		

F-BF.4.					X		
F-TF.1							
F-TF.2							
F-TF.3							
F-TF.4							
G-CO.1.			X	X	X		
G-CO.2.			X	X			
G-CO.3.			X	X			
G-CO.4.			X	X			
G-CO.5.			X	X			
G-CO.6.			X	X			
G-CO.7.			X	X			
G-CO.8.							
G-CO.12.			X	X			
G-C.2			X				
G-C.4			X				
G-GMD.3			X				
G-GMD.4			X				
G-MG.1			X	X	X		
G-MG.2			X	X	X		
G-MG.3			X	X	X		
S-ID.6.a.					X		
S-ID.7					X		
S-ID.8					X		

Mathematics (High School)

Number and Quantity

The Real Number System

N-RN.1. Explain how the definition of the meaning of rational exponents follows from extending the properties of integer exponents to those values, allowing for a notation for radicals in terms of rational exponents.

N-RN.2. Rewrite expressions involving radicals and rational exponents using the properties of exponents.

N-RN.3. Explain why the sum or product of two rational numbers is rational; that the sum of a rational number and an irrational number is irrational; and that the product of a nonzero rational number and an irrational number is irrational.

Quantities

N-Q.1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N-Q.2. Define appropriate quantities for the purpose of descriptive modeling.

N-Q.3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

The Complex Number System

N-CN.1. Know there is a complex number i such that i2= −1, and every complex number has the form a + bi with a and b real.

N-CN.2. Use the relation i2= −1 and the commutative, associative, and distributive properties to add, subtract, and multiply complex numbers.

N-CN.3. (+) Find the conjugate of a complex number; use conjugates to find moduli and quotients of complex numbers.

N-CN.4. (+) Represent complex numbers on the complex plane in rectangular and polar form (including real and imaginary numbers), and explain why the rectangular and polar forms of a given complex number represent the same number.

N-CN.5. (+) Represent addition, subtraction, multiplication, and conjugation of complex numbers geometrically on the complex plane; use properties of this representation for computation. For example, (−1 + √3 i)3= 8 because (−1 + √3 i) has modulus 2 and argument 120°.

N-CN.6. (+) Calculate the distance between numbers in the complex plane as the modulus of the difference, and the midpoint of a segment as the average of the numbers at its endpoints.

N-CN.7. Solve quadratic equations with real coefficients that have complex solutions.

N-CN.8. (+) Extend polynomial identities to the complex numbers. For example, rewrite x2+ 4 as (x + 2i)(x − 2i).

N-CN.9. (+) Know the Fundamental Theorem of Algebra; show that it is true for quadratic polynomials.

Vector and Matrix Quantities

N-VM.1. (+) Recognize vector quantities as having both magnitude and direction. Represent vector quantities by directed line segments, and use appropriate symbols for vectors and their magnitudes (e.g., v, |v|, ||v||, v).

N-VM.2. (+) Find the components of a vector by subtracting the coordinates of an initial point from the coordinates of a terminal point.

N-VM.3. (+) Solve problems involving velocity and other quantities that can be represented by vectors.

N-VM.4. (+) Add and subtract vectors

N-VM.4.a. Add vectors end-to-end, component-wise, and by the parallelogram rule. Understand that the magnitude of a sum of two vectors is typically not the sum of the magnitudes.

N-VM.4.b. Given two vectors in magnitude and direction form, determine the magnitude and direction of their sum.

N-VM.4.c. Understand vector subtraction v − w as v + (−w), where −w is the additive inverse of w, with the same magnitude as w and pointing in the opposite direction. Represent vector subtraction graphically by connecting the tips in the appropriate order, and perform vector subtraction component-wise.

N-VM.5. (+) Multiply a vector by a scalar.

N-VM.5.a. Represent scalar multiplication graphically by scaling vectors and possibly reversing their direction; perform scalar multiplication component-wise, e.g., as c(vx, vy) = (cvx, cvy).

N-VM.5.b. Compute the magnitude of a scalar multiple cv using ||cv|| = |c|v. Compute the direction of cv knowing that when |c|v ≠ 0, the direction of cv is either along v (for c > 0) or against v (for c < 0).

N-VM.6. (+) Use matrices to represent and manipulate data, e.g., to represent payoffs or incidence relationships in a network.

N-VM.7. (+) Multiply matrices by scalars to produce new matrices, e.g., as when all of the payoffs in a game are doubled.

N-VM.8. (+) Add, subtract, and multiply matrices of appropriate dimensions.

N-VM.9. (+) Understand that, unlike multiplication of numbers, matrix multiplication for square

matrices is not a commutative operation, but still satisfies the associative and distributive properties

N-VM.10. (+) Understand that the zero and identity matrices play a role in matrix addition and multiplication similar to the role of 0 and 1 in the real numbers. The determinant of a square matrix is nonzero if and only if the matrix has a multiplicative inverse.

N-VM.11. (+) Multiply a vector (regarded as a matrix with one column) by a matrix of suitable dimensions to produce another vector. Work with matrices as transformations of vectors.

N-VM.12. (+) Work with 2 × 2 matrices as transformations of the plane, and interpret the absolute value of the determinant in terms of area.

Algebra

Seeing Structure in Expressions

A-SSE.1. Interpret expressions that represent a quantity in terms of its context.

A-SSE.1.a. Interpret parts of an expression, such as terms, factors, and coefficients.

A-SSE.1.b. Interpret complicated expressions by viewing one or more of their parts as a single entity. For example, interpret P(1+r)n as the product of P and a factor not depending on P.

A-SSE.2. Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.

A-SSE.3. Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.

A-SSE.3.a. Factor a quadratic expression to reveal the zeros of the function it defines.

A-SSE.3.b. Complete the square in a quadratic expression to reveal the maximum or minimum value of the function it defines.

A-SSE.3.c. Use the properties of exponents to transform expressions for exponential functions.
A-SSE.4. Derive the formula for the sum of a finite geometric series (when the common ratio is not 1), and use the formula to solve problems. For example, calculate mortgage payments.
Arithmetic with Polynomials and Rational Expressions

A-APR.1. Understand that polynomials form a system analogous to the integers, namely, they are closed under the operations of addition, subtraction, and multiplication; add, subtract, and multiply polynomials

A-APR.2. Know and apply the Remainder Theorem: For a polynomial p(x) and a number a, the remainder on division by x − a is p(a), so p(a) = 0 if and only if (x − a) is a factor of p(x).

A-APR.3. Identify zeros of polynomials when suitable factorizations are available, and use the zeros to construct a rough graph of the function defined by the polynomial.

A-APR.4. Prove polynomial identities and use them to describe numerical relationships.

A-APR.5. (+) Know and apply the Binomial Theorem for the expansion of (x+ y)n in powers of x and y for a positive integer n, where x and y are any numbers, with coefficients determined for example by Pascal's Triangle.

A-APR.6. Rewrite simple rational expressions in different forms; write a(x)/b(x)in the form q(x) + r(x)/b(x), where a(x), b(x), q(x), and r(x) are polynomials with the degree of r(x) less than the degree of b(x), using inspection, long division, or, for the more complicated examples, a computer algebra system.

A-APR.7. (+) Understand that rational expressions form a system analogous to the rational numbers, closed under addition, subtraction, multiplication, and division by a nonzero rational expression; add, subtract, multiply, and divide rational expressions.

Creating Equations

A-CED.1. Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions.

A-CED.2. Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.

A-CED.3. Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or nonviable options in a modeling context. For example, represent inequalities describing nutritional and cost constraints on combinations of different foods.

A-CED.4. Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law V =IR to highlight resistance R.

Reasoning with Equations and Inequalities

A-REI.1. Explain each step in solving a simple equation as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct a viable argument to justify a solution method.

A-REI.2. Solve simple rational and radical equations in one variable, and give examples showing how extraneous solutions may arise.

A-REI.3. Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.

A-REI.4. Solve quadratic equations in one variable.

A-REI.4.a. Use the method of completing the square to transform any quadratic equation in x into an equation of the form (x − p)2= q that has the same solutions. Derive the quadratic formula from this form.

A-REI.4.b. Solve quadratic equations by inspection (e.g., for x2= 49), taking square roots, completing the square, the quadratic formula and factoring, as appropriate to the initial form of the equation. Recognize when the quadratic formula gives complex solutions and write them as a ± bi for real numbers a and b.

A-REI.5. Prove that, given a system of two equations in two variables, replacing one equation by the sum of that equation and a multiple of the other produces a system with the same solutions.

A-REI.6. Solve systems of linear equations exactly and approximately (e.g., with graphs), focusing on pairs of linear equations in two variables.

A-REI.7. Solve a simple system consisting of a linear equation and a quadratic equation in two variables algebraically and graphically. For example, find the points of intersection between the line y = −3x and the circle x2+y2= 3.

A-REI.8. (+) Represent a system of linear equations as a single matrix equation in a vector variable.

A-REI.9. (+) Find the inverse of a matrix if it exists and use it to solve systems of linear equations (using technology for matrices of dimension 3 × 3 or greater).

A-REI.10. Understand that the graph of an equation in two variables is the set of all its solutions plotted in the coordinate plane, often forming a curve (which could be a line).

A-REI.11. Explain why the x-coordinates of the points where the graphs of the equations y = f(x) and y = g(x) intersect are the solutions of the equation f(x) = g(x); find the solutions approximately, e.g., using technology to graph the functions, make tables of values, or find successive approximations. Include cases where f(x) and/or g(x)
are linear, polynomial, rational, absolute value, exponential, and logarithmic functions.

A-REI.12.Graph the solutions to a linear inequality in two variables as a half plane (excluding the boundary in the case of a strict inequality), and graph the solution set to a system of linear inequalities in two variables as the intersection of the corresponding half-planes.

Functions

~~Interpreting Functions~~

~~F-IF.1. Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If f is a function and x is an element of its domain, then f(x) denotes the output of f corresponding to the input x. The graph of f is the graph of the equation y = f(x).~~

~~F-IF.2. Use function notation, evaluate functions for inputs in their domains, and interpret statements that use function notation in terms of a context.~~

~~F-IF.3. Recognize that sequences are functions, sometimes defined recursively, whose domain is a subset of the integers. For example, the Fibonacci sequence is defined recursively by f(0) = f(1) = 1, f(n+1) = f(n) + f(n-1) for n ≥ 1.~~

~~F-IF.4. For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. Key features include: intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior; and periodicity.~~

~~F-IF.5. Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes. For example, if the function h(n) gives the number of person-hours it takes to assemble n engines in a factory, then the positive integers would be an appropriate domain for the function.~~

~~F-IF.6. Calculate and interpret the average rate of change of a function (presented symbolically or as a table) over a specified interval. Estimate the rate of change from a graph.~~

~~F-IF.7. Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases.~~

~~F-IF.7.a. Graph linear and quadratic functions and show intercepts, maxima, and minima.~~

~~F-IF.7.b. Graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions.~~
~~F-IF.7.c. Graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior.~~

~~F-IF.7.d. (+) Graph rational functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior.~~

~~F-IF.7.e. Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude.~~

~~F-IF.8. Write a function defined by an expression in different but equivalent forms to reveal and explain different properties of the function.~~

F-IF.8.a. Use the process of factoring and completing the square in a quadratic function to show zeros, extreme values, and symmetry of the graph, and interpret these in terms of a context.

F-IF.8.b. Use the properties of exponents to interpret expressions for exponential functions.

F-IF.9. Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions). For example, given a graph of one quadratic function and an algebraic expression for another, say which has the larger maximum.

Building Functions

F-BF.1. Write a function that describes a relationship between two quantities.

F-BF.1.a. Determine an explicit expression, a recursive process, or steps for calculation from a context.

F-BF.1.b. Combine standard function types using arithmetic operations. For example, build a function that models the temperature of a cooling body by adding a constant function to a decaying exponential, and relate these functions to the model.

F-BF.1.c. (+) Compose functions. For example, if T(y) is the temperature in the atmosphere as a function of height, and h(t) is the height of a weather balloon as a function of time, then T(h(t)) is the temperature at the location of the weather balloon as a function of time.

F-BF.2. Write arithmetic and geometric sequences both recursively and with an explicit formula, use them to model situations, and translate between the two forms.

F-BF.3. Identify the effect on the graph of replacing f(x) by f(x) + k, k f(x), f(kx), and f(x + k) for specific values of k (both positive and negative); find the value of k given the graphs. Experiment with cases and illustrate an explanation of the effects on the graph using technology. Include recognizing even and odd functions from their graphs and algebraic expressions for them.

F-BF.4. Find inverse functions.

F-BF.4.a. Solve an equation of the form f(x) = c for a simple function f that has an inverse and write an expression for the inverse.
F-BF.4.b. (+) Verify by composition that one function is the inverse of another.

F-BF.4.c. (+) Read values of an inverse function from a graph or a table, given that the function has an inverse.

F-BF.4.d. (+) Produce an invertible function from a non-invertible function by restricting the domain.

F-BF.5. (+) Understand the inverse relationship between exponents and logarithms and use this relationship to solve problems involving logarithms and exponents.

Linear, Quadratic, and Exponential Models

F-LE.1. Distinguish between situations that can be modeled with linear functions and with exponential functions.

F-LE.1.a. Prove that linear functions grow by equal differences over equal intervals, and that exponential functions grow by equal factors over equal intervals.

F-LE.1.b. Recognize situations in which one quantity changes at a constant rate per unit interval relative to another.

F-LE.1.c. Recognize situations in which a quantity grows or decays by a constant percent rate per unit interval relative to another

F-LE.2. Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).

F-LE.3. Observe using graphs and tables that a quantity increasing exponentially eventually exceeds a quantity increasing linearly, quadratically, or (more generally) as a polynomial function.

F-LE.4. For exponential models, express as a logarithm the solution to ab ct = d where a, c, and d are numbers and the base b is 2, 10, or e; evaluate the logarithm using technology.

F-LE.5. Interpret the parameters in a linear or exponential function in terms of a context.

Trigonometric Functions

F-TF.1. Understand radian measure of an angle as the length of the arc on the unit circle subtended by the angle.

F-TF.2. Explain how the unit circle in the coordinate plane enables the extension of trigonometric functions to all real numbers, interpreted as radian measures of angles traversed counterclockwise around the unit circle.

F-TF.3. (+) Use special triangles to determine geometrically the values of sine, cosine, tangent for $\pi/3$, $\pi/4$ and $\pi/6$, and use the unit circle to express the values of sine, cosine, and tangent for $\pi - x$, $\pi+x$, and $2\pi - x$ in terms of their values for x, where x is any real number.

F-TF.4. (+) Use the unit circle to explain symmetry (odd and even) and periodicity of trigonometric functions.

F-TF.5. Choose trigonometric functions to model periodic phenomena with specified amplitude, frequency, and midline.

F-TF.6. (+) Understand that restricting a trigonometric function to a domain on which it is always increasing or always decreasing allows its inverse to be constructed.

F-TF.7. (+) Use inverse functions to solve trigonometric equations that arise in modeling contexts; evaluate the solutions using technology, and interpret them in terms of the context.

F-TF.8. Prove the Pythagorean identity sin2 (θ) + cos 2 (θ) = 1 and use it to find sin(θ), cos(θ), or tan(θ) given sin(θ), cos(θ), or tan(θ) and the quadrant of the angle.

F-TF.9. (+) Prove the addition and subtraction formulas for sine, cosine, and tangent and use them to solve problems.

Geometry

Congruence

G-CO.1. Know precise definitions of angle, circle, perpendicular line, parallel line, and line segment, based on the undefined notions of point, line, distance along a line, and distance around a circular arc.

G-CO.2. Represent transformations in the plane using, e.g., transparencies and geometry software; describe transformations as functions that take points in the plane as inputs and give other points as outputs. Compare transformations that preserve distance and angle to those that do not (e.g., translation versus horizontal stretch).

G-CO.3. Given a rectangle, parallelogram, trapezoid, or regular polygon, describe the rotations and reflections that carry it onto itself.

G-CO.4. Develop definitions of rotations, reflections, and translations in terms of angles, circles, perpendicular lines, parallel lines, and line segments.
G-CO.5. Given a geometric figure and a rotation, reflection, or translation, draw the transformed figure using, e.g., graph paper, tracing paper, or geometry software. Specify a sequence of transformations that will carry a given figure onto another.

G-CO.6. Use geometric descriptions of rigid motions to transform figures and to predict the effect of a given rigid motion on a given figure; given two figures, use the definition of congruence in terms of rigid motions to decide if they are congruent.

G-CO.7. Use the definition of congruence in terms of rigid motions to show that two triangles are congruent if and only if corresponding pairs of sides and corresponding pairs of angles are congruent.

G-CO.8. Explain how the criteria for triangle congruence (ASA, SAS, and SSS) follow from the definition of congruence in terms of rigid motions.

G-CO.9. Prove theorems about lines and angles. Theorems include: vertical angles are congruent; when a transversal crosses parallel lines, alternate interior angles are congruent and corresponding angles are congruent; points on a perpendicular bisector of a line segment are exactly those equidistant from the segment's endpoints.

G-CO.10. Prove theorems about triangles. Theorems include: measures of interior angles of a triangle sum to 180°; base angles of isosceles triangles are congruent; the segment joining midpoints of two sides of a triangle is parallel to the third side and half the length; the medians of a triangle meet at a point.

G-CO.11. Prove theorems about parallelograms. Theorems include: opposite sides are congruent, opposite angles are congruent, the diagonals of a parallelogram bisect each other, and conversely, rectangles are parallelograms with congruent diagonals.

G-CO.12. Make formal geometric constructions with a variety of tools and methods (compass and straightedge, string, reflective devices, paper folding, dynamic geometric software, etc.). Copying a segment; copying an angle; bisecting a segment; bisecting an angle; constructing perpendicular lines, including the perpendicular bisector of a line segment; and constructing a line parallel to a given line through a point not on the line.

G-CO.13. Construct an equilateral triangle, a square, and a regular hexagon inscribed in a circle.

Similarity, Right Triangles, and Trigonometry

G-SRT.1. Verify experimentally the properties of dilations given by a center and a scale factor:

G-SRT.1.a. A dilation takes a line not passing through the center of the dilation to a parallel line, and leaves a line passing through the center unchanged.

G-SRT.1.b. The dilation of a line segment is longer or shorter in the ratio given by the scale factor.

G-SRT.2. Given two figures, use the definition of similarity in terms of similarity transformations to decide if they are similar; explain using similarity transformations the meaning of similarity for triangles as the equality of all corresponding pairs of angles and the proportionality of all corresponding pairs of sides.

G-SRT.3. Use the properties of similarity transformations to establish the AA criterion for two triangles to be similar.

G-SRT.4. Prove theorems about triangles. Theorems include: a line parallel to one side of a triangle divides the other two proportionally, and conversely; the Pythagorean Theorem proved using triangle similarity.

G-SRT.5. Use congruence and similarity criteria for triangles to solve problems and to prove relationships in geometric figures.

G-SRT.6. Understand that by similarity, side ratios in right triangles are properties of the angles in the triangle, leading to definitions of trigonometric ratios for acute angles.

G-SRT.7. Explain and use the relationship between the sine and cosine of complementary angles.

G-SRT.8. Use trigonometric ratios and the Pythagorean Theorem to solve right triangles in applied problems.

G-SRT.9. (+) Derive the formula A = 1/2 ab sin(C) for the area of a triangle by drawing an auxiliary line from a vertex perpendicular to the opposite side.

