# 2020 Precision Machining

Program CIP: 48.0503 Machine Shop Technology/Assistant.

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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.

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# Standards

Standards and alignment crosswalks are referenced in the appendices. Mississippi's CTE Precision Machining is aligned to the following standards:

**National Institute for Metalworking Skills, Inc. (NIMS)**
NIMS is the nation's only ANSI-accredited developer of precision manufacturing skills standards and competency assessments. NIMS certify individual skills against standards and accredit programs that meet its quality requirements. Reprinted with permission from NIMS, Copyright © 2008, National Institute for Metalworking Skills, Inc., (703) 352-4971, https://www.nims-skills.org

**College- and Career-Ready 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 Ready 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.
http://mdek12.org/OAE/college-and-career-readiness-standards

**International Society for Technology in Education Standards (ISTE)**
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iste.org

**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*. Published 2015.
p21.org/storage/documents/docs/P21_Framework_Definitions_New_Logo_2015.pdf

Unit specific alignment can be accessed at rcu.msstate.edu/

# Preface

Secondary career and technical education 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; 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 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, please call 662.325.2510.

# Executive Summary

**Pathway Description**

The Precision Machining pathway is designed as a secondary program for preparation to enter the field of precision machining and metal turning. The Precision Machining program includes an introduction to the basic machining metalworking processes. The purpose of the course is to prepare students to continue study in a postsecondary metals program (Precision Machining, Machine Tool Operation, and Automotive Machining) or to begin work at the entry level in a machining occupation. The machining courses found in this curriculum were written to the National Institute for Metalworking Skills (NIMS) credentialing standards.

**College, Career, and Certifications**

The NIMS is a nationally recognized nonprofit organization that was established in 1995 to help develop industry standards to maintain the United States' global competitiveness. NIMS sets industry standards and certifies individuals who meet the quality requirements contained in the industry standards. NIMS also accredits training programs and facilities that meet NIMS' quality requirements. The NIMS organization and standards are accredited by the American National Standards Institute (ANSI) in the metalworking field.

NIMS metalworking standards reflect expertise in areas such as stamping, press brake, roll forming, machining, tool-and-die making, mold making, screw machining, and machine maintenance and repair. All NIMS standards are industry written and industry validated and subjected to regular, periodic reviews under the procedures accredited and audited by ANSI.

The NIMS Level 1 credential consists of bench work, layout, milling, drill press, surface grinding, and lathing between centers. The students are required to perform a NIMS-approved project in each area in order to attain credentialing in those areas. The student must be able to complete the NIMS project with 100% accuracy before being allowed to take an additional online written test. Once both the performance evaluation and the online test are administered and passed, the student will receive a NIMS certification for each area successfully completed, that is, bench work, layout, milling, drill press, surface grinding, and lathing between centers. The NIMS organization awards credentials for each area of competency in the Level 1 module after successful completion of projects and written tests.

NIMS credentials are used throughout the United States by industry to recruit, hire, place, and promote individual workers. NIMS may also be used to measure performance of individuals pursuing metalworking careers. Articulation may be established using the NIMS credentials for articulation among training programs.

Students who study basic machine metalworking processes may pursue, at their cost, a certification with the National Institute for Metalworking Skills, Inc. (NIMS). Students who study this curriculum may pursue certification of the NIMS Level 1 standards for machining. Attaining this certification is optional for the student; therefore, the student is responsible for the financial costs attributed with achievement of the certification.

**Grade Level and Class Size Recommendations**

It is recommended that students enter this program as a tenth grader. Exceptions to this are a district level decision based on class size, enrollment numbers, and maturity of student. The classroom and lab is designed to accommodate a maximum of 15 students.

**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 https://www.rcu.msstate.edu/Curriculum/Manufacturing.aspx?tag=precision

**Teacher Licensure**

The latest CTE teacher licensure information can be found at http://www.mdek12.org/OTL/OEL/career&technical

**Professional Learning**

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

# 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. **Fundamentals of Precision Machining – Course Code: 993405**
2. **Application of Precision Machining – Course Code: 993406**
3. **Theory of Precision Machining – Course Code: 993407**
4. **Advanced Skills of Precision Machining – Course Code: 993408**

**Course Description: Fundamentals of Precision Machining**
Fundamentals of Precision Machining includes an introduction to the field of precision machining as well as fundamentals of safety, tools, basic math, blueprint reading, and milling machinery.

**Course Description: Application of Precision Machining**
Application of Precision Machining emphasizes an overview of safety and leadership, lathe theory, and grinding operations. This course gives students hands-on practice in these areas.

**Course Description: Theory of Precision Machining**
Theory of Precision Machining includes a study of precision machining techniques and advanced lathe operation.

**Course Description: Advanced Skills of Precision Machining**
Advanced Skills of Precision Machining emphasizes the study of precision machining techniques in advanced milling and CNC operations.

**Fundamentals of Precision Machining – Course Code: 993405**

| Unit | Unit Name | Hours |
|---|---|---|
| 1 | Orientation, Leadership, and Basic Safety | 25 |
| 2 | Math, Measuring Tools, and Instruments | 20 |
| 3 | Introduction to Blueprints and Hand and Power Tools | 25 |
| 4 | Bench and Pedestal Grinding (Offhand Grinding) | 25 |
| 5 | Drill Press and Band Saw Theory and Operation | 20 |
| Total | | 120 |

**Application of Precision Machining – Course Code: 993406**

| Unit | Unit Name | Hours |
|---|---|---|
| 6 | Lathe Theory and Operation | 75 |
| 7 | Milling Machine Theory and Operation | 30 |
| 8 | Introduction to Lathe and Milling Skills | 25 |
| Total | | 125 |

**Theory of Precision Machining – Course Code: 993407**

| Unit | Unit Name | Hours |
|---|---|---|
| 9 | Orientation, Advanced Leadership, and Employability Skills | 8 |
| 10 | Basic Safety | 10 |
| 11 | Advanced Lathe Operation | 95 |
| Total | | 113 |

**Advanced Skills of Precision Machining – Course Code: 993408**

| Unit | Unit Name | Hours |
|---|---|---|
| 12 | Advanced Milling Operation | 95 |
| 13 | Grinding Theory and Operation | 15 |
| 14 | Computerized Numerical Control | 10 |
| Total | | 130 |

**Option 2—Two Two-Carnegie-Unit Courses**

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

1. **Precision Machining I—Course Code: 993403**

2. **Precision Machining II—Course Code: 993404**

**Course Description: Precision Machining I**

Precision Machining I includes orientation and leadership, basic safety, math, measuring tools and instruments, blueprints, hand and power tools, lathe theory and operation milling, machine theory and operation, and grinding operations. Safety is emphasized in each unit and every activity.

**Course Description: Precision Machining II**

Precision Machining II includes advanced precision machining techniques in lathing, vertical milling, and computer numerical control (CNC).

**Precision Machining I—Course Code: 993403**

| Unit | Unit Name | Hours |
|---|---|---|
| 1 * | Orientation, Leadership, and Basic Safety | 25 |
| 2 * | Math, Measuring Tools, and Instruments | 20 |
| 3 * | Introduction to Blueprints and Hand and Power Tools | 25 |
| 4 * | Bench and Pedestal Grinding (Offhand Grinding) | 25 |
| 5 * | Drill Press and Band Saw Theory and Operation | 20 |
| 6 * | Lathe Theory and Operation | 75 |
| 7 | Milling Machine Theory and Operation | 30 |
| 8 | Introduction to Lathe and Milling Skills | 25 |
| Total | | 245 |

**Precision Machining II—Course Code: 993404**

| Unit | Unit Name | Hours |
|---|---|---|
| 9* | Orientation, Advanced Leadership, and Employability Skills | 8 |
| 10* | Basic Safety | 10 |
| 11* | Advanced Lathe Operation | 95 |
| 12* | Advanced Milling Operation | 95 |
| 13 | Grinding Theory and Operation | 15 |
| 14 | Computerized Numerical Control | 10 |
| Total | | 233 |

# Research Synopsis

**Introduction**

Resources used in the study of Manufacturing Cluster Pathways consisted of phone interviews with industry contacts as well as industry interviews conducted in person. These interviews were used to determine the immediate needs of industries across the state within the metal fabrication and precision machining occupations. The manufacturing interviews centered on production maintenance, electronic technician, tool and die maker, machinist, and welding jobs that are becoming increasingly difficult to fill. The 2011–2020 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 included curriculum information from 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 the industry interviews.

**Needs of the Future Workforce**

Employers indicated that if individuals came to the workplace with a general understanding of problem solving, they could train new hires in more specific skill areas related to the company's manufacturing needs. All employers express the desperate need for applicants to have work ethics. The interviewees indicated that the most difficult hurdle for them was finding applicants who displayed courtesy, integrity, self-control, a good attitude, morals, and dependability. Above all, employees must be dependable and trustworthy and display a desire to be productive citizens. Most industries indicated they do not hire youth straight out of high school due to the maturity level of the individuals and the maturity level expected to perform the job. Almost all of the interviewees indicated that the employees should have computer skills that relate to the job and also have basic math, reading comprehension, and communication skills.

*Industry Comments and Quotes:*

- "I need people who can read measuring devices and individuals who are computer literate. If an individual comes with basic skills, we can teach them higher order measurement that is done in our production process."
- "We need graduates who can read blueprints and who have good math and computer skills."
- "I need employees who can use precision measurement instruments along with mathematic skills."
- "We need students who have a broad knowledge base. We would prefer to start students learning trades in seventh and eighth grades, narrowing to a more specific curriculum in eleventh and twelfth grades."
- "We need workers who are multi-skilled."
- "We need employees who can problem solve. That way they can work in multiple areas if needed."

| Occupational Title | Employment 2011 | Projected employment 2020 | Change 2011-2020 | | Mean annual wage (in dollars) |
|---|---|---|---|---|---|
| | | | Number | Percent | |
| Machinist | 4,195 | 4,721 | 526 | 13% | $18.90 |
| Model makers and patternmakers, metal and plastic | 121 | 154 | 33 | 27% | $13.98 |
| Tool and die makers | 432 | 494 | 62 | 14% | $23.35 |

Source: EMSI Complete Employment - 20113

## Perkins IV Requirements

The Precision Machining 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 IHL courses that will prepare them for occupations in these fields. Additionally, the Precision Machining curriculum is integrated with academic common core standards. Lastly, the Precision Machining curriculum focuses on ongoing and meaningful professional development for teachers as well as relationships with industry.

## Curriculum Content

*Summary of Standards*

The standards to be included in the Precision Machining curriculum are the Common Core Standards for Mathematics and Science, 21st Century Skills, and the National Educational Technology Standards (NETS) for Students. Combining these standards to create this document results in highly skilled, well-rounded students who are prepared to enter a secondary academic or career and technical program of study. They will also be prepared to academically compete nationally as the Common Core Standards are designed to prep students for success in community colleges, Institutions of Higher Learning, and careers.

*Industry Certification*

The Precision Machining curriculum is written to the National Institute of Metalworking Skills (NIMS) Machining Level One standards.

## Transition to Postsecondary Education

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

## Best Practices

*Innovative Instructional Technologies*

Recognizing that today's students are digital learners, the classroom should be equipped with tools that will teach them in the way they need to learn. The Precision Machining curriculum includes teaching strategies that incorporate 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 an interactive white board and projector, intensifying the interaction between students and teachers during class. Teachers are encouraged to make use of the latest online communication tools such as wikis, blogs, and podcasts. They are also encouraged to teach using the content delivery system Blackboard, which introduces students to education in an online environment and places the responsibility of learning on the student.

*Differentiated Instruction*

Students learn in a variety of ways. Some are visual learners, needing only to read information and study it to succeed. Others are auditory learners, thriving best when information is read aloud to them. Still others are tactile learners, needing to participate actively in their learning experiences. Add the student's background, emotional health, and circumstances, and a very unique learner emerges. To combat this, the Precision Machining curriculum is written to include several instructional methods by using the Understanding by Design (UbD) approach. This method of instruction design leads students to a deeper understanding of course material and provides multiple opportunities for students to succeed in different ways. Many activities are graded by rubrics that allow students to choose the type of product they will produce. By providing various teaching and assessment strategies, students with various learning styles can succeed.

*Career and Technical Education Student Organizations*

There are student organizations for students that would be relevant to this curriculum. Teachers are encouraged to charter one of these organizations if one is not already available to students. The suggested organization for this course is SkillsUSA. Contact information for this and other related organizations is listed under "Professional Organizations" in this document.

**Conclusions**

Based on the previous information, the Precision Machining curriculum will be filled with opportunities to develop workforce skills. Widely used teaching strategies such as cooperative learning, problem-based learning and demonstration will also be included. These will help to prepare students for the hands-on instruction they will likely receive upon entering the workforce. Because many of the instructors make use of the rubrics and teaching and assessment strategies, they will continue to be included in the curriculum document. The curriculum document will be updated regularly to reflect the needs of the precision machining workforce.

# Professional Organizations

Association of Career and Technical Education
1410 King St.
Alexandria, VA 22314
800.826.9972
acteonline.org

International Society for Technology in Education
180 W. 8th Ave., Suite 300
Eugene, OR 97401-2916
800.336.5191
iste.org

Mississippi Manufacturing Association (MMA)
P.O. Box 22607
Jackson, MS 39225
Phone: 601.948.1222
http://www.mma-web.org/

National Institute for Metalworking Skills, Inc.
10565 Fairfax Boulevard, Suite 203
Fairfax, Virginia 22030
Phone: 703.352.4971
FAX: 703.352.4991
https://www.nims-skills.org/

SkillsUSA
14001 SkillsUSA Way
Leesburg, Virginia 20176
Phone: 703-777-8810
FAX: 703-777-8999
https://www.skillsusa.org/

Skills USA – Mississippi
Central High School
359 North West Street
P.O. Box 771
Jackson, MS 39205-0771
Phone 601.359.3075
Fax: 601.354.7788
https://www.md.ek12.org/CTE/SO/SkillsUSA

# 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. The remaining percentage of class time will include instruction in non-tested material, review for end of course testing, and special projects.

**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 will be 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.

**Integrated Academic Topics, 21st Century Skills and Information and Communication Technology Literacy Standards, ACT College Readiness Standards, and Technology Standards for Students**

This section identifies related academic topics as required in the Subject Area Testing Program (SATP) in Algebra I, Biology I, English II, and U.S. History from 1877, which are integrated into the content of the unit. Research-based teaching strategies also incorporate ACT College Readiness standards. This section also identifies the 21st Century Skills and Information and Communication Technology Literacy skills. In addition, national technology standards for students associated with the competencies and suggested objectives for the unit are also identified.

