Alternating Current

Course Planning Tools

Module 26201-20
26201-20
Alternating Current

*Electrical*

**Overview**

The foundation for safe and successful electrical installations is a sound understanding of DC and AC electrical principles. AC electricity also has a frequency component, so knowledge of AC waveforms and the effects of reactive and inductive components in a circuit is essential. This module describes AC circuits and explains how to apply Ohm’s law to solve for unknown circuit values.

**Learning Objective 1**

Successful completion of this module prepares trainees to:

Identify AC waveforms.

a. Define the terminology of sine waves.
b. Define AC phase relationships.
c. Identify nonsinusoidal waveforms.

**Learning Objective 2**

Successful completion of this module prepares trainees to:

Determine unknown values in AC circuits.

a. Find unknown values in purely resistive AC circuits.
b. Find unknown values in inductive AC circuits.
c. Find unknown values in capacitive AC circuits.
d. Find unknown values in combination circuits.

**Learning Objective 3**

Successful completion of this module prepares trainees to:

Make power calculations in AC circuits.
a. Calculate true power.
b. Calculate apparent power.
c. Calculate reactive power.
d. Calculate power factor.
e. Use the power triangle to determine unknown values.

**Learning Objective 4**

*Successful completion of this module prepares trainees to:*
Identify transformers and explain how they operate.

a. Identify the basic components in a transformer.
b. Identify transformer operating characteristics.
c. Calculate turns and voltage ratios.
d. Identify various types of transformers and their applications.

**Performance Tasks**

This is a knowledge-based module. There are no Performance Tasks.

Recommended Teaching Time: 17.5 hours

**Classroom Equipment and Materials**

- Whiteboard and markers
- Pencils and paper
- PowerPoint® Presentations for Module 26201-20
- A variety of standard marker sizes
- Poster board
- Flip chart
- LCD projector and screen
- Computer with Internet access
- Module Review answer key
- Module Examinations
- A copy of the National Electrical Code®
Overview
The electric motor is the workhorse of modern industry. Its functions are almost unlimited. To control the motors that drive machinery and equipment, we must have electrical supply circuits that perform certain functions. They must provide electrical current to cause the motor to operate in the manner needed to make it perform its intended function. This module describes AC and DC motors, including their components, circuits, and connections.

Learning Objective 1
Successful completion of this module prepares trainees to:
Identify direct current (DC) motors and describe their operating characteristics.

a. Understand how DC motors operate.
b. Identify types of DC motors.

Learning Objective 2
Successful completion of this module prepares trainees to:
Identify alternating current (AC) motors and describe their operating characteristics.

a. Understand how AC motors operate.
b. Identify three-phase induction motors.
c. Identify synchronous motors.
d. Identify single-phase induction motors.

Learning Objective 3
Successful completion of this module prepares trainees to:
Identify variable-speed drives and describe their operating characteristics.

a. Identify types of adjustable speed loads.
b. Identify types of motor speed control.

c. Identify braking methods.

Learning Objective 4

Successful completion of this module prepares trainees to:
Identify motor enclosures, frame designations, and operating characteristics.

a. Identify types of motor enclosures.
b. Identify NEMA frame designations.
c. Identify motor operating characteristics using nameplate data.

Learning Objective 5

Successful completion of this module prepares trainees to:
Identify the connections and terminal markings for AC motors.

a. Identify the terminals of wye-connected motors.
b. Identify the terminals of delta-connected motors.

Learning Objective 6

Successful completion of this module prepares trainees to:
Identify the NEC® requirements for motors.

a. Identify NEC® installation requirements.
b. Identify NEC® motor protection requirements.

Performance Tasks

1. Identify various types of motors and their application(s).
2. Collect data from a motor nameplate.
3. Connect the terminals for a dual-voltage motor.