G-SRT.10. (+) Prove the Laws of Sines and Cosines and use them to solve problems.

G-SRT.11. (+) Understand and apply the Law of Sines and the Law of Cosines to find unknown measurements in right and non-right triangles (e.g., surveying problems, resultant forces).

Circles

G-C.1. Prove that all circles are similar.

G-C.2. Identify and describe relationships among inscribed angles, radii, and chords. Include the relationship between central, inscribed, and circumscribed angles; inscribed angles on a diameter are right angles; the radius of a circle is perpendicular to the tangent where the radius intersects the circle.

G-C.3. Construct the inscribed and circumscribed circles of a triangle, and prove properties of angles for a quadrilateral inscribed in a circle.

G-C.4. (+) Construct a tangent line from a point outside a given circle to the circle.
G-C.5. Derive using similarity the fact that the length of the arc intercepted by an angle is proportional to the radius, and define the radian measure of the angle as the constant of proportionality; derive the formula for the area of a sector.

Expressing Geometric Properties with Equations
G-GPE.1. Derive the equation of a circle of given center and radius using the Pythagorean Theorem; complete the square to find the center and radius of a circle given by an equation.

G-GPE.2. Derive the equation of a parabola given a focus and directrix.

G-GPE.3. (+) Derive the equations of ellipses and hyperbolas given the foci, using the fact that the sum or difference of distances from the foci is constant.

~~G-GPE.4. Use coordinates to prove simple geometric theorems algebraically. For example, prove or disprove that a figure defined by four given points in the coordinate plane is a rectangle; prove or disprove that the point (1, √3) lies on the circle centered at the origin and containing the point (0, 2).~~

~~G-GPE.5. Prove the slope criteria for parallel and perpendicular lines and use them to solve geometric problems (e.g., find the equation of a line parallel or perpendicular to a given line that passes through a given point).~~

~~G-GPE.6. Find the point on a directed line segment between two given points that partitions the segment in a given ratio.~~

~~G-GPE.7. Use coordinates to compute perimeters of polygons and areas of triangles and rectangles, e.g., using the distance formula.~~

~~Geometric Measurement and Dimension~~

~~G-GMD.1. Give an informal argument for the formulas for the circumference of a circle, area of a circle, volume of a cylinder, pyramid, and cone. Use dissection arguments, Cavalieri's principle, and informal limit arguments.~~

~~G-GMD.2. (+) Give an informal argument using Cavalieri's principle for the formulas for the volume of a sphere and other solid figures.~~

~~G-GMD.3. Use volume formulas for cylinders, pyramids, cones, and spheres to solve problems.~~

~~G-GMD.4. Identify the shapes of two-dimensional cross-sections of three dimensional objects, and identify three-dimensional objects generated by rotations of two-dimensional objects.~~

~~Modeling with Geometry~~

~~G-MG.1. Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).~~

~~G-MG.2. Apply concepts of density based on area and volume in modeling situations (e.g., persons per square mile, BTUs per cubic foot).~~

~~G-MG.3. Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).~~

~~Statistics and Probability~~

~~Interpreting Categorical and Quantitative Data~~

S-ID.1. Represent data with plots on the real number line (dot plots, histograms, and box plots).

S-ID.2. Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets.

S-ID.3. Interpret differences in shape, center, and spread in the context of the data sets, accounting for possible effects of extreme data points (outliers).

S-ID.4. Use the mean and standard deviation of a data set to fit it to a normal distribution and to estimate population percentages. Recognize that there are data sets for which such a procedure is not appropriate. Use calculators, spreadsheets, and tables to estimate areas under the normal curve.

S-ID.5. Summarize categorical data for two categories in two-way frequency tables. Interpret relative frequencies in the context of the data (including joint, marginal, and conditional relative frequencies). Recognize possible associations and trends in the data.

S-ID.6. Represent data on two quantitative variables on a scatter plot, and describe how the variables are related.

S-ID.6.a. Fit a function to the data; use functions fitted to data to solve problems in the context of the data. Use given functions or choose a function suggested by the context. Emphasize linear, quadratic, and exponential models.

S-ID.6.b. Informally assess the fit of a function by plotting and analyzing residuals.

S-ID.6.c. Fit a linear function for a scatter plot that suggests a linear association.

S-ID.7. Interpret the slope (rate of change) and the intercept (constant term) of a linear model in the context of the data.
S-ID.8. Compute (using technology) and interpret the correlation coefficient of a linear fit.

S-ID.9. Distinguish between correlation and causation.

Making Inferences and Justifying Conclusions

S-IC.1. Understand statistics as a process for making inferences about population parameters based on a random sample from that population.

S-IC.2. Decide if a specified model is consistent with results from a given data-generating process, e.g., using simulation. For example, a model says a spinning coin falls heads up with probability 0.5. Would a result of 5 tails in a row cause you to question the model?

S-IC.3. Recognize the purposes of and differences among sample surveys, experiments, and observational studies; explain how randomization relates to each.

S-IC.4. Use data from a sample survey to estimate a population mean or proportion; develop a margin of error through the use of simulation models for random sampling.

S-IC.5. Use data from a randomized experiment to compare two treatments; use simulations to decide if differences between parameters are significant.

S-IC.6. Evaluate reports based on data.

Conditional Probability and the Rules of Probability

S-CP.1. Describe events as subsets of a sample space (the set of outcomes) using characteristics (or categories) of the outcomes, or as unions, intersections, or complements of other events ("or," "and," "not").

S-CP.2. Understand that two events A and B are independent if the probability of A and B occurring together is the product of their probabilities, and use this characterization to determine if they are independent.

S-CP.3. Understand the conditional probability of A given B as P(A and B)/P(B), and interpret independence of A and B as saying that the conditional probability of A given B is the same as the probability of A, and the conditional probability of B given A is the same as the probability of B.

S-CP.4. Construct and interpret two-way frequency tables of data when two categories are associated with each object being classified. Use the two-way table as a sample space to decide if events are independent and to approximate conditional probabilities. For example, collect data from a random sample of students in your school on their favorite subject among math, science, and English. Estimate the probability that a randomly selected student from your school will favor science given that the student is in tenth grade. Do the same for other subjects and compare the results.

S-CP.5. Recognize and explain the concepts of conditional probability and independence in everyday language and everyday situations. For example, compare the chance of having lung cancer if you are a smoker with the chance of being a smoker if you have lung cancer.

S-CP.6. Find the conditional probability of A given B as the fraction of B's outcomes that also belong to A, and interpret the answer in terms of the model.

S-CP.7. Apply the Addition Rule, P(A or B) = P(A) + P(B) – P(A and B), and interpret the answer in terms of the model.

S-CP.8. (+) Apply the general Multiplication Rule in a uniform probability model, P(A and B) = P(A)P(B|A) = P(B)P(A|B), and interpret the answer in terms of the model.

S-CP.9. (+) Use permutations and combinations to compute probabilities of compound events and solve problems.

Using Probability to Make Decisions

S-MD.1. (+) Define a random variable for a quantity of interest by assigning a numerical value to each event in a sample space; graph the corresponding probability distribution using the same graphical displays as for data distributions.

S-MD.2. (+) Calculate the expected value of a random variable; interpret it as the mean of the probability distribution.

S-MD.3. (+) Develop a probability distribution for a random variable defined for a sample space in which theoretical probabilities can be calculated; find the expected value. For example, find the theoretical probability distribution for the number of correct answers obtained by guessing on all five questions of a multiple-choice test where each question has four choices, and find the expected grade under various grading schemes.

S-MD.4. (+) Develop a probability distribution for a random variable defined for a sample space in which probabilities are assigned empirically; find the expected value. For example, find a current data distribution on the number of TV sets per household in the United States, and calculate the expected number of sets per household. How many TV sets would you expect to find in 100 randomly selected households?

S-MD.5. (+) Weigh the possible outcomes of a decision by assigning probabilities to payoff values and finding expected values.

S-MD.5.a. Find the expected payoff for a game of chance. For example, find the expected winnings from a state lottery ticket or a game at a fast-food restaurant.

S-MD.5.b. Evaluate and compare strategies on the basis of expected values. For example, compare a high-deductible versus a low-deductible automobile insurance policy using various, but reasonable, chances of having a minor or a major accident.

S-MD.6. (+) Use probabilities to make fair decisions (e.g., drawing by lots, using a random number generator).

S-MD.7. (+) Analyze decisions and strategies using probability concepts (e.g., product testing, medical testing, pulling a hockey goalie at the end of a game).

Appendix D: ISTE National Educational Technology Standards for Students (NETS-S)

ISTE Crosswalk for Engineering								
	Unit	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7
Standards								
T1				x	x	x	x	
T2		x	x	x		x	x	x
T3		x	x	x	x	x	x	x
T4			x	x	x	x	x	
T5		x				x	x	x
T6					x	x	x	x

T1 Creativity and Innovation

Students demonstrate creative thinking, construct knowledge, and develop innovative products and processes using technology. Students do the following:

a. Apply existing knowledge to generate new ideas, products, or processes.
b. Create original works as a means of personal or group expression.
c. Use models and simulations to explore complex systems and issues.
d. Identify trends and forecast possibilities.

T2 Communication and Collaboration

Students use digital media and environments to communicate and work collaboratively, including at a distance, to support individual learning and contribute to the learning of others. Students do the following:

a. Interact, collaborate, and publish with peers, experts, or others employing a variety of digital environments and media.
b. Communicate information and ideas effectively to multiple audiences using a variety of media and formats.
c. Develop cultural understanding and global awareness by engaging with learners of other cultures.
d. Contribute to project teams to produce original works or solve problems.

T3 Research and Information Fluency

Students apply digital tools to gather, evaluate, and use information. Students do the following:

a. Plan strategies to guide inquiry.
b. Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media.
c. Evaluate and select information sources and digital tools based on the appropriateness to specific tasks.
d. Process data and report results.

T4 Critical Thinking, Problem Solving, and Decision Making

Students use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources. Students do the following:

a. Identify and define authentic problems and significant questions for investigation.
b. Plan and manage activities to develop a solution or complete a project.
c. Collect and analyze data to identify solutions and/or make informed decisions.
d. Use multiple processes and diverse perspectives to explore alternative solutions.

T5 Digital Citizenship

Students understand human, cultural, and societal issues related to technology and practice legal and ethical behavior. Students do the following:

a. Advocate and practice safe, legal, and responsible use of information and technology.
b. Exhibit a positive attitude toward using technology that supports collaboration, learning, and productivity.
c. Demonstrate personal responsibility for lifelong learning.
d. Exhibit leadership for digital citizenship.

T6 Technology Operations and Concepts

Students demonstrate a sound understanding of technology concepts, systems, and operations. Students do the following:

a. Understand and use technology systems.
b. Select and use applications effectively and productively.
c. Troubleshoot systems and applications.
d. Transfer current knowledge to learning of new technologies.

~~Appendix E: Academic Standards~~

	~~Unit 1~~	~~Unit 2~~	~~Unit 3~~	~~Unit 4~~	~~Unit 5~~	~~Unit 6~~	~~Unit 7~~
~~MS SCIENCE STANDARDS~~							
~~PHY.1.1~~					~~X~~	~~X~~	
~~PHY.1.2~~					~~X~~	~~X~~	
~~PHY.1.3~~						~~X~~	
~~PHY.1.4~~						~~X~~	
~~PHY.1.5~~					~~X~~	~~X~~	
~~PHY.1.6~~					~~X~~	~~X~~	
~~PHY.1.7~~					~~X~~		
~~PHY.1.8~~					~~X~~		
~~PHY.2.1~~					~~X~~	~~X~~	
~~PHY.2.2~~					~~X~~		
~~PHY.2.3~~					~~X~~		
~~PHY.2.4~~					~~X~~	~~X~~	
~~PHY.2.5~~					~~X~~	~~X~~	
~~PHY.2.6~~					~~X~~	~~X~~	
~~PHY.2.7~~					~~X~~	~~X~~	
~~PHY.2.8~~					~~X~~		
~~PHY.2.9~~					~~X~~		
~~PHY.2.10~~					~~X~~		
~~PHY.3.1~~					~~X~~	~~X~~	
~~PHY 3.2~~					~~X~~		
~~PHY.3.3~~					~~X~~		
~~PHY.3.5~~					~~X~~		

~~PHY.3.4~~							
~~PHY.3.6~~							
~~PHY.3.7~~							
~~PHY.3.8~~					~~X~~		
~~PHY.3.9~~					~~X~~		
~~PHY.3.10~~					~~X~~		
~~PHY.3.11~~			~~X~~		~~X~~		
~~PHY.4.4~~							
~~PHY.4.9~~							
~~PHY.5.1~~							
~~PHY.5.2~~							
~~PHY.5.3~~							
~~PHY.5.4~~							
~~PHY.5.5~~							
~~PHY.5.6~~			~~X~~				
~~PHY.5.7~~					~~X~~		
~~PHY.5.8~~					~~X~~		
~~PHY.5.9~~							

~~Mississippi College and Career Readiness Standards – Physics~~

~~PHY.1 One Dimensional Motion~~

~~**Conceptual Understanding:** Linear motion of objects is described by displacement, velocity, and acceleration. These concepts should be introduced as computational and investigative phenomena.~~

~~**PHY.1 Students will investigate and understand how to analyze and interpret data.**~~

~~**PHY.1.1** Investigate and analyze evidence gained through observation or experimental design regarding the one-dimensional (1-D) motion of objects. Design and conduct experiments to generate and interpret graphical evidence of distance,~~

velocity, and acceleration through motion.

PHY.1.2 Interpret and predict 1-D motion based on displacement vs. time, velocity vs. time, or acceleration vs. time graphs (e.g., free-falling objects).

PHY.1.3 Use mathematical and computational analysis to solve problems using kinematic equations.

PHY.1.4 Use graphical analysis to derive kinematic equations.

PHY.1.5 Differentiate and give examples of motion concepts such as distance-displacement, speed-velocity, and acceleration.

PHY.1.6 Design and mathematically/graphically analyze quantitative data to explore displacement, velocity, and acceleration of various objects. Use probe systems, video analysis, graphical analysis software, digital spreadsheets, and/or online simulations.

PHY.1.7 Design different scenarios, and predict graph shapes for distance/time, velocity/time, and acceleration/time graphs.

PHY.1.8 Given a 1D motion graph students should replicate the motion predicted by the graph.

PHY.2 Newton's Laws

Conceptual Understanding: Motion and acceleration can be explained by analyzing the contact interaction of objects. This motion and acceleration can be predicted by analyzing the forces (i.e., normal, tension, gravitational, applied, and frictional) acting on the object and applying Newton's laws of motion.

PHY.2 Students will develop an understanding of concepts related to Newtonian dynamics.

PHY.2.1 Identify forces acting on a system by applying Newton's laws mathematically and graphically (e.g., vector and scalar quantities).

PHY.2.2 Use models such as free-body diagrams to explain and predict the motion of an object according to Newton's law of motion, including circular motion.

PHY.2.3 Use mathematical and graphical techniques to solve vector problems and find net forces acting on a body using free-body diagrams and/or online simulations.

PHY.2.4 Use vectors and mathematical analysis to explore the 2D motion of objects. (i.e. projectile and circular motion).

PHY.2.5 Use mathematical and computational analysis to derive simple equations of motion for various systems using Newton's second law (e.g. net force equations).

PHY.2.6 Use mathematical and computational analysis to explore forces (e.g., friction, force applied, normal, and tension).

PHY.2.7 Analyze real-world applications to draw conclusions about Newton's three laws of motion using online simulations, probe systems, and/or laboratory experiences.

PHY.2.8 Design an experiment to determine the forces acting on a stationary object on an inclined plane. Test your conclusions.

PHY.2.9 Draw diagrams of forces applied to an object, and predict the angle of incline that will result in unbalanced forces acting on the object.

PHY.2.10 Apply the effects of the universal gravitation law to generate a digital/physical graph, and interpret the forces between two masses, acceleration due to gravity, and planetary motion (e.g., situations where g is constant, as in falling bodies).

PHY.2.11 Explain centripetal acceleration while undergoing uniform circular motion to explore Kepler's third law using online simulations, models, and/or probe systems.

PHY.3 Work and Energy

Conceptual Understanding: Work and energy are synonymous. When investigating mechanical energy, energy is the ability to do work. The rate at which work is done is called power. Efficiency is the ratio of power input to the output of the system. In closed systems, energy is conserved.

PHY.3 Students will develop an understanding of concepts related to work and energy.

PHY.3.1 Use mathematical and computational analysis to qualitatively and quantitatively analyze the concept of work, energy, and power to explain and apply the conservation of energy.

PHY.3.2 Use mathematical and computational analysis to explore conservation of momentum and impulse.

PHY.3.3 Through real-world applications, draw conclusions about mechanical potential energy and kinetic energy using online simulations and/or laboratory experiences.

PHY.3.4 Design and conduct investigations to compare conservation of momentum and conservation of kinetic energy in perfectly inelastic and elastic collisions using probe systems, online simulations, and/or laboratory experiences.

PHY.3.5 Investigate, collect data, and summarize the principles of thermodynamics by exploring how heat energy is transferred from higher temperature to lower temperature until equilibrium is reached.

PHY.3.6 **Enrichment**: Design, conduct, and communicate investigations that explore how temperature and thermal energy relate to molecular motion and states of matter.

PHY.3.7 **Enrichment:** Use mathematical and computational analysis to analyze problems involving specific heat and heat capacity.

PHY.3.8 **Enrichment:** Research to compare the first and second laws of thermodynamics as related to heat engines, refrigerators, and thermal efficiency.

PHY.3.9 Explore the kinetic theory in terms of kinetic energy of ideal gases using digital resources.

PHY.3.10 **Enrichment:** Research the efficiency of everyday machines (e.g., automobiles, hair dryers, refrigerators, and washing machines).

PHY.3.11 **Enrichment:** Use an engineering design process to design and build a themed Rube Goldberg-type machine that has six or more steps and complete a desired task (e.g., pop a balloon, fill a bottle, shoot a projectile, or raise an object 35 cm) within an allotted time. Include a poster that demonstrates the calculations of the energy transformation or efficiency of the machine.*

PHY.4 Waves

Conceptual Understanding: Wave properties are the transfer of energy from one place to another. The investigation of these interactions must include simple harmonic motion, sound, and electromagnetic radiation.

PHY.4 **Students will investigate and explore wave properties.**

PHY.4.1 Analyze the characteristics and properties of simple harmonic motions, sound, and light.

PHY.4.2 Describe and model through digital or physical means the characteristics and properties of mechanical waves by simulating and investigating properties of simple harmonic motion.

PHY.4.3 Use mathematical and computational analysis to explore wave characteristics (e.g., velocity, period, frequency, amplitude, phase, and wavelength).

PHY.4.4 Investigate and communicate the relationship between the energy of a wave in terms of amplitude and frequency using probe systems, online simulations, and/or laboratory experiences.

PHY.4.5 Design, investigate, and collect data on standing waves and waves in specific media (e.g., stretched string, water surface, and air) using online simulations, probe systems, and/or laboratory experiences.

PHY.4.6 Explore and explain the Doppler effect as it relates to a moving source and to a moving observer using online simulations, probe systems, and/or real-world experiences.

PHY.4.7 Explain the laws of reflection and refraction, and apply Snell's law to describe the relationship between the angles of incidence and refraction.

