

Test Preparation Study Guide

Illinois Dept. of Natural Resources/Office of Mines and Minerals

Coal Mine Electrician Certification

**UNDERGROUND & SURFACE MINE
ELECTRICIAN**

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Preface

The Code of Federal Regulations, under authority of the Federal Coal Mine Health and Safety Act of 1969 states that “all electrical equipment shall be frequently examined, tested, and properly maintained by a qualified person to insure safe operating conditions.” An individual may become qualified as an underground coal mine electrician as indicated below:

(225 ILCS 705/40.1 new)

Sec. 40.1. Mine electrician. Each applicant for a certificate of competency as mine electrician shall produce evidence of at least one year of experience in performing electrical work in a coal mine or acceptable related industry. The applicant shall pass an examination as to his or her practical and technical knowledge of the nature and properties of electricity, direct and alternating currents, electrical equipment and circuits, permissibility of electrical equipment, the National Electrical Code, and the laws of this State relating to coal mine electricity. To be eligible for taking a mine electrician examination administered by the State Mining Board, the applicant must meet at least one of the following criteria:

- (1) be classified as an apprentice mine electrician and have met the requirements for an apprentice;
- (2) possess a Bachelor of Science degree in electrical engineering and provide evidence of experience;
- (3) possess a current coal mine electrician certification from another state coal mine electrical program; or
- (4) be qualified as a mine electrician, but have not taken a State-approved coal mine electrician examination or a federal coal mine electrician examination.

"Qualified mine electrician" means an individual who has completed the required classroom instruction from an approved college or university and can produce evidence of at least one year of experience in performing electrical work in a coal mine or acceptable related industry.

(225 ILCS 705/40.2 new)

Sec. 40.2. Electrical equipment and systems; examination, testing, and maintenance. All electrical equipment and systems shall be frequently examined and tested and properly maintained by a mine electrician to ensure safe operating conditions. When a potentially dangerous condition is found in electrical equipment or an electrical system, the equipment or system shall be removed from service until the condition is corrected. A record of the examinations shall be kept and made available to the company, the State Mine Inspector, and all other persons interested.

This study guide has been prepared for the Illinois Dept. of Natural Resources/Office of Mines and Minerals specifically to provide guidance for those individuals who desire to prepare themselves for State & Federal qualifications as mine electricians by taking the IDNR/OMM. Coal Mine Electrician Examination. This study guide is not intended to serve as the sole source of preparation, but rather as a tool toward that end.

The study guide is divided into sections for each testing category for underground and surface coal mine electrician qualification. The specific sections are listed below. A set of typical examination questions are provided for each section. Also, in each category an outline is provided which gives topics that are to be tested on in the category.

Test #1 - DC Theory and Application

Test #2- AC Theory and Application

Test #3 - Electric Circuits and Equipment

Test #4- Permissibility of Electric Equipment

Test #5- 75 (Underground)

Test#6-30 CFR Part 77 (Surface)

Test #7- National Electric Code

Test #8-Arc Flash and Illinois Law

FORMULAS

$$E = I \times R$$

$$E = P / I$$

$$E^2 = P \times R$$

$$I = E / R$$

$$I = P / E$$

$$I^2 = P / R$$

$$R = E / I$$

$$R = E^2 / P$$

$$R = P / I^2$$

$$P = I \times E$$

$$P = E^2 / R$$

$$P = I^2 \times R$$

DC SERIES

$$R_{\text{(total)}} = R_1 + R_2 + R_3 + \dots$$

$$E_{\text{(total)}} = E_{R1} = E_{R1} + E_{R3} + \dots$$

DC PARALLEL

$$R_{\text{(total)}} = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$I_{\text{(total)}} = I_{R1} = I_{R2} + I_{R3} + \dots$$

RECTIFIERS

$$1\phi - 1/2 \text{ Wave } DC = .45 \times AC$$

$$1\phi - \text{Full Wave } DC = .9 \times AC$$

$$3\phi - 1/2 \text{ Wave } DC = .675 \times AC$$

$$3\phi - \text{Full Wave } DC = 1.35 \times AC$$

$$1 \text{ Hp.} = 746 \text{ Watts}$$

AC

$$E = I \times Z$$

$$I = E / Z$$

$$Z = E / I$$

$$E_{\text{(effective)}} = .707 \times E_{\text{(peak)}}$$

$$E_{\text{(average)}} = .637 \times E_{\text{(peak)}}$$

$$E_{\text{(peak)}} = 1.414 \times E_{\text{(effective)}}$$

$$E_{\text{(peak to peak)}} = 2 \times E_{\text{(peak)}}$$

$$\text{Power Factor} = \frac{\text{True Power}}{\text{Apparent Power}} = \frac{\text{Watts}}{\text{Volt-Amps}} = \frac{R}{Z}$$

