Heating, Ventilation, Air Conditioning, and Refrigeration

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Office of the State Superintendent of Education
Postsecondary and Career Education Division
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The purpose of this document is to communicate the required Career and Technical Education (CTE) academic standards for the Heating, Ventilation, Air Conditioning, and Refrigeration Program of Study. The academic standards in this document are theoretical and performance-based. The standards contain content from Colorado, Maryland, Tennessee, and Texas and were validated by D.C. business and industry partners. All content is used with permission.

In addition to academic standards, OSSE has incorporated into this document Labor Market Information (LMI) definitions and explanations for the Program of Study; program aligned Industry Recognized Credentials; Work-Based Learning resources and requirements by course level; and a recommended equipment and supply list.

This document is intended for use by educational administrators and practitioners. A similar document is available for each state-approved CTE Program of Study.

HVAC-R Program of Study

Table of Contents

Course Descriptions: HVAC-R		
Course Level	**Course Information**	**Description**
Level I	**Principles of Construction** **OSSEID:** 5020501 **Grades:** 9-12 **Prerequisite:** None **Credit:** 1	Principles of Construction is intended to provide an introduction and lay a solid foundation for those students entering the construction or craft skilled areas. The course provides a strong knowledge of construction safety, construction mathematics, and common hand and power tools. This course also provides communication and occupation skills to assist the student in obtaining and maintaining employment.
Level II	**Heating, Ventilation, Air Conditioning, and Refrigeration Technology I** **OSSEID:** 5020502 **Grades:** 10-12 **Prerequisite:** Principles of Construction **Credit:** 1	In Heating, Ventilation, and Air Conditioning (HVAC) and Refrigeration Technology I, students will gain knowledge and skills needed to enter the industry as technicians in the HVAC and refrigeration industry or building maintenance industry, prepare for a postsecondary degree in a specified field of construction management, or pursue an approved apprenticeship program. Students will acquire knowledge and skills in safety, principles of HVAC theory, use of tools, codes, and installation of HVAC and refrigeration equipment.
Level III	**Heating, Ventilation, Air Conditioning, and Refrigeration Technology II** **OSSEID:** 5020503 **Grades:** 11-12 **Prerequisite:** Heating, Ventilation, Air Conditioning, and Refrigeration Technology I **Credit:** 1	In Heating, Ventilation, Air Conditioning, and Refrigeration Technology II, students will gain advanced knowledge and skills needed to enter the industry as HVAC and refrigeration technicians or building maintenance technicians or supervisors, prepare for a postsecondary degree in a specified field of construction or construction management, or pursue an approved apprenticeship program. Students will acquire knowledge and skills in safety, electrical theory, use of tools, codes, installation of commercial HVAC equipment, heat pumps, troubleshooting techniques, various duct systems, and maintenance practices.
Level IV	**Practicum in Construction Technology** **OSSEID:** 5020504 **Grades:** 12 **Prerequisite:** Heating, Ventilation, Air Conditioning, and Refrigeration Technology II **Credit:** 1	In Practicum in Construction Technology, students will be challenged with the application of knowledge and skills gained in previous construction-related coursework. In many cases, students will be allowed to work at a job (paid or unpaid) outside of school or be involved in local projects the school has approved for this class.

Industry Certifications

OSHA 10
ACCA (Air Conditioning Contractors of America) Refrigerant Handling (EPA 608)
NCCER HVAC, Level 1
EPA HVAC Certification

Work-Based Learning Examples and Resources

Level I Course	Level II Course	Level III Course	Level IV Course
Career Exploration Industry Visits Guest Speakers Participate in a CTSO	**Career Awareness** *All of Level I, plus:* Postsecondary Visits Program-Specific Site Tours Mock Interviews	**Career Preparation** *All of Level I and II, plus:* Job Shadow Paid/Unpaid Internships	**Career Preparation** Paid/Unpaid Internships Apprenticeships

Several resources are available to help instructors meet the Level I and Level II WBL requirements, including:

Career Coach DC (http://careercoachdc.emsicc.com). Online site designed to help students find and connect to a career pathway by providing the most current local data on wages, employment, job postings, and associated education and training. The resource includes a Career Assessment for students.

Nepris (https://dc.nepris.com/). Connects educators and learners with a network of industry professionals virtually, bringing real-world relevance and career exposure to all students. Nepris also provides a skills-based volunteering platform for business and industry professionals to extend their educational outreach.

Virtual Job Shadow (https://virtualjobshadow.com). Provides interactive tools which empower students to discover, plan, and pursue their dreams. Rich video library presents a "day in the life of" view for thousands of occupations.