PHY.4.8 Use ray diagrams and the thin lens equations to solve real-world problems involving object distance from lenses, using a lens bench, online simulations, and/or laboratory experiences.

PHY.4.9 Research the different bands of electromagnetic radiation, including characteristics, properties, and similarities/differences.

PHY.4.10 **Enrichment:** Research the ways absorption and emission spectra are used to study astronomy and the formation of the universe.

PHY.4.11 **Enrichment:** Research digital nonfictional text to defend the wave-particle duality of light (i.e., wave model of light and particle model of light).

PHY.4.12 **Enrichment:** Research uses of the electromagnetic spectrum or photoelectric effect.

PHY.5 Electricity and Magnetism

Conceptual Understanding: In electrical interactions, electrical energy (whether battery or circuit energy) is transformed into other forms of energy. Charged particles and magnetic fields are similar in that they store energy. Magnetic fields exert forces on moving charged particles. Changing magnetic fields cause electrons in wires to move and thus create a current.

PHY.5 Students will investigate the key components of electricity and magnetism.

PHY.5.1 Analyze and explain electricity and the relationship between electricity and magnetism.

PHY.5.2 Explore the characteristics of static charge and how a static charge is generated using simulations.

PHY.5.3 Use mathematical and computational analysis to analyze problems dealing with electric field, electric potential, current, voltage, and resistance as related to Ohm's law.

PHY.5.4 Develop and use models (e.g., circuit drawing and mathematical representation) to explain how electric circuits work by tracing the path of electrons, including concepts of energy transformation, transfer, conservation of energy, electric

charge, and resistance using online simulations, probe systems, and/or laboratory experiences.

PHY.5.5 Design and conduct an investigation of magnetic poles, magnetic flux and magnetic field using online simulations, probe systems, and/or laboratory experiences.

PHY.5.6 Use schematic diagrams to analyze the current flow in series and parallel electric circuits, given the component resistances and the imposed electric potential.

PHY.5.7 Analyze and communicate the relationship between magnetic fields and electrical current by induction, generators, and electric motors (e.g., microphones, speakers, generators, and motors) using Ampere's and Faraday's laws.

PHY.5.8 **Enrichment:** Design and construct a simple motor to develop an explanation of how the motor transforms electrical energy into mechanical energy and work.

PHY.5.9 **Enrichment:** Design and draw a schematic of a circuit that will turn on/off a light from two locations in a room like those found in most homes.

PHY.6 Nuclear Energy

Conceptual Understanding: Nuclear energy is energy stored in the nucleus of the atom. The energy holding atoms together is called binding energy. The binding energy is a huge amount of energy. So, at the subatomic scale, the conservation of energy becomes the conservation of mass-energy.

PHY.6 **Students will demonstrate an understanding of the basic principles of nuclear energy.**

PHY.6.1 Analyze and explain the concepts of nuclear physics.

PHY.6.2 Explore the mass number and atomic number of the nucleus of an isotope of a given chemical element.

PHY.6.3 Investigate the conservation of mass and the conservation of charge by writing and balancing nuclear decay equations for alpha and beta decay.

PHY.6.4 Simulate the process of nuclear decay using online simulations and/or laboratory experiences and using mathematical computations determine the half-life of radioactive isotopes.

2018 Engineering II

Program CIP: 14.0101-Engineering, General

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Mississippi State, MS 39762

The Research and Curriculum Unit (RCU), located in Starkville, MS, as part of Mississippi State University, was established to foster educational enhancements and innovations. In keeping with the land grant mission of Mississippi State University, the RCU is dedicated to improving the quality of life for Mississippians. The RCU enhances intellectual and professional development of Mississippi students and educators while applying knowledge and educational research to the lives of the people of the state. The RCU works within the contexts of curriculum development and revision, research, assessment, professional development, and industrial training.

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Standards

Standards are superscripted in each unit and are referenced in the appendices. Standards in the *Engineering Curriculum Framework and Supporting Materials* are based on the following:

International Technology and Engineering Educators Association (ITEEA) Standards

The International Technology and Engineering Educators Association (ITEEA) is the professional organization for technology, innovation, design, and engineering educators. The standards referenced in this curriculum are reprinted with permission from the International Technology and Engineering Educators Association, Copyright © 2007, http://www.iteea.org/.

The Mississippi Engineering Curriculum Framework is aligned to the 2007 ITEEA Standards for Technological Literacy. An alignment crosswalk can be viewed in the appendix of this document.

College and Career-Ready Standards

The College and Career-Ready Standards emphasize critical thinking, teamwork and problem-solving skills. Students will learn the skills and abilities demanded by the workforce of today and the future. Mississippi adopted Mississippi College- and Career-Ready Standards (MCCRS) because they provide a consistent, clear understanding of what students are expected to learn so that teachers and parents know what they need to do to help them. Reprinted from http://www.mde.k12.ms.us/MCCRS

The Mississippi Engineering Curriculum Framework is aligned to the College and Career Readiness Standards for Mathematics and English Language Arts. An alignment crosswalk can be viewed in the appendix of this document.

Mississippi 2018 College and Career Readiness Standards for Science — Physics

Physics, **a one-credit course,** provides opportunities for students to develop and communicate an understanding of matter and energy through lab-based activities, integrated STEM activities, mathematical expressions, and concept exploration. Concepts covered in this course include kinematics, dynamics, energy, mechanical and electromagnetic waves, and electricity. Laboratory activities, uses of technology, effective communication of results, and research of contemporary scientific theories through various methods are integral components of this course. Science as inquiry is an integral part of the framework, placing emphasis on developing the ability to ask questions, observe, experiment, measure, problem solve, gather data, and communicate findings. Inquiry is not an isolated unit of instruction and must be embedded throughout the content strands.

The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world to increase the depth of understanding based on evidence, logic, and innovation. These concepts are expected to appear throughout the course. As a laboratory-based course, students are expected to utilize the science and engineering practices to design and conduct investigations using appropriate equipment, measurement (SI units), and safety procedures. Students should also design

data tables and draw conclusions using mathematical computations and/or graphical analysis. It is recommended that students actively engage in inquiry activities, laboratory experiences, and scientific research (projects) for a minimum of 30% of class time.

The Mississippi Engineering Curriculum Framework is aligned to the Physics course in the 2018 Mississippi College and Career Readiness Standards for Science. An alignment crosswalk can be viewed in the appendix of this document.

International Society for Technology in Education Standards (ISTE)

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The Mississippi Engineering Curriculum Framework is aligned to ISTE's National Educational Technology Standards for Students. An alignment crosswalk can be viewed in the appendix of this document.

21st Century Skills and Information and Communication Technologies Literacy Standards

In defining 21st-century learning, the Partnership for 21st Century Skills (P21) has embraced five content and skill areas that represent the essential knowledge for the 21st century: global awareness; civic engagement; financial, economic, and business literacy; learning skills that encompass problem-solving, critical thinking, and self-directional skills; and Information and Communication Technology (ICT) literacy.

The Mississippi Engineering Curriculum Framework is aligned to P21's Framework for 21st Century Learning. An alignment crosswalk can be viewed in the appendix of this document.

Technology and Engineering Literacy Framework for the 2014 National Assessment of Educational Progress (NAEP)

"…The 2014 NAEP Technology and Engineering Framework is a statement about what should be expected of students in terms of their knowledge and skills with technology, written to be the basis for an assessment of technology and engineering literacy appropriate for all students. It opens the door to seeing what our K-12 students know about technology and engineering, in the same way that NAEP already assesses their knowledge and capabilities in reading, mathematics, science, and other subjects."

https://www.nagb.org/publications/frameworks/technology/2014-technology-framework.html. Accessed April 26, 2017.

The Mississippi Engineering Curriculum Framework is aligned to 12th grade assessment targets within the National Assessment for Educational Progress' Technology and Engineering Literacy Framework for 2014. An alignment crosswalk can be viewed in the appendix of this document.

Preface

Secondary Career and Technical Education programs in Mississippi are faced with many challenges and opportunities resulting from ongoing educational reforms at the national and state levels. School districts, administrators, and teachers are increasingly being held accountable for providing appropriate and relevant learning activities to every student in the classroom. This accountability is measured through increased requirements for mastery and attainment of competency as documented through both formative and summative assessments. There are also rising calls for more hands-on, applied techniques related to the real world, developing 21st Century skills essential to success in college and career. CTE is well positioned to meet these needs.

The courses in this document reflect the statutory requirements as found in Section 37-3-49, Mississippi Code of 1972, as amended (Section 37-3-46). In addition, this curriculum reflects guidelines imposed by federal and state mandates (Laws, 1988, ch. 487, §14; Laws, 1991, ch. 423, §1; Laws, 1992, ch. 519, §4 eff. from and after July 1, 1992; Carl D. Perkins Vocational Education Act IV, 2007; and Every Student Succeeds Act 2015.)

Mississippi Teacher Professional Resources

The following are resources for Mississippi teachers.

Curriculum, Assessment, Professional Learning, and other program resources can be found at The Research and Curriculum Unit's website: http://www.rcu.msstate.edu

Learning Management System: An online resource

Learning Management System information can be found at the RCU's website, under Professional Learning.

Should you need additional instructions, please call 662.325.2510.

Executive Summary

Pathway Description

Engineering and Mechatronics is a program in pre-engineering, robotics, and automated manufacturing for high school students. The purpose of the program is to provide pupils with expanded knowledge of the use of critical thinking, analysis, problem solving, and technological skills and to enable them to apply knowledge in a technological context. Hands-on experiences related to the application of engineering concepts in the workplace are central to all portions of this course. Students will develop academic, 21st century, and human relations skills and competencies that accompany technical skills for job success to help foster lifelong learning. Students who complete the program will be better prepared to enter and succeed in the engineering and STEM-related workforce or programs offered by Mississippi community and junior colleges, as well as institutions of higher education.

College, Career, and Certifications

Most engineering bachelor's degree programs involve a concentration of study in an engineering specialty along with courses in both mathematics and the physical and life sciences. Many programs also include courses in general engineering. A design course, sometimes accompanied by a computer or laboratory class or both, is part of the curriculum of most programs. General courses not directly related to engineering, such as those in the social sciences or humanities, are also often required.

In addition to the standard bachelor's engineering degree, many colleges offer 2-year or 4-year degree programs in engineering technology (ET). These programs, which usually include various hands-on laboratory classes that focus on current issues in the application of engineering principles, prepare students for practical design and production work, rather than for jobs that require more theoretical and scientific knowledge. Graduates of 4-year technology programs may get jobs similar to those obtained by graduates with a bachelor's degree in engineering. Engineering technology graduates, however, are not qualified to register as professional engineers under the same terms as graduates with degrees in engineering. Some employers regard technology program graduates as having skills between those of a technician and an engineer. A two-year study by the National Academy of Engineering (2016) found that despite a high (and increasing) demand for ET graduates in many fields, there "appears to be little awareness of ET as a field of study or a category of employment." This curriculum attempts to shed some light on these areas as the number of clean, modern, high-tech, and well-paying ET jobs continues to increase in Mississippi, the United States, and internationally.

Although most engineering jobs require a degree, some entry level/base positions that support professionals in engineering and STEM fields require only certifications. One industry certification example (emphasized in this course) signifies skills in using 3D drafting software and can benefit students applying for jobs in the field. These certifications are applicable in both college and careers. Interested students are encouraged to sharpen and expand upon the skills learned in this course in pursuit of a widely recognized certification. Specific 3D drafting certificates depend on the industry sector or company, but the two most valued certifications for high school students at this point are:

- The Certified SolidWorks Associate – Academic (CSWA – Academic)
- AutoDesk Certified User certificate in AutoDesk Inventor (offered by Certiport)

Assessment

The latest assessment blueprint for the curriculum can be found at http://www.rcu.msstate.edu/Curriculum/CurriculumDownload.aspx

Student Prerequisites

In order for students to experience success in the Engineering program, the following prerequisites are suggested:

1. A grade of C or Higher in Pre-Algebra
   and/or
2. TABE Math Computation and TABE Math Applied Score (eighth grade or higher)
   and/or
3. Instructor Approval

Academic Alignment

The *Engineering Curriculum Framework* is aligned to the Physics course content in the Mississippi 2018 College and Career Readiness Standards for Science. The Office of Accreditation has approved the recommendation effective the 2012-2013 school year. The Institutions of Higher Learning the student attends will decide if the equivalent credit can be awarded as a science. * Credits recognized for high school graduation by a school district are different from credits/courses recognized for college acceptance.*

Applied Academic Credit

The latest academic credit information can be found at http://www.mde.k12.ms.us/ACCRED/AAS.
Once there, click the "Mississippi Public School Accountability Standards Year" tab.
Review the appendices for graduation options and superscript information regarding specific programs receiving academic credit.

Licensure Requirements

The most current teacher licensure information can be found at http://www.mde.k12.ms.us/educator-licensure.

Professional Learning

If you have specific questions about the content of any of training sessions provided, please contact the Research and Curriculum Unit at 662.325.2510 and ask for a professional learning specialist.

Option 1 – Four One-Carnegie-Unit Courses

This curriculum consists of four one-credit courses, which should be completed in the following sequence:

Credits 1 and 2 are found in the first year curriculum document.

3. **Engineering Manufacturing Concepts – Course Code: 994004**
4. **Engineering Systems – Course Code: 994005**

Course Description: Engineering Manufacturing Concepts

Engineering Manufacturing Concepts teaches students advanced robotic concepts. Students will also learn valuable workforce readiness skills and prepare for jobs in the field of engineering through exploration of advanced 3D drafting and modern manufacturing systems.

Course Description: Engineering Systems

Engineering Systems is a comprehensive course that focuses on the following three systems: electrical, fluid, and thermal. It also obligates students to engage in a large-scale, comprehensive project that requires a display of various skills acquired during their time in the course.

Engineering Manufacturing Concepts – Course Code: 994004

Unit	Unit Name	Hours
8	Safety Review	5
9	Advanced Computer-Aided Design	20
10	Modern Manufacturing Systems	40
11	Advanced Robotics	65
Total		130

Engineering Systems – Course Code: 994005

Unit	Unit Name	Hours
12	Electrical Systems	50
13	Fluid Power Systems	25
14	Thermal Systems	20
15	Capstone	10
Total		105

Option 2 – Two (2) Two-Carnegie-Unit Courses

This curriculum consists of two (2) two-credit courses, which should be completed in the following sequence:

1. **The first year course content is found in the year one curriculum document.**
2. **Engineering II – Course Code: 994001**

Course Description: Engineering II

Engineering II is a comprehensive course that focuses on Advanced CAD modeling and simulations. It also introduces students to modern manufacturing systems, or how robotics and drafting work together to create products. Electrical, fluid, and thermal systems are covered in more detail due to their relevance in real-world applications and industry. Additionally, the course teaches students advanced robotic concepts. Students will also learn valuable workforce readiness skills and prepare for jobs in the field of engineering, which will be demonstrated with all other parts of the course in a capstone unit.

Engineering II – Course Code: 994001

Unit	Unit Name	Hours
8	Safety Review	5
9	Advanced Computer-Aided Design	20
10	Modern Manufacturing Systems	40
11	Advanced Robotics	65
12	Electrical Systems	50
13	Fluid Power Systems	25
14	Thermal Systems	20
15	Capstone	10
Total		235

Research Synopsis

Introduction

Engineers and ET professionals apply principles of science, mathematics, and technology to develop economical solutions for society. Whether it is working on scientific discoveries or commercial applications, engineering employees are expected to pursue continuing education as technology evolves. Engineering professionals are typically required to obtain a bachelor's degree, though there are several other Engineering Technology (ET) options with variable course and degree requirements. Licensing requirements for engineers usually include a professional degree and at least 3–4 years of practical work experience, but ET careers may involve a professional degree, industry certifications, training, and/or practical work experience. The 2010-2020 occupational employment projections and wage estimates for Mississippi were used to determine where large employment needs would be in the population over a 10-year period. The research also includes information from industry publications, the Mississippi Department of Education, institutions of higher learning, and community and junior colleges regarding articulation agreements and degree requirements. The pathways were affirmed through existing Mississippi curriculum blueprints and the expectations provided in industry interviews.

Needs of the Future Workforce in Mississippi

Data for this synopsis were compiled from the Mississippi Department of Employment Security (2017). Employment opportunities in Mississippi representative of various engineering occupations are listed below.

Table 1.1: Current and Projected Occupation Report (State of Mississippi)

Occupations (Grouped)	Employment		Projected Growth 2012-2022		Average Wage 2017	
	Current (2012)	Projected (2022)	Number	Percent	Hourly	Annual
Chemical Engineering						
Biological Technicians	110	140	30	27.3	$17.93	$37,300
Biomedical Engineers	20	30	10	50.0	$44.79	$93,160
Chemical Engineers	110	120	10	9.1	$48.30	$100,470
Chemical Technicians	330	350	20	6.1	$21.74	$45,220
Materials Engineers	130	150	20	15.4	$45.56	$94,760
Medical and Clinical Laboratory Technicians	1,590	1,680	90	5.7	$17.03	$35,420
Medical and Clinical Laboratory Technologists	1,740	1,850	110	6.3	$27.19	$56,560
Petroleum Engineers	210	230	20	9.5	$44.79	$93,160
Civil Engineering						
Architectural and Engineering Managers	980	1,010	30	3.1	$56.90	$118,360
Civil Engineering Technicians	3,050	3,070	20	0.7	$17.59	$36,580
Civil Engineers	2,230	2,320	90	4.0	$40.73	$84,730
Environmental Engineering Technicians	100	110	10	10.0	$17.82	$37,070
Geological and Petroleum Technicians	100	110	10	10.0	$28.36	$58,990
Surveying and Mapping Technicians	470	480	10	2.1	$19.43	$40,420
Computer and Electrical Engineering						
Broadcast Technicians	210	220	10	4.8	$17.34	$36,080
Computer and Information Research Scientists	80	90	10	12.5	$45.16	$93,940
Computer Engineers and Information System Managers	1,180	1,320	140	11.9	$44.79	$93,160
Electrical and Electronics Engineering Technicians	760	770	10	1.3	$27.33	$56,850
Electrical Engineers	670	690	20	3.0	$46.00	$95,690
Mechanical Engineering						
Electro-Mechanical Technicians	10	10	0	0	$26.98	$56,120

Industrial Engineering Technicians	380	390	10	2.6	$25.16	$52,330
Mechanical Engineering Technicians	240	230	-10	-4.2	$21.74	$45,230
Mechanical Engineers	820	860	40	4.9	$42.82	$89,060

Source: Mississippi Department of Employment Security; www.mdes.ms.gov (accessed June 2017).

Perkins IV Requirements

The Engineering curriculum meets Perkins IV requirements of high-skill, high-wage, and/or high-demand occupations by introducing students to and preparing students for occupations. It also offers students a program of study including secondary, postsecondary, and Institutes of Higher Learning (IHL) courses that will prepare them for occupations in these fields. Additionally, the Engineering curriculum is integrated with the College and Career Readiness Standards (CCRS) and focuses on ongoing and meaningful professional development for teachers as well as relationships with industry.

