Mathematics represents the essence of the sheet metal craft. Mastery of the mathematical calculations needed often separates the skilled from the unskilled. The math required of a sheet metal craft professional is not abstract nor theoretical. Instead, it is directly applied to solving work-related problems and creating each workpiece. Following a review of important mathematical concepts, those same concepts will be applied in this module to creating various offsets and seam allowances. Unlike straight lengths of duct, offsets must often be laid out based on field measurements to fit a specific and unique situation. It is essential that a craft worker learns how to take measurements accurately and between the correct points.

**Learning Objective 1**

Successful completion of this module prepares trainees to:

Solve basic equations.

a. State the sequence of operations used to solve equations.
b. Solve equations that contain various coefficients.
c. Solve equations requiring various mathematical operations.

**Learning Objective 2**

Successful completion of this module prepares trainees to:

Solve mathematical problems related to linear measurements, angles, triangles, circles, and arcs.

a. Solve problems related to linear measurements.
b. Identify, measure, and construct angles using a protractor.
c. Determine the length of right-triangle sides using the Pythagorean theorem.
d. Solve problems related to circles and arcs.
e. Solve problems using basic trigonometric functions.
Learning Objective 3

Successful completion of this module prepares trainees to:

Explain how to make field measurements and calculate offsets.

a. Explain how to use field measuring techniques to gather information for offset calculations.
b. Explain how to measure and fit round pipe offsets and elbows.
c. Explain how to measure and fit rectangular offsets.
d. Explain how to measure and fit parallel offsets.
e. Explain how to measure and fit change-joint transitions.
f. Calculate seam and bend allowances.

Performance Tasks

Perform a field-measuring task and calculate the dimensions needed to layout an offset in round or rectangular duct.

Recommended Teaching Time: 25 hours

Classroom Equipment and Materials

• Whiteboard and markers
• Pencils and paper
• PowerPoint® Presentations for Module 04301
• A variety of standard marker sizes
• Poster board
• Flip chart
• LCD projector and screen
• Computer with Internet access
• Module Review answer key
• Module Examinations

Performance Task 1 Materials

• Tape measures
• Paper and pencil
• Calculator
• Performance Profile Sheets
Overview

By the time plans and specifications have made their way to the construction site, they have been subjected to considerable scrutiny. Their final form is the result of numerous negotiations between the building owner, architect, mechanical engineers, estimators, and craft professionals to arrive at a final system design. It is essential that the plans and specifications are accurately interpreted. Deviation from the plans or a misinterpretation could result in having to demolish and reinstall portions of a system that could lead to a significant loss for the company.

Learning Objective 1

Successful completion of this module prepares trainees to:
Identify and describe the content of various construction plans.

   a. Identify and describe the content of civil plans.
   b. Identify and describe the content of architectural plans.
   c. Identify and describe the content of mechanical plans.
   d. Identify and describe the content of structural plans.
   e. Identify and describe the content of electrical plans.
   f. Identify and describe the content of plumbing plans.
   g. Identify and describe the content of shop drawings.
   h. Identify and describe the content of as-built drawings.
   i. Identify specific information found on construction plans.

Performance Tasks

   1. Accurately locate and identify instructor-requested items and information on one or more mechanical plans.

Recommended Teaching Time: 17.5 hours
Classroom Equipment and Materials

- Whiteboard and markers
- Pencils and paper
- PowerPoint® Presentations for Module 04202
- A variety of standard marker sizes
- Poster board
- Flip chart
- LCD projector and screen
- Computer with Internet access
- Module Review answer key
- Module Examinations

Performance Task 1 Materials

- An HVAC system plan set chosen by the instructor. The plans included with this module may be used, or another set of plans can be used
- A list of items and information to be located and identified in the mechanical plans provided to the trainees
Overview

Radial line development is a sheet metal layout method frequently used for the fabrication of fittings such as cones, reducers, and other tapered shapes. This module describes the principles of radial line development and examines how to lay out and fabricate various sheet metal components using radial line development techniques.

Learning Objective 1

Successful completion of this module prepares trainees to:

Describe how radial line development is used to lay out tapered sheet metal components.

a. State the principles of radial line development.

b. Identify and describe layout tools used for radial line development.

Learning Objective 2

Successful completion of this module prepares trainees to:

Explain how to fabricate sheet metal components using radial line development.

a. Identify and describe fabrication tools and equipment used for radial line development.

b. Explain how to fabricate various sheet metal components using radial line development.

c. Identify complex fittings that use radial line development.