Labor Market Information Definitions and Data

Career and Technical Education programs of study in the District of Columbia must meet at least one of the High Wage, High Skill, and In-Demand definitions below to be considered appropriate for our students and the regional labor market. These definitions were created in collaboration with Career and Technical Education leaders from District of Columbia LEA's, the University of the District of Columbia Community College, and national guidance from Research Triangle International (RTI) and Education Northwest. Additionally, previous work was consulted from researchers at MIT's Labor Wage Index Project and the DC CTE Task Force's 2012 Strategic Plan for the District of Columbia.

Indicator	Definition	Data for the HVAC-R Program of Study (source: EMSI, August 2021)
High Wage	Those occupations that have a 25th percentile wage equal to or greater than the most recent MIT Living Wage Index for one adult in the District of Columbia, and/or leads to a position that pays at least the median hourly or annual wage for the Washington, DC, metropolitan statistical area. *Note: A 25th percentile hourly wage of $20.49 or greater is required to meet this definition.*	**Standard Occupational Code (SOC):** 49-9021.00 HVAC Mechanics and Installers **Hourly Wages** **25th Percentile:** $24.16 **50th Percentile**: $31.00 **75th Percentile:** $38.30
High Skill	Those occupations located within the Washington, DC, metropolitan statistical area with the following education or training requirements: completion of an apprenticeship program; completion of an industry-recognized certification or credential; associate's degree, or higher.	**Typical Entry-Level Education:** Postsecondary Nondegree Award
In-Demand	Those occupations in the Washington, DC, metropolitan statistical area having more than the median number of total ***(growth plus replacement)*** annual openings over a five-year period. *Note: An occupation is required to have an annual growth plus replacement rate of 105 openings, or greater, between 2020-25 to meet this definition.*	**Annual Openings:** 563

Model Six-Year Plan: HVAC-R

College: University of the District of Columbia Community College
Program/CIP:
Plan:

Entity: Office of the State Superintendent of Education
Career Cluster: Architecture and Construction
Program of Study: HVAC-R

High School					College			
Subject	**9th Grade**	**10th Grade**	**11th Grade**	**12th Grade**	**Semester I**	**Semester II**	**Semester III**	**Semester IV**
English (4)	English I	English II	English III	English IV				
Math (4)	Algebra I	Geometry	Algebra II	Math				
Science (4)	Biology	Lab Science	Lab Science	Science				
Social Studies (4)	World History and Geography I: Middle Ages	World History and Geography II: Modern World	U.S. History	U.S. Government (.5) and D.C. History (.5)				
Health (.5) and Physical Ed (1)	Health (.5) Physical Ed (.5)	Physical Ed (.5)						
World Languages (2)			World Language I	World Language II				
Art (.5)		Art (.5)						
Music (.5)		Music (.5)						
Elective / Major Courses	Principles of Construction	HVAC-R I	HVAC-R II	Practicum in Construction Technology				
Total possible college credits completed in high school: XX					***Credit hours required to complete the AAS program: XX***			

Course Standards

Principles of Construction

1. **General requirements.** This course is recommended for students in Grades 9-12. Students shall be awarded one credit for successful completion of this course.

2. **Introduction.**
   A. Career and technical education instruction provides students with industry-aligned content, challenging academic standards, and relevant technical knowledge to further their education and succeed in current or emerging professions.

   B. The Architecture and Construction Career Cluster focuses on designing, planning, managing, building, and maintaining the built environment.

   C. Principles of Construction is intended to provide an introduction and lay a solid foundation for those students entering the construction or craft skilled areas. The course provides a strong knowledge of construction safety, construction mathematics, and common hand and power tools. For safety and liability considerations, limiting course enrollment to 15 students is recommended. This course also provides communication and occupation skills to assist the student in obtaining and maintaining employment.

   D. Students will participate in at least two Career Exploration Work-Based Learning experiences in this course, which might include guest speakers and workplace tours relevant to the program of study.

   E. Students are encouraged to participate in extended learning experiences such as career and technical student organizations and other leadership or extracurricular organizations.

3. **Knowledge and skills.**
   A. **The student demonstrates professional standards/employability skills as required by business and industry. The student is expected to:**
      1. explain the role of an employee in the construction industry;
      2. demonstrate critical-thinking skills;
      3. demonstrate the ability to solve problems using critical-thinking skills;
      4. demonstrate knowledge of basic computer systems;
      5. explain common uses for computers in the construction industry;
      6. define effective relationship skills;
      7. recognize workplace issues such as sexual harassment, stress, and substance abuse;
      8. explain the Occupational Safety and Health Administration (OSHA) General Duty Clause; and
      9. explain OSHA 1926 CFR Subpart C.