Recommended Teaching Time: 20 hours
Classroom Equipment and Materials

• Whiteboard and markers
• Pencils and paper
• PowerPoint® Presentations for Module 26202-20
• A variety of standard marker sizes
• Poster board
• Flip chart
• LCD projector and screen
• Computer with Internet access
• Module Review answer key
• Module Examinations
• A copy of the National Electrical Code®

Performance Tasks 1 and 2
• Appropriate PPE
• Several AC motors
• Several DC motors
• Several dual-voltage motors
• Performance Profile sheets

Performance Task 3
• Appropriate PPE
• Several dual-voltage motors
• Performance Profile sheets
Overview
Electric lighting is used extensively throughout residential structures, commercial businesses, industrial plants, and outdoor sites. It provides illumination for the performance of visual tasks with a maximum of comfort and a minimum of eyestrain and fatigue, allowing individuals to perform their daily living and work-related tasks more easily. This module introduces the principles of human vision and the characteristics of light. It also covers different types of light sources and describes the operating characteristics and installation requirements of various lighting fixtures (luminaires).

Learning Objective 1
Successful completion of this module prepares trainees to:
Explain the relationship between human vision and light.

a. Identify how the human eye operates.
b. Identify the characteristics of light.

Learning Objective 2
Successful completion of this module prepares trainees to:
Evaluate light sources and luminaires to solve common lighting needs.

a. Compare light sources and trends in their use.
b. Choose auxiliary equipment needed for different light sources.

Learning Objective 3
Successful completion of this module prepares trainees to:
Select and install luminaires for various applications.

a. Identify luminaires and their applications.
b. Store and handle lamps and luminaires.
c. Install luminaires.

Performance Task

1. Install one or more of the following luminaires and their associated lamps:

   - Surface-mounted
   - Recessed
   - Suspended
   - Track-mounted

Recommended Teaching Time: 15 hours

Classroom Equipment and Materials

   - Whiteboard and markers
   - Pencils and paper
   - PowerPoint® Presentations for Module 26203-20
   - A variety of standard marker sizes
   - Poster board
   - Flip chart
   - LCD projector and screen
   - Computer with Internet access
   - Module Review answer key
   - Module Examinations
   - A copy of the National Electrical Code®

Performance Task 1

   - Appropriate PPE
   - Various types of halogen, LED, fluorescent, CFL, and HID lamps
   - Different types of surface-mounted, recessed, suspended, and track-mounted lighting fixtures
   - Copies of applicable NEC® requirements
   - Lighting manufacturer installation instructions
   - Performance Profile sheets
Conduit Bending

Overview
The normal installation of intermediate metal conduit (IMC), rigid metal conduit (RMC), and electrical metallic tubing (EMT) requires many changes of direction in the conduit runs, ranging from simple offsets at the point of termination at outlet boxes and cabinets to complicated angular offsets at columns, beams, cornices, and so forth. This module describes how to make conduit bends using mechanical, hydraulic, and electric benders.

Learning Objective 1
Successful completion of this module prepares trainees to:
Identify the NEC® requirements for conduit bends.

   a. Identify the minimum radius requirements for various types of conduit.
   b. Calculate the number of bends per run.

Learning Objective 2
Successful completion of this module prepares trainees to:
Use equations to find bend distances.

   a. Use right-angle mathematics to find bend distances.
   b. Use the circumference of a circle to determine bend distances.

Learning Objective 3
Successful completion of this module prepares trainees to:
Use mechanical benders.

   a. Chart a mechanical bender.
   b. Make mechanical bends.
Learning Objective 4

Successful completion of this module prepares trainees to:
Use electric and hydraulic conduit benders.

a. Use electric conduit benders.
b. Use hydraulic conduit benders.

Learning Objective 5

Successful completion of this module prepares trainees to:
Install PVC conduit.

a. Join PVC conduit.
b. Bend PVC conduit.

Performance Tasks

1. Use an electric or hydraulic bender to bend a stub-up to a precise distance above the deck.
2. Make an offset in a length of conduit to clear an obstruction with 1" (25 mm) clearance between the pipe and the obstruction.
3. Make a saddle in a length of conduit to cross a pipe with 1" (25 mm) clearance between the pipe and the conduit.