Curriculum

The following national standards were referenced for this curriculum:

- International Technology and Engineering Education Association (ITEEA) Standards for Technological Literacy
- 21st Century Skills and Information and Communication Technologies Literacy Standards
- Mississippi College and Career Readiness Standards (CCSS) for math, English language arts, and science (Physics)
- ISTE's National Educational Technology Standards (NETS-S) for Students
- National Assessment of Educational Progress (NAEP) Technology and Engineering Literacy Framework
- The National Research Council's *A Framework for K-12 Science Education*
- 2016 Massachusetts Science and Technology/Engineering Curriculum Framework

A new engineering task force consisting of industry professionals, community college instructors, IHLs, and Career and Technical Education (CTE) educators used current research and curriculum models to reformulate Mississippi's new Engineering curriculum. Mechatronics elements are integrated in this course, but a more specific pathway will be paired with this course in the near future, providing a year two course with an even greater work ready focus.

Best Practices

Innovative Instructional Technologies

Recognizing today's digital learners and the increasing role of technology in industry, the classroom should be equipped with flexible tools that reflect the needs of the student and industry alike. The Engineering curriculum includes content that incorporates current technology. Each classroom should incorporate one teacher desktop or laptop as well as student computers in a networked environment. It is suggested that each classroom be equipped with the best, most current educational technology possible, thus facilitating customized and efficient interactions between students and teachers during class. Project-based instruction infusing technology is an essential approach to grow autonomous, 21st century learners. Teachers are encouraged to investigate Dr. Ruben Puentedura's SAMR (Substitution, Augmentation, Modification, Redefinition) Model to better understand how to infuse technology into lessons. In addition, teachers should make use of the latest online communication tools such as online file sharing, wikis, blogs, vlogs, and podcasts. They are also encouraged to teach using an online

Learning Management System (LMS) such as Canvas, which allows for increased student access, interaction, lesson customization, and assessment and grading automation. Finally, students are encouraged to engage in Maker Ed's Open Portfolio Project to document skill mastery for workforce or college entry.

Differentiated Instruction

While some research suggests that students learn in different ways, there are some approaches that appeal to a wider array of learners and should be considered by more educators. Research suggests that applied, hands-on methods tied to solving real-world problems are more impactful, leading to deeper understanding, more connections to existing knowledge, and greater independence as a learner and problem solver. Combining possible learning styles or preferences, personality types, and other conditions such as student background, emotional health, and home/support circumstances, shows that a very unique learner profile emerges for every student. To meet more students where they are with an appropriate level of rigor, the Engineering curriculum is written to include a variety of performance objectives, which allow students to perform an array of hands-on activities or solve problems by selecting projects. By encouraging various teaching and assessment strategies, students with different learning profiles are more likely to experience success in the classroom, lab, college, and career.

Career and Technical Education Student Organizations

There are at least two relevant student organizations for this curriculum. Teachers are encouraged to charter one of these organizations if one is not already available to students. The suggested organizations for this course are Technology Student Association (TSA) or SkillsUSA, which both feature appropriate projects and/or outputs for Engineering. The point is not necessarily the student organization itself, but the spirit and associated soft skills that develop over an extended period through a nationally recognized outlet. Contact information for these organizations and supplemental applications/outputs are listed under "Student Organizations and Student Competitions" sections of this document. In addition to an ongoing and proactive charter in one of these organizations, teachers are encouraged to engage in at least one student competition depending on what is most appropriate and relevant for the students. In many cases these student organizations will provide a student competition outlet.

Articulation

The latest articulation information for Secondary to Postsecondary can be found at the Mississippi Community College Board (MCCB) website http://www.mccb.edu/

Conclusion

Based on information presented above, Mississippi's updated Engineering curriculum will provide many opportunities for students to develop workforce skills. Applied approaches such as projects, robotics competitions, and hands-on activities will continue to be central to the course, but the method of application will now be open to more possibilities to include solar cars, submersible vehicles, and various robotics platforms. Anticipated project approaches could include unmanned aerial systems or virtual reality. These will help to prepare students for the applied, hands-on skills essential to their success in the workforce. The curriculum document will be updated regularly to reflect changing technologies, pedagogical methods, and the needs of the engineering and engineering technology workforce.

Student Organizations

Teachers are encouraged to charter one student organization (SkillsUSA or TSA), which are listed immediately below:

SkillsUSA
14001 SkillsUSA Way
Leesburg, VA 20176
703.777.8810
http://www.skillsusa.org/

Technology Student Association
1914 Association Drive
Reston, VA 20191-1540
888.860.9010
http://www.tsaweb.org/

Student Competitions

Teachers are encouraged to charter one student organization (above) and at least one of the following student competitions (student org charter and competition may occur in tandem):

BEST Robotics
P.O. Box 1024
Georgetown, TX 78627
http://bestinc.org

FIRST Robotics (FIRST Tech Challenge or FIRST Robotics Competition)
200 Bedford Street
Manchester, NH 03101
https://www.firstinspires.org

MATE (Marine Advanced Technology Education)
Monterey Peninsula College
980 Fremont Street
Monterey, CA 93940
https://www.marinetech.org

SeaPerch National Challenge
2700 Quincy Street, Suite 400
Arlington, VA 22206
http://www.seaperch.org/index

Solar Car Challenge
3505 Cassidy Drive
Plano, TX 75023
http://www.solarcarchallenge.org/challenge/

Transportation and Civil Engineering (TRAC™) Bridge Challenge
Mississippi Department of Transportation (MDOT)
401 Northwest Street
Jackson, MS 38829
http://mdot.ms.gov/stemeducation/site/programs/trac.html

VEX Robotics Competition (through TSA, REC, or both)
1519 Interstate 30 West
Greenville, TX 75402
https://www.vexrobotics.com

Suggested Time on Task

This section indicates an estimated number of clock hours of instruction that should be required to teach the competencies and objectives of the unit. A minimum of 140 hours of instruction is required for each Carnegie unit credit. The curriculum framework should account for approximately 75–80% of the time in the course.

Competencies and Suggested Objectives

A competency represents a general concept that students are expected to master as a requirement for completion of a unit. Students will be expected to demonstrate mastery of all competencies. Suggested objectives represent constituent components that comprise competencies. Satisfactory student performance (as set by the district and the MS CSPAS2) related to objectives will accumulate to indicate mastery of the competency, unit, and overall course.

~~Units 1-7:~~

~~Curriculum/content for Units 1-7 can be found in the year 1 or core document.~~

Unit 8: Safety Review

Competencies and Suggested Objectives
1. Identify course expectations, school policies, and program policies related to this course. a. Identify school rules, policy, and procedures. b. Identify and establish classroom guidelines and procedures. c. Review course standards and affiliated national standards.
2. Utilize proper safety procedures in a laboratory setting. a. Identify, describe, and demonstrate the importance of safety and the proper use of lab equipment. b. Describe safe operating procedures for the equipment utilized in the course. c. Adhere to applicable MSDS and OSHA 10-Hour General Industry Guidelines in the laboratory setting. d. Demonstrate understanding of Lockout/Tagout procedures. e. Complete lab safety assessment with 100% mastery prior to accessing and operating laboratory equipment.

FCI = full course integration
CR = career readiness practice
National and state standard alignments for Unit 8: ITEEA, NAEP, P21, MS CCRS-ELA, MS CCRS-Math, ISTE NETS-S

Unit 9: Advanced Computer Aided Design

Competencies and Suggested Objectives
1. Use CAD analysis tools to manipulate variables and collect data to formulate decisions about prototypes or design solutions. PHY.1.1, PHY.1.2, PHY.1.3, PHY.1.6 a. Determine physical properties of a CAD model including: • Center of gravity • Mass • Volume b. Using finite element analysis, calculate the following for a CAD model: • Displacements • Factor of safety • Strains • Stresses c. Redesign a model based on data collected from CAD analysis.
2. Demonstrate proficiency in CAD software simulations. PHY.2.1, PHY.2.4, PHY.2.5, PHY.2.6, PHY.2.7, PHY.3.1, PHY.3.2, PHY.3.3, PHY.3.8, PHY.3.9, PHY.3.10, PHY.3.11 a. Use animation to analyze an assembly for: • Collision • Motion • Rotation b. Use flow simulations to evaluate fluid dynamics around an object. c. Conduct an analysis of a CAD assembly, draw conclusions about the system, and critique the conclusions based on the adequacy of the model.
3. Incorporate sustainable methodologies. a. Explore CAD sustainability tools and tutorials to include materials, manufacturing, and environmental impact. b. Reevaluate previous designs using sustainable methodologies.

CR = career readiness practice
IC = tied to industry certification
National and state standard alignments for Unit 9: ITEEA, NAEP, P21, MS CCRS-ELA, MS CCRS-Math, ISTE NETS-S, MS CCRS-Physics

Unit 10: Modern Manufacturing Systems

Competencies and Suggested Objectives
1. Use Computer Assisted Machining (CAM) software to create G-code from a CAD model. a. Import and manipulate correct file types to generate the G-code for the desired operation. b. Analyze and comprehend how G-code is generated for modern machines (e.g. CNC, 3D printer, laser engraver/cutter, plasma cutter, and/or waterjet).
2. Use subtractive machining methods to create objects that serve a specific purpose. a. Analyze the components of a Gantry CNC machine and their operation. 1. Utilize feeds and speeds charts to customize G-Code for the operation at hand 2. Explore and properly utilize machine hardware and software to set up workpieces on the machine 3. Create a part for a specified purpose with Gantry CNC machine b. Analyze the components of a laser engraver/cutter machine and their uses. 1. Utilize manufacturer recommendations to create proper cutting specifications for various operations. 2. Research and communicate the difference between raster and vector operations and when to use each. 3. Create an item with laser engraver/cutter.
3. Use additive machining methods to create objects that serve a specific purpose. a. Research and analyze the components of various types of 3D printers and their operation to include: • Electronic beam melting • Fused deposition modeling • Selective laser sintering b. Create a part using a 3D printer that serves a specific purpose. c. Explore and analyze developing additive machining technology. d. Explore the role of additive machining in food structure and advanced welding capabilities. e. Hypothesize and communicate emerging additive machines' impact on the future.
4. Evaluate and determine the most efficient manufacturing process. a. Collect, organize, and interpret data to support use of a suitable manufacturing process for the part at hand to include trade-offs. b. Reevaluate previous designs using sustainable methodologies.

Enrichment: Research emergent processes and materials in order to develop sustainable approaches that include uses for new materials.

FCI = full course integration
CR = career readiness practice
National and state standard alignments for Unit 10: ITEEA, NAEP, P21, MS CCRS-ELA, MS CCRS-Math, ISTE NETS-S

Unit 11: Advanced Robotics

Competencies and Suggested Objectives

1. Develop autonomous and manual control robotics systems that solve a competitive challenge with student teams that include the following elements:

a. Develop and/or use a complex model that allows for manipulation and testing of a proposed process or system using advanced programming languages and concepts to include:

- Boolean Logic
- Digital Inputs and Outputs
- Analog Inputs and Outputs
- Remote Control vs Autonomous
- Timers
- Servos
- Encoders
- Thresholds
- Contact and Non-Contact Sensors
- Subroutines, Loops, and Counters
- Switch Cases
- While Loops
- If - Else Statements
- Variables
- Global Variables
- Manipulators and end effectors
- Communication and collaboration
- Portfolio documentation, including well documented engineering design process

2. Use the engineering design process to solve real-world challenges with robotics.

a. Employ the engineering design process to develop an autonomous system that solves or simulates a real-world challenge using conveyors and mechanical drives while utilizing the following:

- Advanced programming languages (typically C/C++ or PLC)
- Communication and collaboration
- Manipulators
- Portfolio documentation
- Sensory feedback
- Subroutines

3. Ask questions to determine the relationships between Programmable Logic Controllers (PLCs) and autonomous robotics systems to include:

- AND Logic
- Examining Input/Output Relationships
- Latching and Unlatching Outputs
- NOT Logic
- OR Logic
- PLC Monitoring Tools
- Project: Controlling a Sorting System
- Timer On Delay and Timer Off Delay
- Writing and Simulating a Basic Ladder Diagram

Enrichment/Optional: Explore practical applications of kinematic pairs, cam and follower, and linkages

SP = comprise essential elements of student portfolios
CR = career readiness practice
IC = tied to industry certification
National and state standard alignments for Unit 11: ITEEA, NAEP, P21, MS CCRS-ELA, MS CCRS-Math, ISTE NETS-S

Unit 12: Electrical Systems

Competencies and Suggested Objectives

1. Examine electrical systems in engineering. PHY.5.1, PHY.5.2, PHY.5.5
   a. Safely demonstrate the law of electrical charges
   b. Describe the process of manipulating electrical charges to produce a difference of electrical potential (process to produce voltage)
   c. Compare and contrast the makeup of electrical conductors and insulators
   d. Differentiate between electrical voltage and current
   e. Research and communicate variables that allow a material to exhibit properties of electrical resistance
   e. Identify electrical properties of a semiconductor material
   f. Research and communicate real-world examples of relationships between magnetism and electricity
   g. Develop, revise, or use a model based on evidence to predict the relationships between alternating and direct current circuits

2. Examine principles of electrical circuits. PHY.5.4, PHY.5.6, PHY.5.7, PHY.5.8
   a. Develop a model to explain the three parts that make up a simple electrical circuit. (source, path, load)
   b. Differentiate between continuity and open circuit conditions
   c. Using the Institute of Electrical and Electronics Engineers (IEEE STD 315-1975,reaffirmed1993) standards, identify standard schematic symbols for:
      - A/C source
      - Ammeter
      - Battery (D/C)
      - Bulb (lamp)
      - Capacitor
      - Circuit ground (power ground – common)
      - Conductor (connected and unconnected)
      - Diode
      - Fixed resistor
      - Light emitting diode
      - Motor
      - N.O. pushbutton switch
      - Potentiometer
      - SPST switch
      - Transformer
      - Volt meter

3. Apply principles of electricity to evaluate circuit operation for series and parallel circuits. PHY.5.3, PHY.5.9

a. Apply Ohms Law to solve for circuit parameters for voltage, current, and resistance
b. Analyze a circuit diagram for a voltage divider circuit with two loads in series in order to solve for volts, amperes, ohms, and watts
c. Interpret a circuit diagram in order to fabricate a current divider circuit with two loads in parallel to include breadboard circuit exercises
d. Apply Watts Law to solve for circuit parameters of voltage, current, and power
e. Produce a written table to demonstrate relationships of volts, amperes, and ohms
f. Utilize Kirchhoff's Laws to solve for an unspecified circuit voltage or current

4. Examine operation of digital electronic circuits
a. Research and communicate the differences between decimal and binary number systems and appropriate uses for each
b. Contrast digital signals and analog signal characteristics
c. Justify principal advantages of using digital circuits (memory, programmability)

Enrichment: Develop hypotheses regarding future developments in technology based on research.

Enrichment: Operate the digital multi-meter to measure circuit electrical parameters of V, I, or R.
a. Demonstrate proper meter setup for specified measurements.
b. Apply appropriate safety practices and precautions to multi-meter use in various applications including OSHA standard familiarity related to electrical systems.

CR = career readiness practice
National and state standard alignments for Unit 12: ITEEA, NAEP, P21, MS CCRS-ELA, MS CCRS-Math, ISTE NETS-S, MS CCRS-Physics

Unit 13: Fluid Power Systems

Competencies and Suggested Objectives
1. Examine fluid power systems in engineering. a. Examine how Pascal's laws are applied in fluid systems b. Explain what the measurement unit psi is describing c. Calculate force output when given incoming pressure and piston diameter (F = PA) d. Investigate industrial applications in order to communicate differences between pneumatics and hydraulic devices and functions e. Collect and organize data using tables, graphs, or digital tools to show industrial uses for pneumatic hardware components (e.g. air powered tools, industrial actuators, vacuum generators) f. Use mathematical representations to explain absolute pressure and gauge pressure.
2. Identify components of a typical hydraulic system to include the following cylinder types and associated elements: • single-acting type • double-acting type • control valves • filters • hoses • hydraulic fluid • pumps • tanks
3. Demonstrate how pressure differences are related to force. a. Fabricate a simple hydraulic apparatus to demonstrate the force ratio multiplier advantage of a hydraulic system

CR = career readiness practice
National and state standard alignments for Unit 13: ITEEA, NAEP, P21, MS CCRS-ELA, MS CCRS-Math, ISTE NETS-S

Unit 14: Thermal Systems

Competencies and Suggested Objectives
1. Investigate and summarize the principles of thermodynamics. a. Analyze and interpret various historical real-world scenarios where proper understanding of the following concepts were of central importance: b. Kinetic theory of gasses c. Kinetic theory of matter d. Temperature e. Differentiate between heat and temperature f. Describe how the following three modes of heat transfer are important in civil and electrical engineering: • Conduction • Convection • Radiation g. Construct an explanation of observed relationships between variables by applying scientific reasoning to communicate how heat affects phase changes of water
2. Examine thermal systems in engineering. PHY.3.6, PHY.3.7 a. Apply the laws of thermodynamics to analyses of heat engines and refrigerators b. Investigate thermal efficiency in Carnot engines c. Develop, revise, and/or use a model based on evidence to demonstrate thermal conductivity of materials d. Use mathematical concepts and arguments to test and compare proposed solutions to problems involving specific heat and heat capacity 3. Demonstrate knowledge of energy efficiency concepts in modern buildings. a. Design an energy efficient home using modes of heat transfer and laws of thermodynamics

CR = career readiness practice
National and state standard alignments for Unit 14: ITEEA, NAEP, P21, MS CCRS ELA, MS CCRS Math, ISTE NETS S, MS CCRS Physics

Unit 15: Capstone

Competencies and Suggested Objectives

1. Using digital and/or traditional fabrication methods, apply the engineering design process to solve a student-selected, real-world problem (individual, small group, or whole class).
PHY.1.3, PHY.1.6, PHY.2.1, PHY.2.2, PHY.2.3, PHY.2.4, PHY.2.5, PHY.2.6, PHY.2.7, PHY.2.8, PHY.3.11

   a. Research an area of interest or problem that can be developed into an appropriate and manageable project
   b. Use a highly iterative design process including freehand sketching/drawing and/or a CAD program to design, test, or simulate, and assemble models for the project
   c. Apply numerical problem solving techniques and physical calculations whenever appropriate to aide in development of the project
   d. Using appropriate tools and materials, create a physical or digital product or prototype while considering trade-offs (e.g. safety, cost, reliability, aesthetics, maintenance) and craftsmanship
   e. Analyze the potential social and environmental impacts of the developed product or solution at various scales
   f. Develop the project in a way that can easily be shared with others so that they can retrace steps and build on successes
   g. Demonstrate effective interpersonal communication skills in a team setting

2. Present and justify a final capstone project to a jury.
   a. Produce professional quality technical documents with the following elements (Based on NASA BEST Engineering Design Process):
      - Problem Definition
      - Brainstorming Documentation
      - Project Plan and Specifications
      - Project Design and Methods
      - Project Results
      - Conclusion and Future Work
   b. Present project elements in a professional manner using appropriate technology to a jury of peers, teachers, school administrators, and/or community stakeholders
   c. Collect the following work materials in a portfolio to demonstrate proper use of the design process to include:
      - project goals
      - pertinent research findings
      - sketches
      - CAD drawings
      - prototypes (or images of prototypes)
      - working diagrams
      - product specifications and analysis
      - testing methodology and results
      - technical writing samples

3. Exhibit or present the project in a public setting (e.g. Maker Fair, school fair, school board meeting, community STEM/STEAM night, or online).