   B. **The student understands that safe working standards are imperative in the classroom and in the field. The student is expected to:**
      1. explain the idea of a safety culture;
      2. explain the importance of a safety culture in the construction crafts;

3. explain the role of the OSHA in job-site safety;
4. explain fall protection, ladder safety, stair safety, and scaffold safety procedures;
5. demonstrate the use and care of appropriate personal protective equipment, including safety goggles and glasses, hard hats, gloves, safety harnesses, and safety shoes;
6. define safe work procedures around electrical hazards; and
7. explain the importance of Safety Data Sheets (SDS).

C. **The student understands the importance of recognizing potential hazards and preventing accidents in the classroom and in the field. The student is expected to:**
1. identify causes of accidents;
2. identify impacts of accident costs;
3. define hazard recognition;
4. identify struck-by hazards;
5. identify caught-in-between hazards;
6. identify other construction hazards on the jobsite, including hazardous material exposures, environmental elements, welding and cutting hazards, confined spaces, and fires; and
7. explain the importance of hazard communication (HazCom).

D. **The student understands basic construction mathematics. The student is expected to:**
1. add, subtract, multiply, and divide whole numbers with and without a calculator;
2. add, subtract, multiply, and divide fractions;
3. add, subtract, multiply, and divide decimals with and without a calculator;
4. convert decimals to percentages and percentages to decimals; and
5. convert fractions to decimals and decimals to fractions.

E. **The student demonstrates basic measuring practices. The student is expected to:**
1. use a standard ruler, a metric ruler, a measuring tape, and an architectural/engineering scale to measure;
2. explain what the metric system is and how it is important in the construction trade;
3. recognize and use metric units of length, weight, volume, and temperature; and
4. recognize some of the basic shapes used in the construction industry and apply basic geometric principles to measure them.

F. **The student acquires knowledge about care and identification of hand tools. The student is expected to:**
1. recognize and identify the basic hand tools and their purposes for the construction trades;
2. inspect basic hand tools visually to determine if they are safe for use; and
3. use the basic construction hand tools safely and properly.

G. **The student acquires knowledge about care and identification of powered hand tools. The student is expected to:**
1. identify powered hand tools commonly used in the construction trades;
2. practice safe and proper application of powered hand tools commonly used in the construction trades; and
3. explain how to properly maintain and clean powered hand tools commonly used in construction trades.

H. **The student develops the basics of construction drawing. The student is expected to:**
1. interpret and use drawing dimensions;

2. recognize and identify basic construction terms;
3. recognize and identify basic drawing components;
4. recognize and identify commonly used drawing symbols;
5. relate information on construction drawings to actual locations on the print; and
6. recognize different classifications of construction drawings.

I. **The student reads technical drawings and documents to plan a project. The student is expected to:**
1. interpret blueprints and drawings to assist with project planning;
2. recognize elements and symbols of blueprints and drawings;
3. relate information on blueprints to actual locations on the print;
4. recognize different classifications of drawings; and
5. interpret and use drawing dimensions.

J. **The student interprets and presents information used in workplace situations. The student is expected to:**
1. interpret information and instructions presented in written form;
2. interpret information and instructions presented in verbal form;
3. communicate effectively using verbal and writing skills; and
4. communicate effectively on the job using electronic communication devices.

K. **The student identifies ergonomic tools and procedures as well as safe material handling standards. The student is expected to:**
1. define a load;
2. establish a pre-task plan prior to moving a load;
3. apply proper material-handling techniques;
4. choose appropriate material-handling equipment for the task; and
5. recognize hazards and follow safety procedures required for material handling.

L. T**he student develops technology skills. The student is expected to:**
1. Use technology as a tool to research, organize, evaluate, and communicate information;
2. Use digital technologies (computers, PDAs, media players, GPSs, etc.); communication/networking tools, and social networks appropriately to access, manage, integrate, evaluate, and create information to successfully function in a knowledge economy;
3. Demonstrate using current and new technologies specific to the program of study, course, and/or industry; and
4. Apply a fundamental understanding of the ethical/legal issues surrounding the access and use of information technologies.

Heating, Ventilation, Air Conditioning, and Refrigeration Technology I

1. **General requirements.** This course is recommended for students in Grades 10-12. Prerequisite: Principles of Construction. Students shall be awarded one credit for successful completion of this course.