**References**

A list of suggested references is provided for each unit within the accompanying teacher resource document. The list includes some of the primary instructional resources that may be used to teach the competencies and suggested objectives. Again, these resources are suggested, and the list may be modified or enhanced based on needs and abilities of students and on available resources. The teacher resource document can be downloaded at rcu.msstate.edu/Curriculum/CurriculumDownload.aspx

# Unit 1: Orientation, Leadership, and Basic Safety

| **Competencies and Suggested Objectives** |
|---|
| 1. Describe local program and career technical center policies and procedures. DOK1<br>a. Describe local program and career technical center policies and procedures including dress code, attendance, academic requirements, discipline, and transportation regulations. |
| 2. Describe employment opportunities and responsibilities. DOK 2<br>a. Relate employment opportunities including potential earnings, employee benefits, job availability, place of employment, working conditions, and educational requirements to students' success in a secondary or postsecondary manufacturing curriculum.<br>b. Describe basic employee responsibilities. |
| 3. Explore leadership skills and personal development opportunities provided for students by student organizations including SkillsUSA. DOK 2<br>a. Demonstrate effective team-building and leadership skills.<br>b. Practice appropriate work ethics.<br>c. Demonstrate the ability to follow verbal and written instructions and communicate effectively in on-the-job situations.<br>d. Discuss the history of the metal trade industry to include materials, terminology, and techniques. |
| 4. Explain safety in and around manufacturing and electrical situations. DOK 2<br>a. Explain injuries when electrical contact occurs.<br>b. Explain safety around Manufacturing and electrical hazards.<br>c. Explain action to take when an electrical shock occurs.<br>**Note: Safety is to be taught as an ongoing part of the program. Students are required to complete a written safety test with 100% accuracy before entering the shop for lab simulations and projects. This test should be documented in each student's file.** |
| 5. Describe general safety rules for working in a shop/lab and industry. DOK 1<br>a. Describe how to avoid on-site accidents.<br>b. Explain the relationship between housekeeping and safety.<br>c. Explain the importance of following all safety rules and company safety policies.<br>d. Explain the importance of reporting all on-the-job injuries and accidents.<br>e. Explain the need for evacuation policies and the importance of following them.<br>f. Investigate employer's substance abuse policy and how it relates to safety.<br>g. Demonstrate the safety procedures when working near pressurized or high temperature. |
| 6. Identify and apply safety around manufacturing operations. DOK 1<br>a. Use proper safety practices when performing manufacturing operations.<br>b. Recognize and explain personal protective equipment.<br>c. Inspect and care for personal protective equipment. |

| |
|---|
| 7. Explain lifting. DOK 3<br>a. Identify and explain the procedures for lifting heavy objects. |
| 8. Explain the safety data sheet (SDS). DOK 2<br>a. Explain the function of the SDS.<br>b. Interpret the requirements of the SDS. |
| 9. Explain fires. DOK 1<br>a. Explain the process by which fires start.<br>b. Explain fire prevention of various flammable liquids.<br>c. Explain the classes of fire and the types of extinguishers. |

# Unit 2: Math, Measuring Tools, and Instruments

| **Competencies and Suggested Objectives** |
|---|
| 1. Apply the four basic math skills with whole numbers, fractions, and percentages. DOK 1<br>a. Add, subtract, multiply, and divide whole numbers, decimals, and fractions.<br>b. Convert whole numbers to fractions, and convert fractions to whole numbers.<br>c. Convert decimals to percents and percents to decimals.<br>d. Convert fractions to decimals.<br>e. Convert fractions to percents. |
| 2. Perform basic mathematical calculations related to machine shop operations. DOK 1<br>a. Convert metric measurements to English measurements.<br>b. Solve basic angles and sides.<br>c. Calculate the amount of material for a given project.<br>d. Compute distances according to a drawn plan. |
| 3. Identify and perform functions using various measuring tools and instruments (micrometers, dial indicators, height gauge, and digital caliper). DOK 2<br>a. Read a rule to the nearest 1/32 in.<br>b. Lay out lines with a rule.<br>c. Describe the care and use of various rules. |

# Unit 3: Introduction to Blueprints and Hand and Power Tools

| **Competencies and Suggested Objectives** |
| --- |
| 1. Read, analyze, and design a blueprint. DOK 2<br>a. Identify terms and symbols commonly used on blueprints.<br>b. Relate information on prints to real parts/models.<br>c. Interpret various symbols to locate various elements.<br>d. Interpret a plan to determine layout.<br>e. Explain basic layout of a blueprint.<br>f. Describe the information in a title block.<br>g. Identify the lines used on blueprints. |
| 2. Demonstrate the use and maintenance of various hand and power tools. DOK 3<br>a. Identify and discuss the use of common hand and power tools.<br>b. Discuss rules of safety.<br>c. Select and demonstrate the use of tools.<br>d. Explain the procedures for maintenance. |

# Unit 4: Bench and Pedestal Grinding (Offhand Grinding)

| **Competencies and Suggested Objectives** |
| --- |
| 1. Describe safety in operating a bench or pedestal grinder, and the reasons for using offhand grinding. DOK 3<br>a. Describe grinding safety.<br>b. Describe safety rules that apply to bench and pedestal grinding.<br>c. Identify grit and abrasive properties and bonding agents.<br>d. Define grain size, bond grade, and bond type. |
| 2. Perform maintenance operations to manufacturer's specifications and grinding operations to teacher's specifications. DOK 4<br>a. Remove and replace a grinding wheel.<br>b. Dress a wheel flat.<br>c. Grind a work piece flat and parallel. Grind a work piece square, to an angular surface, and to dimension. |

# Unit 5: Drill Press and Band Saw Theory and Operation

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| **Competencies and Suggested Objectives** |
| --- |
| 1. Identify and describe the types of drilling machines, including hand powered and drill press, and the rules for safe operation of each. DOK 2<br>a. Describe safety rules for the safe use of a hand power drill and drill press.<br>b. Identify work-holding and setup devices in drill press operations.<br>c. Lay out holes and drill, ream, countersink, and counter bore according to project specifications. |
| 2. Identify and describe the safe operation of the types of power saws. DOK 2<br>a. Identify and describe rules for safe use of power saws.<br>b. Describe factors that determine saw blade selection.<br>c. Describe factors to consider in the care and cleaning of power saws.<br>d. Lay out and cut stock with a band saw according to specifications. |

# Unit 6: Lathe Theory and Operation

| **Competencies and Suggested Objectives** |
| --- |
| 1. Identify the parts, rules, and care of the metal lathe. DOK 3<br>a. Identify the four major parts of the lathe.<br>b. Set up a lathe, and determine the rpm and feed rate according to manufacturer's specifications for the basic lathe operations.<br>c. Explain the advantages and disadvantages of carbide tip cutting tools, and demonstrate how to freehand grind a high-speed steel (HSS) turning tool. |
| 2. Perform procedures for a machining operation. DOK 3<br>a. Identify terms and procedures for lathe operations.<br>b. Discuss the rules of safety.<br>c. Demonstrate centering a work piece in a four-jaw chuck on the lathe.<br>d. Face a part to length.<br>e. Perform a straight turning operation.<br>f. Perform a chamfer operation.<br>g. Perform a center drilling operation.<br>h. Perform a knurling operation.<br>i. Perform a cutoff operation.<br>j. Tap a blind hole.<br>k. Cut external and internal threads on the lathe.<br>l. Install a chuck on a lathe.<br>m. Mount and align a part in a four-jaw chuck on a lathe to instructor's specifications.<br>n. Turn a taper with a compound rest and a taper attachment.<br>o. Perform a boring operation.<br>p. Perform wet and dry cuts. |

# Unit 7: Milling Machine Theory and Operation

| **Competencies and Suggested Objectives** |
| --- |
| 1. Differentiate between the types of vertical milling machines. DOK 2<br>a. Identify the different types of vertical milling machines.<br>b. Explain the use and safety of each type of milling machine. |
| 2. Identify the parts, cutting tools, and basic maintenance of a vertical milling machine. DOK 2<br>a. Identify the major parts of a vertical mill.<br>b. Identify the cutting tools used on a vertical mill.<br>c. Clean and lubricate a vertical mill following manufacturer's specifications.<br>d. Determine the rpm and feed rate. |
| 3. Perform operations on a milling machine. DOK 4<br>a. Perform operations on a vertical milling machine.<br>b. Perform the end milling, side milling, slotting, drilling, reaming, boring, and fly cutting operations. Mount cutters and cutter holders, and mount and align a swivel vise; mill a key seat, a given angle, and a straight boring operation; align the head square to the table, perform a mill operation with head tilted to 45°, and divide head operations. |

# Unit 8: Introduction to Lathe and Milling Skills

| **Competencies and Suggested Objectives** |
| --- |
| 1. Lathe: Describe safety precautions, methods for measuring thread pitch diameters, and calculation of dimensions using taper formulas with 0.010 tolerance. DOK 2<br>a. Describe safety precautions.<br>b. Describe methods for measuring thread pitch diameters.<br>c. Calculate dimensions using taper formulas.<br>d. Turn a taper with taper attachment, and turn a taper with compound. Also perform boring, cutting external threads to relief, picking up threads, and cutting internal threads. |
| 2. Mill: Align a vise using a dial indicator to 0.005 tolerance, and mill a quarter-inch keyway to 0.005 tolerance. DOK 2<br>a. Perform drilling, counter sinking and counter boring, and aligning and starting a tap. |

# Unit 9: Orientation, Advanced Leadership, and Employability Skills

| **Competencies and Suggested Objectives** |
|---|
| 1. Describe local program and vocational center policies and procedures. DOK 1<br>a. Describe local program and vocational center policies and procedures including dress code, attendance, academic requirements, discipline, and transportation regulations. |
| 2. Describe employment opportunities and responsibilities. DOK 2<br>a. Describe employment opportunities including potential earnings, employee benefits, job availability, place of employment, working conditions, and educational requirements.<br>b. Describe basic employee responsibilities.<br>c. Design a resume and complete a job application. |
| 3. Demonstrate the ability to follow verbal and written instructions and communicate effectively in on-the-job situations. DOK<br>a. Perform projects through written instruction.<br>b. Perform projects through oral instruction. |

# Unit 10: Basic Safety

| |
|---|
| **Review and Reinforcement** |
| **Note: SAFETY IS TO BE TAUGHT AS AN ONGOING PART OF THE COURSE THROUGHOUT THE YEAR.** |
| **Competencies and Suggested Objectives** |
| 1. Describe general safety rules for working in a shop, laboratory, and/or industry. DOK 1<br>a. Describe how to avoid on-site accidents.<br>b. Explain the relationship between housekeeping and safety.<br>c. Explain the importance of following all safety rules and company safety policies.<br>d. Explain the importance of reporting all on-the-job injuries, accidents, and near misses.<br>e. Explain the need for evacuation policies and the importance of following them.<br>f. Explain the employer's substance-abuse policy and how it relates to safety.<br>g. Explain the safety procedures when working near pressurized or high temperatures.<br>**Note: Safety is to be taught as an ongoing part of the program. Students are required to complete a written safety test with 100% accuracy before entering the shop for lab simulations and projects. This test should be documented in each student's file.** |
| 2. Identify and apply safety around manufacturing operations. DOK 1<br>a. Use proper safety practices when welding or working around manufacturing operations.<br>b. Explain the term "proximity work." |
| 3. Identify and explain use of various barriers and confinements. DOK 2<br>a. Explain the safety requirements for working in confined areas.<br>b. Explain and practice lock-out/tag-out procedures.<br>c. Explain the different barriers and barricades and how they are used.<br>d. Recognize and explain personal protective equipment (PPE).<br>e. Inspect and care for personal protective equipment (PPE). |
| 4. Explain lifting. DOK 2, SAF<br>a. Identify and explain the procedures for lifting heavy objects. |
| 5. Explain the Safety Data Sheet (SDS). DOK 1<br>a. Explain the function of the SDS.<br>b. Interpret the requirements of the SDS. |
| 6. Explain fires. DOK 2, SAF<br>a. Explain the process by which fires start.<br>b. Explain fire prevention of various flammable liquids.<br>c. Explain the classes of fires and the types of extinguishers. |
| 7. Explain safety in and around electrical situations. DOK 3<br>a. Explain injuries when electrical contact occurs.<br>b. Explain safety around electrical hazards.<br>c. Explain actions to take when an electrical shock occurs |

# Unit 11: Advanced Lathe Operation

| **Competencies and Suggested Objectives** |
| --- |
| 1. Describe safety precautions, methods for measuring thread-pitch diameters, and calculation of dimensions using taper formulas to 0.003 tolerance. DOK 2<br>a. Describe methods for measuring thread-pitch diameters.<br>b. Calculate dimensions using taper formulas. |
| 2. Perform various operations according to specifications. DOK 2<br>a. Perform chamfer, recessing, knurling, drilling and recessing a hole, aligning and starting a tap using a lathe center, and cutoff.<br>b. Perform turning a taper with taper attachment, turning a taper with compound, boring, cutting external threads to relief, picking up threads, and cutting internal threads. |

# Unit 12: Advanced Milling Operation

| **Competencies and Suggested Objectives** |
| --- |
| 1. Adjust speed and feed rates, clean and lubricate, mount arbors and adjust arbor support bushing, mount a cutter, mill a key-way, and perform selected operations. DOK 2<br>a. Adjust machine speed and feed rates; clean and lubricate.<br>b. Mount arbors and adjust arbor support bushing and mount a cutter according to specifications.<br>c. Perform selected operations according to specifications. |
| 2. Mount and remove cutters and cutter holders, align a vise using a dial indicator, and perform selected vertical milling and boring operations. DOK 2<br>a. Mount and remove cutters and cutter holders; mount and align a vise.<br>b. Perform selected milling and boring operations according to specifications. |

# Unit 13: Grinding Theory and Operation

| **Competencies and Suggested Objectives** |
| --- |
| 1. Describe safety, magnetic chuck work, surface grinding operations, and reasons for truing and balancing a grinding wheel. DOK 3<br>a. Describe grinding safety.<br>b. Describe safety rules that apply to magnetic chuck work.<br>c. Identify surface grinding operations.<br>d. Explain reasons for truing and balancing grinding wheels. |

# Unit 14: Computerized Numerical Control

| **Competencies and Suggested Objectives** |
| --- |
| 1. Describe computerized numerical control (CNC), including the codes and the input of a pre-written program. DOK 2<br>a. Describe the operations of CNC.<br>b. Describe codes used in a CNC machine. |
| 2. Safely operate a computerized numerical control (CNC) machine. DOK 2<br>a. Debug the program.<br>b. Download the program.<br>c. Execute the program.<br>d. Input a pre-written program into a PC.<br>e. Print a hard copy of the program. |

# Student Competency Profile

**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, Leadership, and Basic Safety** | | |
| | 1. | Describe local program and career technical center policies and procedures. |
| | 2. | Describe employment opportunities and responsibilities. |
| | 3. | Explore leadership skills and personal development opportunities provided for students by student organizations including SkillsUSA. |
| | 4. | Explain safety in and around manufacturing and electrical situations. |
| | 5. | Describe general safety rules for working in a shop/lab and industry. |
| | 6. | Identify and apply safety around manufacturing operations. |
| | 7. | Explain lifting. |
| | 8. | Explain the safety data sheet (SDS). |
| | 9. | Explain fires. |
| **Unit 2: Math, Measuring Tools, and Instruments** | | |
| | 1. | Apply the four basic math skills with whole numbers, fractions, and percentages. |
| | 2. | Perform basic mathematical calculations related to machine shop operations. |
| | 3. | Identify and perform functions using various measuring tools and instruments (micrometers, dial indicators, height gauge, and digital caliper). |
| **Unit 3: Introduction to Blueprints and Hand and Power Tools** | | |
| | 1. | Read, analyze, and design a blueprint. |
| | 2. | Demonstrate the use and maintenance of various hand and power tools. |
| **Unit 4: Bench and Pedestal Grinding (Offhand Grinding)** | | |
| | 1. | Describe safety in operating a bench or pedestal grinder, and the reasons for using offhand grinding. |
| | 2. | Perform maintenance operations to manufacturer's specifications and grinding operations to teacher's specifications. |
| **Unit 5: Drill Press and Band Saw Theory and Operation** | | |
| | 1. | Identify and describe the types of drilling machines, including hand powered and drill press, and the rules for safe operation of each. |
| | 2. | Identify and describe the safe operation of the types of power saws. |

| | | |
|---|---|---|
| **Unit 6: Lathe Theory and Operation** | | |
| | 1. | Identify the parts, rules, and care of the metal lathe. |
| | 2. | Perform procedures for a machining operation. |
| **Unit 7: Milling Machine Theory and Operation** | | |
| | 1. | Differentiate between the types of vertical milling machines. |
| | 2. | Identify the parts, cutting tools, and basic maintenance of a vertical milling machine. |
| | 3. | Perform operations on a milling machine. |
| **Unit 8: Introduction to Lathe and Milling Skills** | | |
| | 1. | Lathe: Describe safety precautions, methods for measuring thread pitch diameters, and calculation of dimensions using taper formulas with 0.010 tolerance. |
| | 2. | Mill: Align a vise using a dial indicator to 0.005 tolerance, and mill a quarter-inch keyway to 0.005 tolerance. |
| **Unit 9: Orientation, Advanced Leadership, and Employability Skills** | | |
| | 1. | Describe local program and vocational center policies and procedures. |
| | 2. | Describe employment opportunities and responsibilities. |
| | 3. | Demonstrate the ability to follow verbal and written instructions and communicate effectively in on-the-job situations. |
| **Unit 10: Basic Safety** | | |
| | 1. | Describe general safety rules for working in a shop, laboratory, and/or industry. |
| | 2. | Identify and apply safety around manufacturing operations. |
| | 3. | Identify and explain use of various barriers and confinements. |
| | 4. | Explain lifting. |
| | 5. | Explain the Safety Data Sheet (SDS). |
| | 6. | Explain fires. |
| | 7. | Explain safety in and around electrical situations. |
| **Unit 11: Advanced Lathe Operation** | | |
| | 1. | Describe safety precautions, methods for measuring thread pitch diameters, and calculation of dimensions using taper formulas to 0.003 tolerance. |
| | 2. | Perform various operations according to specifications. |
| **Unit 12: Advanced Milling Operation** | | |
| | 1. | Adjust speed and feed rates, clean and lubricate, mount arbors and adjust arbor support bushing, mount a cutter, mill a key-way, and perform selected operations. |
| | 2. | Mount and remove cutters and cutter holders, align a vise using a dial indicator, and perform selected vertical milling and boring operations. |
| **Unit 13: Grinding Theory and Operation** | | |
| | 1. | Describe safety, magnetic chuck work, surface grinding operations, and reasons for truing and balancing a grinding wheel. |