Enrichment:

1. Augment the capstone project by crossing curricular boundaries, integrating one or more Maker-style domains:

- Architecture
- ArtBots
- Construction
- Deconstruction and repair or repurposing/tinkering
- Energy/Electricity (e.g. alternative energy)
- Flight
- Farming/gardening/food production
- Food and culinary arts
- Launching/propulsion (rockets and projectiles)
- Light and circuits (e.g. LED and electroluminescent wire)
- Materials and their life cycles (i.e. material origins, uses, recycling, reuse, repurpose – cradle-to-cradle or cradle-to-grave)
- Mechanics
- Motors and switches (including robotics)
- Musical instruments and/or music production
- Papercraft/cardboard construction
- Programming, microcontrollers, soft circuits/wearables, and sound circuits
- Sensors and robots (sensing and interactions)
- Smart home technologies and IoT
- Textiles
- Vehicles/transportation (e.g. bicycles)
- Water
- Woodworking/carpentry and metal fabrication

2. Participate in a work study or job shadowing experience

a. Work under the guidance of the Engineering instructor and the sponsoring engineer
b. Display effective interpersonal skills
c. Exercise tact, discretion, and confidentiality
d. Observe and record the engineers' work environment, tasks, and procedures
e. Complete tasks assigned by the engineer

SP = comprise essential elements of student portfolios
CR = career readiness practice
National and state standard alignments for Unit 15: ITEEA, NAEP, P21, MS CCRS ELA, ISTE NETS-S, MS CCRS Physics

Student Competency Checklist

Student Name: _____

This record is intended to serve as a method of noting student achievement of the competencies in each unit. It can be duplicated for each student, and it can serve as a cumulative record of competencies achieved in the course.

In the blank before each competency, place the date on which the student mastered the competency.

Unit 1 – 7: Curriculum/content for Units 1 – 7 can be found in the year 1 or core document.		
Unit 8: Safety Review		
	1.	Identify course expectations, school policies, and program policies related to this course.
	2.	Utilize proper safety procedures in a laboratory setting.
Unit 9: Advanced Computer Aided Design		
	1.	Use CAD analysis tools to manipulate variables and collect data to formulate decisions about prototypes or design solutions.
	2.	Demonstrate proficiency in CAD software simulations.
	3.	Incorporate sustainable methodologies.
Unit 10: Modern Manufacturing Systems		
	1.	Use Computer Assisted Machining (CAM) software to create G-code from a CAD model.
	2.	Use subtractive machining methods to create objects that serve a specific purpose.
	3.	Use additive machining methods to create objects that serve a specific purpose.
	4.	Evaluate and determine the most efficient manufacturing process.
Unit 11. Advanced Robotics		
	1.	Develop autonomous and manual control robotics systems that solve a competitive challenge with student teams that include the following elements.
	2.	Use the engineering design process to solve real-world challenges with robotics.
	3.	Ask questions to determine the relationships between Programmable Logic Controllers (PLCs) and which autonomous robotics systems to include.
Unit 12: Electrical Systems		
	1.	Examine electrical systems in engineering.
	2.	Examine principles of electrical circuits.
	3.	Apply principles of electricity to evaluate circuit operation for series and parallel circuits.
	4.	Examine operation of digital electronic circuits.
Unit 13: Fluid Power Systems		
	1.	Examine fluid power systems in engineering.

	2.	Identify components of a typical hydraulic system to include the following cylinder types and associated elements.
	3.	Demonstrate how pressure differences are related to force.
Unit 14. Thermal Systems		
	1.	Investigate and summarize the principles of thermodynamics.
	2.	Examine thermal systems in engineering.
	3.	Demonstrate knowledge of energy efficiency concepts in modern buildings.
Unit 15: Capstone		
	1.	Using digital and/or traditional fabrication methods, apply the engineering design process to solve a student-selected, real-world problem (individual, small group, or whole class).
	2.	Present and justify a final capstone project to a jury.

Appendix A: National Standards

International Technology and Engineering Education Association (ITEEA) – Standards for Technological Literacy

	Units	Unit 8	Unit 9	Unit 10	Unit 11	Unit 12	Unit 13	Unit 14	Unit 15
Standards for Technological Literacy									
STL1			x	x	x	x	x	x	x
STL2			x	x	x	x	x	x	x
STL3		x	x	x	x	x	x	x	
STL4					x				
STL5		x	x	x	x	x	x	x	
STL6		x	x	x	x	x	x	x	
STL7									
STL8								x	x
STL9				x	x	x	x	x	x
STL10		x	x	x	x	x	x	x	x
STL11									x
STL12		x	x	x	x	x	x	x	x
STL13		x	x	x	x	x	x	x	
STL14							x		
STL15					x		x		
STL16		x		x	x		x		
STL17			x					x	x
STL18						x			
STL19		x		x		x		x	
STL20					x	x			

International Technology and Engineering Education Association (ITEEA) – Standards for Technological Literacy

STL1 Students will develop an understanding of the characteristics and scope of technology.
STL2 Students will develop an understanding of the core concepts of technology.
STL3 Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.
STL4 Students will develop an understanding of the cultural, social, economic, and political effects of technology.
STL5 Students will develop an understanding of the effects of technology on the environment.
STL6 Students will develop an understanding of the role of society in the development of and use of technology.
STL7 Students will develop an understanding of the influence of technology on history.
STL8 Students will develop an understanding of the attributes of design.
STL9 Students will develop an understanding of engineering design.
STL10 Students will develop an understanding of the role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving.
STL11 Students will develop the abilities to apply the design process.

~~STL12 Students will develop the abilities to use and maintain technological products and systems.~~
~~STL13 Students will develop the abilities to assess the impact of products and systems.~~
~~STL14 Students will develop an understanding of and be able to select and use medical technologies.~~
~~STL15 Students will develop an understanding of and be able to select and use agricultural and related biotechnologies.~~
~~STL16 Students will develop an understanding of and be able to select and use energy and power technologies.~~
~~STL17 Students will develop an understanding of and be able to select and use information and communication technologies.~~
~~STL18 Students will develop an understanding of and be able to select and use transportation technologies.~~
~~STL19 Students will develop an understanding of and be able to select and use manufacturing technologies.~~
~~STL20 Students will develop an understanding of and be able to select and use construction technologies.~~

NAEP Standard	Unit 8	Unit 9	Unit 10	Unit 11	Unit 12	Unit 13	Unit 14	Unit 15
T.12.1			X	X				X
T.12.2			X	X				X
T.12.3			X	X				X
T.12.4			X	X				X
T.12.5			X	X				X
T.12.6			X	X				X
T.12.7			X	X				X
T.12.8			X	X				X
T.12.9			X	X				X
T.12.10			X	X				X
T.12.11			X	X				X
T.12.12			X	X				X
T.12.13			X	X				X
T.12.14			X	X				X
T.12.15			X	X				X
D.12.1		X	X	X	X		X	X
D.12.2		X	X	X	X		X	X
D.12.3		X	X	X	X		X	X
D.12.4		X	X	X	X		X	X
D.12.5		X	X	X	X		X	X
D.12.6		X	X	X	X		X	X
D.12.7		X	X	X	X		X	X
D.12.8		X	X	X	X		X	X
D.12.9		X	X	X	X		X	X
D.12.10		X	X	X	X		X	X
D.12.11		X	X	X	X		X	X
D.12.12		X	X	X	X		X	X
D.12.13		X	X	X	X		X	X
D.12.14		X	X	X	X		X	X
D.12.15		X	X	X	X		X	X
D.12.16		X	X	X	X		X	X
D.12.17		X	X	X	X		X	X
D.12.18		X	X	X	X		X	X
D.12.19		X	X	X	X		X	X
I.12.1	X	X		X	X	X	X	X
I.12.2	X	X		X	X	X	X	X
I.12.3	X	X		X	X	X	X	X
I.12.4		X		X	X	X	X	X
I.12.5		X		X	X	X	X	X
I.12.6		X		X	X	X	X	X
I.12.7		X		X	X	X	X	X
I.12.8		X		X	X	X	X	X
I.12.9		X		X	X	X	X	X
I.12.10	X	X		X	X	X	X	X
I.12.11	X	X		X	X	X	X	X
I.12.12		X		X	X	X	X	X
I.12.13		X		X	X	X	X	X

Students know that:

T.12.1: The decision to develop a new technology is influenced by societal opinions and demands. These driving forces differ from culture to culture.

T.12.2: Changes caused by the introduction and use of a new technology can range from gradual to rapid and from subtle to obvious and can change over time. These changes may vary from society to society as a result of differences in a society's economy, politics, and culture.

Students are able to:

T.12.3: Choose an appropriate technology to help solve a given societal problem, and justify the selection based on an analysis of criteria and constraints, available resources, likely trade-offs, and relevant environmental and cultural concerns.

T.12.4: Analyze cultural, social, economic, or political changes (separately or together) that may be triggered by the transfer of a specific technology from one society to another. Include both anticipated and unanticipated effects.

Students know that:

T.12.5: Many technologies have been designed to have a positive impact on the environment and to monitor environmental change over time to provide evidence for making informed decisions.

T.12.6: Development and modification of any technological system needs to take into account how the operation of the system will affect natural resources and ecosystems.

Students are able to:

T.12.7: Identify a complex global environmental issue, develop a systematic plan of investigation, and propose an innovative sustainable solution.

Students know that:

T.12.8: Information technology allows access to vast quantities of data, expertise, and knowledge through a wide array of devices and formats to answer questions, solve problems, and inform the decision-making process.

T.12.9: Information technologies such as artificial intelligence, image enhancement and analysis, and sophisticated computer modeling and simulation, create new types of information that may have profound effects on society. These new types of information must be evaluated carefully.

T.12.10: The development of communication technologies that enable people to access vast quantities of information and publish their ideas globally has implications for governments, organizations, and individuals.

Students are able to:

T.12.11: Give examples to illustrate the effects on society of the recording, distribution, and access to information and knowledge that have occurred in history, and discuss the effects of those revolutions on societal change.

Students know that:

T.12.12: Decisions made about the use of a technology may have intended and unintended consequences, and these consequences may be different for different groups of people and may change over time. Decisions about the use of a technology should consider different points of view.

T.12.13: Disparities in the technologies available to different groups of people have consequences for public health and prosperity, but deciding whether to introduce a new technology should consider local resources and the role of culture in acceptance of the new technology.

Students are able to:

T.12.14: Analyze responsibilities of different individuals and groups, ranging from citizens and entrepreneurs to political and government officials, with respect to a controversial technological issue.

T.12.15: Demonstrate the responsible and ethical use of information and communication technologies by distinguishing between kinds of information that should and should not be publicly shared and describing the consequences of a poor decision.

Students know that:

D.12.1: Advances in science have been applied by engineers to design new products, processes, and systems, while improvements in technology have enabled breakthroughs in scientific knowledge.

D.12.2: Engineers use science, mathematics, and other disciplines to improve technology, while scientists use tools devised by engineers to advance knowledge in their disciplines. This interaction has deepened over the past century.

D.12.3: The evolution of tools, materials, and processes has played an essential role in the development and advancement of civilization, from the establishment of cities and industrial societies to today's global trade and commerce networks.

Students are able to:

D.12.4: Take into account trade-offs among several factors when selecting a material for a given application.

D.12.5: Design a new tool to accomplish a task more efficiently.

Students know that:

D.12.6: Engineering design is a complicated process in which creative steps are embedded in content knowledge and research on the challenge. Decisions on trade-offs involve systematic comparisons of all costs and benefits, and final steps may involve redesigning for optimization.

D.12.7: Specifications involve criteria, which may be weighted in various ways, and constraints, which can include natural laws and available technologies. Evaluation is a process for determining how well a solution meets the requirements.

Students are able to:

D.12.8: Meet a sophisticated design challenge by identifying criteria and constraints, predicting how these will affect the solution, researching and generating ideas, and using trade-offs to balance competing values in selecting the best solution.

D.12.9: Construct and test several models to see if they meet the requirements of a problem. Combine features to achieve the best solution.

D.12.10: Communicate the entire design process from problem definition to evaluation of the final design, taking into account relevant criteria and constraints, including aesthetic and ethical considerations as well as purely logical decisions.

Students know that:

D.12.11: The stability of a system depends on all of its components and how they are connected, with more complicated systems tending to require more energy and to be more vulnerable to error and failure. Negative feedback loops tend to increase the stability and efficiency of systems.

D.12.12: Technological systems are embedded within larger technological, social, natural, and environmental systems.

Students are able to:

D.12.13: Examine a system to predict how it will perform with a given set of inputs in a given situation and how performance will change if the components or interactions of the system are changed.

D.12.14: Redesign a complex machine by modifying or rearranging its subsystems in order to optimize its efficiency.

D.12.15: Construct and test a manufacturing system composed of several machines to accomplish a given goal. Redesign the system to optimize its efficiency.

Students know that:

D.12.16: Products and structures of various kinds can be redesigned to eliminate frequent malfunctions and reduce the need for regular maintenance.

Students are able to:

D.12.17: Analyze a system malfunction using logical reasoning (such as a fault tree) and appropriate diagnostic tools and instruments. Devise strategies and recommend tools for fixing the problem.

D.12.18: Analyze a complicated system to identify ways that it might fail in the future. Identify the most likely failure points and recommend safeguards to avoid future failures.

D.12.19: Taking into account costs and current trends in technology, identify how long a product should be maintained and repaired and how it might be redesigned to lessen negative environmental impacts.

Students know that:

I.12.1: Effective collaboration requires careful selection of team members, monitoring of progress, strategies for reaching agreement when there are opposing points of view, and iterative improvement of collaborative processes. Information and communication technologies can be used to record and share different viewpoints and to collect and tabulate the views of groups of people.

Students are able to:

I.12.2: Work through a simulation of a collaborative process. Negotiate team roles and resources, draw upon the expertise and strengths of other team members and remote experts, monitor progress toward goals, and reflect on and refine team processes for achieving goals.

I.12.3: Synthesize input from multiple sources to communicate ideas to a variety of audiences using various media, genres, and formats.

Students know that:

I.12.4: Advanced search techniques can be used with digital and network tools and media resources to locate information and to check the credibility and expertise of sources.

Students are able to:

I.12.5: Select digital and network tools and media resources to gather information and data on a practical task, and justify choices based on the tools' efficiency and effectiveness for a given purpose.

I.12.6: Search media and digital resources on a community or world issue and evaluate the timeliness and accuracy of the information as well as the credibility of the source.

Students are able to:

I.12.7: Use digital tools and resources to identify a complicated global issue and develop a systematic plan of investigation. Present findings in terms of pros and cons of two or more innovative sustainable solutions.

I.12.8: Use digital tools to collect, analyze, and display data in order to design and conduct complicated investigations in various subject areas. Explain rationale for the design and justify conclusions based on observed patterns in the data.

I.12.9: Having conducted a simulation of a system using a digital model, draw conclusions about the system, or propose possible solutions to a problem or ways to reach a goal based on outcomes of the simulation. Critique the conclusions based on the adequacy of the model.

Students know that:

I.12.10: Legal requirements governing the use of copyrighted information and ethical guidelines for appropriate citations are intended to protect intellectual property.

~~**Students are able to:**~~

~~**I.12.11:** Identify or provide examples of responsible and ethical behavior that follow the letter and spirit of current laws concerning personal and commercial uses of copyrighted material as well as accepted ethical practices when using verbatim quotes, images, or ideas generated by others.~~

~~**Students know that:**~~

~~**I.12.12:** A variety of digital tools exist for a given purpose. The tools differ in features, capacities, operating modes, and style. Knowledge about many different ICT tools is helpful in selecting the best tool for a given task.~~

~~**Students are able to:**~~

~~**I.12.13:** Demonstrate the capability to use a variety of digital tools to accomplish a task or develop a solution for a practical problem. Justify the choice of tools, explain why other tools were not used based on specific features of the tools, and summarize the results.~~

Appendix B: 21st Century Skills[1]

	Unit 8	Unit 9	Unit 10	Unit 11	Unit 12	Unit 13	Unit 14	Unit 15
21st Century Standards								
CS1							x	x
CS2			x					x
CS3								
CS4								
CS5		x	x				x	x
CS6		x	x	x	x	x	x	x
CS7	x	x	x	x	x	x	x	x
CS8	x	x	x	x	x	x	x	x
CS9	x	x	x	x	x	x	x	x
CS10							x	x
CS11	x	x	x	x	x	x	x	x
CS12		x	x	x	x	x	x	x
CS13	x	x	x	x	x	x	x	x
CS14	x	x	x	x	x	x	x	x
CS15	x	x	x	x	x	x	x	x
CS16		x	x	x	x	x	x	x

CSS1 21st Century Themes

CS1 Global Awareness

1. Using 21st century skills to understand and address global issues
2. Learning from and working collaboratively with individuals representing diverse cultures, religions, and lifestyles in a spirit of mutual respect and open dialogue in personal, work, and community contexts
3. Understanding other nations and cultures, including the use of non-English languages

CS2 Financial, Economic, Business, and Entrepreneurial Literacy

1. Knowing how to make appropriate personal economic choices
2. Understanding the role of the economy in society
3. Using entrepreneurial skills to enhance workplace productivity and career options

CS3 Civic Literacy

1. Participating effectively in civic life through knowing how to stay informed and understanding governmental processes
2. Exercising the rights and obligations of citizenship at local, state, national, and global levels
3. Understanding the local and global implications of civic decisions

CS4 Health Literacy

[1] *21st century skills.* (n.d.). Washington, DC: Partnership for 21st Century Skills.

1. Obtaining, interpreting, and understanding basic health information and services and using such information and services in ways that enhance health
2. Understanding preventive physical and mental health measures, including proper diet, nutrition, exercise, risk avoidance, and stress reduction
3. Using available information to make appropriate health-related decisions
4. Establishing and monitoring personal and family health goals
5. Understanding national and international public health and safety issues

CS5 Environmental Literacy

1. Demonstrate knowledge and understanding of the environment and the circumstances and conditions affecting it, particularly as relates to air, climate, land, food, energy, water, and ecosystems.
2. Demonstrate knowledge and understanding of society's impact on the natural world (e.g., population growth, population development, resource consumption rate, etc.).
3. Investigate and analyze environmental issues, and make accurate conclusions about effective solutions.
4. Take individual and collective action toward addressing environmental challenges (e.g., participating in global actions, designing solutions that inspire action on environmental issues).

