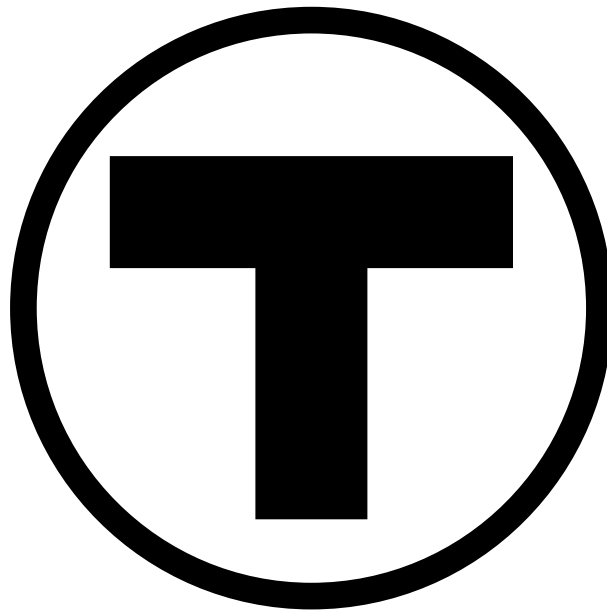


2009
Subway Operations
Railcar Repairer Technical Assessment
Study Guide



Massachusetts Bay Transportation Authority

Development Concepts

Introduction

This Study guide is being provided by the MBTA to help potential candidates for the Railcar Repairer position understand the specific technical knowledge requirements of the position and to help them prepare for the Railcar Repairer Technical Assessment, which is part of the selection process for the Railcar Repairer position.

Background

A Railcar Repairer performs highly skilled technical services involving the inspection, troubleshooting and repair of all electrical, electronic and mechanical equipment on MBTA heavy and light rail vehicles and performs other related duties as required.

Major responsibilities of the Railcar Repairer are to:

Perform preventive and corrective maintenance as well as inspect, service, adjust, calibrate, align, and diagnose all electronic, high and low voltage electrical and mechanical systems, propulsion, printed circuit boards, microprocessors, amplifiers, logic gates, operation of thyristors, various applications of capacitors, relay switches, logic, static converter for regulation, motors, trucks, pneumatic-hydraulic brakes, compressors, generating heat and air conditioning and other car related components to ensure optimum operating efficiency consistent with design requirements.

Connect and operate electronic, electrical and mechanical diagnostic test equipment to determine proper function and detect potential malfunction to assure prescribed performance.

Troubleshoot and solve unusual and complex equipment malfunctions, determine and make corrective repairs by applying working knowledge and understanding of all electronic, electrical and mechanical equipment, technical publications, wiring diagrams, test techniques and blueprints.

The Study Guide outlines by knowledge area specific topics that are important for a Railcar Repairer to know in order to successfully complete the responsibilities of the job. These same knowledge areas and topics are the basis for the Railcar Repairer Technical Assessment. Sufficient knowledge of these areas and topics should improve a candidate's potential for passing the Railcar Repairer Technical Assessment.

Content Review

Safety

General

Tag-Out

Lock-Out

Pinch Points

Confined Spaces

Personal Protective Equipment

Eye Protection

Hearing Protection

Steel-toed Shoes

Protective Headgear

Clothing – Safe / Unsafe

MSDS

Material Safety Data Sheets (MSDS)

- What are they?
- What safety information do they contain?

Electrical Safety

De-energizing the potential energy in electrical circuits, such as capacitors and batteries.

Using GFI (ground fault interruption) circuits to power equipment when working in wet environments.

Working with and near high voltage electrical systems.

Mechanical Safety

Pinch Points

De-energizing the potential energy stored in mechanical systems in the form of pressurized fluids (gases, liquids), rotational energy or due to gravity (loads being able to fall).

Safe lifting and rigging of loads.

Fire Safety

Class A, B, C fire extinguishers and their proper uses.