2. **Introduction.**
   A. Career and technical education instruction provides students with industry-aligned content, challenging academic standards, and relevant technical knowledge to further their education and succeed in current or emerging professions.

   B. The Architecture and Construction Career Cluster focuses on designing, planning, managing, building, and maintaining the built environment.

   C. In Heating, Ventilation, and Air Conditioning (HVAC) and Refrigeration Technology I, students will gain knowledge and skills needed to enter the industry as technicians in the HVAC and refrigeration industry or building maintenance industry, prepare for a postsecondary degree in a specified field of construction management, or pursue an approved apprenticeship program. Students will acquire knowledge and skills in safety, principles of HVAC theory, use of tools, codes, and installation of HVAC and refrigeration equipment.

   D. Students will participate in at least two Career Awareness Work-Based Learning experiences in this course, which might include informational interviews or job shadowing relevant to the program of study.

   E. Students are encouraged to participate in extended learning experiences such as career and technical student organizations and other leadership or extracurricular organizations.

3. **Knowledge and skills.**
   A. **The student demonstrates professional standards/employability skills as required by business and industry. The student is expected to:**
      1. identify job opportunities with their accompanying job duties in occupations such as electrician, building maintenance technician or manager, and electrical engineer; and
      2. research career pathways along with the education, job skills, and experience required to achieve a career goal.

   B. **The student learns the basic principles of HVAC and refrigeration. The student is expected to:**
      1. explain the basic principles of HVAC;
      2. describe what the Clean Air Act means to the HVAC and refrigeration industry; and
      3. identify the types of schedules and drawings used by the HVAC and refrigeration industry.

   C. **The student applies knowledge and skills in mathematics as they relate to HVAC and the principles of refrigeration. The student is expected to:**
      1. identify similar units of measurement in both English and the International System (S.I.) of units;
      2. calculate and convert measured values and volumes expressed in mathematical equations and formulas; and
      3. convert temperature values between Celsius and Fahrenheit.

D. **The student selects, prepares, connects, and installs copper and plastic piping and fittings. The student is expected to:**
   1. state the precautions that must be taken when installing refrigerant piping;
   2. select, cut, and bend the right copper tubing for the job;
   3. safely connect tubing, using flare and compression fittings;
   4. determine the correct hardware and supports needed for refrigerant pipe installations;
   5. describe the basic requirements needed to identify and install various types of plastic pipe and state their uses;
   6. demonstrate various methods used to pressure test HVAC systems;
   7. identify types of plastic pipe and state their uses; and
   8. cut and join lengths of plastic pipe.

E. **The student cuts, threads, and joins ferrous piping. The student is expected to:**
   1. assemble and operate the tools used for soldering;
   2. prepare tubing and fittings for soldering;
   3. identify the purposes and uses of solder and solder fluxes;
   4. solder copper tubing fittings;
   5. assemble and operate the tools used for brazing;
   6. prepare tubing and fittings for brazing;
   7. identify the purposes and uses of filler metals and fluxes used for brazing;
   8. braze copper tubing and fittings;
   9. identify the inert gases that can be used safely to purge tubing when brazing;
   10. identify the types of ferrous metal pipes;
   11. accurately measure the sizes of ferrous metal pipes;
   12. identify the common malleable iron fittings;
   13. cut, ream, and thread ferrous metal pipe;
   14. join lengths of threaded pipe together and install fittings;
   15. describe the main points to consider when installing pipe runs; and
   16. describe the methods used to join grooved piping.

F. **The student knows electrical principles, power generation and distribution, electrical components, direct current circuits, and electrical safety. The student is expected to:**
   1. explain how electrical power is distributed;
   2. describe how voltage, current, resistance, and power are related;
   3. calculate the current, voltage, and resistance in a circuit using Ohm's law;
   4. calculate how much power is consumed by a circuit using the power formula;
   5. describe the differences between series and parallel circuits and calculate loads in each;
   6. describe the purpose and operation of the various electrical components used in HVAC equipment;
   7. state and demonstrate the safety precautions that must be followed when working on electrical equipment;
   8. make voltage, current, and resistance measurements using electrical test equipment; and
   9. read and interpret common electrical symbols.

G. **The student learns the principles of heat transfer, refrigeration, pressure-temperature relationships, and the components and accessories used in air conditioning systems. The student is expected to:**

1. explain how heat transfer occurs in a cooling system, demonstrating an understanding of the terms and concepts used in the refrigeration cycle;
2. calculate the temperature and pressure relationships at key points in the refrigeration cycle;
3. under supervision, use temperature- and pressure-measuring instruments to make readings at key points in the refrigeration cycle;
4. identify commonly used refrigerants and demonstrate the procedures for handling these refrigerants;
5. identify the major components of a cooling system and explain how each type works;
6. identify the major accessories available for cooling systems and explain how each works;
7. identify the control devices used in cooling systems and explain how each works; and
8. demonstrate the correct methods to be used when piping a refrigeration system.