| | | |
|---|---|---|
| **~~Unit 14: Computerized Numerical Control~~** | | |
| | ~~1.~~ | ~~Describe computerized numerical control (CNC), including the codes and the input of a pre-written program.~~ |
| | ~~2.~~ | ~~Safely operate a computerized numerical control (CNC) machine.~~ |
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# Appendix A: Industry Standards

| NIMS Crosswalk for Precision Machining | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Unit 1 | Unit 2 | Unit 3 | Unit 4 | Unit 5 | Unit 6 | Unit 7 | Unit 8 | Unit 9 | Unit 10 | Unit 11 | Unit 12 | Unit 13 | Unit 14 |
| NIMS LEVEL ONE | | | | | | | | | | | | | | | |
| L1B | | | X | X | X | X | X | X | X | X | X | X | X | X | X |
| LIL | | | X | X | | X | X | X | X | | | X | X | | |
| 1VM | | | X | X | | | | X | X | | | | X | | |
| 1DP | | | X | X | X | X | | | | | | | | | |
| 1SG | | | X | X | | | | X | X | | | | X | X | |
| 1TB | | | X | X | | | X | | X | | | X | X | | |
| 1TC | | | X | X | | | X | | X | | | X | | | |
| 1CM | | | X | X | | | | | | | | | | | X |
| 1CT | | | X | X | | | | | | | | | | | X |

**National Institute for Metalworking Skills (NIMS)**
**NIMS Machining Level 1**

**L1B - Benchwork**
Given a process plan, blueprint, and access to hand tools, produce a part with two holes prepared for hand tapping, a hole prepared (reamed) for the press fit of a bushing, and a stud for one of the tapped holes. Deburr the part, hand drill and hand tap the holes, press in the bushing, and install the stud. File chamfer.

Other Evaluation Criteria
1. Free of sharp edges or burrs
2. Go/NoGo gauge for the threads
3. Length of stud within 0.03 of basic dimension and square to surface
Accuracy Level: +/- 0.015 unless otherwise specified on the blueprint

**LIL - Layout**
Given a surface plate, surface gage, layout height gage, combination set, scriber, layout ink, prick punch, ball-peen hammer, process plan, and part print, lay out hole locations, radii, and surfaces matching the specifications.

Other Evaluation Criteria
1. Layout ink is applied to the surface appropriately.
2. Lines are struck once.
3. Intersections are clean and clear.
4. Punch marks are centered on intersections.
Accuracy Level: +/- 0.015 unless otherwise specified on the blueprint

**1VM - Vertical Milling**

Given raw material, print, hand, precision, and cutting tools, as well as access to an appropriate vertical milling machine and its accessories, produce a part matching the blueprint specifications using appropriate trade techniques and speeds and feeds. The part specified should require squaring up from the raw state, have at least one milled slot, require the location of at least two drilled and reamed holes within positional tolerance of 0.014 in., and have three steps controlled by tolerances of +/- 0.005 in.

Other Evaluation Criteria
1. Finishes are at least 125 Ra microinches.
2. No sharp edges
Accuracy Level: +/- 0.015 on all fractions, +/- 0.005 on all decimals unless otherwise specified on the blueprint
Finished surfaces are to be square within 0.005 over 4 in.
Finished surfaces are to be 125 Ra microinches unless otherwise specified.

**1DP - Drill Press**
Given a part print and hand, precision, and cutting tools, as well as access to a drill press and its accessories, produce a part matching the process plan and the blueprint specifications. Each hole must have at least two secondary operations. The secondary operations will consist of reaming, spot facing, countersinking, counterboring, and counterdrilling. At least one hole must be a blind hole and one a through hole. At least one hole will/may be power tapped.

Other Evaluation Criteria
1. Finishes are at least 250 Ra microinches.
2. No sharp edges
3. The mouths of all holes are lightly countersunk.
Accuracy Level: +/- 1/64 on all fractions, holes square within 0.005 per inch, drilled diameters, +0.006, -0.000
Reamed diameters are +0.001, -0.000, +/- 0.005 on all decimals unless otherwise specified on the blueprint.

**1SG - Surface Grinding**
Given a block squared up on a mill, part print, hand and precision tools, and choice of a grinding wheels, as well as access to a surface grinder and its accessories, dress the wheel, produce a part matching the print specifications using appropriate trade techniques. The part specified will be in the semi-finished state having been squared up and milled. Finishing the part will require the precision finishing of the six faces of the block to tolerances common to precision grinding for squareness, size, and surface finish characteristics.

Other Evaluation Criteria
1. Finishes are at least 32 Ra microinches or better.
2. Free of sharp edges
Accuracy Level: +/- 0.001 on all decimals unless otherwise specified on the print. Square within 0.001 over 4 in.

**1TB - Turning - Between Centers**

Given raw material, process plan, part print, and hand, precision, and cutting tools, as well as access to an appropriate turning machine and its accessories, produce a part matching the process plan and the part print specifications using appropriate trade techniques and speeds and feeds. The part specified should have at least three diameters within +/- 0.002, one UNC external thread, one UNF external thread, and require part be turned end for end to complete.

Other Evaluation Criteria
1. Finishes are at least 125 Ra microinches.
2. No sharp edges
Accuracy Level: +/- 0.015 on all fractions, +/- 0.005 on all decimals unless otherwise specified on the part print
Diameters are to be coaxial within 0.002 total runout.

**1TC - Turning – Chucking**
Given raw material, part print, and hand, precision, and cutting tools, as well as access to an appropriate turning machine and its accessories, produce a part matching the print specifications using appropriate trade techniques and speeds and feeds. The part specified should have at least three diameters within +/- 0.005 in., two bores within +/- 0.005 in., one UNC external thread, and require at least two chuckings or other workholding setup.

Other Evaluation Criteria
1. Finishes are at least 125 Ra microinches.
2. No sharp edges
Accuracy Level: +/- 0.015 on all fractions, +/- 0.005 on all decimals unless otherwise specified on the blueprint
Diameters are to be coaxial within 0.002 total runout.

**1CM - CNC Milling**
Performance Standard
Write a program at the machine or off-line. Set up the machining operation, and perform standards given on mill operations (2.10) to develop a simple part (with linear and circular interpolations).
Accuracy Level: Match the requirements of the part print and 63 Ra microinch finish.

**1CT - CNC Turning**
Performance Standard
Write a program at the machine or off-line. Set up the machining operation, and perform all standards given on lathe operations (2.9) to develop a simple part (with linear and circular interpolations).
Accuracy Level: Match the requirements of the part print.

# Appendix B: 21st Century Skills[1]

**21st Century Crosswalk for Precision Machining**

| | Units | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Standards** | | | | | | | | | | | | | | | | | | | | | | |
| CS1 | | | | | | | | | | | | | | | | | | | | | | |
| CS2 | | X | | | | | | | | X | | | | | | | | | | | | |
| CS3 | | X | | | | | | | | X | X | | | | | | | | | | | |
| CS4 | | X | | | | | | | | | X | | | | | | | | | | | |
| CS5 | | X | | | | | | | | | X | | | | | | | | | | | |
| CS6 | | | X | X | X | X | X | X | X | X | | X | X | X | X | | | | | | | |
| CS7 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| CS8 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| CS9 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| CS10 | | X | | | | | | | | X | | | | | | | | | | | | |
| CS11 | | X | X | X | | | | | | X | X | | | | X | | | | | | | |
| CS12 | | X | | | | | | | | X | | | | | | | | | | | | |
| CS13 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| CS14 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| CS15 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| CS16 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| | | X | X | X | X | X | X | X | 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. 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

[1] *21st century skills.* (n.d.). Washington, DC: Partnership for 21st Century Skills.

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
2. Be Responsible to Others

# Appendix C: International Society for Technology in Education Standards (ISTE)

| ISTE Crosswalk for Precision Machining | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Unit 1 | Unit 2 | Unit 3 | Unit 4 | Unit 5 | Unit 6 | Unit 7 | Unit 8 | Unit 9 | Unit 10 | Unit 11 | Unit 12 | Unit 13 | Unit 14 |
| **ISTE Standards** | | | | | | | | | | | | | | | |
| T1 | | X | X | X | | | | | | X | | | | | X |
| T2 | | X | X | X | | | | | | X | | | | | X |
| T3 | | X | X | X | | | | | | X | | | | | X |
| T4 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| T5 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| T6 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| T7 | | X | X | X | | | | | | X | | | | | X |

**T1** Empowered Learner
**T2** Digital Citizen
**T3** Knowledge Constructor
**T4** Innovative Designer
**T5** Computational Thinker
**T6** Creative Communicator
**T7** Global Collaborator

**T1** Empowered Learner

Students leverage technology to take an active role in choosing, achieving and demonstrating competency in their learning goals, informed by the learning sciences. Students:

a. Articulate and set personal learning goals, develop strategies leveraging technology to achieve them and reflect on the learning process itself to improve learning outcomes.
b. Build networks and customize their learning environments in ways that support the learning process.
c. Use technology to seek feedback that informs and improves their practice and to demonstrate their learning in a variety of ways.
d. Understand the fundamental concepts of technology operations, demonstrate the ability to choose, use and troubleshoot current technologies and are able to transfer their knowledge to explore emerging technologies.

**T2** Digital Citizen

Students recognize the rights, responsibilities and opportunities of living, learning and working in an interconnected digital world, and they act and model in ways that are safe, legal and ethical. Students:

a. Cultivate and manage their digital identity and reputation and are aware of the permanence of their actions in the digital world.
b. Engage in positive, safe, legal and ethical behavior when using technology, including social interactions online or when using networked devices.
c. Demonstrate an understanding of and respect for the rights and obligations of using and sharing intellectual property.
d. Manage their personal data to maintain digital privacy and security and are aware of data-collection technology used to track their navigation online.

**T3** Knowledge Constructor

Students critically curate a variety of resources using digital tools to construct knowledge, produce creative artifacts and make meaningful learning experiences for themselves and others. Students:

a. Plan and employ effective research strategies to locate information and other resources for their intellectual or creative pursuits.
b. Evaluate the accuracy, perspective, credibility and relevance of information, media, data or other resources.
c. Curate information from digital resources using a variety of tools and methods to create collections of artifacts that demonstrate meaningful connections or conclusions.
d. Build knowledge by actively exploring real-world issues and problems, developing ideas and theories and pursuing answers and solutions.

**T4** Innovative Designer

Students use a variety of technologies within a design process to identify and solve problems by creating new, useful or imaginative solutions. Students:

a. Know and use a deliberate design process for generating ideas, testing theories, creating innovative artifacts or solving authentic problems.
b. Select and use digital tools to plan and manage a design process that considers design constraints and calculated risks.
c. Develop, test and refine prototypes as part of a cyclical design process.
d. Exhibit a tolerance for ambiguity, perseverance and the capacity to work with open-ended problems.

**T5** Computational Thinker

Students develop and employ strategies for understanding and solving problems in ways that leverage the power of technological methods to develop and test solutions. Students:

a. Formulate problem definitions suited for technology-assisted methods such as data analysis, abstract models and algorithmic thinking in exploring and finding solutions.
b. Collect data or identify relevant data sets, use digital tools to analyze them, and represent data in various ways to facilitate problem-solving and decision-making.
c. Break problems into component parts, extract key information, and develop descriptive models to understand complex systems or facilitate problem-solving.
d. Understand how automation works and use algorithmic thinking to develop a sequence of steps to create and test automated solutions.

**T6** Creative Communicator

Students communicate clearly and express themselves creatively for a variety of purposes using the platforms, tools, styles, formats and digital media appropriate to their goals. Students:

a. Choose the appropriate platforms and tools for meeting the desired objectives of their creation or communication.
b. Create original works or responsibly repurpose or remix digital resources into new creations.
c. Communicate complex ideas clearly and effectively by creating or using a variety of digital objects such as visualizations, models or simulations.
d. Publish or present content that customizes the message and medium for their intended audiences.

**T7** Global Collaborator

Students use digital tools to broaden their perspectives and enrich their learning by collaborating with others and working effectively in teams locally and globally. Students:

a. Use digital tools to connect with learners from a variety of backgrounds and cultures, engaging with them in ways that broaden mutual understanding and learning.
b. Use collaborative technologies to work with others, including peers, experts or community members, to examine issues and problems from multiple viewpoints.
c. Contribute constructively to project teams, assuming various roles and responsibilities to work effectively toward a common goal.
d. Explore local and global issues and use collaborative technologies to work with others to investigate solutions.

# Appendix D: College and Career Ready Standards – English Language Arts

**ELA Crosswalk for Precision Machining**

| | Units | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Standards | | | | | | | | | | | | | | | | | | | | | | |
| RL.9.1 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| RL.9.2 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| RL.9.3 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| RL.9.4 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | X | | |
| RL.9.5 | | | | | | | | | | | | | | | | | | | | | | |
| RL.9.6 | | X | | | | | | | | X | | | | | | | | | | | | |
| RL.9.7 | | | | | | | | | | | | | | | | | | | | | | |
| RL.9.8 | | | | | | | | | | | | | | | | | | | | | | |
| RL.9.9 | | | | | | | | | | | | | | | | | | | | | | |
| RL.9.10 | | | | | | | | | | | | | | | | | | | | | | |
| RL.9.10 | | | | | | | | | | | | | | | | | | | | | | |
| RI.9.3 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| RI.9.5 | | | | | | | | | | | | | | | | | | | | | | |
| RI.9.6 | | | | | | | | | | | | | | | X | | | | | | | |
| RI.9.7 | | | | | | | | | | | | | | | | | | | | | | |
| RI.9.8 | | | | | | | | | | | | | | | | | | | | | | |
| RI.9.9 | | | | | | | | | | | | | | | | | | | | | | |
| W.9.1 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| W.9.2 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| W.9.3 | | X | | | | | | | | X | | | | | | | | | | | | |
| W.9.4 | | X | | | | | | | | X | | | | | | | | | | | | |
| W.9.5 | | X | | | | | | | | X | | | | | | | | | | | | |
| W.9.6 | | X | | | | | | | | X | | | | | | | | | | | | |
| W.9.7 | | X | | | | | | | | X | | | | | | | | | | | | |
| W.9.8 | | X | | | | | | | | X | | | | | | | | | | | | |
| W.9.9 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| W.9.10 | | | | | | | | | | | | | | | | | | | | | | |
| SL.9.1 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| SL.9.2 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| SL.9.3 | | | | | | | | | | | | | | | | | | | | | | |
| SL.9.4 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| SL.9.5 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| SL.9.6 | | | | | | | | | | | | | | | | | | | | | | |
| L.9.1 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| L.9.2 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| L.9.3 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| L.9.4 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| L.9.5 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| L.9.6 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| RL.10.10 | | | | | | | | | | | | | | | | | | | | | | |
| RH.9-10.1 | | | | | | | | | | | | | | | | | | | | | | |
| RH.9-10.2 | | | | | | | | | | | | | | | | | | | | | | |
| RH.9-10.3 | | | | | | | | | | | | | | | | | | | | | | |
| RH.9-10.4 | | | | | | | | | | | | | | | | | | | | | | |
| RH.9-10.5 | | | | | | | | | | | | | | | | | | | | | | |
| RH.9-10.6 | | | | | | | | | | | | | | | | | | | | | | |
| RH.9-10.7 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| RH.9-10.8 | | | | | | | | | | | | | | | | | | | | | | |
| RH.9-10.9 | | | | | | | | | | | | | | | | | | | | | | |
| RH.9-10.10 | | | | | | | | | | | | | | | | | | | | | | |
| RST.9-10.1 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |

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| RST.9-10.2 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| RST.9-10.3 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| RST.9-10.4 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| RST.9-10.5 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| RST.9-10.6 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| RST.9-10.7 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| RST.9-10.8 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| RST.9-10.9 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| RST.9-10.10 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| WHST.9-10.1 | | | | | | | | | | | | | | | | | | | | | | |
| WHST.9-10.2 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| WHST.9-10.3 | | | | | | | | | | | | | | | | | | | | | | |
| WHST.9-10.4 | | X | | | | | | | X | | | | | | | | | | | | | |
| WHST.9-10.5 | | X | | | | | | | X | | | | | | | | | | | | | |
| WHST.9-10.6 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| WHST.9-10.7 | | X | | | | | | | X | | | | | | | | | | | | | |
| WHST.9-10.8 | | X | | | | | | | X | | | | | | | | | | | | | |
| WHST.9-10.9 | | X | | | | | | | X | | | | | | | | | | | | | |
| WHST.9-10.10 | | | | | | | | | | | | | | | | | | | | | | |
| RL.11.1 | | | | | | | | | | | | | | | | | | | | | | |
| RL.11.2 | | | | | | | | | | | | | | | | | | | | | | |
| RL.11.3 | | | | | | | | | | | | | | | | | | | | | | |
| RL.11.4 | | | | | | | | | | | | | | | | | | | | | | |
| RL.11.5 | | | | | | | | | | | | | | | | | | | | | | |
| RL.11.6 | | | | | | | | | | | | | | | | | | | | | | |
| RL.11.7 | | | | | | | | | | | | | | | | | | | | | | |
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| RL.11.10 | | | | | | | | | | | | | | | | | | | | | | |
| RI.11.3 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| RI.11.4 | | | | | | | | | | | | | | | | | | | | | | |
| RI.11.5 | | | | | | | | | | | | | | | | | | | | | | |
| RI.11.6 | | | | | | | | | | | | | | | | | | | | | | |
| RI.11.7 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| RI.11.8 | | | | | | | | | | | | | | | | | | | | | | |
| RI.11.9 | | | | | | | | | | | | | | | | | | | | | | |
| RI.11.10 | | | | | | | | | | | | | | | | | | | | | | |
| W.11.1 | | | | | | | | | | | | | | | | | | | | | | |
| W.11.2 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| W.11.3 | | | | | | | | | | | | | | | | | | | | | | |
| W.11.4 | | X | | | | | | | X | | | | | | | | | | | | | |
| W.11.5 | | X | | | | | | | X | | | | | | | | | | | | | |
| W.11.6 | | X | | | | | | | X | | | | | | | | | | | | | |
| W.11.7 | | | | | | | | | | | | | | | | | | | | | | |
| W.11.8 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| W.11.9 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| W.11.10 | | | | | | | | | | | | | | | | | | | | | | |
| SL.11.1 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| SL.11.2 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| SL.11.3 | | | | | | | | | | | | | | | | | | | | | | |
| SL.11.4 | | | | | | | | | | | | | | | | | | | | | | |
| SL.11.5 | | | | | | | | | | | | | | | | | | | | | | |
| SL.11.6 | | | | | | | | | | | | | | | | | | | | | | |
| L.11.1 | | | | | | | | | | | | | | | | | | | | | | |
| L.11.2 | | | | | | | | | | | | | | | | | | | | | | |
| L.11.3 | | | | | | | | | | | | | | | | | | | | | | |
| L.11.4 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| RL.12.10 | | | | | | | | | | | | | | | | | | | | | | |
| RH.11-12.1 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| RH.11-12.2 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |
| RH.11-12.3 | | | | | | | | | | | | | | | | | | | | | | |
| RH.11-12.4 | | | | | | | | | | | | | | | | | | | | | | |
| RH.11-12.5 | | | | | | | | | | | | | | | | | | | | | | |
| RH.11-12.6 | | | | | | | | | | | | | | | | | | | | | | |
| RH.11-12.7 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | |

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| RH.11-12.8 | | | | | | | | | | | | | | | | | | | | | |
| RH.11-12.9 | | | | | | | | | | | | | | | | | | | | | |
| RH.11-12.10 | | | | | | | | | | | | | | | | | | | | | |
| RST.11-12.1 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | |
| RST.11-12.2 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | |
| RST.11-12.3 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | |
| RST.11-12.4 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | |
| RST.11-12.5 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | |
| RST.11-12.6 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | |
| RST.11-12.7 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | |
| RST.11-12.8 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | |
| RST.11-12.9 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | |
| RST.11-12.10 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | |
| WHST.11-12.1 | | | | | | | | | | | | | | | | | | | | | |
| WHST.11-12.2 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | |
| WHST.11-12.6 | | X | | | | | | | X | | | | | | | | | | | | |
| WHST.11-12.8 | | X | | | | | | | X | | | | | | | | | | | | |

College and Career Ready English I

Reading Literature Key Ideas and Details

RL.9.1 Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text.

RL.9.2 Determine a theme or central idea of a text and analyze in detail its development over the course of the text, including how it emerges and is shaped and refined by specific details; provide an objective summary of the text.

RL.9.3 Analyze how complex characters (e.g., those with multiple or conflicting motivations) develop over the course of a text, interact with other characters, and advance the plot or develop the theme.

Craft and Structure

RL.9.4 Determine the meaning of words and phrases as they are used in the text, including figurative and connotative meanings; analyze the cumulative impact of specific word choices on meaning and tone (e.g., how the language evokes a sense of time and place; how it sets a formal or informal tone).

RL.9.5 Analyze how an author's choices concerning how to structure a text, order events within it (e.g., parallel plots), and manipulate time (e.g., pacing, flashbacks) create such effects as mystery, tension, or surprise.

RL.9.6 Analyze a particular point of view or cultural experience reflected in a work of literature from outside the United States, drawing on a wide reading of world literature.

Integration of Knowledge and Ideas

RL.9.7 Analyze the representation of a subject or a key scene in two different artistic mediums, including what is emphasized or absent in each treatment (e.g., Auden's "Musée des Beaux Arts" and Breughel's Landscape with the Fall of Icarus).

RL.9.8 Not applicable to literature.

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RL.9.9 Analyze how an author draws on and transforms source material in a specific work (e.g., how Shakespeare treats a theme or topic from Ovid or the Bible or how a later author draws on a play by Shakespeare).

Range of Reading and Level of Text Complexity

RL.9.10 By the end of grade 9, read and comprehend literature, including stories, dramas, and poems, in the grades 9-10 text complexity band proficiently, with scaffolding as needed at the high end of the range.

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Reading Informational Text Key Ideas and Details

RI.9.3 Analyze how the author unfolds an analysis or series of ideas or events, including the order in which the points are made, how they are introduced and developed, and the connections that are drawn between them.

Craft and Structure

RI.9.5 Analyze in detail how an author's ideas or claims are developed and refined by particular sentences, paragraphs, or larger portions of a text (e.g., a section or chapter).

RI.9.6 Determine an author's point of view or purpose in a text and analyze how an author uses rhetoric to advance that point of view or purpose.

Integration of Knowledge and Ideas

RI.9.7 Analyze various accounts of a subject told in different mediums (e.g., a person's life story in both print and multimedia), determining which details are emphasized in each account.

RI.9.8 Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and sufficient; identify false statements and fallacious reasoning.

RI.9.9 Analyze seminal U.S. documents of historical and literary significance (e.g., Washington's Farewell Address, the Gettysburg Address, Roosevelt's Four Freedoms speech, King's "Letter from Birmingham Jail"), including how they address related themes and concepts.

College and Career Ready English I

Writing Text Types and Purposes

W.9.1 Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

W.9.1a Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that establishes clear relationships among claim(s), counterclaims, reasons, and evidence.

W.9.1b Develop claim(s) and counterclaims fairly, supplying evidence for each while pointing out the strengths and limitations of both in a manner that anticipates the audience's knowledge level and concerns.

W.9.1c Use words, phrases, and clauses 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.

W.9.1d Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

W.9.1e Provide a concluding statement or section that follows from and supports the argument presented.

W.9.2 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.

W.9.2a Introduce a topic; organize complex ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

W.9.2b Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

W.9.2c Use appropriate and varied transitions to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts.

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W.9.2d Use precise language and domain-specific vocabulary to manage the complexity of the topic.

W.9.2e Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

W.9.2f 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.9.3 Write narratives to develop real or imagined experiences or events using effective technique, well-chosen details, and well-structured event sequences.

W.9.3a Engage and orient the reader by setting out a problem, situation, or observation, establishing one or multiple point(s) of view, and introducing a narrator and/or characters; create a smooth progression of experiences or events.

W.9.3b Use narrative techniques, such as dialogue, pacing, description, reflection, and multiple plot lines, to develop experiences, events, and/or characters.
W.9.3c Use a variety of techniques to sequence events so that they build on one another to create a coherent whole.
W.9.3d Use precise words and phrases, telling details, and sensory language to convey a vivid picture of the experiences, events, setting, and/or characters.
W.9.3e 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.9.4 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.9.5 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 9–10.)
W.9.6 Use technology, including the Internet, to produce, publish, and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically.

Research to Build and Present Knowledge

W.9.7 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.

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W.9.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.
W.9.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.
W.9.9a Apply grades 9–10 Reading standards to literature (e.g., "Analyze how an author draws on and transforms source material in a specific work [e.g., how Shakespeare treats a theme or topic from Ovid or the Bible or how a later author draws on a play by Shakespeare]").
W.9.9b Apply grades 9–10 Reading standards to literary nonfiction (e.g., "Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and sufficient; identify false statements and fallacious reasoning").

Range of Writing

W.9.10 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 audience.

College and Career Ready English I

SL.9.1 Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
SL.9.1a 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.
SL.9.1b Work with peers to set rules for collegial discussions and decision making (e.g., informal consensus, taking votes on key issues, presentation of alternate views), clear goals and deadlines, and individual roles as needed.
SL.9.1c Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.

SL.9.1d Respond thoughtfully to diverse perspectives, summarize points of agreement and disagreement, and, when warranted, qualify or justify their own views and understanding and make new connections in light of the evidence and reasoning presented.
SL.9.2 Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source.
SL.9.3 Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric, identifying any fallacious reasoning or exaggerated or distorted evidence.

Presentation of Knowledge and Ideas

SL.9.4 Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.

College and Career Ready English I

SL.9.5 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.9.6 Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate. (See grades 9–10 Language standards 1 and 3 for specific expectations.)

College and Career Ready English I
Language
Conventions of Standard English

L.9.1 Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.
L.9.1a Use parallel structure.*
L.9.1b Use various types of phrases (noun, verb, adjectival, adverbial, participial, prepositional, absolute) and clauses (independent, dependent; noun, relative, adverbial) to convey specific meanings and add variety and interest to writing or presentations.
L.9.2 Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.
L.9.2a Use a semicolon (and perhaps a conjunctive adverb) to link two or more closely related independent clauses.
L.9.2b Use a colon to introduce a list or quotation.
L.9.2c Spell correctly

Knowledge of Language

L.9.3 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
L.9.3a Write and edit work so that it conforms to the guidelines in a style manual (e.g., MLA Handbook, Turabian's Manual for Writers) appropriate for the discipline and writing type.

Vocabulary Acquisition and Use

L.9.4 Determine or clarify the meaning of unknown and multiple-meaning words and phrases based on grades 9–10 reading and content, choosing flexibly from a range of strategies.
L.9.4a 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.
L.9.4b Identify and correctly use patterns of word changes that indicate different meanings or parts of speech (e.g., analyze, analysis, analytical; advocate, advocacy).

College and Career Ready English I

L.9.4c 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, or its etymology.
L.9.4d 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.9.5 Demonstrate understanding of figurative language, word relationships, and nuances in word meanings.

L.9.5a Interpret figures of speech (e.g., euphemism, oxymoron) in context and analyze their role in the text.

L.9.5b Analyze nuances in the meaning of words with similar denotations.

L.9.6 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.

College and Career Ready English II

Range of Reading and Level of Text Complexity

RL.10.10 By the end of grade 10, read and comprehend literature, including stories, dramas, and poems, at the high end of the grades 9-10 text complexity band independently and proficiently.

Grades 9-10: Literacy in History/SS

Reading in History/Social Studies Key Ideas and Details

RH.9-10.1 Cite specific textual evidence to support analysis of primary and secondary sources, attending to such features as the date and origin of the information.

RH.9-10.2 Determine the central ideas or information of a primary or secondary source; provide an accurate summary of how key events or ideas develop over the course of the text.

RH.9-10.3 Analyze in detail a series of events described in a text; determine whether earlier events caused later ones or simply preceded them.

Craft and Structure

RH.9-10.4 Determine the meaning of words and phrases as they are used in a text, including vocabulary describing political, social, or economic aspects of history/social science.

RH.9-10.5 Analyze how a text uses structure to emphasize key points or advance an explanation or analysis.

RH.9-10.6 Compare the point of view of two or more authors for how they treat the same or similar topics, including which details they include and emphasize in their respective accounts.

Integration of Knowledge and Ideas

RH.9-10.7 Integrate quantitative or technical analysis (e.g., charts, research data) with qualitative analysis in print or digital text.

RH.9-10.8 Assess the extent to which the reasoning and evidence in a text support the author's claims.

RH.9-10.9 Compare and contrast treatments of the same topic in several primary and secondary sources.

Range of Reading and Level of Text Complexity

RH.9-10.10 By the end of grade 10, read and comprehend history/social studies texts in the grades 9-10 text complexity band independently and proficiently.

Grades 9-10: Literacy in Science and Technical Subjects

Reading in Science and Technical Subjects Key Ideas and Details

RST.9-10.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

RST.9-10.2 Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.

RST.9-10.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

Craft and Structure

RST.9-10.4 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 9-10 texts and topics.

RST.9-10.5 Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).

RST.9-10.6 Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, defining the question the author seeks to address.

Integration of Knowledge and Ideas

RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

RST.9-10.8 Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.

RST.9-10.9 Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts

Range of Reading and Level of Text Complexity

RST.9-10.10 By the end of grade 10, read and comprehend science/technical texts in the grades 9-10 text complexity band independently and proficiently.

Grades 9-10: Writing in History/SS, Science, and Technical Subjects

Writing Text Types and Purposes

WHST.9-10.1 Write arguments focused on discipline-specific content.

WHST.9-10.1a Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that establishes clear relationships among the claim(s), counterclaims, reasons, and evidence.

WHST.9-10.1b Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form and in a manner that anticipates the audience's knowledge level and concerns.

WHST.9-10.1c Use words, phrases, and clauses 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.

WHST.9-10.1d Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

WHST.9-10.1e Provide a concluding statement or section that follows from or supports the argument presented.

WHST.9-10.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

WHST.9-10.2a Introduce a topic and organize ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

WHST.9-10.2b Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.

Grades 9-10

Writing in History/SS, Science, and Technical Subjects

WHST.9-10.2c Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among ideas and concepts.

WHST.9-10.2d Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers.

WHST.9-10.2e Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

WHST.9-10.2f 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).

WHST.9-10.3 Not Applicable

Production and Distribution of Writing

WHST.9-10.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
WHST.9-10.5 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.9-10.6 Use technology, including the Internet, to produce, publish, and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically.

Research to Build and Present Knowledge

WHST.9-10.7 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.9-10.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.
WHST.9-10.9 Draw evidence from informational texts to support analysis, reflection, and research.

Grades 9-10
Writing in History/SS, Science, and Technical Subjects
Range of Writing

WHST.9-10.10 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.

English III
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 a 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.

English III

Reading Informational Text Key Ideas and Details

Rl.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

Rl.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).

Rl.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.

Rl.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

Rl.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.