Performance Tasks

1. Lay out and fabricate four of the following six fittings:

   • Symmetrical tapered duct
   • Round duct intersecting a taper
   • Off-center tapered duct
• Square-to-square tapered duct
• Shoe tee intersecting a taper on center
• 90-degree tapered elbow

Recommended Teaching Time: 20 hours

Classroom Equipment and Materials

• Whiteboard and markers
• Pencils and paper
• PowerPoint® Presentations for Module 04203
• A variety of standard marker sizes
• Poster board
• Flip chart
• LCD projector and screen
• Computer with Internet access
• Module Review answer key
• Module Examinations

Performance Task 1 Materials

• Appropriate PPE
• Common sheet metal layout and fabrication tools and equipment
• Appropriate sheet metal stock for fabrication
• Performance Profile sheets
Overview

Triangulation is one of three methods used to lay out and fabricate sheet metal fittings. More specifically, it is the process of using trigonometry to lay out patterns and calculate true line lengths. It is often used to lay out some of the more difficult fittings used by sheet metal workers, including square-to-round fittings, roof collars, stacks and caps, and fittings that join at unusual angles. This module describes the triangulation process and how it is used to develop patterns for fabricating sheet metal duct fittings.

Learning Objective 1

Successful completion of this module prepares trainees to:

Describe the triangulation method and explain how it is used to lay out and fabricate fittings.

- a. Describe triangulation and how it is accomplished.
- b. Explain the process through which usable patterns are created using triangulation.
- c. Fabricate unique fittings using triangulation.
- d. Identify complex fittings that use triangulation.

Performance Tasks

1. Select one fitting described in this Trainee Guide and successfully lay out and fabricate the fitting to the instructor’s specifications.

Recommended Teaching Time: 47.5 hours

Classroom Equipment and Materials

- Whiteboard and markers
- Pencils and paper
- PowerPoint® Presentations for Module 04306
- A variety of standard marker sizes
- Poster board
• Flip chart
• LCD projector and screen
• Computer with Internet access
• Module Review answer key
• Module Examinations

Performance Task 1
• Appropriate PPE
• Appropriate sheet metal stock for fabrication
• Tape measures
• Paper and pencil
• Calculators
• Prick punch
• Ruler
• Protractor
• Pittsburgh brake
• Sheet metal
• Sheet metal snips
• Other common sheet metal layout and fabrication tools and equipment
• Performance Profile Sheets
Overview
To ensure a product of consistent quality and promote professionalism in the craft, the sheet metal industry requires standards that identify the best way to fabricate and install ductwork. In addition to industry standards, governments at the local, state, and federal level develop and maintain building codes in the interest of public safety. While adherence to industry standards is largely voluntary, contractors are legally obligated to follow building codes.

It is essential for a professional in the sheet metal craft to know what codes apply in a given region and ensure that installations are in compliance. Most contract work requires conformance to certain industry standards by specification. When specified in contract documents, conformance to those standards is no longer voluntary. This module presents information regarding common industry standards and building codes that apply to the sheet metal craft.

Learning Objective 1
Successful completion of this module prepares trainees to:
Identify and describe codes and standards organizations and the contents of the predominant SMACNA standard for the sheet metal industry.

a. Identify and describe codes and standards and the organizations that publish them.
b. Identify and describe the contents of the SMACNA HVAC metal and flexible duct fabrication standard.

Learning Objective 2
Successful completion of this module prepares trainees to:
Explain how to determine specific duct characteristics based on the expected pressure and size.

a. Identify duct-pressure classes and the related duct-sealing requirements.
b. Explain how to determine duct gauge, connection spacing, and longitudinal seam type.
Performance Tasks

1. Using the example of shop standards herein, use tables, figures, and notes to determine correct hanger sizes and spacings to solve an instructor-specified duct-suspension scenario.
2. Using the example of shop standards herein, locate standards for rectangular ducts in various instructor-specified pressure classes.

Recommended Teaching Time: 7.5 hours

Classroom Equipment and Materials

- Whiteboard and markers
- Pencils and paper
- PowerPoint® Presentations for Module 04204
- A variety of standard marker sizes
- Poster board
- Flip chart
- LCD projector and screen
- Computer with Internet access
- Module Review answer key
- Module Examinations

Performance Task 1 Materials

- Trainee Guides
- Instructor-developed list of rectangular duct sizes and their pressure classes, with the information desired listed next to each one
- Performance profile sheets

Performance Task 2 Materials

- Trainee Guides
- Instructor-developed duct-suspension scenario that provides the necessary information for trainees to determine the required hanger characteristics and spacing.
- Performance profile sheets
Bend Allowances

Course Planning Tools

Module 04206
Overview
When metal is bent, a portion of the length of the flat piece is consumed in the bend. Metal on the inside of the bend is compressed, while the metal on the outside is stretched. To make sure the final piece has the proper dimensions after the bend, an allowance must be added to the dimensions of the stretchout to compensate for the distance around the bend.