H. **The student learns heating fundamentals, types and designs of furnaces and their components, and basic procedures for installing and servicing furnaces. The student is expected to:**
1. explain the three methods by which heat is transferred and give an example of each;
2. describe how combustion occurs and identify the by-products of combustion;
3. identify the various types of fuels used in heating;
4. identify the major components and accessories of an induced draft and condensing gas furnace and explain the function of each component;
5. describe the factors that must be considered when installing a furnace;
6. identify the major components of a gas furnace and describe how each works;
7. use a manometer under supervision to measure and adjust manifold pressure on a gas furnace;
8. identify the major components of an oil furnace and describe how each component works; and
9. perform furnace preventive maintenance procedures such as cleaning and filter replacement under supervision.

I. **The student gains knowledge and skills related to air distribution systems. The student is expected to:**
1. describe the airflow and pressures in a basic forced-air distribution system;
2. explain the differences between propeller and centrifugal fans and blowers;
3. identify the various types of duct systems and explain why and where each type is used;
4. demonstrate or explain the installation of metal, fiberboard, and flexible duct;
5. demonstrate or explain the installation of fittings and transitions used in duct systems;
6. demonstrate or explain the use and installation of diffusers, registers, and grilles used in duct systems;
7. demonstrate or explain the use and installation of dampers used in duct systems;
8. demonstrate or explain the use and installation of insulation and vapor barriers used in duct systems;
9. identify the instruments used to make measurements in air systems and explain the use of each instrument; and
10. make accurate temperature, air pressure, and velocity measurements in an air distribution system.

J. **The student develops technology skills. The student is expected to:**
1. Use technology as a tool to research, organize, evaluate, and communicate information;
2. Use digital technologies (computers, PDAs, media players, GPSs, etc.); communication/networking tools, and social networks appropriately to access, manage, integrate, evaluate, and create information to successfully function in a knowledge economy;

3. Demonstrate using current and new technologies specific to the program of study, course, and/or industry; and
4. Apply a fundamental understanding of the ethical/legal issues surrounding the access and use of information technologies.

Heating, Ventilation, Air Conditioning, and Refrigeration Technology II

1. **General requirements.** This course is recommended for students in Grades 11 and 12. Prerequisite: Heating, Ventilation, Air Conditioning, and Refrigeration Technology I. Recommended prerequisite: Principles of Architecture or Principles of Construction. Students shall be awarded two credits for successful completion of this course.

2. **Introduction.**
   A. Career and technical education instruction provides students with industry-aligned content, challenging academic standards, and relevant technical knowledge to further their education and succeed in current or emerging professions.

   B. The Architecture and Construction Career Cluster focuses on designing, planning, managing, building, and maintaining the built environment.

   C. In Heating, Ventilation, Air Conditioning, and Refrigeration Technology II, students will gain advanced knowledge and skills needed to enter the industry as HVAC and refrigeration technicians or building maintenance technicians or supervisors, prepare for a postsecondary degree in a specified field of construction or construction management, or pursue an approved apprenticeship program. Students will acquire knowledge and skills in safety, electrical theory, use of tools, codes, installation of commercial HVAC equipment, heat pumps, troubleshooting techniques, various duct systems, and maintenance practices.

   D. Students will participate in a Career Preparation Work-Based Learning experience in this course, which might include paid or unpaid internship experiences relevant to the program of study.

   E. Students are encouraged to participate in extended learning experiences such as career and technical student organizations and other leadership or extracurricular organizations.

3. **Knowledge and skills.**
   A. **The student demonstrates professional standards/employability skills as required by business and industry. The student is expected to:**
      1. identify job opportunities with their accompanying job duties in occupations such as electrician, building maintenance technician or manager, and electrical engineer; and
      2. research career pathways along with the education, job skills, and experience required to achieve a career goal.

   B. **The student learns the principles of commercial air systems. The student is expected to:**
      1. identify the differences between types of commercial air systems;
      2. identify the type of building in which a particular type of system is used; and
      3. explain the typical range of capacities for a commercial air system.