Rl.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).

Rl.11.9 Analyze seventeenth , eighteenth , and nineteenth century foundational U.S. documents of historical and literary significance (including Them 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

Rl.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.

English III

Writing

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

W.11.1a 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.

W.11.1b 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.

W.11.1c 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.

W.11.1d Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

W.11.1e 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.

W.11.2a 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.

English III

W.11.2b 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.

W.11.2c 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.

W.11.2d Use precise language, domain-specific vocabulary, and techniques such as metaphor, simile, and analogy to manage the complexity of the topic.

W.11.2e Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

W.11.2f 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.

W.11.3a 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.

W.11.3b Use narrative techniques, such as dialogue, pacing, description, reflection, and multiple plot lines, to develop experiences, events, and/or characters.

W.11.3c 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).

W.11.3d Use precise words and phrases, telling details, and sensory language to convey a vivid picture of the experiences, events, setting, and/or characters.

W.11.3e 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.)

English III

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.)

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.

W.11.9a 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").

W.11.9b 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.

English III

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.

SL11.1a 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.

SL.11.1b Work with peers to promote civil, democratic discussions and decision-making, set clear goals and deadlines, and establish individual roles as needed.

SL.11.1c 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.

SL.11.1d 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.

English III

SL11.5 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 for specific expectations.)

English III

Language

Conventions of Standard English

L.11.1a Apply the understanding that usage is a matter of convention, can change over time, and is sometimes contested.

L.11.1b 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.11.2a Observe hyphenation conventions.

L.11.3a 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.

L.11.4b Identify and correctly use patterns of word changes that indicate different meanings or parts of speech (e.g., conceive, conception, conceivable).

English IV

Range of Reading and Level of Text Complexity

RL.12.10 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.

Grades 11-12: Literacy in History/SS

Reading in History/Social Studies Key Ideas and Details

RH.11-12.1 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.11-12.2 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.11-12.3 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.11-12.4 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.11-12.5 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.11-12.6 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.11-12.7 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.11-12.8 Evaluate an author's premises, claims, and evidence by corroborating or challenging them with other information.

RH.11-12.9 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.11-12.10 By the end of grade 12, read and comprehend history/social studies texts in the grades 11–CCR text complexity band independently and proficiently.

Grades 11-12: Literacy in Science and Technical Subjects

Reading in Science and Technical Subjects Key Ideas and Details

RST. 11-12.1 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.11-12.2 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.11-12.3 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.11-12.4 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.11-12.5 Analyze how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas.

RST.11-12.6 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.

RST.11-12.7 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.11-12.8 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.11-12.9 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.11-12.10 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.

Grades 11-12: Writing I History/SS, Science and Technical Subjects

Writing

Text Types and Purposes

WHST.11-12.1a 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.

WHST.11-12.1b 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.

WHST.11-12.1c 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.

WHST.11-12.2a 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.

Grades 11-12: Writing I History/SS, Science and Technical Subjects

WHST.11-12.2d 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.

Production and Distribution of Writing

WHST.11-12.6 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.

WHST.11-12.8 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.

# Appendix E: College and Career Ready Standards – Mathematics

| Mathematics Crosswalk for Precision Machining | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Units | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| Standards | | | | | | | | | | | | | | | | | | | | | | |
| N-Q.1 | | | X | X | X | X | X | X | X | | X | X | X | X | X | | | | | | | |
| N-Q.2 | | | | | | | | | | | | | | | | | | | | | | |
| N-Q.3 | | | X | X | X | X | X | X | X | | X | X | X | X | X | | | | | | | |
| 8.EE.8 | | | | | | | | | | | | | | | | | | | | | | |
| A-SSE.1 | | | | | | | | | | | | | | | | | | | | | | |
| A-SSE.2 | | | | | | | | | | | | | | | | | | | | | | |
| A-SSE.3 | | | | | | | | | | | | | | | | | | | | | | |
| A-SSE.4 | | | | | | | | | | | | | | | | | | | | | | |
| A-CED.1 | | | | | | | | | | | | | | | | | | | | | | |
| A-CED.2 | | | | | | | | | | | | | | | | | | | | | | |
| A-CED.3 | | | | | | | | | | | | | | | | | | | | | | |
| A-CED.4 | | | | | | | | | | | | | | | | | | | | | | |
| A-REI.2 | | | | | | | | | | | | | | | | | | | | | | |
| A-REI.3 | | | | | | | | | | | | | | | | | | | | | | |
| A-REI.4 | | | | | | | | | | | | | | | | | | | | | | |
| A-REI.5 | | | | | | | | | | | | | | | | | | | | | | |
| A-REI.6 | | | | | | | | | | | | | | | | | | | | | | |
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| 8.G.7 | | | X | X | | X | X | X | X | | | X | X | X | X | | | | | | | |
| 8.G.8 | | | X | X | | X | X | X | X | | | X | X | X | X | | | | | | | |
| G-CO.1 | | | X | X | | X | X | X | X | | | X | X | X | X | | | | | | | |
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| ~~G-CO.11~~ | | | ~~X~~ | ~~X~~ | | ~~X~~ | ~~X~~ | ~~X~~ | ~~X~~ | | | ~~X~~ | ~~X~~ | ~~X~~ | ~~X~~ | | | | | | | |
| ~~G-CO.12~~ | | | ~~X~~ | ~~X~~ | | ~~X~~ | ~~X~~ | ~~X~~ | ~~X~~ | | | ~~X~~ | ~~X~~ | ~~X~~ | ~~X~~ | | | | | | | |
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## ~~Mathematics Standards~~

~~Number and Quantity~~

~~Reason quantitatively and use unites to solve problems~~

~~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.*~~

Algebra

Analyze and solve linear equations and pairs of simultaneous linear equations

8.EE.8 Analyze and solve pairs of simultaneous linear equations.

a. Understand that solutions to a system of two linear equations in two variables correspond to points of intersection of their graphs, because points of intersection satisfy both equations simultaneously.

b. Solve systems of two linear equations in two variables algebraically, and estimate solutions by graphing the equations. Solve simple cases by inspection. For example, $3x + 2y = 5$ and $3x + 2y = 6$ have no solution because $3x + 2y$ cannot simultaneously be 5 and 6.

c. Solve real-world and mathematical problems leading to two linear equations in two variables. For example, given coordinates for two pairs of points, determine whether the line through the first pair of points intersects the line through the second pair.

Interpret the structure of expressions

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

a. Interpret parts of an expression, such as terms, factors, and coefficients.

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

c. Use the properties of exponents to transform expressions for exponential functions. For example the expression $1.15t$ can be rewritten as $[1.151/12] 12t \approx 1.01212t$ to reveal the approximate equivalent monthly interest rate if the annual rate is 15%.

Creating equations that describe numbers or relationships

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 non-viable 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.*

Solve equations and inequalities in one variable

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

Solve systems of equations

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.

Represent and solve equations and inequalities graphically

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

Define, evaluate, and compare functions

8.F.1 Understand that a function is a rule that assigns to each input exactly one output. The graph of a function is the set of ordered pairs consisting of an input and the corresponding output. 1

8.F.2 Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions). For example, given a linear function represented by a table of values and a linear function represented by an algebraic expression, determine which function has the greater rate of change.

8.F.3 Interpret the equation $y = mx + b$ as defining a linear function, whose graph is a straight line; give examples of functions that are not linear. For example, the function $A = s2$ giving the area of a square as a function of its side length is not linear because its graph contains the points (1,1), (2,4) and (3,9), which are not on a straight line.

Use functions to model relationships between quantities

8.F.4 Construct a function to model a linear relationship between two quantities. Determine the rate of change and initial value of the function from a description of a relationship or from two (x, y) values, including reading these from a table or from a graph. Interpret the rate of change and initial value of a linear function in terms of the situation it models, and in terms of its graph or a table of values.

8.F.5 Describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing or decreasing, linear or nonlinear). Sketch a graph that exhibits the qualitative features of a function that has been described verbally.

Understand the concept of a function and use function notation

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 $n \geq 1$.

Interpret functions that arise in applications in terms of the context

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.* Analyze functions using different representations Supporting

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.* a. Graph linear and quadratic functions and show intercepts, maxima, and minima.

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.

Build a function that models a relationship between two quantities

F-BF.1 Write a function that describes a relationship between two quantities.* a. Determine an explicit expression, a recursive process, or steps for calculation from a context.

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.*

Construct and compare linear, quadratic, and exponential models and solve problems

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

a. Prove that linear functions grow by equal differences over equal intervals and that exponential functions grow by equal factors over equal intervals.

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

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.* Interpret expressions for functions in terms of the situation they model Supporting

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

Geometry

Understand and apply the Pythagorean Theorem

8.G.6 Explain a proof of the Pythagorean Theorem and its converse.

8.G.7 Apply the Pythagorean Theorem to determine unknown side lengths in right triangles in real-world and mathematical problems in two and three dimensions.

8.G.8 Apply the Pythagorean Theorem to find the distance between two points in a coordinate system.

Experiment with transformations in the plane

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.

Understand congruence in terms of rigid motions

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.

Prove geometric theorems

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.

Statistics and Probability

Investigate patterns of association in bivariate data

8.SP.1 Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association.

8.SP.2 Know that straight lines are widely used to model relationships between two quantitative variables. For scatter plots that suggest a linear association, informally fit a straight line, and informally assess the model fit by judging the closeness of the data points to the line.

8.SP.3 Use the equation of a linear model to solve problems in the context of bivariate measurement data, interpreting the slope and intercept. For example, in a linear model for a biology experiment, interpret a slope of 1.5 cm/hr as meaning that an additional hour of sunlight each day is associated with an additional 1.5 cm in mature plant height.

8.SP.4 Understand that patterns of association can also be seen in bivariate categorical data by displaying frequencies and relative frequencies in a two-way table. Construct and interpret a two-way table summarizing data on two categorical variables collected from the same subjects. Use relative frequencies calculated for rows or columns to describe possible association between the two variables. For example, collect data from students in your class on whether or not they have a curfew on school nights and whether or not they have assigned chores at home. Is there evidence that those who have a curfew also tend to have chores?

Summarize, represent, and interpret data on a single count or measurement variable

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).*

Summarize, represent, and interpret data on two categorical and quantitative variables

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.*

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.

c. Fit a linear function for a scatter plot that suggests a linear association.

Interpret linear models

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.*

Algebra I

Number and Quantity

Use properties of rational and irrational numbers

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.

Reason quantitatively and use units to solve problems

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.*

Algebra

Interpret the structure of expressions

A-SSE.1 Interpret expressions that represent a quantity in terms of its context.*
a. Interpret parts of an expression, such as terms, factors, and coefficients.
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 Use the structure of an expression to identify ways to rewrite it. For example, see x4 − y 4 as (x2 ) 2 − (y2 ) 2 thus recognizing it as a difference of squares that can be factored as (x2 − y 2 ) (x2 + y2 ).

Write expressions in equivalent forms to solve problems

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. Factor a quadratic expression to reveal the zeros of the function it defines.
b. Complete the square in a quadratic expression to reveal the maximum or minimum value of the function it defines.
c. Use the properties of exponents to transform expressions for exponential functions. For example the expression 1.15t can be rewritten as [1.151/12] 12t ≈ 1.01212t to reveal the approximate equivalent monthly interest rate if the annual rate is 15%.

Algebra I

Perform arithmetic operations on polynomials

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.

Understand the relationship between zeros and factors of polynomials

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.

Create equations that describe numbers or relationships

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 non-viable 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.*

Understand solving equations as a process of reasoning and explain the reasoning

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.

Solve equations and inequalities in one variable

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. 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.

b. Solve quadratic equations by inspection (e.g., for x 2 = 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.

Algebra I

Solve systems of equations

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.

Represent and solve equations and inequalities graphically

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

Understand the concept of a function and use function notation

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

Interpret functions that arise in applications in terms of the context

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.*

Algebra I

Analyze functions using different representations

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.*

a. Graph linear and quadratic functions and show intercepts, maxima, and minima.

b. Graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions.

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

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.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. B

Build a function that models a relationship between two quantities
F-BF.1 Write a function that describes a relationship between two quantities.*
a. Determine an explicit expression, a recursive process, or steps for calculation from a context.

Build new functions from existing functions
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

Construct and compare linear, quadratic, and exponential models and solve problems
F-LE.1 Distinguish between situations that can be modeled with linear functions and with exponential functions.*
a. Prove that linear functions grow by equal differences over equal intervals and that exponential functions grow by equal factors over equal intervals.
b. Recognize situations in which one quantity changes at a constant rate per unit interval relative to another.
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.*

Algebra I
Interpret expressions for functions in terms of the situation they model
F-LE.5 Interpret the parameters in a linear or exponential function in terms of a context.*

Statistics and Probability *
Summarize, represent, and interpret data on a single count or measurement variable
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).*

Summarize, represent, and interpret data on two categorical and quantitative variables
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.*
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.
b. Informally assess the fit of a function by plotting and analyzing residuals.
c. Fit a linear function for a scatter plot that suggests a linear association.

Interpret linear models
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.*

Geometry Course
Geometry
Experiment with transformations in the plane

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.

Understand congruence in terms of rigid motions

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.

Prove geometric theorems

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.

Geometry Course
Make geometric constructions

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.

Understand similarity in terms of similarity transformations

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

Prove theorems involving similarity

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.

Define trigonometric ratios and solve problems involving right triangles

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.*

Understand and apply theorems about 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.

Find arc lengths and areas of sectors of circles

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.

Translate between the geometric description and the equation for a conic section A

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.

Use coordinates to prove simple geometric theorems algebraically

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.*

Explain volume formulas and use them to solve problems

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.3 Use volume formulas for cylinders, pyramids, cones, and spheres to solve problems.*

Visualize relationships between two-dimensional and three-dimensional objects

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.

Apply geometric concepts in modeling situations

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).*

Algebra II

Number and Quantity

Extend the properties of exponents to rational exponents

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. For example, we define 51/3 to be the cube root of 5 because we want [51/3] 3 = 5(1/3) 3 to hold, so [51/3] 3 must equal 5.

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

Reason quantitatively and use units to solve problems

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

Perform arithmetic operations with complex numbers

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.

Use complex numbers in polynomial identities and equations

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

Algebra

Interpret the structure of expressions

A-SSE.2 Use the structure of an expression to identify ways to rewrite it. For example, see x4 − y 4 as (x2) 2 − (y2) 2, thus recognizing it as a difference of squares that can be factored as (x2 − y 2) (x2 + y2).

Write expressions in equivalent forms to solve problems

A-SSE.3 Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.* c. Use the properties of exponents to transform expressions for exponential functions. For example the expression 1.15t can be rewritten as [1.151/12] 12t ≈ 1.01212t to reveal the approximate equivalent monthly interest rate if the annual rate is 15%.

Algebra II

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.*

Understand the relationship between zeros and factors of 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.

Use polynomial identities to solve problems

A-APR.4 Prove polynomial identities and use them to describe numerical relationships. For example, the polynomial identity (x2 + y2) 2 = (x2 − y 2) 2 + (2xy) 2 can be used to generate Pythagorean triples.

Rewrite rational expressions

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.

Create equations that describe numbers or relationships

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.*

Understand solving equations as a process of reasoning and explain the reasoning

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.

Solve equations and inequalities in one variable

A-REI.4 Solve quadratic equations in one variable. b. Solve quadratic equations by inspection (e.g., for x 2 = 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.

Algebra II

Solve systems of equations

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.

Represent and solve equations and inequalities graphically

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.*

Functions

Understand the concept of a function and use function notation

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.

Interpret functions that arise in applications in terms of the context

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.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.*

Analyze functions using different representations

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.*

c. Graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior.

e. Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude.

Algebra II

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

b. Use the properties of exponents to interpret expressions for exponential functions. For example, identify percent rate of change in functions such as $y = (1.02)t$ , $y = (0.97)t$ , $y = (1.01)12t$, $y = (1.2)t/10$, and classify them as representing exponential growth and decay.

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.

Build a function that models a relationship between two quantities

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

a. Determine an explicit expression, a recursive process, or steps for calculation from a context.