CSS2 Learning and Innovation Skills

CS6 Creativity and Innovation

1. Think Creatively
2. Work Creatively with Others
3. Implement Innovations

CS7 Critical Thinking and Problem Solving

1. Reason Effectively
2. Use Systems Thinking
3. Make Judgments and Decisions
4. Solve Problems

CS8 Communication and Collaboration

1. Communicate Clearly
2. Collaborate with Others

CSS3 Information, Media and Technology Skills

CS9 Information Literacy

1. Access and Evaluate Information
2. Use and Manage Information

CS10 Media Literacy

1. Analyze Media
2. Create Media Products

CS11 ICT Literacy

1. Apply Technology Effectively

CSS4 Life and Career Skills

CS12 Flexibility and Adaptability

1. Adapt to change
2. Be Flexible

CS13 Initiative and Self-Direction

1. Manage Goals and Time
2. Work Independently
3. Be Self-directed Learners

CS14 Social and Cross-Cultural Skills

1. Interact Effectively with others
2. Work Effectively in Diverse Teams

CS15 Productivity and Accountability

1. Manage Projects
2. Produce Results

CS16 Leadership and Responsibility

1. Guide and Lead Others

Appendix C: College and Career Readiness Standards

College and Career Readiness Standards for English Language Arts

	Unit 8	Unit 9	Unit 10	Unit 11	Unit 12	Unit 13	Unit 14	Unit 15
Standards								
RL.11.1	x							x
RL.11.2	x							x
RL.11.4	x							x
RI.11.1	x			x				x
RI.11.2	x			x				x
RI.11.3	x			x				x
RI.11.4	x		x	x	x	x	x	x
RI.11.7	x							
W.11.1								x
W.11.2								x
W.11.3								x
W.11.4								x
W.11.6								x
W.11.7			x	x	x	x	x	x
W11.8								x
W.11.9								x
W.11.10								x
SL.11.1				x				x
SL.11.2								x
SL.11.3								x

SL.11.4								
SL.11.5								x
SL.11.6								x
L.11.1								x
L.11.2								x
L.11.3								x
L.11.4	x	x	x	x	x	x	x	x
L.11.5	x	x	x	x	x	x	x	x
L.11.6	x	x	x	x	x	x	x	x
RH.11.1								x
RH.11.2								x
RH.11.3								x
RH.11.4	x	x	x	x	x	x	x	x
RH.11.5	x	x	x	x	x	x	x	x
RH.11.6								x
RH.11.7								x
RH.11.8								x
RH.11.9								x
RST.11.1	x	x	x	x	x	x	x	x
RST.11.2	x	x	x	x	x	x	x	x
RST.11.3	x	x	x	x	x	x	x	x
RST.11.4	x	x	x	x	x	x	x	x
RST.11.5	x	x	x	x	x	x	x	x
RST.11.6	x	x	x	x	x	x	x	x
RST.11.7	x	x	x	x	x	x	x	x
RST.11.8	x	x	x	x	x	x	x	x
RST.11.9	x	x	x	x	x	x	x	x
RST.11.10	x	x	x	x	x	x	x	x
WHST.11.1								x
WHST.11.2								x
WHST.11.4								x
WHST.11.5								x

WHST.11.6								x
WHST.11.7				x	x	x	x	x
WHST.11.8								x
WHST.11.9								x
WHST.11.10	x	x	x	x	x	x	x	x

Reading Standards for Literature (11-12)
College and Career Readiness Anchor Standards for *Reading Literature*
Key Ideas and Details

RL.11.1. Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text, including determining where the text leaves matters uncertain.

RL.11.2. Determine two or more themes or central ideas of a text and analyze their development over the course of the text, including how they interact and build on one another to produce a complex account; provide an objective summary of the text.

RL.11.3. Analyze the impact of the author's choices regarding how to develop and relate elements of a story or drama (e.g., where a story is set, how the action is ordered, how the characters are introduced and developed).

Craft and Structure

RL.11.4. Determine the meaning of words and phrases as they are used in the text, including figurative and connotative meanings; analyze the impact of specific word choices on meaning and tone, including words with multiple meanings or language that is particularly fresh, engaging, or beautiful. (Include Shakespeare as well as other authors.)

RL.11.5. Analyze how an author's choices concerning how to structure specific parts of a text (e.g., the choice of where to begin or end a story, the choice to provide a comedic or tragic resolution) contribute to its overall structure and meaning as well as its aesthetic impact.

RL.11.6. Analyze a case in which grasping point of view requires distinguishing what is directly stated in a text from what is really meant (e.g., satire, sarcasm, irony, or understatement).

Integration of Knowledge and Ideas

RL.11.7. Analyze multiple interpretations of a story, drama, or poem (e.g., recorded or live production of a play or recorded novel or poetry), evaluating how each version interprets the source text. (Include at least one play by Shakespeare and one play by an American dramatist.)

RL.11.8. (Not applicable to literature)

RL.11.9. Demonstrate knowledge of eighteenth-, nineteenth- and early-twentieth-century foundational works of American literature, including how two or more texts from the same period treat similar themes or topics.

Range of Reading and Level of Text Complexity

RL.11.10. By the end of grade 11, read and comprehend literature, including stories, dramas, and poems, in the grades 11–CCR text complexity band proficiently, with scaffolding as needed at the high end of the range.
By the end of grade 12, read and comprehend literature, including stories, dramas, and poems, at the high end of the grades 11–CCR text complexity band independently and proficiently.

Reading Standards for Informational Text (11-12)
College and Career Readiness Anchor Standards for *Informational Text*

Key Ideas and Details

RI.11.1. Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text, including determining where the text leaves matters uncertain.

RI.11.2. Determine two or more central ideas of a text and analyze their development over the course of the text, including how they interact and build on one another to provide a complex analysis; provide an objective summary of the text.

RI.11.3. Analyze a complex set of ideas or sequence of events and explain how specific individuals, ideas, or events interact and develop over the course of the text.

Craft and Structure

RI.11.4. Determine the meaning of words and phrases as they are used in a text, including figurative, connotative, and technical meanings; analyze how an author uses and refines the meaning of a key term or terms over the course of a text (e.g., how Madison defines faction in Federalist No. 10).

RI.11.5. Analyze and evaluate the effectiveness of the structure an author uses in his or her exposition or argument, including whether the structure makes points clear, convincing, and engaging.

RI.11.6. Determine an author's point of view or purpose in a text in which the rhetoric is particularly effective, analyzing how style and content contribute to the power, persuasiveness, or beauty of the text.

Integration of Knowledge and Ideas

RI.11.7. Integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a question or solve a problem.

RI.11.8. Delineate and evaluate the reasoning in seminal U.S. texts, including the application of constitutional principles and use of legal reasoning (e.g., in U.S. Supreme Court majority opinions and dissents) and the premises, purposes, and arguments in works of public advocacy

(e.g., The Federalist, presidential addresses).

RI.11.9. Analyze seventeenth-, eighteenth-, and nineteenth-century foundational U.S. documents of historical and literary significance (including The Declaration of Independence, the Preamble to the Constitution, the Bill of Rights, and Lincoln's Second Inaugural Address) for their themes, purposes, and rhetorical features.

Range of Reading and Level of Text Complexity

RI.11.10. By the end of grade 11, read and comprehend literary nonfiction in the grades 11–CCR text complexity band proficiently, with scaffolding as needed at the high end of the range.

By the end of grade 12, read and comprehend literary nonfiction at the high end of the grades 11–CCR text complexity band independently and proficiently.

College and Career Readiness Anchor Standards for *Writing*

Text Types and Purposes

W.11.1. Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

a. Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences claim(s), counterclaims, reasons, and evidence.

b. Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant evidence for each while pointing out the strengths and limitations of both in a manner that anticipates the audience's knowledge level, concerns, values, and possible biases.

c. Use words, phrases, and clauses as well as varied syntax to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims.

d. Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

e. Provide a concluding statement or section that follows from and supports the argument presented.

W.11.2. Write informative/explanatory texts to examine and convey complex ideas, concepts, and information clearly and accurately through the effective selection, organization, and analysis of content.

a. Introduce a topic; organize complex ideas, concepts, and information so that each new element builds on that which precedes it to create a unified whole; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

b. Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the

audience's knowledge of the topic.

c. Use appropriate and varied transitions and syntax to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts.

d. Use precise language, domain-specific vocabulary, and techniques such as metaphor, simile, and analogy to manage the complexity of the topic.

e. Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

f. Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).

W.11.3. Write narratives to develop real or imagined experiences or events using effective technique, well-chosen details, and well-structured event sequences.

a. Engage and orient the reader by setting out a problem, situation, or observation and its significance, establishing one or multiple point(s) of view, and introducing a narrator and/or characters; create a smooth progression of experiences or events.

b. Use narrative techniques, such as dialogue, pacing, description, reflection, and multiple plot lines, to develop experiences, events, and/or characters

c. Use a variety of techniques to sequence events so that they build on one another to create a coherent whole and build toward a particular tone and outcome (e.g., a sense of mystery, suspense, growth, or resolution).

d. Use precise words and phrases, telling details, and sensory language to convey a vivid picture of the experiences, events, setting, and/or characters.

e. Provide a conclusion that follows from and reflects on what is experienced, observed, or resolved over the course of the narrative.

Production and Distribution of Writing

W.11.4. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)

W.11.5. Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (Editing for conventions should demonstrate command of Language standards 1–3 up to and including grades 11–12 on page 54.)

W.11.6. Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.

Research to Build and Present Knowledge

W.11.7. Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

W.11.8. Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.

W.11.9. Draw evidence from literary or informational texts to support analysis, reflection, and research.

a. Apply grades 11–12 Reading standards to literature (e.g., "Demonstrate knowledge of eighteenth-, nineteenth- and early-twentieth-century foundational works of American literature, including how two or more texts from the same period treat similar themes or topics").

b. Apply grades 11–12 Reading standards to literary nonfiction (e.g., "Delineate and evaluate the reasoning in seminal U.S. texts, including the application of constitutional principles and use of legal reasoning [e.g., in U.S. Supreme Court Case majority opinions and dissents] and the premises, purposes, and arguments in works of public advocacy [e.g., The Federalist, presidential addresses]").

Range of Writing

W.11.10. Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

College and Career Readiness Anchor Standards for *Speaking and Listening*

Comprehension and Collaboration

SL.11.1. Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 11–12 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

a. Come to discussions prepared, having read and researched material under study; explicitly draw on that preparation by referring to evidence from texts and other research on the topic or issue to stimulate a thoughtful, well-reasoned exchange of ideas.

b. Work with peers to promote civil, democratic discussions and decision-making, set clear goals and deadlines, and establish individual roles as needed.

c. Propel conversations by posing and responding to questions that probe reasoning and evidence; ensure a hearing for a full range of positions on a topic or issue; clarify, verify, or

challenge ideas and conclusions; and promote divergent and creative perspectives.

d. Respond thoughtfully to diverse perspectives; synthesize comments, claims, and evidence made on all sides of an issue; resolve contradictions when possible; and determine what additional information or research is required to deepen the investigation or complete the task.

SL.11.2. Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data.

SL.11.3. Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric, assessing the stance, premises, links among ideas, word choice, points of emphasis, and tone used.

Presentation of Knowledge and Ideas

SL.11.4. Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks.

SL.11.5. Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

SL.11.6. Adapt speech to a variety of contexts and tasks, demonstrating a command of formal English when indicated or appropriate. (See grades 11–12 Language standards 1 and 3 on page 54 for specific expectations.)

College and Career Readiness Anchor Standards for *Language*

Conventions of Standard English

L.11.1. Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

a. Apply the understanding that usage is a matter of convention, can change over time, and is sometimes contested.

b. Resolve issues of complex or contested usage, consulting references (e.g., Merriam-Webster's Dictionary of English Usage, Garner's Modern American Usage) as needed.

L.11.2. Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

a. Observe hyphenation conventions.

b. Spell correctly.

Knowledge of Language

L.11.3. Apply knowledge of language to understand how language functions in different contexts, to make effective choices for meaning or style, and to comprehend more fully when reading or listening.

a. Vary syntax for effect, consulting references (e.g., Tufte's Artful Sentences) for guidance as needed; apply an understanding of syntax to the study of complex texts when reading.

Vocabulary Acquisition and Use

L.11.4. Determine or clarify the meaning of unknown and multiple-meaning words and phrases based on grades 11–12 reading and content, choosing flexibly from a range of strategies.

a. Use context (e.g., the overall meaning of a sentence, paragraph, or text; a word's position or function in a sentence) as a clue to the meaning of a word or phrase.

b. Identify and correctly use patterns of word changes that indicate different meanings or parts of speech (e.g., conceive, conception, conceivable).

c. Consult general and specialized reference materials (e.g., dictionaries, glossaries, thesauruses), both print and digital, to find the pronunciation of a word or determine or clarify its precise meaning, its part of speech, its etymology, or its standard usage.

d. Verify the preliminary determination of the meaning of a word or phrase (e.g., by checking the inferred meaning in context or in a dictionary).

L.11.5. Demonstrate understanding of figurative language, word relationships, and nuances in word meanings.

a. Interpret figures of speech (e.g., hyperbole, paradox) in context and analyze their role in the text.

b. Analyze nuances in the meaning of words with similar denotations.

L.11.6. Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

Reading Standards for Literacy in History/Social Studies (11–12)

Key Ideas and Details

RH.11.1 Cite specific textual evidence to support analysis of primary and secondary sources, connecting insights gained from specific details to an understanding of the text as a whole.

RH.11.2. Determine the central ideas or information of a primary or secondary source; provide an accurate summary that makes clear the relationships among the key details and ideas

RH.11.3. Evaluate various explanations for actions or events and determine which explanation best accords with textual evidence, acknowledging where the text leaves matters uncertain

Craft and Structure

RH.11.4. Determine the meaning of words and phrases as they are used in a text, including analyzing how an author uses and refines the meaning of a key term over the course of a text (e.g., how Madison defines faction in Federalist No. 10).

RH.11.5. Analyze in detail how a complex primary source is structured, including how key sentences, paragraphs, and larger portions of the text contribute to the whole.

RH.11.6. Evaluate authors' differing points of view on the same historical event or issue by assessing the
authors' claims, reasoning, and evidence.

Integration of Knowledge and Ideas

RH.11.7. Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, as well as in words) in order to address a question or solve a problem.

RH.11.8. Evaluate an author's premises, claims, and evidence by corroborating or challenging them with other information.

RH.11.9. Integrate information from diverse sources, both primary and secondary, into a coherent understanding of an idea or event, noting discrepancies among sources.

Range of Reading and Level of Text Complexity

RH.11.10. By the end of grade 12, read and comprehend history/social studies texts in the grades 11–CCR text complexity band independently and proficiently.

Reading Standards for Literacy in Science and Technical Subjects (11-12)

Key Ideas and Details

RST.11.1. Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

RST.11.2. Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

RST.11.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

Craft and Structure

RST.11.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11–12 texts and topics.

RST.11.5. Analyze how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas.

RST.11.6. Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, identifying important issues that remain unresolved.

Integration of Knowledge and Ideas

RST.11.7. Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

RST.11.8. Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

RST.11.9. Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

Range of Reading and Level of Text Complexity

RST.11.10. By the end of grade 12, read and comprehend science/technical texts in the grades 11–CCR text complexity band independently and proficiently.

Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects (11-12)

Text Types and Purposes

WHST.11.1. Write arguments focused on discipline-specific content.

a. Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence.

b. Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form that anticipates the audience's knowledge level, concerns, values, and possible biases.

c. Use words, phrases, and clauses as well as varied syntax to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and

evidence, and between claim(s) and counterclaims.

d. Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

e. Provide a concluding statement or section that follows from or supports the argument presented.

WHST.11.2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

a. Introduce a topic and organize complex ideas, concepts, and information so that each new element builds on that which precedes it to create a unified whole; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

b. Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

c. Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts.

d. Use precise language, domain-specific vocabulary and techniques such as metaphor, simile, and analogy to manage the complexity of the topic; convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers.

e. Provide a concluding statement or section that follows from and supports the information or explanation provided (e.g., articulating implications or the significance of the topic).

WHST.11.3. (Not applicable as a separate requirement)

Production and Distribution of Writing

WHST.11.4. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

WHST.11.5. Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.

WHST.11.6. Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.

Research to Build and Present Knowledge

WHST.11.7. Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when

appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

WHST.11.8. Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.

WHST.11.9. Draw evidence from informational texts to support analysis, reflection, and research.

Range of Writing

WHST.11.10. Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Mississippi College and Career Readiness Standards for Mathematics

	Units	Unit 8	Unit 9	Unit 10	Unit 11	Unit 12	Unit 13	Unit 14	Unit 15
Common Core Standards									
N-O.1.		X	X	X	X	X	X	X	
N-O.2.		X	X	X	X	X	X	X	
N-O.3.		X	X	X	X	X	X	X	
N-VM.1		X		X	X				
N-VM.2		X		X	X				
N-VM.3		X		X	X				
N-VM.4.a		X		X	X				
N-VM.4.b		X		X	X				
N-VM.4.c		X		X	X				
N-VM.5.a		X		X	X				
N-VM.5.b		X		X	X				
A-SSE.1		X		X	X	X	X	X	
A-SSE.1.a		X		X	X	X	X	X	
A-SSE.1.b		X		X	X	X	X	X	
A-SSE.2		X		X	X	X	X	X	
A-CED.1		X		X	X	X	X	X	
A-CED.2		X		X	X	X	X	X	
A-CED.4		X		X	X	X	X	X	

A-REI.1		X		X	X	X		X	
A-REI.10		X		X	X	X		X	
A-REI.11		X		X	X	X		X	
F-IF.1		X		X	X	X		X	
F-IF.6		X		X	X	X		X	
F-BF.1				X	X	X		X	
F-BF.1.c				X	X	X		X	
F-BF.4.				X	X	X		X	
F-TF.1				X	X				
F-TF.2				X	X				
F-TF.3				X	X				
F-TF.4				X	X				
G-CO.1.									
G-CO.2.		X							
G-CO.3.		X							
G-CO.4.		X							
G-CO.5.		X							
G-CO.6.		X							
G-CO.7.		X							
G-CO.8.									
G-CO.12.		X							
G-CO.13.									
G-SRT.2									
G-SRT.5				X	X				
G-SRT.6				X	X				
G-SRT.7				X	X				
G-SRT.8				X	X				
G-C.2				X	X				
G-C.4				X	X				
G-GMD.3				X	X				
G-GMD.4				X	X				
G-MG.1		X	X	X	X	X	X	X	
G-MG.2		X	X	X	X	X	X	X	
G-MG.3		X		X	X	X	X	X	
S-ID.6.a.				X	X			X	
S-ID.7				X	X			X	

S-ID.8				X	X			X	

Mathematics (High School)

Number and Quantity

The Real Number System

N-RN.1. Explain how the definition of the meaning of rational exponents follows from extending the properties of integer exponents to those values, allowing for a notation for radicals in terms of rational exponents.

N-RN.2. Rewrite expressions involving radicals and rational exponents using the properties of exponents.

N-RN.3. Explain why the sum or product of two rational numbers is rational; that the sum of a rational number and an irrational number is irrational; and that the product of a nonzero rational number and an irrational number is irrational.

Quantities

N-Q.1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N-Q.2. Define appropriate quantities for the purpose of descriptive modeling.

N-Q.3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

The Complex Number System

N-CN.1. Know there is a complex number i such that $i^2 = -1$, and every complex number has the form a + bi with a and b real.

N-CN.2. Use the relation $i^2 = -1$ and the commutative, associative, and distributive properties to add, subtract, and multiply complex numbers.

N-CN.3. (+) Find the conjugate of a complex number; use conjugates to find moduli and quotients of complex numbers.

N-CN.4. (+) Represent complex numbers on the complex plane in rectangular and polar form (including real and imaginary numbers), and explain why the rectangular and polar forms of a given complex number represent the same number.

N-CN.5. (+) Represent addition, subtraction, multiplication, and conjugation of complex numbers geometrically on the complex plane; use properties of this representation for computation. For example, $(-1 + \sqrt{3}\, i)^3 = 8$ because $(-1 + \sqrt{3}\, i)$ has modulus 2 and argument 120°.

N-CN.6. (+) Calculate the distance between numbers in the complex plane as the modulus of the difference, and the midpoint of a segment as the average of the numbers at its endpoints.

N-CN.7. Solve quadratic equations with real coefficients that have complex solutions.

N-CN.8. (+) Extend polynomial identities to the complex numbers. For example, rewrite x2+ 4 as (x + 2i)(x − 2i).

N-CN.9. (+) Know the Fundamental Theorem of Algebra; show that it is true for quadratic polynomials.