Learning Objective 1
Successful completion of this module prepares trainees to:
Identify bending factors and explain how to determine bend allowances.

a. Identify bend profiles and factors that affect metal bending.
b. Explain how to determine bend allowances through approximation.
c. Explain how to determine bend allowances with precision.

Learning Objective 2
Successful completion of this module prepares trainees to:
Explain how to develop a stretchout and make metal bends.

a. Explain how to develop a stretchout and implement reference lines.
b. Calculate bend allowances, develop a stretchout, and explain how to bend mating hat channel.

Performance Tasks
1. Calculate the bend allowance, develop the stretchout, and fabricate two sections of nested channel (dimensions and metal gauge at the instructor’s discretion).

Recommended Teaching Time: 7.5 hours
Classroom Equipment and Materials

- Whiteboard and markers
- Pencils and paper
- PowerPoint® Presentations for Module 04206
- A variety of standard marker sizes
- Poster board
- Flip chart
- LCD projector and screen
- Computer with Internet access
- Module Review answer key
- Module Examinations

Performance Task 1 Materials

- Appropriate PPE
- Calculator
- Scribe
- Straightedge
- Combination square
- Pencil and felt-tipped marker
- Hand punch and prick punch
- Sheet metal hammer
- Mallet
- Screwdriver and pliers
- Drill and drill bits
- Reamer
- Tape measure
- Circumference rule
- Sheet metal gauge
- Sheet metal snips
- Shearing, bending, and forming machines
- Performance Profile Sheets
Soldering is a process in which a heated metal alloy is used as a filler metal to fasten sheet metal parts, seal seams, and connect piping. To do a professional soldering job, craftsmen must know how to prepare the material being soldered, choose the appropriate materials, and use the required tools. Because the soldering process involves chemicals and hot surfaces, it can be hazardous. Craftworkers must learn how to solder carefully and safely while making effective, sound joints. Soldering is a skill that requires practice as well as knowledge.

**Learning Objective 1**

Successful completion of this module prepares trainees to:
Identify and describe tools and materials used to solder sheet metal.

- a. Identify and describe various solders and their applications.
- b. Identify and describe various flux products.
- c. Identify and describe soldering irons and tips.

**Learning Objective 2**

Successful completion of this module prepares trainees to:
Describe how to prepare and solder sheet metal workpieces.

- a. Explain how to properly fit and prepare sheet metal joints for soldering.
- b. Explain how to apply flux and solder a joint.
- c. Describe the process of soldering various types of sheet metal joints.

**Learning Objective 3**

Successful completion of this module prepares trainees to:
Describe how to prepare and solder copper tubing.
a. Describe how to prepare copper tubing and fittings for soldering.
b. Describe how to solder copper tubing.

Performance Tasks

1. Clean and forge a soldering iron.
2. Tin a soldering iron.
3. Tack solder to hold two pieces in the horizontal position.
4. Solder a lap seam in the flat position.
5. Form, set, and solder a grooved lock seam.
6. Solder a bottom seam on a round container.
7. Properly set up and shut down an acetylene single-tank torch set.
8. Properly prep and solder copper tubing in various planes.

Recommended Teaching Time: 15 hours

Classroom Equipment and Materials

- Whiteboard and markers
- Pencils and paper
- PowerPoint® Presentations for Module 04207
- A variety of standard marker sizes
- Poster board
- Flip chart
- LCD projector and screen
- Computer with Internet access
- Module Review answer key
- Module Examinations

Performance Task 1

- Appropriate PPE
- 1- or 1 1/2-pound (0.5 or 0.7 kilogram) soldering iron
- Coarse-cut flat file and single-cut fine file
- Sal ammoniac block
- Wire or bar 50/50 tin-lead solder
- Soldering furnace or self-contained torch/soldering iron
• Ball peen hammer  
• Vise  
• Anvil  
• Soap, water, and a clean cloth  
• Performance Profile Sheets

Performance Task 2
• Appropriate PPE  
• 1- or 1 1/2-pound (0.5 or 0.7 kilogram) soldering iron  
• Coarse-cut flat file and single-cut fine file  
• Sal ammoniac block  
• Wire or bar 50/50 tin-lead solder  
• Soldering furnace or self-contained torch/soldering iron  
• Ball peen hammer  
• Vise  
• Anvil  
• Soap, water, and a clean cloth  
• Performance Profile sheets