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

Build new functions from existing functions

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. 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. For example, $f(x) = 2x\ 3$ or $f(x) = (x+1)/(x\ 1)$ for $x \neq 1$.

Construct and compare linear, quadratic, and exponential models and solve problems

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.4 For exponential models, express as a logarithm the solution to $abct = d$ where a, c, and d are numbers and the base b is 2, 10, or e; evaluate the logarithm using technology.*

Interpret expressions for functions in terms of the situation they model

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

Algebra II

Extend the domain of trigonometric functions using the unit circle

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.

Model periodic phenomena with trigonometric functions

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

Prove and apply trigonometric identities

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

Geometry

Translate between the geometric description and the equation for a conic section

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

Statistics and Probability

Summarize, represent, and interpret data on a single count or measurement variable

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.*

Summarize, represent, and interpret data on two categorical and quantitative variables

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

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.

Algebra II

Understand and evaluate random processes underlying statistical experiments

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?*

Make inferences and justify conclusions from sample surveys, experiments, and observational studies

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.*

Understand independence and conditional probability and use them to interpret data

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.*

Use the rules of probability to compute probabilities of compound events in a uniform probability model

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.*

Integrated Mathematics
Number and Quantity
Reason quantitatively and use units to solve problems

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.*

Algebra
Interpret the structure of expressions

A-SSE.1 Interpret expressions that represent a quantity in terms of its context.*
a. Interpret parts of an expression, such as terms, factors, and coefficients.
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.

Write expressions in equivalent forms to solve problems

A-SSE.3 Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.*
c. Use the properties of exponents to transform expressions for exponential functions. For example the expression 1.15t can be rewritten as [1.151/12] 12t ≈ 1.01212t to reveal the approximate equivalent monthly interest rate if the annual rate is 15%.

Create equations that describe numbers or relationships

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 non-viable 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.*

Integrated Mathematics I
Solve equations and inequalities in one variable

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

Solve systems of equations

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.

Represent and solve equations and inequalities graphically

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

Understand the concept of a function and use function notation

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 $n \geq 1$.

Interpret functions that arise in applications in terms of the context

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.*

Integrated Mathematics I

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.*

Analyze functions using different representations

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.*

a. Graph linear and quadratic functions and show intercepts, maxima, and minima.

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.

Build a function that models a relationship between two quantities

F-BF.1 Write a function that describes a relationship between two quantities.* a. Determine an explicit expression, a recursive process, or steps for calculation from a context.

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.*

Construct and compare linear, quadratic, and exponential models and solve problems

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

a. Prove that linear functions grow by equal differences over equal intervals and that exponential functions grow by equal factors over equal intervals.

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

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.*

Interpret expressions for functions in terms of the situation they model

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

Integrated Mathematics I

Geometry

Experiment with transformations in the plane

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.

Understand congruence in terms of rigid motions

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.

Prove geometric theorems

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.

Integrated Mathematics I

Statistics and Probability

Summarize, represent, and interpret data on a single count or measurement variable

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).*

Summarize, represent, and interpret data on two categorical and quantitative variables

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.*

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.
e. Fit a linear function for a scatter plot that suggests a linear association.

Interpret linear models

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.*

Integrated Mathematics I
Number and Quantity
Extend the properties of exponents to rational exponents

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. For example, we define 51/3 to be the cube root of 5 because we want [51/3] 3 = 5(1/3) 3 to hold, so [51/3] 3 must equal 5.
N-RN.2 Rewrite expressions involving radicals and rational exponents using the properties of exponents.

Use properties of rational and irrational numbers

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.

Reason quantitatively and use units to solve problems

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

Perform arithmetic operations with complex numbers

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.

Use complex numbers in polynomial identities and equations

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

Algebra
Interpret the structure of expressions

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

Integrated Mathematics II

A-SSE.2 Use the structure of an expression to identify ways to rewrite it. For example, see x4 − y 4 as (x2 ) 2 − (y2 ) 2, thus recognizing it as a difference of squares that can be factored as (x2 − y 2 ) (x2 + y2 ).

Write expressions in equivalent forms to solve problems

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. Factor a quadratic expression to reveal the zeros of the function it defines.
b. Complete the square in a quadratic expression to reveal the maximum or minimum value of the function it defines.

Perform arithmetic operations on polynomials

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.

Create equations that describe numbers or relationships

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.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.*

Understand solving equations as a process of reasoning and explain the reasoning M

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.

Solve equations and inequalities in one variable

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

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.

b. Solve quadratic equations by inspection (e.g., for x 2 = 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.

Solve systems of equations

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.

Functions

Interpret functions that arise in applications in terms of the context M

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.*

Analyze functions using different representations

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.*

a. Graph linear and quadratic functions and show intercepts, maxima, and minima.

b. Graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions.

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.

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.

b. Use the properties of exponents to interpret expressions for exponential functions. For example, identify percent rate of change in functions such as y = (1.02)t , y = (0.97)t , y = (1.01)12t, y = (1.2)t/10, and classify them as representing exponential growth and decay.

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.

Integrated Mathematics II

Build a function that models a relationship between two quantities

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

a. Determine an explicit expression, a recursive process, or steps for calculation from a context.

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.

Build new functions from existing functions

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.

Geometry

Understand similarity in terms of similarity transformations

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

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.

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.

Prove theorems using similarity

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.

Define trigonometric ratios and solve problems involving right triangles

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.

Integrated Mathematics II

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

Explain volume formulas and use them to solve problems

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.3 Use volume formulas for cylinders, pyramids, cones, and spheres to solve problems.*

Statistics and Probability*

Summarize, represent, and interpret data on two categorical and quantitative variables

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

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.
b. Informally assess the fit of a function by plotting and analyzing residuals.

Understand independence and conditional probability and use them to interpret data

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.

Integrated Mathematics II

Use the rules of probability to compute probabilities of compound events in a uniform probability model

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.*

Integrated Mathematics III

Number and Quantity

Reason quantitatively and use units to solve problems

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

Algebra

Interpret the structure of expressions

A-SSE.2 Use the structure of an expression to identify ways to rewrite it. For example, see $x^4 - y^4$ as $(x^2)^2 - (y^2)^2$, thus recognizing it as a difference of squares that can be factored as $(x^2 - y^2)(x^2 + y^2)$.

Write expressions in equivalent forms to solve problems

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.*

Understand the relationship between zeros and factors of 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.

Use polynomial identities to solve problems

A-APR.4 Prove polynomial identities and use them to describe numerical relationships. For example, the polynomial identity $(x^2 + y^2)^2 = (x^2 - y^2)^2 + (2xy)^2$ can be used to generate Pythagorean triples.

~~Rewrite rational expressions~~

~~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.~~

~~Integrated Mathematics III~~

~~Create equations that describe numbers or relationships~~

~~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.*~~

~~Understand solving equations as a process of reasoning and explain the reasoning~~

~~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.~~

~~Represent and solve equations and inequalities graphically~~

~~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.*~~

~~Interpret functions that arise in applications in terms of the context~~

~~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.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.*~~

~~Analyze functions using different representations~~

~~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.* c. Graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior. e. Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude.~~

~~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.~~

~~Build new functions from existing functions~~

~~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. 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. For example, f(x) =2x3 or f(x) = (x+1)/(x-1) for x ≠ 1.~~

~~Construct and compare linear, quadratic, and exponential models and solve problems~~

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

Extend the domain of trigonometric functions using the unit circle

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.

Model periodic phenomena with trigonometric functions

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

Prove and apply trigonometric identities

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

Integrated Mathematics III

Geometry

Make geometric constructions

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.

Understand and apply theorems about 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.

Find arc lengths and areas of sectors of circles

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.

Translate between the geometric description and the equation for a conic section

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.

Use coordinates to prove simple geometric theorems algebraically

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).

Integrated Mathematics III

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.*

Visualize relationships between two-dimensional and three-dimensional objects

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.

Apply geometric concepts in modeling situations

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*

Summarize, represent, and interpret data on a single count or measurement variable S

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.*

Summarize, represent, and interpret data on two categorical and quantitative variables

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

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.

b. Informally assess the fit of a function by plotting and analyzing residuals.

Understand and evaluate random processes underlying statistical experiments

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

Integrated Mathematics III

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?*

Make inferences and justify conclusions from sample surveys, experiments, and observational studies

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.*

Advanced Mathematics Plus

Number and Quantity

Perform arithmetic operations with complex numbers

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

Represent complex numbers and their operations on the complex plane

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.

Use complex numbers in polynomial identities and equations

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

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

Represent and model with vector 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., $v$, $|v|$, $\|v\|$, $\mathbf{v}$).

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.

Advanced Mathematics Plus

Perform operations on vectors

N-VM.4 Add and subtract vectors.

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.

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

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.

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

b. Compute the magnitude of a scalar multiple $cv$ using $\|cv\| = |c|v$. Compute the direction of $cv$ knowing that when $|c|v \neq 0$, the direction of $cv$ is either along $v$ (for $c > 0$) or against $v$ (for $c < 0$).

Perform operations on matrices and use matrices in applications

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 $2 \times 2$ matrices as transformations of the plane, and interpret the absolute value of the determinant in terms of area.

Algebra

Use polynomial identities to solve problems

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.

Advanced Mathematics Plus

Rewrite rational expressions

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.

Solve systems of equations

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 $3 \times 3$ or greater).

Functions

Analyze functions using different representations

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.*

d. Graph rational functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior.

Build a function that models a relationship between two quantities

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

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.

Build new functions from existing functions

F-BF.4 Find inverse functions.

b. Verify by composition that one function is the inverse of another.

c. Read values of an inverse function from a graph or a table, given that the function has an inverse.

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.

Advanced Mathematics Plus

Extend the domain of trigonometric functions using 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.

Model periodic phenomena with trigonometric functions

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. *

Prove and apply trigonometric identities

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

Geometry

Apply trigonometry to general triangles

G-SRT.9 Derive the formula A = ½ 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).

Understand and apply theorems about circles
G-C.4 Construct a tangent line from a point outside a given circle to the circle.

Translate between the geometric description and the equation for a conic section
Advanced Mathematics Plus
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.

Explain volume formulas and use them to solve problems
G-GMD.2 Give an informal argument using Cavalieri's principle for the formulas for the volume of a sphere and other solid figures.

Statistics and Probability*
Use the rules of probability to compute probabilities of compound events in a uniform probability 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.*

Calculate expected values and use them to solve problems
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?*

Advanced Mathematics Plus
Use probability to evaluate outcomes of decisions
S-MD.5 Weigh the possible outcomes of a decision by assigning probabilities to payoff values and finding expected values. *
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.
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).*

# 2024 Precision Machining

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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.

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# Acknowledgments

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Mr. Matt Miller, vice chair
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# Standards

Standards and alignment crosswalks are referenced in the appendix. 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 precision machining is aligned to the following standards:

**National Institute for Metalworking Skills, Inc. (NIMS)**
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**International Society for Technology in Education Standards (ISTE)**
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iste.org

**College- and Career-Ready Standards**
College- and career-readiness standards emphasize critical thinking, teamwork, and problem-solving skills. Students will learn the skills and abilities required 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 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, 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, contact the RCU at 662.325.2510 or helpdesk@rcu.msstate.edu.

# Executive Summary

**Pathway Description**
The Precision Machining pathway is designed as a secondary program for preparation to enter the fields of precision machining and metal turning. The Precision Machining program includes an introduction to the basic machining metalworking processes. The purpose of the course is to prepare students to continue study in a postsecondary metals program (Precision Machining, Machine Tool Operation, and Automotive Machining) or to begin work at the entry level in a machining occupation. The machining courses found in this curriculum align with the National Institute for Metalworking Skills (NIMS) credentialing standards.

**College, Career, and Certifications**
NIMS is a nationally recognized nonprofit organization established in 1995 to help develop industry standards to maintain the United States' global competitiveness. NIMS sets industry standards and certifies individuals who meet the quality requirements contained in the industry standards. NIMS also accredits training programs and facilities that meet NIMS's quality requirements. The NIMS organization and standards are accredited by the American National Standards Institute (ANSI) in the metalworking field.

The NIMS Level 1 credential consists of bench work, layout, milling, drill press, surface grinding, and lathing between centers. Students are required to perform a NIMS-approved project in each area in order to attain credentialing in those areas. Students must be able to complete the NIMS project with 100% accuracy before being allowed to take an additional online written test. Once the performance evaluation and the online test are administered and passed, the students will receive a NIMS certification for each area successfully completed—bench work, layout, milling, drill press, surface grinding, and lathing between centers. The NIMS organization awards credentials for each competency area in the Level 1 module after the successful completion of projects and written tests.

**Grade Level and Class Size Recommendations**
It is recommended that students enter this program as sophomores. 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, with only one class with the teacher at a time.

**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 Test of Adult Basic Education (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

**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 training sessions provided, please contact the RCU at 662.325.2510 or helpdesk@rcu.msstate.edu.

# Course Outlines

**Option 1—Four 1-Carnegie-Unit Courses**

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

1. **Fundamentals of Precision Machining—Course Code: 993405**
2. **Application of Precision Machining—Course Code: 993406**
3. **Theory of Precision Machining—Course Code: 993407**
4. **Advanced Skills of Precision Machining—Course Code: 993408**

**Course Description: Fundamentals of Precision Machining**
Fundamentals of Precision Machining includes an introduction to the field of precision machining and the fundamentals of safety, tools, basic math, blueprint reading, and milling machinery.

**Course Description: Application of Precision Machining**
Application of Precision Machining emphasizes an overview of safety and leadership, lathe theory, and grinding operations and gives students hands-on practice in these areas.

**Course Description: Theory of Precision Machining**
Theory of Precision Machining includes a study of precision machining techniques and advanced lathe operation.

**Course Description: Advanced Skills of Precision Machining**
Advanced Skills of Precision Machining emphasizes the study of precision machining techniques in advanced milling and computer numerical control (CNC) operations.

**Fundamentals of Precision Machining—Course Code: 993405**

| Unit | Unit Title | Hours |
|---|---|---|
| 1 | Orientation, Leadership, and Basic Safety | 25 |
| 2 | Math, Measuring Tools, and Instruments | 25 |
| 3 | Introduction to Blueprints and Hand and Power Tools | 30 |
| 4 | Bench and Pedestal Grinding (Offhand Grinding) | 30 |
| 5 | Drill Press and Band Saw Theory and Operation | 30 |
| **Total** | | **140** |

**Application of Precision Machining—Course Code: 993406**

| Unit | Unit Title | Hours |
|---|---|---|
| 6 | Lathe Theory and Operation | 75 |
| 7 | Milling Machine Theory and Operation | 40 |
| 8 | Introduction to Lathe and Milling Skills | 25 |
| **Total** | | **140** |

**Theory of Precision Machining—Course Code: 993407**

| Unit | Unit Title | Hours |
|---|---|---|
| 9 | Orientation, Advanced Leadership, and Employability Skills | 8 |
| 10 | Basic Safety | 17 |
| 11 | Advanced Lathe Operation | 115 |
| **Total** | | **140** |

**Advanced Skills of Precision Machining—Course Code: 993408**

| Unit | Unit Title | Hours |
|---|---|---|
| 12 | Advanced Milling Operation | 95 |
| 13 | Grinding Theory and Operation | 15 |
| 14 | Computerized Numerical Control | 30 |
| **Total** | | **140** |

**Option 2—Two 2-Carnegie-Unit Courses**

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

1. **Precision Machining I—Course Code: 993403**
2. **Precision Machining II—Course Code: 993404**

**Course Description: Precision Machining I**
Precision Machining I includes orientation and leadership, basic safety, math, measuring tools and instruments, blueprints, hand and power tools, lathe theory and operation milling, machine theory and operation, and grinding operations. Safety is emphasized in each unit and every activity.

**Course Description: Precision Machining II**
Precision Machining II includes advanced precision machining techniques in lathing, vertical milling, and CNC.