Vector and Matrix Quantities

N-VM.1. (+) Recognize vector quantities as having both magnitude and direction. Represent vector quantities by directed line segments, and use appropriate symbols for vectors and their magnitudes (e.g., v, |v|, ||v||, v).

N-VM.2. (+) Find the components of a vector by subtracting the coordinates of an initial point from the coordinates of a terminal point.

N-VM.3. (+) Solve problems involving velocity and other quantities that can be represented by vectors.

N-VM.4. (+) Add and subtract vectors

N-VM.4.a. Add vectors end-to-end, component-wise, and by the parallelogram rule. Understand that the magnitude of a sum of two vectors is typically not the sum of the magnitudes.

N-VM.4.b. Given two vectors in magnitude and direction form, determine the magnitude and direction of their sum.

N-VM.4.c. Understand vector subtraction v − w as v + (−w), where −w is the additive inverse of w, with the same magnitude as w and pointing in the opposite direction. Represent vector subtraction graphically by connecting the tips in the appropriate order, and perform vector subtraction component-wise.

N-VM.5. (+) Multiply a vector by a scalar.
N-VM.5.a. Represent scalar multiplication graphically by scaling vectors and possibly reversing their direction; perform scalar multiplication component-wise, e.g., as c(vx, vy) = (cvx, cvy).

N-VM.5.b. Compute the magnitude of a scalar multiple cv using ||cv|| = |c|v. Compute the direction of cv knowing that when |c|v ≠ 0, the direction of cv is either along v (for c > 0) or against v (for c < 0).

N-VM.6. (+) Use matrices to represent and manipulate data, e.g., to represent payoffs or incidence relationships in a network.

N-VM.7. (+) Multiply matrices by scalars to produce new matrices, e.g., as when all of the

payoffs in a game are doubled.

N-VM.8. (+) Add, subtract, and multiply matrices of appropriate dimensions.

N-VM.9. (+) Understand that, unlike multiplication of numbers, matrix multiplication for square matrices is not a commutative operation, but still satisfies the associative and distributive properties

N-VM.10. (+) Understand that the zero and identity matrices play a role in matrix addition and multiplication similar to the role of 0 and 1 in the real numbers. The determinant of a square matrix is nonzero if and only if the matrix has a multiplicative inverse.

N-VM.11. (+) Multiply a vector (regarded as a matrix with one column) by a matrix of suitable dimensions to produce another vector. Work with matrices as transformations of vectors.

N-VM.12. (+) Work with 2 × 2 matrices as transformations of the plane, and interpret the absolute value of the determinant in terms of area.

Algebra

Seeing Structure in Expressions

A-SSE.1. Interpret expressions that represent a quantity in terms of its context.

A-SSE.1.a. Interpret parts of an expression, such as terms, factors, and coefficients.

A-SSE.1.b. Interpret complicated expressions by viewing one or more of their parts as a single entity. For example, interpret P(1+r)n as the product of P and a factor not depending on P.

A-SSE.2. Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.

A-SSE.3. Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.

A-SSE.3.a. Factor a quadratic expression to reveal the zeros of the function it defines.

A-SSE.3.b. Complete the square in a quadratic expression to reveal the maximum or minimum value of the function it defines.

A-SSE.3.c. Use the properties of exponents to transform expressions for exponential functions.

A-SSE.4. Derive the formula for the sum of a finite geometric series (when the common ratio is not 1), and use the formula to solve problems. For example, calculate mortgage payments.

Arithmetic with Polynomials and Rational Expressions

A-APR.1. Understand that polynomials form a system analogous to the integers, namely, they are closed under the operations of addition, subtraction, and multiplication; add, subtract, and

multiply polynomials

A-APR.2. Know and apply the Remainder Theorem: For a polynomial p(x) and a number a, the remainder on division by x − a is p(a), so p(a) = 0 if and only if (x − a) is a factor of p(x).

A-APR.3. Identify zeros of polynomials when suitable factorizations are available, and use the zeros to construct a rough graph of the function defined by the polynomial.

A-APR.4. Prove polynomial identities and use them to describe numerical relationships.

A-APR.5. (+) Know and apply the Binomial Theorem for the expansion of (x+ y)n in powers of x and y for a positive integer n, where x and y are any numbers, with coefficients determined for example by Pascal's Triangle.

A-APR.6. Rewrite simple rational expressions in different forms; write a(x)/b(x)in the form q(x) + r(x)/b(x), where a(x), b(x), q(x), and r(x) are polynomials with the degree of r(x) less than the degree of b(x), using inspection, long division, or, for the more complicated examples, a computer algebra system.

A-APR.7. (+) Understand that rational expressions form a system analogous to the rational numbers, closed under addition, subtraction, multiplication, and division by a nonzero rational expression; add, subtract, multiply, and divide rational expressions.

Creating Equations

A-CED.1. Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions.

A-CED.2. Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.

A-CED.3. Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or nonviable options in a modeling context. For example, represent inequalities describing nutritional and cost constraints on combinations of different foods.

A-CED.4. Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law V =IR to highlight resistance R.

Reasoning with Equations and Inequalities

A-REI.1. Explain each step in solving a simple equation as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct a viable argument to justify a solution method.

A-REI.2. Solve simple rational and radical equations in one variable, and give examples showing how extraneous solutions may arise.

A-REI.3. Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.

A-REI.4. Solve quadratic equations in one variable.

A-REI.4.a. Use the method of completing the square to transform any quadratic equation in x into an equation of the form (x − p)2= q that has the same solutions. Derive the quadratic formula from this form.

A-REI.4.b. Solve quadratic equations by inspection (e.g., for x2= 49), taking square roots, completing the square, the quadratic formula and factoring, as appropriate to the initial form of the equation. Recognize when the quadratic formula gives complex solutions and write them as a ± bi for real numbers a and b.

A-REI.5. Prove that, given a system of two equations in two variables, replacing one equation by the sum of that equation and a multiple of the other produces a system with the same solutions.

A-REI.6. Solve systems of linear equations exactly and approximately (e.g., with graphs), focusing on pairs of linear equations in two variables.

A-REI.7. Solve a simple system consisting of a linear equation and a quadratic equation in two variables algebraically and graphically. For example, find the points of intersection between the line y = −3x and the circle x2+y2= 3.

A-REI.8. (+) Represent a system of linear equations as a single matrix equation in a vector variable.

A-REI.9. (+) Find the inverse of a matrix if it exists and use it to solve systems of linear equations (using technology for matrices of dimension 3 × 3 or greater).

A-REI.10. Understand that the graph of an equation in two variables is the set of all its solutions plotted in the coordinate plane, often forming a curve (which could be a line).

A-REI.11. Explain why the x-coordinates of the points where the graphs of the equations y = f(x) and y = g(x) intersect are the solutions of the equation f(x) = g(x); find the solutions approximately, e.g., using technology to graph the functions, make tables of values, or find successive approximations. Include cases where f(x) and/or g(x) are linear, polynomial, rational, absolute value, exponential, and logarithmic functions.

A-REI.12.Graph the solutions to a linear inequality in two variables as a half plane (excluding the boundary in the case of a strict inequality), and graph the solution set to a system of linear inequalities in two variables as the intersection of the corresponding half-planes.

Functions

Interpreting Functions

F-IF.1. Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If f is a function

and x is an element of its domain, then f(x) denotes the output of f corresponding to the input x. The graph of f is the graph of the equation y = f(x).

F-IF.2. Use function notation, evaluate functions for inputs in their domains, and interpret statements that use function notation in terms of a context.

F-IF.3. Recognize that sequences are functions, sometimes defined recursively, whose domain is a subset of the integers. For example, the Fibonacci sequence is defined recursively by f(0) = f(1) = 1, f(n+1) = f(n) + f(n-1) for n ≥ 1.

F-IF.4. For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. Key features include: intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior; and periodicity.

F-IF.5. Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes. For example, if the function h(n) gives the number of person-hours it takes to assemble n engines in a factory, then the positive integers would be an appropriate domain for the function.

F-IF.6. Calculate and interpret the average rate of change of a function (presented symbolically or as a table) over a specified interval. Estimate the rate of change from a graph.

F-IF.7. Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases.

F-IF.7.a. Graph linear and quadratic functions and show intercepts, maxima, and minima.

F-IF.7.b. Graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions.

F-IF.7.c. Graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior.

F-IF.7.d. (+) Graph rational functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior.

F-IF.7.e. Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude.

F-IF.8. Write a function defined by an expression in different but equivalent forms to reveal and explain different properties of the function.

F-IF.8.a. Use the process of factoring and completing the square in a quadratic function to show zeros, extreme values, and symmetry of the graph, and interpret these in terms of a context.

F-IF.8.b. Use the properties of exponents to interpret expressions for exponential functions.

F-IF.9. Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions). For example, given a graph of one quadratic function and an algebraic expression for another, say which has the larger maximum.

Building Functions

F-BF.1. Write a function that describes a relationship between two quantities.

F-BF.1.a. Determine an explicit expression, a recursive process, or steps for calculation from a context.

F-BF.1.b. Combine standard function types using arithmetic operations. For example, build a function that models the temperature of a cooling body by adding a constant function to a decaying exponential, and relate these functions to the model.

F-BF.1.c. (+) Compose functions. For example, if T(y) is the temperature in the atmosphere as a function of height, and h(t) is the height of a weather balloon as a function of time, then T(h(t)) is the temperature at the location of the weather balloon as a function of time.

F-BF.2. Write arithmetic and geometric sequences both recursively and with an explicit formula, use them to model situations, and translate between the two forms.

F-BF.3. Identify the effect on the graph of replacing f(x) by f(x) + k, k f(x), f(kx), and f(x + k) for specific values of k (both positive and negative); find the value of k given the graphs. Experiment with cases and illustrate an explanation of the effects on the graph using technology. Include recognizing even and odd functions from their graphs and algebraic expressions for them.

F-BF.4. Find inverse functions.

F-BF.4.a. Solve an equation of the form f(x) = c for a simple function f that has an inverse and write an expression for the inverse.

F-BF.4.b. (+) Verify by composition that one function is the inverse of another.

F-BF.4.c. (+) Read values of an inverse function from a graph or a table, given that the function has an inverse.

F-BF.4.d. (+) Produce an invertible function from a non-invertible function by restricting the domain.

F-BF.5. (+) Understand the inverse relationship between exponents and logarithms and use this relationship to solve problems involving logarithms and exponents.

Linear, Quadratic, and Exponential Models

F-LE.1. Distinguish between situations that can be modeled with linear functions and with exponential functions.

F-LE.1.a. Prove that linear functions grow by equal differences over equal intervals, and that exponential functions grow by equal factors over equal intervals.

F-LE.1.b. Recognize situations in which one quantity changes at a constant rate per unit interval relative to another.

F-LE.1.c. Recognize situations in which a quantity grows or decays by a constant percent rate per unit interval relative to another

F-LE.2. Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).

F-LE.3. Observe using graphs and tables that a quantity increasing exponentially eventually exceeds a quantity increasing linearly, quadratically, or (more generally) as a polynomial function.

F-LE.4. For exponential models, express as a logarithm the solution to ab ct = d where a, c, and d are numbers and the base b is 2, 10, or e; evaluate the logarithm using technology.

F-LE.5. Interpret the parameters in a linear or exponential function in terms of a context.

Trigonometric Functions

F-TF.1. Understand radian measure of an angle as the length of the arc on the unit circle subtended by the angle.

F-TF.2. Explain how the unit circle in the coordinate plane enables the extension of trigonometric functions to all real numbers, interpreted as radian measures of angles traversed counterclockwise around the unit circle.

F-TF.3. (+) Use special triangles to determine geometrically the values of sine, cosine, tangent for π/3, π/4 and π/6, and use the unit circle to express the values of sine, cosine, and tangent for π− x, π+x, and 2π− x in terms of their values for x, where x is any real number.

F-TF.4. (+) Use the unit circle to explain symmetry (odd and even) and periodicity of trigonometric functions.

F-TF.5. Choose trigonometric functions to model periodic phenomena with specified amplitude, frequency, and midline.

F-TF.6. (+) Understand that restricting a trigonometric function to a domain on which it is always increasing or always decreasing allows its inverse to be constructed.

F-TF.7. (+) Use inverse functions to solve trigonometric equations that arise in modeling contexts; evaluate the solutions using technology, and interpret them in terms of the context.

F-TF.8. Prove the Pythagorean identity sin2 (θ) + cos 2 (θ) = 1 and use it to find sin(θ), cos(θ), or tan(θ) given sin(θ), cos(θ), or tan(θ) and the quadrant of the angle.

F-TF.9. (+) Prove the addition and subtraction formulas for sine, cosine, and tangent and use them to solve problems.

Geometry

Congruence

G-CO.1. Know precise definitions of angle, circle, perpendicular line, parallel line, and line segment, based on the undefined notions of point, line, distance along a line, and distance around a circular arc.

G-CO.2. Represent transformations in the plane using, e.g., transparencies and geometry software; describe transformations as functions that take points in the plane as inputs and give other points as outputs. Compare transformations that preserve distance and angle to those that do not (e.g., translation versus horizontal stretch).

G-CO.3. Given a rectangle, parallelogram, trapezoid, or regular polygon, describe the rotations and reflections that carry it onto itself.

G-CO.4. Develop definitions of rotations, reflections, and translations in terms of angles, circles, perpendicular lines, parallel lines, and line segments.

G-CO.5. Given a geometric figure and a rotation, reflection, or translation, draw the transformed figure using, e.g., graph paper, tracing paper, or geometry software. Specify a sequence of transformations that will carry a given figure onto another.

G-CO.6. Use geometric descriptions of rigid motions to transform figures and to predict the effect of a given rigid motion on a given figure; given two figures, use the definition of congruence in terms of rigid motions to decide if they are congruent.

G-CO.7. Use the definition of congruence in terms of rigid motions to show that two triangles are congruent if and only if corresponding pairs of sides and corresponding pairs of angles are congruent.

G-CO.8. Explain how the criteria for triangle congruence (ASA, SAS, and SSS) follow from the definition of congruence in terms of rigid motions.

G-CO.9. Prove theorems about lines and angles. Theorems include: vertical angles are congruent; when a transversal crosses parallel lines, alternate interior angles are congruent and corresponding angles are congruent; points on a perpendicular bisector of a line segment are exactly those equidistant from the segment's endpoints.

G-CO.10. Prove theorems about triangles. Theorems include: measures of interior angles of a triangle sum to 180°; base angles of isosceles triangles are congruent; the segment joining midpoints of two sides of a triangle is parallel to the third side and half the length; the medians of a triangle meet at a point.

G-CO.11. Prove theorems about parallelograms. Theorems include: opposite sides are congruent,

opposite angles are congruent, the diagonals of a parallelogram bisect each other, and conversely, rectangles are parallelograms with congruent diagonals.

G-CO.12. Make formal geometric constructions with a variety of tools and methods (compass and straightedge, string, reflective devices, paper folding, dynamic geometric software, etc.). Copying a segment; copying an angle; bisecting a segment; bisecting an angle; constructing perpendicular lines, including the perpendicular bisector of a line segment; and constructing a line parallel to a given line through a point not on the line.

G-CO.13. Construct an equilateral triangle, a square, and a regular hexagon inscribed in a circle.

Similarity, Right Triangles, and Trigonometry

G-SRT.1. Verify experimentally the properties of dilations given by a center and a scale factor:

G-SRT.1.a. A dilation takes a line not passing through the center of the dilation to a parallel line, and leaves a line passing through the center unchanged.

G-SRT.1.b. The dilation of a line segment is longer or shorter in the ratio given by the scale factor.

G-SRT.2. Given two figures, use the definition of similarity in terms of similarity transformations to decide if they are similar; explain using similarity transformations the meaning of similarity for triangles as the equality of all corresponding pairs of angles and the proportionality of all corresponding pairs of sides.

G-SRT.3. Use the properties of similarity transformations to establish the AA criterion for two triangles to be similar.

G-SRT.4. Prove theorems about triangles. Theorems include: a line parallel to one side of a triangle divides the other two proportionally, and conversely; the Pythagorean Theorem proved using triangle similarity.

G-SRT.5. Use congruence and similarity criteria for triangles to solve problems and to prove relationships in geometric figures.

G-SRT.6. Understand that by similarity, side ratios in right triangles are properties of the angles in the triangle, leading to definitions of trigonometric ratios for acute angles.

G-SRT.7. Explain and use the relationship between the sine and cosine of complementary angles.

G-SRT.8. Use trigonometric ratios and the Pythagorean Theorem to solve right triangles in applied problems.

G-SRT.9. (+) Derive the formula $A = 1/2\ ab\ \sin(C)$ for the area of a triangle by drawing an auxiliary line from a vertex perpendicular to the opposite side.

G-SRT.10. (+) Prove the Laws of Sines and Cosines and use them to solve problems.

G-SRT.11. (+) Understand and apply the Law of Sines and the Law of Cosines to find unknown measurements in right and non-right triangles (e.g., surveying problems, resultant forces).

Circles

G-C.1. Prove that all circles are similar.

G-C.2. Identify and describe relationships among inscribed angles, radii, and chords. Include the relationship between central, inscribed, and circumscribed angles; inscribed angles on a diameter are right angles; the radius of a circle is perpendicular to the tangent where the radius intersects the circle.

G-C.3. Construct the inscribed and circumscribed circles of a triangle, and prove properties of angles for a quadrilateral inscribed in a circle.

G-C.4. (+) Construct a tangent line from a point outside a given circle to the circle.

G-C.5. Derive using similarity the fact that the length of the arc intercepted by an angle is proportional to the radius, and define the radian measure of the angle as the constant of proportionality; derive the formula for the area of a sector.

Expressing Geometric Properties with Equations

G-GPE.1. Derive the equation of a circle of given center and radius using the Pythagorean Theorem; complete the square to find the center and radius of a circle given by an equation.

G-GPE.2. Derive the equation of a parabola given a focus and directrix.

G-GPE.3. (+) Derive the equations of ellipses and hyperbolas given the foci, using the fact that the sum or difference of distances from the foci is constant.

G-GPE.4. Use coordinates to prove simple geometric theorems algebraically. For example, prove or disprove that a figure defined by four given points in the coordinate plane is a rectangle; prove or disprove that the point $(1, \sqrt{3})$ lies on the circle centered at the origin and containing the point $(0, 2)$.

G-GPE.5. Prove the slope criteria for parallel and perpendicular lines and use them to solve geometric problems (e.g., find the equation of a line parallel or perpendicular to a given line that passes through a given point).

G-GPE.6. Find the point on a directed line segment between two given points that partitions the segment in a given ratio.

G-GPE.7. Use coordinates to compute perimeters of polygons and areas of triangles and rectangles, e.g., using the distance formula.

Geometric Measurement and Dimension

G-GMD.1. Give an informal argument for the formulas for the circumference of a circle, area of

a circle, volume of a cylinder, pyramid, and cone. Use dissection arguments, Cavalieri's principle, and informal limit arguments.

G-GMD.2. (+) Give an informal argument using Cavalieri's principle for the formulas for the volume of a sphere and other solid figures.

G-GMD.3. Use volume formulas for cylinders, pyramids, cones, and spheres to solve problems.

G-GMD.4. Identify the shapes of two-dimensional cross-sections of three dimensional objects, and identify three-dimensional objects generated by rotations of two-dimensional objects.

Modeling with Geometry

G-MG.1. Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).