Recommended Teaching Time: 15 hours

Classroom Equipment and Materials

- Whiteboard and markers
- Pencils and paper
- PowerPoint® Presentations for Module 26204-20
- A variety of standard marker sizes
- Poster board
- Flip chart
- LCD projector and screen
- Computer with Internet access
- Module Review answer key
- Module Examinations
• A copy of the *National Electrical Code*®

**Performance Task 1**
• Appropriate PPE
• Bending protractors
• Manufacturers’ bending charts
• Electric and/or hydraulic conduit bender
• Straightedges
• Performance Profile sheets

**Performance Task 2**
• Appropriate PPE
• Bending protractors
• Manufacturers’ bending charts
• Electric and/or hydraulic conduit bender
• Straightedges
• Performance Profile sheets

**Performance Task 3**
• Appropriate PPE
• Bending protractors
• Manufacturers’ bending charts
• Electric and/or hydraulic conduit bender
• Straightedges
• Performance Profile sheets
Overview
Pull boxes and junction boxes are provided in an electrical installation to facilitate the installation of conductors, or to provide a junction point for the connection of conductors, or both. This module describes how to size and install pull and junction boxes. It also identifies various specialty enclosures, including conduit bodies, FS and FD boxes, and handholes.

Learning Objective 1
Successful completion of this module prepares trainees to:
Identify boxes and fittings.

a. Select pull and junction boxes.
b. Select and install fittings.

Learning Objective 2
Successful completion of this module prepares trainees to:
Size pull and junction boxes.

a. Size pull and junction boxes for systems under 1,000V.
b. Size pull and junction boxes for systems over 1,000V.

Learning Objective 3
Successful completion of this module prepares trainees to:
Identify specialty enclosures.

a. Identify conduit bodies and other cast enclosures.
b. Select and install handholes.
Performance Tasks

1. Identify various NEMA boxes.
2. Properly select, install, and support pull and junction boxes over 100 cu in (1,650 cu cm) in size.
3. Identify various conduit bodies and fittings.

Recommended Teaching Time: 12.5 hours

Classroom Equipment and Materials

- Whiteboard and markers
- Pencils and paper
- PowerPoint® Presentations for Module 26205-20
- A variety of standard marker sizes
- Poster board
- Flip chart
- LCD projector and screen
- Computer with Internet access
- Module Review answer key
- Module Examinations
- A copy of the National Electrical Code®

Performance Task 1

- Appropriate PPE
- Various NEMA boxes
- Performance Profile sheets

Performance Task 2

- Appropriate PPE
- Various types of pull and junction boxes
- Drill and fasteners
- Wall area for box installation
- Performance Profile sheets

Performance Task 3

- Appropriate PPE
• Various conduit bodies
• Various fittings
• Performance Profile sheets
Overview

In most cases, the installation of conductors in raceway systems is merely routine. However, there are certain practices that can reduce labor and materials and help prevent damage to the conductors. This module describes how to prepare conduit for conductors. It also explains how to set up and complete a cable-pulling operation.

Learning Objective 1

Successful completion of this module prepares trainees to:
Install cable in conduit systems.

a. Plan the installation.
b. Identify a pulling location and set up the cable reels.
c. Prepare raceways for conductors.
d. Install a pull line.
e. Prepare the cable ends for pulling.
f. Select cable-pulling equipment.

Learning Objective 2

Successful completion of this module prepares trainees to:
Set up for high-force cable pulling.

a. Set up the feeding end.
b. Support conductors.
c. Pull cable in cable trays.

Learning Objective 3

Successful completion of this module prepares trainees to:
Identify cable limitations when pulling.

a. Calculate the allowable tension on pulling devices.
b. Calculate the allowable tension on conductors.
c. Calculate the sidewall loading.

Performance Tasks

1. Prepare multiple conductors for pulling in a raceway system.
2. Prepare multiple conductors for pulling using a wire-pulling basket.