**Precision Machining I—Course Code: 993403**

| Unit | Unit Title | Hours |
|---|---|---|
| 1 | Orientation, Leadership, and Basic Safety | 25 |
| 2 | Math, Measuring Tools, and Instruments | 25 |
| 3 | Introduction to Blueprints and Hand and Power Tools | 30 |
| 4 | Bench and Pedestal Grinding (Offhand Grinding) | 30 |
| 5 | Drill Press and Band Saw Theory and Operation | 30 |
| 6 | Lathe Theory and Operation | 75 |
| 7 | Milling Machine Theory and Operation | 40 |
| 8 | Introduction to Lathe and Milling Skills | 25 |
| **Total** | | **280** |

**Precision Machining II—Course Code: 993404**

| Unit | Unit Title | Hours |
|---|---|---|
| 9 | Orientation, Advanced Leadership, and Employability Skills | 8 |
| 10 | Basic Safety | 17 |
| 11 | Advanced Lathe Operation | 115 |
| 12 | Advanced Milling Operation | 95 |
| 13 | Grinding Theory and Operation | 15 |
| 14 | Computerized Numerical Control | 30 |
| **Total** | | **280** |

# Career Pathway Outlook

**Overview**

Precision machining professionals operate equipment that creates the parts for consumer products. According to the Precision Machined Products Association (PMPA), precision machinists make the components critical to today's technologies. These machining professionals will operate lathes, mills, molding, casting, or core-making machines while adjusting machine settings and repairing or replacing damaged cutting tools during production. Career fields in precision machining include machine setters that understand welding, soldering, brazing, milling, and planning; machine operators and tenders; CNC tool operators and programmers; model makers; foundry mold and coremakers; patternmakers; etc. The largest employers of metal and plastic machine workers are fabricated metal product manufacturing (25%), plastics and rubber products manufacturing (17%), transportation equipment manufacturing (15%), primary metal manufacturing (11%), and machinery manufacturing (11%). Industrial partners in Mississippi have mentioned that students need to become multi-taskers and problem-solvers, develop the ability to read blueprints, read precision measuring instruments, understand production processes, have math and computer skills, and be willing to research precision machining-related trades. Employers indicated that if individuals entered the workplace with problem-solving skills, specifically, this would assist in their training to meet a company's manufacturing needs. The top five national occupations that make up metal and plastic machine careers are as follows: (1) cutting, punching, and press machine setters and operators, (2) molding, core-making, and casting machine setters and operators, (3) CNC tool operators, (4) multiple machine tool setters and operators, and (5) grinding, lapping, polishing, and buffing machine tool setters and operators.

Most careers in precision machining require at least an associate degree, although careers with the highest earning potential—engineers and postsecondary teachers, for example—usually require advanced degrees.

**Needs of the Future Workforce**

From 2021 to 2031, about 101,700 openings for metal and plastic machine workers are projected each year, on average, according to the U.S. Bureau of Labor Statistics. In Mississippi, the average employment growth total from 2020 to 2030 is projected to increase by 9.5% for all general occupations combined. The data given in Table 1.1 below, including the average hourly earnings, was compiled from the Mississippi Department of Employment Security in 2022.

Table 1.1: Current and Projected Occupation Report

| Description | Jobs, 2020 | Projected Jobs, 2030 | Change (Number) | Change (Percent) | Average Hourly Earnings, 2022 |
|---|---|---|---|---|---|
| Adhesive Bonding Machine Operators and Tenders | 390 | 390 | 0 | 0.0% | $12.96 |

| | | | | | |
|---|---|---|---|---|---|
| Aircraft Mechanics and Service Technicians | 1,130 | 1,180 | 50 | 4.4% | $32.28 |
| Avionics Technicians | 90 | 90 | 0 | 0.0% | $34.11 |
| Calibration and Engineering Technologists and Technicians | 600 | 650 | 50 | 8.3% | $22.17 |
| Cleaning, Washing, and Metal Pickling Equipment Operators and Tenders | 40 | 50 | 10 | 25.0% | $12.56 |
| Coating, Painting, and Spraying Machine Setters, Operators, and Tenders | 1,830 | 1,830 | 0 | 0.0% | $20.63 |
| Crushing, Grinding, and Polishing Machine Setters, Operators, and Tenders | 240 | 240 | 0 | 0.0% | $15.97 |
| Extruding, Forming, Pressing, and Compacting Machine Setters, Operators, and Tenders | 740 | 760 | 20 | 2.7% | $18.31 |
| Industrial Engineering Technologists and Technicians | 360 | 380 | 20 | 5.6% | $31.59 |
| Industrial Machinery Mechanics | 5,110 | 5,450 | 340 | 6.7% | $26.26 |
| Machinist | 2,880 | 3,040 | 160 | 5.6% | $19.88 |
| Maintenance Workers, Machinery | 520 | 560 | 40 | 7.7% | $23.69 |
| Mechanical Engineering Technologists and Technicians | 100 | 110 | 10 | 10.0% | $24.88 |
| Medical Appliance Technicians | 160 | 210 | 50 | 31.3% | $21.41 |
| Metal-Refining Furnace Operators and Tenders | 180 | 190 | 10 | 5.6% | $17.20 |
| Mixing and Blending Machine Setters, Operators, and Tenders | 1,350 | 1,410 | 60 | 4.4% | $19.55 |
| Motorboat Mechanics and Service Technicians | 130 | 140 | 10 | 7.7% | $18.08 |
| Motorcycle Mechanics | 130 | 140 | 10 | 7.7% | $19.11 |
| Multiple Machine Tool Setters, Operators, and Tenders, Metal and Plastic | 520 | 530 | 10 | 1.9% | $16.42 |

| | | | | | |
|---|---|---|---|---|---|
| Packaging and Filling Machine Operators and Tenders | 3,040 | 3,300 | 260 | 8.6% | $14.11 |
| Pourers and Casters, Metal | 50 | 50 | 0 | 0.0% | $16.65 |
| Precision Instrument and Equipment Repairers | 120 | 120 | 0 | 0.0% | $25.88 |
| Rolling Machine Setters, Operators, and Tenders, Metal and Plastic | 430 | 430 | 0 | 0.0% | $14.97 |
| Separating, Filtering, Clarifying, Precipitating, and Still Machine Setters, Operators, and Tenders | 80 | 80 | 0 | 0.0% | $18.72 |
| Sheet Metal Workers | 1,510 | 1,570 | 60 | 4.0% | $21.86 |

*Source*: Mississippi Department of Employment Security; mdes.ms.gov (2022).

**Perkins V Requirements and Academic Infusion**

The Precision Machining curriculum meets Perkins V requirements of introducing students to and preparing them for high-skill, high-wage occupations in metalworking fields. It also offers students a program of study, including secondary, postsecondary, and institutions of higher learning courses, that will further prepare them for metalworking 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 Precision Machining 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' backgrounds, emotional health, and circumstances, for example—create unique learners. By providing various teaching and assessment strategies, students with various learning preferences can have more opportunity 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 Precision Machining curriculum. SkillsUSA is an example of a student organization with many outlets for manufacturing. Student organizations provide participants and members with growth opportunities and competitive events. They also open the doors to the world of manufacturing 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 Precision Machining curriculum for group work. Students need to be able to work collaboratively with others and solve problems without excessive conflict to function in today's workforce. The Precision Machining curriculum provides opportunities for students to work together and help each other complete complex tasks. There are many field experiences within the Precision Machining curriculum that will allow and encourage collaboration with professionals currently in the metalworking field.

*Work-Based Learning*

Work-based learning is an extension of understanding competencies taught in the Precision Machining 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 to 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 electrical professionals. Thus, supervised collaboration and immersion into the manufacturing industry around the students are keys to students' success, knowledge, and skills development.

# Professional Organizations

Association of Career and Technical Education
acteonline.org

International Society for Technology in Education
iste.org

Mississippi Manufacturing Association (MMA)
mma-web.org

National Institute for Metalworking Skills, Inc.
nims-skills.org

SkillsUSA
skillsusa.org

Skills USA—Mississippi
mdek12.org/CTE/SO/SkillsUSA

# 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 will be 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.

**Teacher Resources**
All teachers should request to be added to the Canvas Resource Guide for their course. For questions or 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. This material will greatly enhance the learning experiences of students. If the precision machining program is using a national certification, work-based learning, or another measure of accountability that aligns with Perkins V as a quality indicator, this material could very well be assessed 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, Leadership, and Basic Safety

| **Competencies and Suggested Objectives** |
|---|
| 1. Describe local program and career technical center policies and procedures. DOK1<br>a. Describe local program and career technical center policies and procedures, including dress code, attendance, academic requirements, discipline, and transportation regulations. |
| 2. Describe employment opportunities and responsibilities. DOK2<br>a. Relate employment opportunities, including potential earnings, employee benefits, job availability, place of employment, working conditions, and educational requirements to students' success in a secondary or postsecondary manufacturing curriculum.<br>b. Describe basic employee responsibilities. |
| 3. Explore leadership skills and personal development opportunities provided to students by student organizations, including SkillsUSA. DOK2<br>a. Demonstrate effective team-building and leadership skills.<br>b. Practice appropriate work ethics.<br>c. Demonstrate the ability to follow verbal and written instructions and communicate effectively in on-the-job situations.<br>d. Discuss the history of the metal trade industry to include materials, terminology, and techniques. |
| 4. Explain safety in and around electrical situations. DOK2<br>a. Explain injuries when electrical contact occurs.<br>b. Explain safety around electrical hazards.<br>c. Explain the actions to take when an electrical shock occurs. |
| 5. Describe general safety rules for working in a shop, laboratory, and/or industry. DOK1<br>a. Describe how to avoid on-site accidents.<br>b. Explain the relationship between housekeeping and safety.<br>c. Explain the importance of following all safety rules and company safety policies.<br>d. Explain the importance of reporting all on-the-job injuries, accidents. and near misses.<br>e. Explain the need for evacuation policies and the importance of following them.<br>f. Investigate the employer's substance abuse policy and how it relates to safety.<br>g. Demonstrate the safety procedures when working near pressurized or high temperatures. |
| 6. Identify and apply safety around manufacturing operations. DOK1<br>a. Use proper safety practices when performing manufacturing operations.<br>b. Recognize and explain personal protective equipment (PPE).<br>c. Inspect and care for PPE. |
| 7. Explain lifting. DOK3<br>a. Identify and explain the procedures for lifting heavy objects. |
| 8. Explain the safety data sheet (SDS). DOK2<br>a. Explain the function of the SDS.<br>b. Interpret the requirements of the SDS. |

9. Explain fires. DOK1
    a. Explain the process by which fires start.
    b. Explain fire prevention of various flammable liquids.
    c. Explain the classes of fire and the types of extinguishers.

**Note:** Safety is to be taught as an ongoing part of the program. Students are required to complete a written safety test with 100% accuracy before entering the shop for lab simulations and projects. This test should be documented in each student's file.

# Unit 2: Math, Measuring Tools, and Instruments

| Competencies and Suggested Objectives |
|---|
| 1. Apply the four basic math skills with whole numbers, fractions, and percentages. DOK1<br>a. Add, subtract, multiply, and divide whole numbers, decimals, and fractions.<br>b. Convert whole numbers to fractions and fractions to whole numbers.<br>c. Convert decimals to percents and percents to decimals.<br>d. Convert fractions to decimals.<br>e. Convert fractions to percents. |
| 2. Perform basic mathematical calculations related to machine shop operations. DOK1<br>a. Convert metric measurements to English measurements.<br>b. Solve basic angles and sides.<br>c. Calculate the amount of material for a given project.<br>d. Compute distances according to a drawn plan. |
| 3. Identify and perform functions using various measuring tools and instruments (e.g., micrometer, dial indicator, height gauge, and digital caliper). DOK2<br>a. Read a rule to the nearest 1/32 in.<br>b. Lay out lines with a rule.<br>c. Describe the care and use of various rules. |

# Unit 3: Introduction to Blueprints and Hand and Power Tools

| Competencies and Suggested Objectives |
|---|
| 1. Read, analyze, and design a blueprint. DOK2<br>a. Identify terms and symbols commonly used on blueprints.<br>b. Relate information on prints to real parts/models.<br>c. Interpret various symbols to locate various elements.<br>d. Interpret a plan to determine the layout.<br>e. Explain the basic layout of a blueprint.<br>f. Describe the information in a title block.<br>g. Identify the lines used on blueprints. |
| 2. Demonstrate the use and maintenance of various hand and power tools. DOK3<br>a. Identify and discuss the use of common hand and power tools.<br>b. Discuss the rules of safety.<br>c. Select and demonstrate the use of tools.<br>d. Explain the procedures for maintenance. |

# Unit 4: Bench and Pedestal Grinding (Offhand Grinding)

| **Competencies and Suggested Objectives** |
|---|
| 1. Describe safety in operating a bench or pedestal grinder and the reasons for using offhand grinding. DOK3<br>a. Describe grinding safety.<br>b. Describe the safety rules that apply to bench and pedestal grinding.<br>c. Identify grit and abrasive properties and bonding agents.<br>d. Define grain size, bond grade, and bond type. |
| 2. Perform maintenance operations to a manufacturer's specifications and grinding operations to the teacher's specifications. DOK4<br>a. Remove and replace a grinding wheel.<br>b. Dress a wheel flat.<br>c. Grind a workpiece flat and parallel.<br>d. Grind a workpiece square, to an angular surface, and to dimension. |

# Unit 5: Drill Press and Band Saw Theory and Operation

| Competencies and Suggested Objectives |
|---|
| 1. Identify and describe the types of drilling machines, including hand-powered and drill press, and the rules for the safe operation of each. DOK2<br>a. Describe the rules for the safe use of a hand-powered drill and drill press.<br>b. Identify work-holding and setup devices in drill press operations.<br>c. Lay out holes and drill, ream, countersink, and counterbore according to project specifications. |
| 2. Identify and describe the safe operation of the types of power saws. DOK2<br>a. Identify and describe the rules for the safe use of power saws.<br>b. Describe factors that determine saw blade selection.<br>c. Describe factors to consider in the care and cleaning of power saws.<br>d. Lay out and cut stock with a band saw according to specifications. |

# Unit 6: Lathe Theory and Operation

| Competencies and Suggested Objectives |
|---|
| 1. Identify the parts, rules, and care of the metal lathe. DOK3<br>a. Identify the four major parts of the lathe.<br>b. Set up a lathe and determine the rpm and feed rate according to the manufacturer's specifications for the basic lathe operations.<br>c. Explain the advantages and disadvantages of carbide tip cutting tools and demonstrate how to freehand grind using a high-speed steel (HSS) turning tool. |
| 2. Perform procedures for a machining operation. DOK3<br>a. Identify terms and procedures for lathe operations.<br>b. Discuss the rules of safety.<br>c. Demonstrate centering a workpiece in a four-jaw chuck on the lathe.<br>d. Face a part to length.<br>e. Perform a straight turning operation.<br>f. Perform a chamfer operation.<br>g. Perform a center drilling operation.<br>h. Perform a knurling operation.<br>i. Perform a cutoff operation.<br>j. Tap a blind hole.<br>k. Cut external and internal threads on the lathe.<br>l. Install a chuck on a lathe.<br>m. Mount and align a part in a four-jaw chuck on a lathe to the instructor's specifications.<br>n. Turn a taper with a compound rest and a taper attachment.<br>o. Perform a boring operation.<br>p. Perform wet and dry cuts. |

# Unit 7: Milling Machine Theory and Operation

| Competencies and Suggested Objectives |
|---|
| 1. Differentiate between the types of vertical milling machines. DOK2<br>a. Identify the different types of vertical milling machines.<br>b. Explain the use and safety of each type of milling machine. |
| 2. Identify the parts, cutting tools, and basic maintenance of a vertical milling machine. DOK2<br>a. Identify the major parts of a vertical mill.<br>b. Identify the cutting tools used on a vertical mill.<br>c. Clean and lubricate a vertical mill following the manufacturer's specifications.<br>d. Determine the rpm and feed rate. |
| 3. Perform operations on a milling machine. DOK4<br>a. Perform operations on a vertical milling machine.<br>b. Perform end milling, side milling, slotting, drilling, reaming, boring, and fly cutting operations. Mount cutters and cutter holders; mount and align a swivel vise; mill a key seat, a given angle, and a straight boring operation; align the head square to the table; perform a mill operation with head tilted to 45°; and divide head operations. |