Electrical

DC Basics

Voltage

- Definition

Current

- Definition

Resistance

- Definition

Power

- $P = I * V$
- $P = I^2 * R$

Ohm's Law

- Definition

Resistors

- Series Circuits
- Parallel Circuits
- Typical applications

Capacitors

- How do they work?
- Function in a circuit / typical applications

Inductors

- How do they work?
- Function in a circuit / typical applications

Simple Circuits

- Voltage Measurements between points / components
- Current Measurements between points / components

AC Basics

AC Basics

- Alternating current
- Frequency
- Peak voltage
- RMS voltage

Transformers

- Basic electro-magnetic theory
- Induced current flow
- Transformer types – step up / step down
- Ratios

Circuit Components

Switches & Relays

- Normally-open, Normally-closed switches
- Limit switches
- Relays
- Pressure Switches
- Solenoids
- Rotary Cam switches
- Rotary switches

Sensors

- Pressure Transducers
- Hall effect sensors
- Proximity Sensors
- Optical Sensors

Other Devices

- Optical Couplers
- Encoders
- LEDs
- Fluorescent Light Systems
 - Troubleshooting failures

Batteries

- Cables / Connections
- Battery condition
- Specific Gravity
- Charging
- Safe disconnection
- Troubleshooting

Basic Electronics

Semiconductors – definition

Diodes – definition and function

- Diode current flow in a circuit
- Voltage drop across a diode
- Full wave / Half wave bridge

Inverters / Rectifiers

- Block Diagram
- Operation

SCR / IGBT / GTO Devices

Pulse width modulation

Electrostatic Discharge prevention

Printed Circuit Board

- Safe handling practices
- Multi-layer
- Surface Mount

Instrumentation & Measurement

Voltmeters

- What is a voltmeter?
- Voltage ranges
- How is a voltmeter connected to a circuit?

Ammeters

- What is an ammeter?
- Types of ammeters / match to application
- How is an ammeter connected to a circuit?

Ohmmeters

- What is an ohmmeter?
- How is an ohmmeter connected to a circuit?
- How is an ohmmeter used to check motor winding integrity?

Digital Multimeters

- What is a digital multimeter (DMM)?
- Scale selection
- Continuity measurement

Oscilloscopes

- What is an oscilloscope?
- How is it typically used?
- What are typical waveforms observed?

Infrared Imaging / Thermography

- What is infrared imaging / thermography
- How is it typically used??

Meggers

- What is a Megger?
- How is it typically used?

Digital Controls

Input / Output (I/O)

- Component identification from input/output schematics
- Typical digital inputs, outputs
- Typical analog inputs, outputs
- Basic input/output schematic understanding
- Discrete Output operation and wiring

Ladder Logic (LL)

- Boolean gate logic
- Boolean gate logic operations
- Logic operation from ladder logic schematics and symbols
- Basic Ladder Logic understanding

Motors

AC / DC Motors

- Differences / advantages between AC / DC motors
- AC Motor components and function
 - Single phase
 - Three phase
- DC Motor components and function
- Rotation direction changes (AC / DC)
- Basic motor troubleshooting
- Control voltage versus load voltage

Motor Control Circuits

- Motor control schematics
- Motor acceleration control (resistance based)
- Variable Frequency Drive basics
 - Block diagram
 - Troubleshooting
- Regenerative, dynamic braking

Wiring & Connections

Conductors

- Labeling
- Stripping / preparation
- Size vs Load considerations
- Resistance / Losses
- Failure modes

Connectors

- Types and selection
- Mechanical lug terminations
- Crimped multi-pin connectors
- Wire termination preparation & tools
- Crimping & tools
- Soldering & fluxes

Hand Tools

Normal hand tool use

Fuse Pullers

Wire Strippers

Crimpers

Wire Cutters

Schematics

Circuits

- Identification of purpose or function
- Sequence of operation of a circuit: if / then situations (*if "X" are the conditions, and you do "Y", then what happens?*)
- Anticipated Voltage Readings at circuit connection points

Symbols

- ANSI / ISO Standard Symbols
- Motors
- Inputs – switches (pressure, flow, temperature, limit, etc.)
- Outputs – motors, pumps, fans, solenoids
- Power sources / controls – batteries, disconnects, contactors, fuses, knife switches

PC Computer Skills

Hardware – Cable Connections

Software

- Browser Commands
- File Menu Structure
- Mouse Commands

Mechanical

Measurement and Tools

Rulers

- Use

Micrometers

- Types
- Selection and use
- Measurement techniques

Calipers

- Dial
- Digital
- Measurement techniques

Go / No-Go Gages

- Function
- Applications

Hand Tools

- Function
- Selection and use
- Torque Wrenches
- Surface cleaning (abrasive pads, sandpaper, etc.)