Performance Tasks 3, 4, 5, and 6
• Appropriate PPE  
• Necessary sheet metal and steel materials, including material to prepare a grove lock seam and a previously prepared round container with a bottom seam  
• Properly tinned 1-pound (0.45 kilogram) soldering iron  
• Wire or bar 50/50 tin-lead solder  
• Soldering flux and acid swab or brush  
• Soldering furnace or self-contained torch/soldering iron  
• Sal ammoniac block  
• Non-asbestos board or similar backing material  
• Soap, water, and a clean cloth  
• C-clamp style locking pliers  
• Performance Profile sheets

Performance Tasks 7 and 8
• Appropriate PPE  
• Copper tubing; 1/2” to 3/4” ID recommended
• Copper fittings, such as couplings and elbows
• Air-acetylene torch sets
• 95-5 solder
• Paste flux for copper
• Flux brushes
• Tape measures
• Tubing cutters
• Reamers
• Fitting brushes
• Wet and dry rags
• Performance Profile Sheets
Module Six (03109) introduces the fundamental concepts of air movement and explains how these concepts form the basis for air distribution system design. With an understanding of these fundamentals, trainees are introduced to air measurement devices and the mechanical equipment used to initiate and maintain air movement. The module concludes with a review of air distribution system components and design strategies for different climates. Trainees will also practice using various air measurement devices and interpret charts related to air distribution system sizing.

Objectives

Learning Objective 1
- Describe the factors related to air movement and its measurement in air distribution systems.
  a. Describe how pressure, velocity, and volume are interrelated in airflow.
  b. Describe air distribution in a typical residential system.
  c. Identify common air measurement instruments.

Learning Objective 2
- Describe the mechanical equipment and materials used to create air distribution systems.
  a. Describe various blower styles and applications.
  b. Describe various fan designs and applications.
  c. Demonstrate an understanding of the Fan Laws.
  d. Describe common duct materials and fittings.
  e. Identify the characteristics of common grilles, registers, and dampers.

Learning Objective 3
- Identify the different approaches to air distribution system design and energy conservation.
  a. Identify air system design strategies for cold climates.
  b. Identify air system design strategies for warm climates.
  c. Explain the importance of maximizing energy efficiency through the proper insulation, sealing, and testing of air distribution systems.

Performance Tasks

Performance Task 1 (Learning Objective 1)
- Use a tachometer to measure blower motor rpm.

Performance Task 2 (Learning Objectives 1 and 2)
- Read and interpret equivalent length charts and required air volume/duct size charts.

Performance Task 3 (Learning Objective 1)
- Use a manometer to measure static pressure in a duct system.

Performance Task 4 (Learning Objective 2)
- Use a velometer to measure the velocity of airflow at the output of air system supply diffusers and registers.

Performance Task 5 (Learning Objective 1)
- Use a velometer to calculate system cfm.

Teaching Time: 15 hours
(Six 2.5-Hour Sessions)
Session time may be adjusted to accommodate your class size, schedule, and teaching style.

Prerequisites
Completion of NCCER Core Curriculum.

Before You Begin
As you prepare for each session, allow sufficient time to review the course objectives, content, visual aids (including the PowerPoint® presentation), and these lesson plans, and to gather the required equipment and materials. Consider time required for demonstrations, laboratories, field trips, and testing.

Using your access code, download the written examinations and performance profile sheets from www.nccerirc.com. The passing score for submission into NCCER’s Registry is 70% or above for the written examination; performance testing is graded pass or fail.
**Classroom Equipment and Materials**

- Whiteboard/chalkboard
- Markers/chalk
- Pencils and paper
- HVAC Level One PowerPoint® Presentations
- DVD player
- LCD projector and screen
- Computer
- Calculators
- Copies of the Module Examination and Performance Profile Sheets

**Equipment and Performance Testing**

- U-tube manometers and/or inclined-tube manometers
- Electronic manometers (optional)
- Velometers
- Rotating vane anemometers (optional)
- Hot-wire anemometers (optional)
- Contact and non-contact tachometers, or instruments that combine the two functions
- SMACNA HVAC Duct Design Calculator, or equal tool, for sizing duct

**Personal protective equipment:**

- Standard eye protection
- Work gloves
- Proper footwear as designated by the instructor or training facility provider
- Hearing protection as designated by the instructor or training facility provider
- Hard hats

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**Additional Resources**

This module presents thorough resources for task training. The following resource material is suggested for further study.