TRANSFORMERS

$$\frac{T_{\text{(primary)}}}{T_{\text{(secondary)}}} = \frac{E_{\text{(primary)}}}{E_{\text{(secondary)}}} = \frac{I_{\text{(secondary)}}}{I_{\text{(primary)}}}$$

$$E_{\phi-N} = E_{\phi-\phi} / 1.732$$

$$E_{\phi-\phi} = E_{\phi-N} \times 1.732$$

TO FIND	DC	SINGLE-PHASE	THREE-PHASE
AMPS (when HP is known)	$\frac{HP \times 746}{E}$	$\frac{HP \times 746}{E}$	$\frac{HP \times 746}{E \times 1.732}$
AMPS (when KW is known)	$\frac{KW \times 1000}{E}$	$\frac{KW \times 1000}{E}$	$\frac{KW \times 1000}{E \times 1.732}$
AMPS (when KVA is known)		$\frac{KVA \times 1000}{E}$	$\frac{KVA \times 1000}{E \times 1.732}$
KW (Amps & Volts known)	$\frac{I \times E}{1000}$	$\frac{I \times E}{1000}$	$\frac{I \times E \times 1.732}{1000}$
KW or KVA (Hp. known)	$\frac{Hp. \times 746}{1000}$	$\frac{Hp. \times 746}{1000}$	$\frac{Hp. \times 746}{1000}$
KVA (Amps & Volts known)		$\frac{I \times E}{1000}$	$\frac{I \times E \times 1.732}{1000}$
HP. (Amps & Volts known)	$\frac{I \times E}{746}$	$\frac{I \times E}{746}$	$\frac{I \times E \times 1.732}{746}$
SHORT-CIRCUIT AMPS		$\frac{I_{\text{(Full load)}}}{\% Z}$	$\frac{I_{\text{(Full load)}}}{\% Z}$

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BASIC ELECTRICITY

This study guide is only to prepare you to take the State Examination for the Illinois Mine Electrical Card. At the present time MSHA accepts the state examination in order to receive the Federal Qualification Card. You should already have some training in some mining area in electricity in order to take the test. This study guide will not make you an electrician.

In order to successfully complete the state examination you must have some knowledge of basic electricity. You do not have to be an Electrical Engineer but you must have at least a minimum of knowledge of basic electricity.

Electricity is the movement of electrons. As you were taught in school everything that is matter in the universe is made up of atoms. An atom is basically like the sun with the planets revolving around it. The atom consists of a core with protons and neutrons with electrons orbiting around the core. Protons are charged positive and the electrons are charged negative. Neutrons have no charge. If an atom has more electrons than protons we say in electricity that it has a negative charge. If the atom has more protons than neutrons it is charged positive. If the number of protons and electrons are the same the atom is stable or with no charge.

All of us have played with permanent magnets as children. We say they have a north pole and south pole. The opposite poles attract and similar poles repel. This basically how the charges in electricity work. The positive and negative charges attract one another. The amount of attraction is called difference in potential.

If a material consists of atoms that have electrons that are easily displaced from the atom, this material can make a good conductor for electricity. Gold, silver, copper, and aluminum are examples of good conductors. However it is too expensive to use gold, silver, etc to make wiring; most conductors or wires are made of copper or aluminum. Good conductors must have a low coefficient of expansion (will not stretch a great amount when around heat) and be flexible.

If the material consists of atoms that have electrons that are hard to displace, this material makes a good insulator (rubber, plastic, glass, etc).

Some materials are constructed so they are good conductors at times and at times they are poor conductors. These type of blended materials are called semi-conductors (diodes, SCRs, etc.)

Electrons want to find themselves a home where they have a mate. In other words they want to go to an atom that has a positive charge or more protons than electrons. The only way they can get there is to travel inside some type of conductor. When an electron enters a

conductor one leaves the other end. The electron that enters hits one and it in turn jumps to the next atom dislodges one and he goes on until the end of conductor is reached and one gets to the atom that is attracting. A very simple illustration is to imagine a pipe full of marbles with the pipe being the conductor and the marbles electrons. When you push one in another falls out the other end; this is movement of electrons or electricity flowing.

We must have a way of measuring electron flow. Electrons are invisible to the eye and are very, very minute particles but they have tremendous energy. We use the term coulomb to establish an amount of electrons. In other words how many they are. If we could place them in a bucket or pail we could say we had so many coulombs of electrons in the bucket. One coulomb of electrons is 6,280,000,000,000,000,000 electrons. You never hear anyone say that motor is pulling 500 coulombs per second. In electricity if we want to know how much current something is pulling we say amps. Amps are when the electrons are flowing and a measurement of this. If one coulomb of electrons pass a point flowing in a conduct in one second we say we have a current flow of one ampere. Current flow is measured in amps and for the purpose of this examination we will use the symbol I for current flow.

In order for the electrons to flow they must have a conductor and must have a reason to want to move. We said earlier they want to go where needed or where there is a lack of electrons. If they are not needed they will not move. So we must have a difference in potential or unlike charges, some type of electromotive force (EMF), or pressure to have current flow (electron movement). In electricity we use the term voltage to indicate this force. Anytime you see the words electromotive force, EMF, pressure, or difference in potential this is voltage. Voltage is measured in volts. The electrical symbol we will use for this examination is E . A difference in potential or electricity can be made in a lot of different ways. Through chemical energy of batteries, generators, photo cells, rubbing some materials together, thermocouples, pressure applied to a crystal are some of the ways a voltage can be created.