   C. **The student knows the principles of venting fossil-fuel furnaces and the proper methods for selecting and installing vent systems for gas-fired heating equipment. The student is expected to:**
      1. describe the principles of combustion and explain complete and incomplete combustion;
      2. describe the content of flue gas and explain how it is vented;
      3. identify the components of a furnace vent system;

4. describe how to select and install a vent system;
5. perform the adjustments necessary to achieve proper combustion in a gas furnace;
6. describe the techniques for venting different types of furnaces;
7. explain the various draft control devices used with natural-draft furnaces;
8. calculate the size of a vent required for a given application; and
9. adjust a thermostat heat anticipator.

D. **The student gains knowledge of hot water heating systems, focusing on safe operation of the low-pressure boiler and piping systems commonly used in residential applications. The student is expected to:**
1. explain the terms and concepts used when working with hot-water heating;
2. identify the major components of hot-water heating;
3. explain the purpose of each component of hot-water heating;
4. demonstrate the safety precautions used when working with hot-water systems;
5. demonstrate how to operate selected hot-water systems;
6. demonstrate how to safely perform selected operating procedures on low-pressure systems;
7. identify the common piping configurations used with hot-water heating;
8. explain how to read the pressure across a water system circulating pump;
9. calculate heating water flow rates; and
10. select a pump for a given application.

E. **The student learns the basic principles, processes, and devices used to control humidity and air clean-lines as well as devices used to conserve energy in HVAC systems. The student is expected to:**
1. explain why it is important to control humidity in a building;
2. recognize the various kinds of humidifiers used with HVAC systems and explain why each is used;
3. demonstrate how to install and service the humidifiers used in HVAC systems;
4. recognize the kinds of air filters used with HVAC systems and explain why each is used;
5. demonstrate how to install and service the filters used in HVAC systems;
6. use a manometer or differential pressure gauge to measure the friction loss of an air filter;
7. identify accessories commonly used with air conditioning systems to improve indoor air quality and reduce energy cost and explain the function of each, including humidity control devices, air filtration devices, and energy conservation devices; and,
8. demonstrate or describe how to clean an electronic air cleaner.

F. **The student gains the knowledge and skills in the handling of refrigerant and equipment servicing procedures to service HVAC systems in an environmentally safe manner. The student is expected to:**
1. identify the common types of leak detectors and explain how each is used;
2. perform leak detection tests using selected methods;
3. identify the service equipment used for evacuating a system and explain why each item of equipment is used;
4. perform system evacuation and dehydration;
5. identify the service equipment used for recovering refrigerant from a system and for recycling the recovered refrigerant and explain why each item of equipment is used;
6. perform a refrigerant recovery;
7. evacuate a system to a deep vacuum;

8. identify the service equipment used for charging refrigerant into a system and explain why each item of equipment is used;
9. use nitrogen to purge a system; and
10. charge refrigerant into a system using various methods, including weight, superheat, sub-cooling, and charging pressure chart.

G. **The student gains knowledge of transformers, single-phase and three-phase power distribution, capacitors, theory and operation of induction motors, and instruments and techniques used in testing alternating current circuits and components. The student is expected to:**
1. describe the operation of various types of transformers;
2. explain how alternating current is developed and draw a sine wave;
3. identify single-phase and three-phase wiring arrangements;
4. explain how phase shift occurs in inductors and capacitors;
5. describe the types of capacitors and their applications;
6. explain the operation of single-phase and three-phase induction motors;
7. identify the various types of single-phase motors and their applications;
8. state and demonstrate the safety precautions that must be followed when working with electrical equipment; and
9. test alternating current components, including capacitors, transformers, and motors.

H. **The student learns the theory of solid-state electronics as well as the operation, use, and testing of the various electronic components used in HVAC equipment. The student is expected to:**
1. explain the theory of electronics and semiconductors;
2. explain how various semiconductor devices such as diodes, light-emitting diodes, and photodiodes work and how the devices are used in power and control circuits;
3. identify different types of resistors and explain how their resistance values can be determined;
4. describe the operation and function of thermistors and cad cells;
5. test semiconductor components; and
6. identify the connectors on a personal computer.

I. **The student learns the operation, testing, and adjustment of conventional and electronic thermostats as well as the operation of common electrical, electronic, and pneumatic circuits used to control HVAC systems. The student is expected to:**
1. explain the function of a thermostat in an HVAC system;
2. describe different types of thermostats and explain how the thermostats are used;
3. demonstrate the correct installation and adjustment of a thermostat;
4. explain the principles applicable to all control systems;
5. identify the various types of electromechanical, electronic, and pneumatic HVAC controls and explain their function and operation;
6. describe a systematic approach for electrical troubleshooting of HVAC equipment and components;
7. recognize and use equipment manufacturers' troubleshooting aids to troubleshoot HVAC equipment;
8. demonstrate how to isolate electrical problems to faulty power distribution, load, or control circuits;
9. identify the service instruments needed to troubleshoot HVAC electrical equipment;
10. make electrical troubleshooting checks and measurements on circuits and components common to all HVAC equipment; and
11. isolate and correct malfunctions in a cooling system control circuit.