Power Tools

- Pneumatic tools (impact wrenches, ratchets)
- Electric Drill / Drill Presses
- Bench Grinders / Right Angle Grinders

Fluid Power (Hydraulics and Pneumatics)

Theory

- Differences between liquids (hydraulics) and gases (pneumatics)
- Stored (potential) energy
- Force calculation (pressure times area)

Pumps

- Common terms
- Common pump types

Components

- Cylinders
- Pressure Gauges

Valves & Flow Control

- Directional control valves
- Pressure regulation valves (control and relief)
- Flow control valves
 - Meter in / Meter out
- Check valves
- Valve operation and effect on fluid flow
- Orifice Plates

Piping, Tubing and Connections

- Pipe types
- Tubing types
- Connections / Components (Pipe and Tubing)
 - Types
 - Selection and use
- Assembly techniques
 - Crimping
 - Threading
 - Flaring
 - "Swagelok"

Mechanical Systems & Components

Fasteners

- Fastener types, selection and use
- Fastener grades and fit
- Screw threads
 - Pitch
 - Internal / External, Coarse / Fine threads
- Torquing and pre-loading
- Methods of locking fasteners
- Shear pins
- Specialty fasteners – ¼ turn devices

Lubrication

- Lubrication principles
 - Purpose
 - Viscosity, flash point and pour point
- Types of lubricants
 - Oils / greases
- Lubricant selection and use, including compatibility
- Application methods
 - Oils / greases
- Factors affecting lubricant performance
- Other materials: anti-seize; spray lubricants

Seals

- Lip Seals function and installation
- O-ring selection and use
- Gasket removal, installation and use
- Shaft seals

Couplings

- Types
- Selection and use
- Shaft preparation / installation / removal
- Purpose of alignment

Belts & Pulleys

- Types / sizes
- Selection and use
- Troubleshooting

Bearings

- Types
- Selection and use
- Installation and removal techniques
- Troubleshooting typical problems

Gearboxes

- Components
- Troubleshooting

Lead Screws / Ball Screws

- Operation
- Troubleshooting

Material Handling & Rigging

Rigging

- Load balancing
- Calculation of load center of gravity

Slings – usage and loading

- Wear indications – slings, wire rope, chain, hooks

Fork Truck Operation

- Safe loads, capacity

Air Compressors & Driers

Components

Operation

Troubleshooting

Air Conditioning Systems

Components

Schematic of basic flow

Troubleshooting

Refrigerant Charts (Type, Temperature, Pressure)

Oxyacetylene Cutting and Welding

Theory of combustion

Gas set-up and operation

Torch set-up and operation

Troubleshooting

Schematics

Hydraulic and Pneumatic Circuits

- Identification of purpose or function
- Sequence of operation of a circuit: if / then situations (*if "X" are the conditions, and you do "Y", then what happens?*)

Symbols

- Pumps
- Valves
- Motion Devices (cylinders, actuators, etc.)
- Auxiliary Devices (receivers, dryers, heat exchangers, etc.)

Print Reading & Instructions/Procedures

- Data acquisition from prints and instructions
- Reading and comprehension of instructions and procedures

Troubleshooting / Problem-Solving

Cause & Effect

The nature of troubleshooting is understanding that problems occur because specific events have taken place. What we usually observe when we come to the scene of a problem are the *results or the effects* of something that happened – many times we do not or can not immediately observe what *caused* the problem originally.

In some instances, the *effects* of the root (“original”) cause are repaired and then later occur again because the underlying *root cause* was not determined and repaired.

Care must also be taken to determine *all* of the causes of a problem, for in many instances there may be several important causes.

The ability to troubleshoot effectively (quickly and accurately) is prized by employers the world over. This skill is usually dependent upon a certain level of experience with the equipment, system or processes that require troubleshooting. However, having an understanding of the techniques and methods of troubleshooting can give anyone an improved opportunity to solve problems quickly and accurately, even without extensive experience with the problem equipment.