Recommended Teaching Time: 10 hours

Classroom Equipment and Materials

• Whiteboard and markers
• Pencils and paper
• PowerPoint® Presentations for Module 26206-20
• A variety of standard marker sizes
• Poster board
• Flip chart
• LCD projector and screen
• Computer with Internet access
• Module Review answer key
• Module Examinations
• A copy of the National Electrical Code®

Performance Task 1

• Appropriate PPE
• Manufacturers’ literature with maximum pulling tension information
• Multiple conductors
• Wire-pulling baskets
• All equipment necessary to prepare multiple conductors for pulling in a raceway system
• Performance Profile sheets

Performance Task 2

• Appropriate PPE
• Manufacturers’ literature with maximum pulling tension information
• Multiple conductors
• Wire-pulling baskets
• All equipment necessary for pulling multiple conductors using a wire-pulling basket
• Performance Profile sheets
Overview
Cable trays are the usual means of supporting cable systems in industrial applications. This module covers various types of cable tray, supports, and associated fittings. It also explains how to determine the loads on a cable tray and calculate fill per NEC® requirements.

Learning Objective 1
Successful completion of this module prepares trainees to:
Identify cable tray components.
   a. Select cable tray fittings.
   b. Identify cable tray supports.

Learning Objective 2
Successful completion of this module prepares trainees to:
Calculate the load on a cable tray.
   a. Determine the load on supports.
   b. Identify types of failure under load.
   c. Identify installation requirements for cable tray.

Learning Objective 3
Successful completion of this module prepares trainees to:
Determine cable tray fill.
   a. Determine the number of conductors allowed in cable tray operating at 2,000V or less.
   b. Identify derating factors for cable tray conductors.
Performance Tasks

1. Generate a list of materials for a cable tray layout. List all the components required, including the fasteners required to complete the system.
2. Join two straight, ladder-type cable tray sections together.

Recommended Teaching Time: 7.5 hours

Classroom Equipment and Materials

- Whiteboard and markers
- Pencils and paper
- PowerPoint® Presentations for Module 26207-20
- A variety of standard marker sizes
- Poster board
- Flip chart
- LCD projector and screen
- Computer with Internet access
- Module Review answer key
- Module Examinations
- A copy of the National Electrical Code®

Performance Task 1

- Paper
- Writing utensils
- Performance Profile sheets

Performance Task 2

- Appropriate PPE
- Tools and materials needed to join two straight, ladder-type cable tray sections together
- Performance Profile sheets
Conductor Terminations and Splices

Overview

Anyone involved with electrical systems of any type must be familiar with wire connectors and splicing, as they are both necessary to make the numerous electrical joints required during the course of an electrical installation. This module explains how to prepare cable ends for terminations and splices. It also describes how to train cable at termination points and describes crimping techniques.

Learning Objective 1

Successful completion of this module prepares trainees to:
Strip and train conductors.

  a. Strip small conductors.
  b. Strip large conductors.
  c. Bend cable and train conductors.

Learning Objective 2

Successful completion of this module prepares trainees to:
Make wire connections.

  a. Install various types of connectors.
  b. Make aluminum connections.
  c. Install control and signal cables.

Learning Objective 3

Successful completion of this module prepares trainees to:
Reinsulate electrical connections.

  a. Tape electrical connections.
b. Install heat-shrink insulators.
c. Use motor connection kits.

**Performance Tasks**

1. Terminate conductors using selected crimp-type and mechanical-type terminals and connectors.
2. Terminate conductors on a terminal strip.
3. Insulate selected types of wire splices and/or install a motor connection kit.