J. **The student learns the tools, instruments, and techniques used in troubleshooting gas heating appliances, including how to isolate and correct faults. The student is expected to:**
1. describe the operating sequence for gas heating equipment;
2. interpret control circuit diagrams for gas heating systems;
3. describe the operation of various types of burner ignition methods;
4. identify the tools and instruments used when troubleshooting gas heating systems;
5. demonstrate using the tools and instruments required for troubleshooting gas heating systems; and
6. isolate and correct malfunctions in gas heating systems.

K. **The student learns the techniques and equipment used in troubleshooting cooling equipment and analyzing system temperatures and pressures in order to isolate faults. The student is expected to:**
1. describe a systematic approach for troubleshooting cooling systems and components;
2. isolate problems to electrical and mechanical functions in cooling systems;
3. recognize and use equipment manufacturers' troubleshooting aids to troubleshoot cooling systems;
4. identify and use the service instruments needed to troubleshoot cooling systems;
5. troubleshoot selected problems in cooling equipment; and
6. state the safety precautions associated with cooling troubleshooting.

L. **The student learns the principles of reverse-cycle heating, the operation of various types of heat pumps, and the mechanisms of heat pump control circuits and learns to install and service heat pumps. The student is expected to:**
1. describe the principles of reverse-cycle heating;
2. identify heat pumps by type and general classification;
3. describe various types of geothermal water loops and their application;
4. list the components of heat pump systems;
5. describe the role and operation of electric heat in common heat pump systems;
6. describe common heat pump ratings such as coefficient of performance, heating season performance factor, and seasonal energy efficiency ratio;
7. demonstrate heat pump installation and service procedures;
8. identify and install refrigerant circuit accessories commonly associated with heat pumps;
9. analyze a heat pump control circuit; and
10. isolate and correct malfunctions in a heat pump.

M. **The student selects the application and installation of various types of fasteners, gaskets, seals, and lubricants, as well as the installation and adjustment of different types of belt drives, bearings, and couplings. The student is expected to:**
1. identify, explain, and install threaded and non-threaded fasteners;
2. identify, remove, and install types of gaskets, packings, and seals;
3. identify types of lubricants and explain their uses;
4. use lubrication equipment to lubricate motor bearings;
5. identify the types of belt drives, explain their uses, and demonstrate procedures used to install or adjust them;
6. identify and explain types of couplings;
7. demonstrate procedures used to remove, install, and align couplings;

8. identify types of bearings and explain their uses;
9. explain causes of bearing failures;
10. demonstrate procedures used to remove and install bearings;
11. perform preventive maintenance inspection and cleaning procedures; and
12. list ways to develop and maintain good customer relations.

N. **The student demonstrates how to layout, fabricate, install, and join sheet metal ductwork. The student is expected to:**
1. identify and describe the types of sheet metal;
2. define properties of steel and aluminum alloys;
3. describe a layout method and perform proper cutting;
4. join sheet metal duct sections using proper seams and connectors;
5. describe proper hanging and support methods for sheet metal ductwork;
6. describe thermal and acoustic insulation principles;
7. select, apply, and seal the proper insulation for sheet metal ductwork;
8. describe guidelines for installing components such as register, diffusers, grilles, dampers, access doors, and zoning accessories; and
9. install takeoffs and attach flexible duct to a sheet metal duct.

O. **The student gains the knowledge and skills to layout, fabricate, install, join, attach, and support fiberglass ductwork and fittings. The student is expected to:**
1. identify types of fiberglass duct, including flexible duct;
2. describe fiberglass duct layout and some basic fabrication methods;
3. describe the various closure methods for sealing fiberglass duct;
4. fabricate selected duct modules and fittings using the appropriate tools;
5. describe hanging and support methods for fiberglass duct;
6. describe how to repair major and minor damage to fiberglass duct; and
7. install takeoffs and attach flexible duct to a fiberglass duct.