G-MG.2. Apply concepts of density based on area and volume in modeling situations (e.g., persons per square mile, BTUs per cubic foot).

G-MG.3. Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

Statistics and Probability

Interpreting Categorical and Quantitative Data

S-ID.1. Represent data with plots on the real number line (dot plots, histograms, and box plots).

S-ID.2. Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets.

S-ID.3. Interpret differences in shape, center, and spread in the context of the data sets, accounting for possible effects of extreme data points (outliers).

S-ID.4. Use the mean and standard deviation of a data set to fit it to a normal distribution and to estimate population percentages. Recognize that there are data sets for which such a procedure is not appropriate.
Use calculators, spreadsheets, and tables to estimate areas under the normal curve.

S-ID.5. Summarize categorical data for two categories in two-way frequency tables. Interpret relative frequencies in the context of the data (including joint, marginal, and conditional relative frequencies). Recognize possible associations and trends in the data.

S-ID.6. Represent data on two quantitative variables on a scatter plot, and describe how the variables are related.

S-ID.6.a. Fit a function to the data; use functions fitted to data to solve problems in the context of the data. Use given functions or choose a function suggested by the context. Emphasize linear,

~~quadratic, and exponential models.~~

~~S-ID.6.b. Informally assess the fit of a function by plotting and analyzing residuals.~~

~~S-ID.6.c. Fit a linear function for a scatter plot that suggests a linear association.~~

~~S-ID.7. Interpret the slope (rate of change) and the intercept (constant term) of a linear model in the context of the data.~~

~~S-ID.8. Compute (using technology) and interpret the correlation coefficient of a linear fit.~~

~~S-ID.9. Distinguish between correlation and causation.~~

~~Making Inferences and Justifying Conclusions~~

~~S-IC.1. Understand statistics as a process for making inferences about population parameters based on a random sample from that population.~~

~~S-IC.2. Decide if a specified model is consistent with results from a given data-generating process, e.g., using simulation. For example, a model says a spinning coin falls heads up with probability 0.5. Would a result of 5 tails in a row cause you to question the model?~~

~~S-IC.3. Recognize the purposes of and differences among sample surveys, experiments, and observational studies; explain how randomization relates to each.~~

~~S-IC.4. Use data from a sample survey to estimate a population mean or proportion; develop a margin of error through the use of simulation models for random sampling.~~

~~S-IC.5. Use data from a randomized experiment to compare two treatments; use simulations to decide if differences between parameters are significant.~~

~~S-IC.6. Evaluate reports based on data.~~

~~Conditional Probability and the Rules of Probability~~

~~S-CP.1. Describe events as subsets of a sample space (the set of outcomes) using characteristics (or categories) of the outcomes, or as unions, intersections, or complements of other events ("or," "and," "not").~~

~~S-CP.2. Understand that two events A and B are independent if the probability of A and B occurring together is the product of their probabilities, and use this characterization to determine if they are independent.~~

~~S-CP.3. Understand the conditional probability of A given B as P(A and B)/P(B), and interpret independence of A and B as saying that the conditional probability of A given B is the same as the probability of A, and the conditional probability of B given A is the same as the probability of B.~~

~~S-CP.4. Construct and interpret two-way frequency tables of data when two categories are~~

associated with each object being classified. Use the two-way table as a sample space to decide if events are independent and to approximate conditional probabilities. For example, collect data from a random sample of students in your school on their favorite subject among math, science, and English. Estimate the probability that a randomly selected student from your school will favor science given that the student is in tenth grade. Do the same for other subjects and compare the results.

S-CP.5. Recognize and explain the concepts of conditional probability and independence in everyday language and everyday situations. For example, compare the chance of having lung cancer if you are a smoker with the chance of being a smoker if you have lung cancer.

S-CP.6. Find the conditional probability of A given B as the fraction of B's outcomes that also belong to A, and interpret the answer in terms of the model.

S-CP.7. Apply the Addition Rule, P(A or B) = P(A) + P(B) – P(A and B), and interpret the answer in terms of the model.

S-CP.8. (+) Apply the general Multiplication Rule in a uniform probability model, P(A and B) = P(A)P(B|A) = P(B)P(A|B), and interpret the answer in terms of the model.

S-CP.9. (+) Use permutations and combinations to compute probabilities of compound events and solve problems.

Using Probability to Make Decisions

S-MD.1. (+) Define a random variable for a quantity of interest by assigning a numerical value to each event in a sample space; graph the corresponding probability distribution using the same graphical displays as for data distributions.

S-MD.2. (+) Calculate the expected value of a random variable; interpret it as the mean of the probability distribution.

S-MD.3. (+) Develop a probability distribution for a random variable defined for a sample space in which theoretical probabilities can be calculated; find the expected value. For example, find the theoretical probability distribution for the number of correct answers obtained by guessing on all five questions of a multiple-choice test where each question has four choices, and find the expected grade under various grading schemes.

S-MD.4. (+) Develop a probability distribution for a random variable defined for a sample space in which probabilities are assigned empirically; find the expected value. For example, find a current data distribution on the number of TV sets per household in the United States, and calculate the expected number of sets per household. How many TV sets would you expect to find in 100 randomly selected households?

S-MD.5. (+) Weigh the possible outcomes of a decision by assigning probabilities to payoff values and finding expected values.

S-MD.5.a. Find the expected payoff for a game of chance. For example, find the expected winnings from a state lottery ticket or a game at a fast-food restaurant.

~~S-MD.5.b. Evaluate and compare strategies on the basis of expected values. For example, compare a high-deductible versus a low-deductible automobile insurance policy using various, but reasonable, chances of having a minor or a major accident.~~

~~S-MD.6. (+) Use probabilities to make fair decisions (e.g., drawing by lots, using a random number generator).~~

~~S-MD.7. (+) Analyze decisions and strategies using probability concepts (e.g., product testing, medical testing, pulling a hockey goalie at the end of a game).~~

Appendix D: International Society for Technology in Education Standards (ISTE

	Unit	Unit 8	Unit 9	Unit 10	Unit 11	Unit 12	Unit 13	Unit 14	Unit 15
ISTE Standards									
T1			x	x	x	x	x	x	x
T2		x	x	x	x	x	x	x	x
T3		x	x	x		x	x	x	x
T4		x	x	x	x	x	x	x	x
T5			x						x
T6			x	x	x	x	x	x	x

T1 Creativity and Innovation

Students demonstrate creative thinking, construct knowledge, and develop innovative products and processes using technology. Students do the following:

a. Apply existing knowledge to generate new ideas, products, or processes.
b. Create original works as a means of personal or group expression.
c. Use models and simulations to explore complex systems and issues.
d. Identify trends and forecast possibilities.

T2 Communication and Collaboration

Students use digital media and environments to communicate and work collaboratively, including at a distance, to support individual learning and contribute to the learning of others. Students do the following:

a. Interact, collaborate, and publish with peers, experts, or others employing a variety of digital environments and media.
b. Communicate information and ideas effectively to multiple audiences using a variety of media and formats.
c. Develop cultural understanding and global awareness by engaging with learners of other cultures.
d. Contribute to project teams to produce original works or solve problems.

T3 Research and Information Fluency

Students apply digital tools to gather, evaluate, and use information. Students do the following:

a. Plan strategies to guide inquiry.
b. Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media.
c. Evaluate and select information sources and digital tools based on the appropriateness to specific tasks.
d. Process data and report results.

T4 Critical Thinking, Problem Solving, and Decision Making

Students use critical thinking skills to plan and conduct research, manage projects, solve

problems, and make informed decisions using appropriate digital tools and resources. Students do the following:

a. Identify and define authentic problems and significant questions for investigation.
b. Plan and manage activities to develop a solution or complete a project.
c. Collect and analyze data to identify solutions and/or make informed decisions.
d. Use multiple processes and diverse perspectives to explore alternative solutions.

T5 Digital Citizenship

Students understand human, cultural, and societal issues related to technology and practice legal and ethical behavior. Students do the following:

a. Advocate and practice safe, legal, and responsible use of information and technology.
b. Exhibit a positive attitude toward using technology that supports collaboration, learning, and productivity.
c. Demonstrate personal responsibility for lifelong learning.
d. Exhibit leadership for digital citizenship.

T6 Technology Operations and Concepts

Students demonstrate a sound understanding of technology concepts, systems, and operations. Students do the following:

a. Understand and use technology systems.
b. Select and use applications effectively and productively.
c. Troubleshoot systems and applications.
d. Transfer current knowledge to learning of new technologies.

Appendix E: Academic Standards

	UNIT 8	UNIT 9	UNIT 10	UNIT 11	UNIT 12	UNIT 13	UNIT 14	UNIT 15
MS SCIENCE STANDARDS								
PHY.1.1		X						
PHY.1.2		X						
PHY.1.3		X						X
PHY.1.4								
PHY.1.5								
PHY.1.6		X						X
PHY.1.7								
PHY.1.8								
PHY.2.1		X						X
PHY.2.2								X
PHY.2.3								X
PHY.2.4		X						X
PHY.2.5		X						X
PHY.2.6		X						X
PHY.2.7		X						X
PHY.2.8								X
PHY.2.9								
PHY.2.10								
PHY.3.1		X						X
PHY 3.2		X						X
PHY.3.3		X						X
PHY.3.5								
PHY 3.4								
PHY.3.6							X	
PHY.3.7							X	
PHY.3.8		X						
PHY.3.9		X						

~~PHY.3.10~~		~~X~~						
~~PHY.3.11~~		~~X~~						~~X~~
~~PHY.4.4~~								
~~PHY.4.9~~								
~~PHY.5.1~~					~~X~~			
~~PHY.5.2~~					~~X~~			
~~PHY.5.3~~					~~X~~			
~~PHY.5.4~~					~~X~~			
~~PHY.5.5~~					~~X~~			
~~PHY.5.6~~					~~X~~			
~~PHY.5.7~~					~~X~~			
~~PHY.5.8~~					~~X~~			
~~PHY.5.9~~					~~X~~			

PHY.1 One-Dimensional Motion

Mississippi College and Career Readiness Standards – Physics

Conceptual Understanding: Linear motion of objects is described by displacement, velocity, and acceleration. These concepts should be introduced as computational and investigative phenomena.

PHY.1 Students will investigate and understand how to analyze and interpret data.

PHY.1.1 Investigate and analyze evidence gained through observation or experimental design regarding the one-dimensional (1-D) motion of objects. Design and conduct experiments to generate and interpret graphical evidence of distance, velocity, and acceleration through motion.

PHY.1.2 Interpret and predict 1-D motion based on displacement vs. time, velocity vs. time, or acceleration vs. time graphs (e.g., free-falling objects).

PHY.1.3 Use mathematical and computational analysis to solve problems using kinematic equations.

PHY.1.4 Use graphical analysis to derive kinematic equations.

PHY.1.5 Differentiate and give examples of motion concepts such as distance-displacement, speed-velocity, and acceleration.

PHY.1.6 Design and mathematically/graphically analyze quantitative data to explore displacement, velocity, and acceleration of various objects. Use probe systems, video analysis, graphical analysis software, digital spreadsheets, and/or online simulations.

PHY.1.7 Design different scenarios, and predict graph shapes for distance/time, velocity/time, and acceleration/time graphs.

PHY.1.8 Given a 1D motion graph students should replicate the motion predicted by the graph.

PHY.2 Newton's Laws

Conceptual Understanding: Motion and acceleration can be explained by analyzing the contact interaction of objects. This motion and acceleration can be predicted by analyzing the forces (i.e., normal, tension, gravitational, applied, and frictional) acting on the object and applying Newton's laws of motion.

PHY.2 Students will develop an understanding of concepts related to Newtonian dynamics.

PHY.2.1 Identify forces acting on a system by applying Newton's laws mathematically and graphically (e.g., vector and scalar quantities).

PHY.2.2 Use models such as free-body diagrams to explain and predict the motion of an object according to Newton's law of motion, including circular motion.

PHY.2.3 Use mathematical and graphical techniques to solve vector problems and find net forces acting on a body using free-body diagrams and/or online simulations.

PHY.2.4 Use vectors and mathematical analysis to explore the 2D motion of objects. (i.e. projectile and circular motion).

PHY.2.5 Use mathematical and computational analysis to derive simple equations of motion for various systems using Newton's second law (e.g. net force equations).

PHY.2.6 Use mathematical and computational analysis to explore forces (e.g., friction force applied, normal, and tension).

PHY.2.7 Analyze real-world applications to draw conclusions about Newton's three laws of motion using online simulations, probe systems, and/or laboratory experiences.

PHY.2.8 Design an experiment to determine the forces acting on a stationary object on an inclined plane. Test your conclusions.

PHY.2.9 Draw diagrams of forces applied to an object, and predict the angle of incline that will result in unbalanced forces acting on the object.

PHY.2.10 Apply the effects of the universal gravitation law to generate a digital/physical graph, and interpret the forces between two masses, acceleration due to gravity, and planetary motion (e.g., situations where g is constant, as in falling bodies).

PHY.2.11 Explain centripetal acceleration while undergoing uniform circular motion to explore Kepler's third law using online simulations, models, and/or probe systems.

PHY.3 Work and Energy

Conceptual Understanding: Work and energy are synonymous. When investigating mechanical energy, energy is the ability to do work. The rate at which work is done is called power. Efficiency is the ratio of power input to the output of the system. In closed systems, energy is conserved.

PHY.3 Students will develop an understanding of concepts related to work and energy.

PHY.3.1 Use mathematical and computational analysis to qualitatively and quantitatively analyze the concept of work, energy, and power to explain and apply the conservation of energy.

PHY.3.2 Use mathematical and computational analysis to explore conservation of momentum and impulse.

PHY.3.3 Through real-world applications, draw conclusions about mechanical potential

energy and kinetic energy using online simulations and/or laboratory experiences.

PHY.3.4 Design and conduct investigations to compare conservation of momentum and conservation of kinetic energy in perfectly inelastic and elastic collisions using probe systems, online simulations, and/or laboratory experiences.

PHY.3.5 Investigate, collect data, and summarize the principles of thermodynamics by exploring how heat energy is transferred from higher temperature to lower temperature until equilibrium is reached.

PHY.3.6 **Enrichment**: Design, conduct, and communicate investigations that explore how temperature and thermal energy relate to molecular motion and states of matter.

PHY.3.7 **Enrichment:** Use mathematical and computational analysis to analyze problems involving specific heat and heat capacity.

PHY.3.8 **Enrichment:** Research to compare the first and second laws of thermodynamics as related to heat engines, refrigerators, and thermal efficiency.

PHY.3.9 Explore the kinetic theory in terms of kinetic energy of ideal gases using digital resources.

PHY.3.10 **Enrichment:** Research the efficiency of everyday machines (e.g., automobiles, hair dryers, refrigerators, and washing machines).

PHY.3.11 **Enrichment:** Use an engineering design process to design and build a themed Rube Goldberg type machine that has six or more steps and complete a desired task (e.g., pop a balloon, fill a bottle, shoot a projectile, or raise an object 35 cm) within an allotted time. Include a poster that demonstrates the calculations of the energy transformation or efficiency of the machine.*

PHY.4 Waves

Conceptual Understanding: Wave properties are the transfer of energy from one place to another. The investigation of these interactions must include simple harmonic motion, sound, and electromagnetic radiation.

PHY.4 Students will investigate and explore wave properties.

PHY.4.1 Analyze the characteristics and properties of simple harmonic motions, sound, and light.

PHY.4.2 Describe and model through digital or physical means the characteristics and properties of mechanical waves by simulating and investigating properties of simple harmonic motion.

PHY.4.3 Use mathematical and computational analysis to explore wave characteristics (e.g., velocity, period, frequency, amplitude, phase, and wavelength).

PHY.4.4 Investigate and communicate the relationship between the energy of a wave in terms of amplitude and frequency using probe systems, online simulations, and/or laboratory experiences.

PHY.4.5 Design, investigate, and collect data on standing waves and waves in specific media (e.g., stretched string, water surface, and air) using online simulations, probe systems, and/or laboratory experiences.

PHY.4.6 Explore and explain the Doppler effect as it relates to a moving source and to a moving observer using online simulations, probe systems, and/or real-world experiences.

PHY.4.7 Explain the laws of reflection and refraction, and apply Snell's law to describe the relationship between the angles of incidence and refraction.

PHY.4.8 Use ray diagrams and the thin lens equations to solve real-world problems involving object distance from lenses, using a lens bench, online simulations, and/or laboratory experiences.

PHY.4.9 Research the different bands of electromagnetic radiation, including characteristics, properties, and similarities/differences.

PHY.4.10 **Enrichment:** Research the ways absorption and emission spectra are used to study astronomy and the formation of the universe.

PHY.4.11 **Enrichment:** Research digital nonfictional text to defend the wave-particle duality of light (i.e., wave model of light and particle model of light).

PHY.4.12 **Enrichment:** Research uses of the electromagnetic spectrum or photoelectric effect.

PHY.5 Electricity and Magnetism

Conceptual Understanding: In electrical interactions, electrical energy (whether battery or circuit energy) is transformed into other forms of energy. Charged particles and magnetic fields are similar in that they store energy. Magnetic fields exert forces on moving charged particles. Changing magnetic fields cause electrons in wires to move and thus create a current.

PHY.5 Students will investigate the key components of electricity and magnetism.

PHY.5.1 Analyze and explain electricity and the relationship between electricity and magnetism.

PHY.5.2 Explore the characteristics of static charge and how a static charge is generated using simulations.

PHY.5.3 Use mathematical and computational analysis to analyze problems dealing with electric field, electric potential, current, voltage, and resistance as related to Ohm's law.

PHY.5.4 Develop and use models (e.g., circuit drawing and mathematical representation) to explain how electric circuits work by tracing the path of electrons, including concepts of energy transformation, transfer, conservation of energy, electric charge, and resistance using online simulations, probe systems, and/or laboratory experiences.

PHY.5.5 Design and conduct an investigation of magnetic poles, magnetic flux and magnetic field using online simulations, probe systems, and/or laboratory experiences.

PHY.5.6 Use schematic diagrams to analyze the current flow in series and parallel electric circuits, given the component resistances and the imposed electric potential.

PHY.5.7 Analyze and communicate the relationship between magnetic fields and electrical current by induction, generators, and electric motors (e.g., microphones, speakers, generators, and motors) using Ampere's and Faraday's laws.

PHY.5.8 **Enrichment:** Design and construct a simple motor to develop an explanation of how the motor transforms electrical energy into mechanical energy and work.

PHY.5.9 **Enrichment:** Design and draw a schematic of a circuit that will turn on/off a light from two locations in a room like those found in most homes.

PHY.6 Nuclear Energy

Conceptual Understanding: Nuclear energy is energy stored in the nucleus of the atom. The energy holding atoms together is called binding energy. The binding energy is a huge amount of energy. So, at the subatomic scale, the conservation of energy becomes the conservation of mass-energy.

PHY.6 Students will demonstrate an understanding of the basic principles of nuclear energy.

PHY.6.1 Analyze and explain the concepts of nuclear physics.

PHY.6.2 Explore the mass number and atomic number of the nucleus of an isotope of a given chemical element.

PHY.6.3 Investigate the conservation of mass and the conservation of charge by writing and balancing nuclear decay equations for alpha and beta decay.

PHY.6.4 Simulate the process of nuclear decay using online simulations and/or laboratory experiences and using mathematical computations determine the half-life of radioactive isotopes.