Some steps and methods that can be helpful are:

- Condition assessment - what does the physical evidence mean?
- Linking the physical evidence to probable causes.
- Investigating the probable causes to determine if they were contributors to the problem.
- Determining the root cause(s).
- Use of a Cause & Effect diagram (“fish bone” diagram) to ensure that all potential causes were considered.
- Use of “5 Whys”
 - If you ask “*why did this happen*” enough times, it will lead you to the root cause. For example, a shaft has broken:
 - “*Why (1) has it broken?*” It was subjected to extreme stress because of misalignment.
 - “*Why (2) was it subjected to misalignment?*” Because the pillow block bearing at one end had shifted.
 - “*Why (3) did the bearing shift?*” Because the bolts holding it in place failed.
 - “*Why (4) did the bolts fail?*” Because improper bolts (ungraded versus grade 5) bolts were used.
 - “*Why (5) were ungraded bolts used?*” The repair procedure did not specify the correct bolt type.
 - You can then correct the repair procedure, use grade 5 bolts to retain the bearing and prevent the replacement shaft from failing in the same manner.

Reference Materials

Listed below are books and web sites that may be of use in preparing for the Railcar Repairer position. The books, in general, are listed in order of helpfulness and all are available through Amazon.com or Borders Bookstores. The information provided is the book title (underlined), the book's author (or editor) and the book's ISBN number (international identification number – any bookstore can identify a book by its ISBN number) – it is easy to search on Amazon, for example, by the ISBN number alone.

The web sites all have relevant information that can be helpful in understanding real-world situations and solutions.

Books

Audel Millwrights and Mechanics Guide

Thomas B. Davis, Carl A. Nelson
ISBN 978-0764541711

Audel Welding Pocket Reference

James E. Brumbaugh, Rex Miller
ISBN 978-0764588099

Audel Electrical Course for Apprentices and Journeymen

Paul Rosenberg
ISBN 978-0764542008

Modern Refrigeration and Air Conditioning

Andrew D. Althouse, Carl H. Turnquist and Alfred F. Bracciano
ISBN 978-1590702802

Industrial Mechanics and Maintenance

Larry Chastain
ISBN 978-0135150962

Fundamentals of Electronics Circuits and Devices, 4th Edition

Russell L. Meade
ISBN 978-1418005382

Mechanical Trades Pocket Manual, 3rd Edition

Carl A. Nelson
ISBN 978-0025886650

IPT's Electrical Training Manual, Spiral Bound Edition
Herb Putz
ISBN 978-0920855249

Web Sites

GENERAL REFERENCE

Wikipedia – Online encyclopedia

http://en.wikipedia.org/wiki/Main_Page

WikiHow – Online encyclopedia of how to do things

<http://www.wikihow.com/Main-Page>

GENERAL MAINTENANCE

Plant Engineering, Maintenance and Reliability Resources

<http://www.maintenanceresources.com/>

Plant Maintenance Resource Center

www.plant-maintenance.com

Maintenance World

<http://www.maintenanceworld.com/>

MECHANICAL

Bearings

Timken Bearing Knowledge Center

<http://www.timken.com/en-us/knowledge/Pages/default.aspx>

How Stuff Works – Bearings

<http://science.howstuffworks.com/bearing3.htm>

Wikipedia Entry

http://en.wikipedia.org/wiki/Ball_bearing

Seals

Wikipedia Entry, with links to vendor sites

http://en.wikipedia.org/wiki/Radial_shaft_seal

Gasket replacement

http://www.automedia.com/Engine_Gasket_Replacement/ccr20011101eg/1

Development Concepts

Power Transmission

How gears work.

<http://science.howstuffworks.com/gear.htm>

Wikipedia section on Gears

<http://en.wikipedia.org/wiki/Gears>

Gates Industrial Power Transmission

http://www.gates.com/index.cfm?location_id=534

Gates Belt Drive Maintenance Manual

<http://www.gates.com/campaignPM/index.cfm?go=btgtspm1103&CFID=5454292&CFTOKEN=13755298>

Fluid Power

Fundamentals of Pneumatics

http://www.nfpa.com/Education/Edu_LearningOpps_SelfPacedFundamentalsPneumatic.asp

Fundamentals of Hydraulics

http://www.nfpa.com/Education/Edu_LearningOpps_SelfPacedFundamentalsHyd.asp

How Hydraulics Work - Basic

<http://science.howstuffworks.com/hydraulic1.htm>

Parker Hydraulics – search for Service Manuals

<http://www.parker.com/portal/site/PARKER/menuitem.eb20258a5093aeecb1935b1076108a0c/?vgnnextoid=5a2880961f66e010VgnVCM1000000308a8c0RCRD&vgnnextfmt=default#results>

Gates Hose; to get the really good stuff, you need to establish a user name and password, using basic personal information.