**Classroom Equipment and Materials**

- Whiteboard and markers
- Pencils and paper
- PowerPoint® Presentations for Module 26208-20
- A variety of standard marker sizes
- Poster board
- Flip chart
- LCD projector and screen
- Computer with Internet access
- Module Review answer key
- Module Examinations
- A copy of the *National Electrical Code®*

**Performance Task 1**

- Appropriate PPE
- Crimp-on connectors (color coded)
- Mechanical connectors
- Aluminum conductor connectors
- Hand-operated crimping tools
- Hydraulic crimping tools
- Cordless crimping tools
- Corded crimping tools
- Universal crimping tools
- Type MC cable
- Weatherproof connectors for Type MC cable
• Control and signal cable
• Terminal blocks
• Performance Profile sheets

**Performance Task 2**
• Appropriate PPE
• Crimp-type and mechanical-type terminals
• Crimp-type and mechanical-type connectors
• Terminal strips
• Performance Profile sheets

**Performance Task 3**
• Appropriate PPE
• Insulating material
• Wire splices
• Motor connection kits
• Performance Profile sheets
Overview
The grounding system is a major part of the electrical system. Its purpose is to protect life and equipment against the various electrical faults that can occur. This module explains the grounding and bonding requirements of NEC Article 250. It also explains how to size the main and system bonding jumpers as well as the grounding electrode conductor for various AC systems.

Learning Objective 1
Successful completion of this module prepares trainees to:
Identify grounding requirements and applications.

a. Identify the purpose of grounding and bonding.
b. Identify the grounding requirements for various systems.

Learning Objective 2
Successful completion of this module prepares trainees to:
Identify service grounding methods.

a. Size and install a grounding electrode conductor.
b. Select other electrodes.

Learning Objective 3
Successful completion of this module prepares trainees to:
Size and select equipment grounding.

a. Size an equipment grounding conductor.
b. Ground an enclosure.
Learning Objective 4

Successful completion of this module prepares trainees to:

Bond service equipment.

a. Size the main bonding jumper.
b. Bond multiple service disconnects.
c. Bond enclosures and equipment.

Learning Objective 5

Successful completion of this module prepares trainees to:

Ground and bond separately derived systems.

a. Ground separately derived systems.
b. Install grounding at more than one building.

Learning Objective 6

Successful completion of this module prepares trainees to:

Test for effective grounds.

a. Measure earth resistance using the fall-of-potential method.
b. Complete a three-point test.

Performance Tasks

1. Size the minimum required grounding electrode conductor for a 200A service fed by 3/0 copper.
2. Using the proper fittings, connect one end of a No. 4 AWG bare copper grounding wire to a length of 3/4" (MD 21) galvanized water pipe and the other end to the correct terminal in a main panelboard.
3. Install two lengths of Type NM cable in a switch box using Type NM cable clamps:
   • Strip the ends of the cable to conform with National Electrical Code® requirements.
   • Secure the cable in the switch box and tighten the cable clamps.
   • Connect and secure the equipment grounding conductors according to NEC® requirements, and secure to the switch box with either a ground clip or a grounding screw.
4. Size the minimum required equipment grounding conductor in each conduit for a 400A feeder gap using two parallel runs of 3/0 copper.

5. Size the minimum required bonding jumper for a copper water pipe near a separately derived system (transformer) where the secondary conductors are 500 kcmil copper.

Recommended Teaching Time: 15 hours

Classroom Equipment and Materials

- Whiteboard and markers
- Pencils and paper
- PowerPoint® Presentations for Module 26209-20
- A variety of standard marker sizes
- Poster board
- Flip chart
- LCD projector and screen
- Computer with Internet access
- Module Review answer key
- Module Examinations
- A copy of the National Electrical Code®

Performance Task 1

- Appropriate PPE
- Enough copies of NEC Table 250.66 for each trainee
- Performance Profile sheets

Performance Task 2

- Appropriate PPE
- No. 4 AWG bare copper grounding wire
- 3/4" (MD 21) galvanized water pipe
- A main panelboard
- All necessary tools for making connections
- Performance Profile sheets

Performance Task 3

- Appropriate PPE
- Enough copies of NEC Table 250.122 for each trainee
• Grounding clips and/or grounding screws
• Grounding receptacles
• Type NM cable
• Switch boxes
• Type NM cable clamps
• Performance Profile sheets