P. **The student develops technology skills. The student is expected to:**
1. Use technology as a tool to research, organize, evaluate, and communicate information;
2. Use digital technologies (computers, PDAs, media players, GPSs, etc.); communication/networking tools, and social networks appropriately to access, manage, integrate, evaluate, and create information to successfully function in a knowledge economy;
3. Demonstrate using current and new technologies specific to the program of study, course, and/or industry; and
4. Apply a fundamental understanding of the ethical/legal issues surrounding the access and use of information technologies.

Practicum in Construction Technology

1. **General requirements.** This course is recommended for students in Grade 12. The practicum course is a paid or unpaid capstone experience for students participating in a coherent sequence of career and technical education courses in the Architecture and Construction Career Cluster. Prerequisite: Construction Technology II, Building Maintenance Technology II; Electrical Technology II; Heating, Ventilation, and Air Conditioning (HVAC) and Refrigeration Technology II; or Plumbing Technology I. Students shall be awarded one credit for successful completion of this course.

2. **Introduction.**
   A. Career and technical education instruction provides students with industry-aligned content, challenging academic standards, and relevant technical knowledge to further their education and succeed in current or emerging professions.

   B. The Architecture and Construction Career Cluster focuses on designing, planning, managing, building, and maintaining the built environment.

   C. In Practicum in Construction Technology, students will be challenged with the application of knowledge and skills gained in previous construction-related coursework. In many cases, students will be allowed to work at a job (paid or unpaid) outside of school or be involved in local projects the school has approved for this class.

   D. Students will participate in a Career Preparation Work-Based Learning experience in this course, which includes paid or unpaid internship, pre-apprenticeship, or apprenticeship experiences relevant to the program of study.

   E. Students are encouraged to participate in extended learning experiences such as career and technical student organizations and other leadership or extracurricular organizations.

3. **Knowledge and skills.**
   A. **The student demonstrates professional standards/employability skills as required by business and industry. The student is expected to:**
      1. explain the role of an employee in the construction industry;
      2. demonstrate critical-thinking skills;
      3. demonstrate the ability to solve problems using critical-thinking skills;
      4. demonstrate knowledge of basic computer systems;
      5. explain common uses for computers in the construction industry;
      6. demonstrate effective relationship skills; and
      7. recognize workplace issues such as sexual harassment, stress, and substance abuse.

   B. **The student develops a management plan for a project or an activity. The student is expected to:**
      1. identify and describe the steps required to complete a project using project management processes, including initiating, planning, executing, monitoring and controlling, and closing a project;
      2. determine and acquire the resources needed to complete a project; and
      3. develop a project schedule.

C. **The student applies the appropriate codes, laws, standards, or regulations related to a research and development project. The student is expected to:**
   1. identify areas where codes, laws, standards, or regulations may be required;
   2. locate the appropriate codes, laws, standards, or regulations; and
   3. interpret and comply with the appropriate codes, laws, standards, or regulations.

D. **The student describes the expectations for each project using a flowchart. The student is expected to:**
   1. use an assessment strategy to determine the task's needs;
   2. describe why each task needs to be in the order it has been assigned;
   3. assess the time frame for each task; and
   4. plot a completed project flowchart expectation.

E. **The student solves problems, thinks critically, and makes decisions related to research, design, and development. The student is expected to:**
   1. develop or improve the project by following a problem-solving strategy;
   2. apply critical-thinking strategies to the analysis and evaluation of proposed technological solutions; and
   3. apply decision-making techniques to the selection of technological solutions.

F. **The student describes the costs associated with the project. The student is expected to:**
   1. develop a bill of materials list for the complete project;
   2. develop a budget, including a cost list, for the complete project; and
   3. determine the most effective way to minimize project costs.

G. **The student applies communication, mathematics, and science knowledge and skills to the construction activities. The student is expected to:**
   1. write technical reports;
   2. deliver technical presentations to the instructor;
   3. identify and describe the mathematical concepts used in projects; and
   4. identify and describe the scientific concepts used in projects.

H. **The student uses advanced tools, materials, processes, and procedures in the construction project. The student is expected to:**
   1. determine and use the appropriate technology needed to solve a problem or complete a task;
   2. evaluate the use of technology in a given situation; and
   3. describe the factors that influence the use of technology in a variety of situations.

I. **The student develops technology skills. The student is expected to:**
   1. Use technology as a tool to research, organize, evaluate, and communicate information;
   2. Use digital technologies (computers, PDAs, media players, GPSs, etc.); communication/networking tools, and social networks appropriately to access, manage, integrate, evaluate, and create information to successfully function in a knowledge economy;
   3. Demonstrate using current and new technologies specific to the program of study, course, and/or industry; and
   4. Apply a fundamental understanding of the ethical/legal issues surrounding the access and use of information technologies.