- *Thermal and Moisture Protection.* Alachua FL: NCCER.
- *Insulating Pipes, Ducts, and Water Heaters.* Alachua FL: NCCER.

There are a number of online resources available for trainees who would like more information on HVAC/R systems and their application. A search for additional information may be assigned as homework to interested trainees.

Instructors should view any videos that may be identified in the lesson plan before using them to ensure their suitability. The videos can provide teachable moments in both proper and improper work processes and behaviors. Be prepared to stop the videos at appropriate times to point out and discuss both proper and improper issues.

Instructors are also encouraged to locate additional audiovisual aids available on the Internet, make personal videos, and take still pictures related to the HVAC/R trade and add them to the PowerPoint® presentations throughout the program.

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**Safety Considerations**

This module requires that trainees work with and in the vicinity of functioning HVAC equipment. Electrical and mechanical safety must be emphasized at all times. Trainees should be carefully observed to ensure that they wear the proper PPE, follow safe practices, and give due respect to the hazards of energized and operating HVAC/R systems. Any deficiencies must be corrected to ensure future trainee safety as they begin working with even more hazardous systems later in their training and career. All practice sessions and performance tasks must be completed under your direct supervision.
The Lesson Plan for this module is divided into six 2.5-hour sessions. This time includes 10 minutes for administrative tasks and a 10-minute break per session.

**SESSION ONE**

Session One explores the relationship between airflow and pressure in air distribution systems. The instruments used to make various measurements in an air distribution system are introduced, along with information about their operation and use.

1. Show the Session One PowerPoint® presentation.
2. Assign the Kickoff Activity to get trainees engaged and provide them with a practical means of focusing their learning in this module.
3. Present the measureable pressure values in a duct system.
4. Review the movement of air through a simple, yet complete air distribution system.
5. Introduce temperature and humidity instruments.
6. Introduce pressure and velocity measurement devices.
7. Introduce measurements that measure rotational speed.

**SESSION THREE**

Session Three focuses on the equipment and materials that comprise a basic, complete air distribution system. The primary equipment, materials, and components are explored in detail individually.

1. Show the Session Three PowerPoint® presentation.
2. Identify different types of blowers and fans and their performance characteristics.
3. Present the Fan Laws and explain how they are used.
4. Introduce the basic concepts of design and related codes.
5. Review the materials and components used to construct duct.

**SESSION TWO**

Session Two is a laboratory and Performance Task session. Instructors demonstrate the use and operation of instruments such as tachometers and manometers. Trainees then practice using the same instruments and may complete Performance Tasks 1, 3, 4, and 5.

1. Note that no PowerPoint® presentation is associated with this session.
2. Demonstrate the use of tachometers.
3. Have trainees use tachometers under your supervision.
4. Demonstrate the use of one or more types of manometer to measure duct pressure.
5. Have trainees use manometers under your supervision.

6. Demonstrate the use of velometers and/or anemometers to measure outlet and duct velocity.
7. Have trainees use a velometer to take various measurements and use the information to calculate airflow volume in a duct.
Session Four is a laboratory and Performance Task session. Instructors demonstrate the use of common duct-sizing aids using simple one-line layouts. Have trainees then practice sizing ducts and provide an opportunity to practice and/or complete Performance Task 2.

1. Note that no PowerPoint® presentation is associated with this session.
2. Demonstrate the use of duct-sizing aids based on a simple one-line diagram prepared prior to the session.
3. Have trainees practice sizing duct for a similar one-line layout using different air volume values.

Session Six is a review and testing session. Have trainees complete the Module Review Questions and Trade Terms Quiz. Alternatively, these may be assigned as homework at the end of Session Five. Go over the Module Review Questions in class prior to the exam and answer any questions that the trainees may have.

1. Have trainees complete the written examination. Any outstanding performance testing must be completed during this session as well.
2. Record the testing results on Training Report Form 200, and submit the report to your Training Program Sponsor.

Session Five introduces trainees to the various air distribution system layouts used in residential applications. Duct sealing, insulation, and vapor barriers are also explored.

1. Show the Session Five PowerPoint® presentation.
2. Introduce various perimeter systems.
3. Introduce different extended plenum systems.
4. Compare and contrast approaches for warm and cold climates.
5. Introduce various overhead design approaches.
6. Emphasize the importance of duct sealing and insulation and discuss the process of duct leakage testing.
### Materials Checklist for Module 03109, Air Distribution Systems

<table>
<thead>
<tr>
<th>Equipment and Materials</th>
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<th>Tools</th>
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<tbody>
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To the extent possible, and as required for performance testing, provide a selection of the tools listed for each session; alternatively, photos may be used to teach tool identification.