# Unit 8: Introduction to Lathe and Milling Skills

| Competencies and Suggested Objectives |
|---|
| 1. Lathe: Describe safety precautions, methods for measuring thread-pitch diameters, and calculation of dimensions using taper formulas with 0.010 tolerance. DOK2<br>a. Describe safety precautions.<br>b. Describe methods for measuring thread-pitch diameters.<br>c. Calculate dimensions using taper formulas.<br>d. Turn a taper with a taper attachment and turn a taper with a compound. Perform boring, cutting external threads to relief, picking up threads, and cutting internal threads. |
| 2. Mill: Align a vise using a dial indicator to 0.005 tolerance and mill a quarter-inch keyway to 0.005 tolerance. DOK2<br>a. Perform drilling, countersinking and counterboring, and aligning and starting a tap. |

# Unit 9: Orientation, Advanced Leadership, and Employability Skills

| Competencies and Suggested Objectives |
|---|
| 1. Describe local program and career technical center policies and procedures. DOK1<br>a. Describe local program and career technical center policies and procedures, including dress code, attendance, academic requirements, discipline, and transportation regulations. |
| 2. Describe employment opportunities and responsibilities. DOK2<br>a. Describe employment opportunities, including potential earnings, employee benefits, job availability, place of employment, working conditions, and educational requirements.<br>b. Describe basic employee responsibilities.<br>c. Design a résumé and complete a job application. |
| 3. Demonstrate the ability to follow verbal and written instructions and communicate effectively in on-the-job situations. DOK3<br>a. Perform projects through written instruction.<br>b. Perform projects through oral instruction. |

# Unit 10: Basic Safety

| **Review and Reinforcement** |
|---|
| **Competencies and Suggested Objectives** |
| 1. Describe general safety rules for working in a shop, laboratory, and/or industry. DOK1<br>a. Describe how to avoid on-site accidents.<br>b. Explain the relationship between housekeeping and safety.<br>c. Explain the importance of following all safety rules and company safety policies.<br>d. Explain the importance of reporting all on-the-job injuries, accidents, and near misses.<br>e. Explain the need for evacuation policies and the importance of following them.<br>f. Explain the employer's substance abuse policy and how it relates to safety.<br>g. Demonstrate the safety procedures when working near pressurized or high temperatures. |
| 2. Identify and apply safety around manufacturing operations. DOK1<br>a. Use proper safety practices when welding or working around manufacturing operations.<br>b. Explain the term "proximity work." |
| 3. Identify and explain the use of various barriers and confinements. DOK2<br>a. Explain the safety requirements for working in confined areas.<br>b. Explain and practice lock-out/tag-out procedures.<br>c. Explain the different barriers and barricades and how they are used.<br>d. Recognize and explain personal protective equipment (PPE).<br>e. Inspect and care for PPE. |
| 4. Explain lifting. DOK2, SAF<br>a. Identify and explain the procedures for lifting heavy objects. |
| 5. Explain the safety data sheet (SDS). DOK1<br>a. Explain the function of the SDS.<br>b. Interpret the requirements of the SDS. |
| 6. Explain fires. DOK2, SAF<br>a. Explain the process by which fires start.<br>b. Explain fire prevention of various flammable liquids.<br>c. Explain the classes of fires and the types of extinguishers. |
| 7. Explain safety in and around electrical situations. DOK3<br>a. Explain injuries when electrical contact occurs.<br>b. Explain safety around electrical hazards.<br>c. Explain the actions to take when an electrical shock occurs. |

**Note:** Safety is to be taught as an ongoing part of the program. Students are required to complete a written safety test with 100% accuracy before entering the shop for lab simulations and projects. This test should be documented in each student's file.

# Unit 11: Advanced Lathe Operation

| Competencies and Suggested Objectives |
|---|
| 1. Describe safety precautions, methods for measuring thread-pitch diameters, and calculation of dimensions using taper formulas to 0.003 tolerance. DOK2<br>a. Describe methods for measuring thread-pitch diameters.<br>b. Calculate dimensions using taper formulas. |
| 2. Perform various operations according to specifications. DOK2<br>a. Perform chamfer, recessing, knurling, drilling and recessing a hole, aligning and starting a tap using a lathe center, and cutoff.<br>b. Perform turning a taper with a taper attachment, turning a taper with a compound, boring, cutting external threads to relief, picking up threads, and cutting internal threads. |

# Unit 12: Advanced Milling Operation

| Competencies and Suggested Objectives |
|---|
| 1. Adjust speed and feed rates, clean and lubricate, mount arbors and adjust arbor support bushing, mount a cutter, mill a keyway, and perform selected operations. DOK2<br>a. Adjust machine speed and feed rates; clean and lubricate.<br>b. Mount arbors and adjust arbor support bushing and mount a cutter according to specifications.<br>c. Perform selected operations according to specifications. |
| 2. Mount and remove cutters and cutter holders, align a vise using a dial indicator, and perform selected vertical milling and boring operations. DOK2<br>a. Mount and remove cutters and cutter holders; mount and align a vise.<br>b. Perform selected milling and boring operations according to specifications. |

# Unit 13: Grinding Theory and Operation

| Competencies and Suggested Objectives |
| --- |
| 1. Describe safety, magnetic chuck work, surface grinding operations, and reasons for truing and balancing a grinding wheel. DOK3<br>a. Describe grinding safety.<br>b. Describe safety rules that apply to magnetic chuck work.<br>c. Identify surface grinding operations.<br>d. Explain reasons for truing and balancing grinding wheels. |

# Unit 14: Computerized Numerical Control

| Competencies and Suggested Objectives |
|---|
| 1. Describe computerized numerical control (CNC), including the codes and the input of a pre-written program. DOK2<br>a. Describe the operations of CNC.<br>b. Describe codes used in a CNC machine. |
| 2. Safely operate a CNC machine. DOK2<br>a. Debug the program.<br>b. Download the program.<br>c. Execute the program.<br>d. Input a pre-written program into a PC.<br>e. Print a hard copy of the program. |

# Student Competency Profile

**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, Leadership, and Basic Safety** | | |
| | 1. | Describe local program and career technical center policies and procedures. |
| | 2. | Describe employment opportunities and responsibilities. |
| | 3. | Explore leadership skills and personal development opportunities provided to students by student organizations, including SkillsUSA. |
| | 4. | Explain safety in and around electrical situations. |
| | 5. | Describe general safety rules for working in a shop, laboratory, and/or industry. |
| | 6. | Identify and apply safety around manufacturing operations. |
| | 7. | Explain lifting. |
| | 8. | Explain the safety data sheet (SDS). |
| | 9. | Explain fires. |
| **Unit 2: Math, Measuring Tools, and Instruments** | | |
| | 1. | Apply the four basic math skills with whole numbers, fractions, and percentages. |
| | 2. | Perform basic mathematical calculations related to machine shop operations. |
| | 3. | Identify and perform functions using various measuring tools and instruments (e.g., micrometer, dial indicator, height gauge, and digital caliper). |
| **Unit 3: Introduction to Blueprints and Hand and Power Tools** | | |
| | 1. | Read, analyze, and design a blueprint. |
| | 2. | Demonstrate the use and maintenance of various hand and power tools. |
| **Unit 4: Bench and Pedestal Grinding (Offhand Grinding)** | | |
| | 1. | Describe safety in operating a bench or pedestal grinder, and the reasons for using offhand grinding. |
| | 2. | Perform maintenance operations to a manufacturer's specifications and grinding operations to the teacher's specifications. |
| **Unit 5: Drill Press and Band Saw Theory and Operation** | | |
| | 1. | Identify and describe the types of drilling machines, including hand-powered and drill press, and the rules for the safe operation of each. |
| | 2. | Identify and describe the safe operation of the types of power saws. |

| | | |
|---|---|---|
| **Unit 6: Lathe Theory and Operation** | | |
| | 1. | Identify the parts, rules, and care of the metal lathe. |
| | 2. | Perform procedures for a machining operation. |
| **Unit 7: Milling Machine Theory and Operation** | | |
| | 1. | Differentiate between the types of vertical milling machines. |
| | 2. | Identify the parts, cutting tools, and basic maintenance of a vertical milling machine. |
| | 3. | Perform operations on a milling machine. |
| **Unit 8: Introduction to Lathe and Milling Skills** | | |
| | 1. | Lathe: Describe safety precautions, methods for measuring thread-pitch diameters, and calculation of dimensions using taper formulas with 0.010 tolerance. |
| | 2. | Mill: Align a vise using a dial indicator to 0.005 tolerance and mill a quarter-inch keyway to 0.005 tolerance. |
| **Unit 9: Orientation, Advanced Leadership, and Employability Skills** | | |
| | 1. | Describe local program and career technical center policies and procedures. |
| | 2. | Describe employment opportunities and responsibilities. |
| | 3. | Demonstrate the ability to follow verbal and written instructions and communicate effectively in on-the-job situations. |
| **Unit 10: Basic Safety** | | |
| | 1. | Describe general safety rules for working in a shop, laboratory, and/or industry. |
| | 2. | Identify and apply safety around manufacturing operations. |
| | 3. | Identify and explain the use of various barriers and confinements. |
| | 4. | Explain lifting. |
| | 5. | Explain the safety data sheet (SDS). |
| | 6. | Explain fires. |
| | 7. | Explain safety in and around electrical situations. |
| **Unit 11: Advanced Lathe Operation** | | |
| | 1. | Describe safety precautions, methods for measuring thread-pitch diameters, and calculation of dimensions using taper formulas to 0.003 tolerance. |
| | 2. | Perform various operations according to specifications. |
| **Unit 12: Advanced Milling Operation** | | |
| | 1. | Adjust speed and feed rates, clean and lubricate, mount arbors and adjust arbor support bushing, mount a cutter, mill a keyway, and perform selected operations. |
| | 2. | Mount and remove cutters and cutter holders, align a vise using a dial indicator, and perform selected vertical milling and boring operations. |
| **Unit 13: Grinding Theory and Operation** | | |
| | 1. | Describe safety, magnetic chuck work, surface grinding operations, and reasons for truing and balancing a grinding wheel. |

| Unit 14: Computerized Numerical Control | | |
|---|---|---|
| | 1. | Describe computerized numerical control (CNC), including the codes and the input of a pre-written program. |
| | 2. | Safely operate a CNC machine. |

# Appendix A: Industry Standards

| | Units | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Standards** | | | | | | | | | | | | | | | |
| **Level 1** | | | | | | | | | | | | | | | |
| L1B | | | X | X | X | X | X | X | X | X | X | X | X | X | X |
| LIL | | | X | X | | X | X | X | X | | | X | X | | |
| 1VM | | | X | X | | | | X | X | | | | X | | |
| 1DP | | | X | X | X | X | | | | | | | | | |
| 1SG | | | X | X | | | | X | X | | | | X | X | |
| 1TB | | | X | X | | | X | | X | | | X | X | | |
| 1TC | | | X | X | | | X | | X | | | X | | | |
| 1CM | | | X | X | | | | | | | | | | | X |
| 1CT | | | X | X | | | | | | | | | | | X |

National Institute for Metalworking Skills (NIMS) - NIMS Machining Level 1

**L1B Benchwork**

1. Given a process plan, blueprint, and access to hand tools, produce a part with two holes prepared for hand tapping, a hole prepared (reamed) for the press fit of a bushing, and a stud for one of the tapped holes. Deburr the part, hand drill and hand tap the holes, press in the bushing, and install the stud. File chamfer.

**Other Evaluation Criteria**

1. Free of sharp edges or burrs
2. Go/NoGo gauge for the threads
3. Length of stud within 0.03 of basic dimension and square to surface

*Accuracy Level: +/- 0.015 unless otherwise specified on the blueprint*

**LIL Layout**

1. Given a surface plate, surface gage, layout height gage, combination set, scriber, layout ink, prick punch, ball-peen hammer, process plan, and part print, lay out hole locations, radii, and surfaces matching the specifications.

**Other Evaluation Criteria**

1. Layout ink is applied to the surface appropriately.
2. Lines are struck once.
3. Intersections are clean and clear.
4. Punch marks are centered on intersections.

*Accuracy Level: +/- 0.015 unless otherwise specified on the blueprint.*

**1VM Vertical Milling**

1. Given raw material, print, hand, precision, and cutting tools, as well as access to an appropriate vertical milling machine and its accessories, produce a part matching the blueprint specifications using appropriate trade techniques and speeds and feeds. The part specified should require squaring up from the raw state, have at least one milled slot, require the location of at least two drilled and reamed holes within positional tolerance of 0.014 in., and have three steps controlled by tolerances of +/- 0.005 in.

**Other Evaluation Criteria**

1. Finishes are at least 125 Ra microinches.

2. No sharp edges

*Accuracy Level: +/- 0.015 on all fractions, +/- 0.005 on all decimals unless otherwise specified on the blueprint.*
*Finished surfaces are to be square within 0.005 over 4 in.*
*Finished surfaces are to be 125 Ra microinches unless otherwise specified.*

**1DP Drill Press**

1. Given a part print and hand, precision, and cutting tools, as well as access to a drill press and its accessories, produce a part matching the process plan and the blueprint specifications. Each hole must have at least two secondary operations. The secondary operations will consist of reaming, spot facing, countersinking, counterboring, and counterdrilling. At least one hole must be a blind hole and one a through hole. At least one hole will/may be power tapped.

**Other Evaluation Criteria**

1. Finishes are at least 250 Ra microinches.
2. No sharp edges
3. The mouths of all holes are lightly countersunk.

*Accuracy Level: +/- 1/64 on all fractions, holes square within 0.005 per inch, drilled diameters, +0.006, -0.000*
*Reamed diameters are +0.001, -0.000, +/- 0.005 on all decimals unless otherwise specified on the blueprint.*

**1SG Surface Grinding**

1. Given a block squared up on a mill, part print, hand and precision tools, and choice of a grinding wheels, as well as access to a surface grinder and its accessories, dress the wheel, produce a part matching the print specifications using appropriate trade techniques. The part specified will be in the semi-finished state having been squared up and milled. Finishing the part will require the precision finishing of the six faces of the block to tolerances common to precision grinding for squareness, size, and surface finish characteristics.

**Other Evaluation Criteria**

1. Finishes are at least 32 Ra microinches or better.
2. Free of sharp edges

*Accuracy Level: +/- 0.001 on all decimals unless otherwise specified on the print.*
*Square within 0.001 over 4 in.*

**1TB Turning – Between Centers**

1. Given raw material, process plan, part print, and hand, precision, and cutting tools, as well as access to an appropriate turning machine and its accessories, produce a part matching the process plan and the part print specifications using appropriate trade techniques and speeds and feeds. The part specified should have at least three diameters within +/- 0.002, one UNC external thread, one UNF external thread, and require part be turned end for end to complete.

**Other Evaluation Criteria**

1. Finishes are at least 125 Ra microinches.
2. No sharp edges

*Accuracy Level: +/- 0.015 on all fractions, +/- 0.005 on all decimals unless otherwise specified on the part print*
*Diameters are to be coaxial within 0.002 total runout.*

**1TC Turning – Chucking**

1. Given raw material, part print, and hand, precision, and cutting tools, as well as access to an appropriate turning machine and its accessories, produce a part matching the print specifications using appropriate trade techniques and speeds and feeds. The part specified should have at least three diameters within +/- 0.005 in., two bores within +/- 0.005 in., one UNC external thread, and require at least two chuckings or other workholding setup.

**Other Evaluation Criteria**

1. Finishes are at least 125 Ra microinches.
2. No sharp edges

*Accuracy Level: +/- 0.015 on all fractions, +/- 0.005 on all decimals unless otherwise specified on the blueprint*

*Diameters are to be coaxial within 0.002 total runout.*

**1CM CNC Milling**

1. Performance Standard: Write a program at the machine or off-line. Set up the machining operation, and perform standards given on mill operations (2.10) to develop a simple part (with linear and circular interpolations).
2. Accuracy Level: Match the requirements of the part print and 63 Ra microinch finish.

**1CT CNC Turning**

1. Performance Standard: Write a program at the machine or off-line. Set up the machining operation, and perform all standards given on lathe operations (2.9) to develop a simple part (with linear and circular interpolations).
2. Accuracy Level: Match the requirements of the part print.