**Performance Task 4**
• Enough copies of *NEC Table 250.122* for each trainee
• Performance Profile sheets

**Performance Task 5**
• Copies of appropriate *NEC®* sections and tables
• Performance Profile sheets
Overview

All electrical circuits and their related components are subject to destructive overcurrents, due to harsh environments, general deterioration, accidental damage, damage from natural causes, excessive expansion, and overloading of the electrical system. Reliable protective devices prevent or minimize costly damage to transformers, conductors, motors, equipment, and the many other components and loads that make up the complete electrical system. Fuses and circuit breakers are two types of automatic overload devices that are normally used in electrical circuits to prevent fires and the destruction of the circuit and its associated equipment. This module describes the operating principles of circuit breakers and fuses, and explains how to select and install overcurrent devices.

Learning Objective 1

Successful completion of this module prepares trainees to:
Identify the function of overcurrent protective devices.

a. Identify types of overcurrent conditions.
b. Identify NEC® requirements for overcurrent protective devices.

Learning Objective 2

Successful completion of this module prepares trainees to:
Size and select circuit breakers.

a. Identify circuit breaker components.
b. Identify circuit breaker types and ratings.

Learning Objective 3

Successful completion of this module prepares trainees to:
Size and select fuses.

a. Identify fuse types and markings.
b. Size fuses.
c. Coordinate the operation of overcurrent protective devices.

Performance Task

1. Identify the following on one or more circuit breaker(s) and fuse(s):

   • Number of poles
   • Load rating
   • Voltage rating
   • Amperage interrupting rating

Recommended Teaching Time: 12.5 hours

Classroom Equipment and Materials

• Whiteboard and markers
• Pencils and paper
• PowerPoint® Presentations for Module 26210-20
• A variety of standard marker sizes
• Poster board
• Flip chart
• LCD projector and screen
• Computer with Internet access
• Module Review answer key
• Module Examinations
• A copy of the National Electrical Code®

Performance Task 1

• Appropriate PPE
• Various sizes and types of circuit breakers and fuses
• Performance Profile sheets
Control Systems and Fundamental Concepts

Overview

Contactors are used to make or break the circuit to high-current, non-motor loads, or are used in motor circuits if overload protection is separately provided. Meanwhile, a relay is an electromagnetic device whose contacts are used in the control circuits of magnetic starters, contactors, solenoids, timers, and other relays. This module describes the operating principles of contactors and relays, including both mechanical and solid-state devices. It also explains how to select and install relays and troubleshoot control circuits.

Learning Objective 1

Successful completion of this module prepares trainees to:

Identify magnetic and mechanically held contactors.

   a. Select lighting contactors.
   b. Make forward and reverse motor contactor connections.
   c. Select mechanically held contactors.

Learning Objective 2

Successful completion of this module prepares trainees to:

Select and troubleshoot relays.

   a. Select control relays.
   b. Select timers and timing relays.
   c. Select solid-state relays.
   d. Select overload relays.
   e. Troubleshoot relays.

Learning Objective 3

Successful completion of this module prepares trainees to:
Install low-voltage remote control switching systems.

a. Identify remote control switching system components and operating characteristics.
b. Plan and install a remote control switching system.

**Performance Task**

1. Mount and connect a 120V lighting contactor with a three-wire pushbutton control.

Recommended Teaching Time: 12.5 hours

**Classroom Equipment and Materials**

- Whiteboard and markers
- Pencils and paper
- PowerPoint® Presentations for Module 26211-20
- A variety of standard marker sizes
- Poster board
- Flip chart
- LCD projector and screen
- Computer with Internet access
- Module Review answer key
- Module Examinations
- A copy of the *National Electrical Code*®

**Performance Task 1**

- Appropriate PPE
- Contactors
- Pushbutton controls
- Hand tools for mounting
- Performance Profile sheets