- Gates Industrial Hose Catalog
- Gates Hydraulic Catalog
- White Papers

<http://gatesprograms.com/mobileequipment>

Swagelok gaugeable tube fittings

<http://www.swagelok.com/downloads/webcatalogs/en/ms-01-140.pdf>

Swagelok tube fitting resources

http://www.swagelok.com/search/find_resources.aspx

Development Concepts

Tools

Stanley Tool – Tool Use (basic)

http://www.stanleytools.com/default.asp?TYPE=STATICLEFT&PAGE=tooltips.htm&LEFT=left_tooltips.htm

Do-It-Yourself – Hand tool use (basic)

<http://www.doityourself.com/scat/handtools>

eHow website – Safe hand tool use (basic)

http://www.ehow.com/how_2337754_safely-use-basic-hand-tools.html

Snap-On Tools (descriptions)

<http://buy1.snapon.com/catalog/catalog.asp>

Snap-On Tools – Other websites

<http://www.snapon.com/othersites.asp>

How to use basic shop machine tools

<http://web.mit.edu/2.670/www/Tutorials/Machining/Description.html>

Air Conditioning

EPA website for service technicians

<http://www.epa.gov/ozone/title6/609/technicians/index.html>

WikiHow – Air conditioning

<http://www.wikihow.com/Fix-Your-Car's-Air-Conditioner>

Welding / OAC

Hobart e Learning center

<http://www.hobartwelders.com/elearning/>

Reference Library of Articles on a wide variety of topics. OK reading, but not comprehensive.

<http://www.maintenanceresources.com/referencelibrary/index.htm>

Wikipedia entry for Oxygen-Acetylene welding and cutting

http://en.wikipedia.org/wiki/Oxy-fuel_welding_and_cutting

ELECTRICAL

Excellent content on electrical/electronic topics, based upon question and answers.

- Basic Electricity
- DC Electric Circuits
- AC Electric Circuits
- Network analysis techniques:
- Discrete semiconductor devices and circuits:
- Analog Integrated Circuits
- Digital Circuits
- Mathematics for Electronics
- Circuit Animations
- Math Animations

<http://www.openbookproject.net/books/socratic/doc/topical.html>

Another group of online texts covering electrical/electronics fundamentals:

- Volume 1 DC
Volume 2 AC
- Volume 3 Semiconductors
- Volume 4 Digital
- Volume 5 Reference
- Volume 6 Experiments

<http://openbookproject.net/electricCircuits/>

Circuit Diagrams – Wikipedia entry

http://en.wikipedia.org/wiki/Circuit_diagram

Rockwell Automation Literature Library

http://literature.rockwellautomation.com/idc/groups/public/documents/webassets/browse_category.hcst

SquareD Technical Library

<http://ecatalog.squared.com/techlib/>

EC&M Training

<http://ecmweb.com/training/>

Crane Controls

The Electric Controller and Manufacturing Company – Crane Controls, but good basic information on electrical controls

<http://www.ecandm.net/Support.aspx>

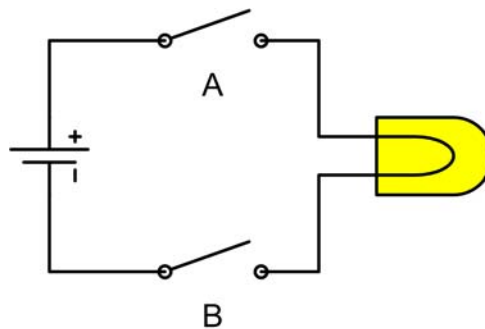
Development Concepts

Example Questions

The questions on the Railcar Repairer Technical Assessment will be multiple choice, with four answers (typically) to choose from for each question. Only one answer will be correct. Carefully read the question and all answers. When you have made your choice, you will have the opportunity to select one answer as correct.

Shown below are six questions as examples of what questions may look like; one question has its own illustration, one has no illustration, and in two cases there are two questions referring to a the same illustration.

1. For this electrical circuit, which switch or switches need to be closed for the lamp to be lit?



CORRECT
ANSWER

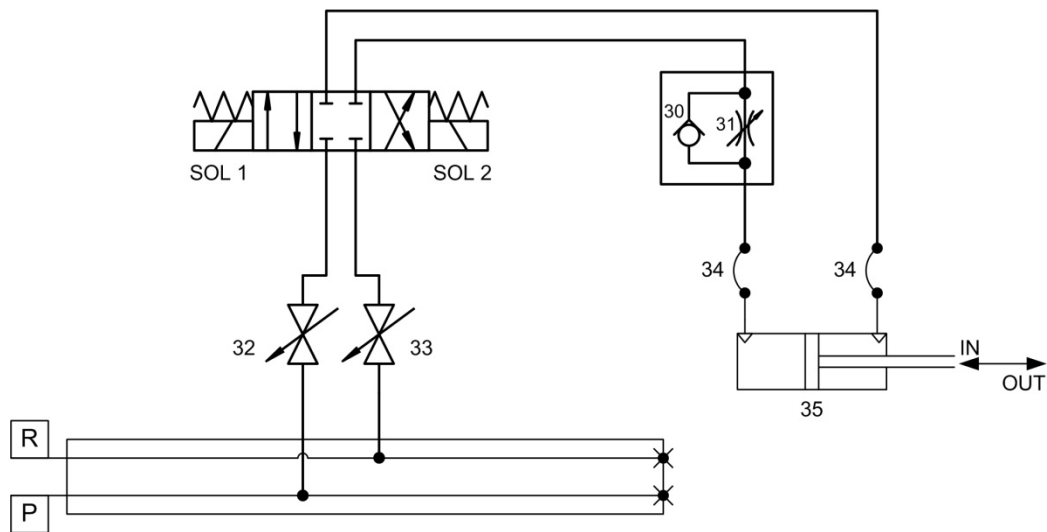
- A. Switch A
- B. Switch B
- C. Switch A and B
- D. The lamp is on already.

2. A ball bearing is designed to:

- A. Make small clicking sounds every time the ball bearings rotate.
- B. Support any kind of ball so it doesn't roll away.
- C. Hold a shaft or other round objects and keep them from rotating.
- D. Make components it supports rotate with less friction.

CORRECT
ANSWER

Please use the illustration below with example questions 3 and 4.



3. What is the function of component #30?

CORRECT

ANSWER

- A. It is a flow control device that meters flow.
- B. It is a flow control device that prevents flow in one direction.**
- C. It is a pressure relief device.
- D. It is a hose connection point.

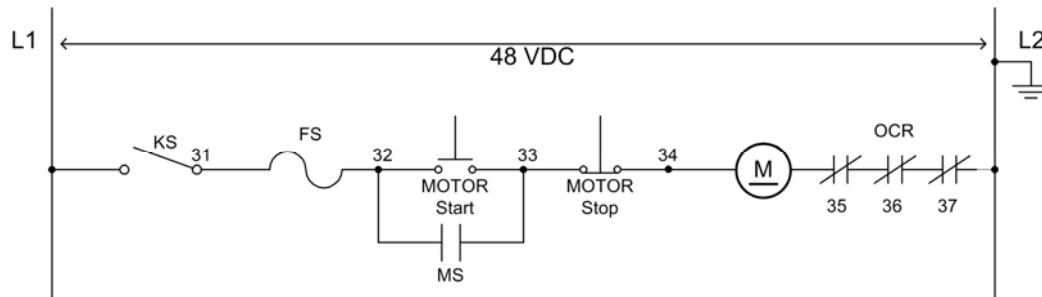
4. If SOL 2 is energized, in what direction does component 35 move?

CORRECT

ANSWER

- A. Component 35 has no moving parts.
- B. It moves IN.
- C. It moves OUT.**
- D. It doesn't move.

Please use the illustration below with example questions 5 and 6.



5. What is the function of component FS?
- A. It is a fuse, which protects the motor from running too fast.
 - B. It is a flexible umbilical, or connector, to the motor.
 - C. It is a foreign object umbrella, which protects the motor from dirt and other environmental debris.

CORRECT
ANSWER

D. It is a fuse, which protects the motor from excessive current.

6. If the knife switch is closed and the motor start pushbutton activated and the motor starter relay sealed in, what would you expect to read with a voltage meter between points 33 and 34?

CORRECT
ANSWER

A. 0 VDC

B. 24 VDC

C. 48 VDC

D. 120 VAC