All conductors and materials do not have the same freedom for electrons to move within themselves. Some materials etc hold back electrons and does not allow them to move as fast through the conductor or material. This resists movement. Anything that opposes current flow is known as resistance. The symbol R designates the resistance in the material or circuit.

We have now discussed Voltage, Current Flow and Resistance. There is a relationship in an electrical circuit of the above terms. A man by the name of Ohms discovered this relationship and we call it ohms law. It simply states that it takes one volt of pressure to push one amp of current through one ohm of resistance. To express in symbols it is $E = I \times R$. The above statement appears to be very simple and it is. But you will determine later on when working problems you really don't understand what it is saying. Once you grasp what ohms law really means you will not have any trouble working any DC problem.

Another area we need to discuss is Power. You can have voltage and resistance but until electrons start flowing no power is being used. Visualize a car sitting still in a room and you have a person available to push it. The person has the ability to push so much (voltage) and to move the car you must overcome the resistance (resistance). You have both voltage and resistance but are using no power because the car is not moving. So in order to use power in an electrical circuit you must have electron flow. Once the car starts moving you are utilizing power or energy. The electrical symbol we shall use for this examination is P. Power is measured in watts.

If you move 33,000 lbs one foot in one minute you have used one horsepower. In electricity we measure power in watts. If we are using one watt of power we are moving one ampere of electricity with a force of one volt. We use the following formula to calculate watts in a circuit: $P = E \times I$.

To convert horsepower to watts or watts to horsepower: There are 746 watts of electrical power in one horsepower. $1\text{HP} = 746 \text{ watts}$

ELECTROMAGNETISM:

When a current flows through a wire it develops a magnetic field around the wire. If the current is reversed through the wire the magnetic field builds up in the opposite direction. This principle is very important in electricity. It is what makes motors, transformers, etc perform as they do.

Also if we pass a wire through a magnetic field it will cause current flow through the wire.

Electromagnetism is the effect of a magnetic field being built up around a wire or coil of wire by passing current through the coil or wire.

DC THEORY AND APPLICATION

ILLINOIS MINE ELECTRICIAN STUDY GUIDE

DC Theory and Application Outline

- A. Definitions
 - 1. Semiconductors
 - 2. Electric Current
 - 3. Direct Current
 - 4. Conventional Current Flow
 - 5. Electronic Current Flow
 - 6. Voltage
 - 7. Electromagnetism
 - 8. Rectifier
 - 9. Diode
- B. Ohm's Laws
 - 1. Applied to Series DC Circuits
 - a. Total circuit current
 - b. Total circuit resistance
 - c. Voltage drop across each series resistor
 - 2. Applied to Parallel DC Circuits
 - a. Total circuit current
 - b. Equivalent or total circuit resistance
 - c. Voltage drop across each parallel resistor
- C. Power Formula
 - 1. Total power consumed by the circuit
 - a. Series circuits
 - b. Parallel circuits
 - 2. Power dissipated by individual resistors
 - a. Series circuits
 - b. Parallel circuits
- D. Battery Connections and Resulting Voltage
 - 1. Series
 - 2. Parallel
 - 3. Series-Parallel
- E. DC Motors
 - 1. Operating characteristics of various types of DC motors
 - a. Series
 - b. Shunt
 - c. Compound
 - 2. Connections of various types of DC motors
 - a. Series
 - b. Shunt
 - c. Compound
 - 3. Typical symptoms of low voltage applied to DC motors
 - 4. Methods of changing the rotation of DC motors
- F. DC Equipment Grounding Methods (Shuttle Cars)
 - 1. Diode
 - 2. Third wire (separate frame ground conductor)
- G. DC Motor HP to KW Conversion
 - 1. $0.746 \text{ KW} = 1 \text{ HP}$
 - 2. $746 \text{ W} = 1 \text{ HP}$

MAGNETISM

Theory of Magnetism

Modern theory attributes magnetism to the motion of electrons within the atom, for it is known that moving electron constitutes an electric current and that an electric current produces a magnetic effect. One may think of a magnetic material as being made up of many very small magnets. When an un-magnetized magnetic material is placed in a magnetic field, these small magnets align themselves in a definite direction as the intensity of the field is increased, and magnetic poles of increasing strength are produced in the substance. The multitude of tiny magnets are lined up so that all the north poles face one direction and all of the south poles in the opposite direction. Thus the billions of millions of individual molecular magnets, because they all face the same direction, aid one another in creating a strong magnetic field.

Iron and steel can be made to attract other pieces of iron and steel. This attraction is known as magnetism. The bar magnet shown below has a north and a south end just as the earth has a North and a South pole, in fact the earth can be considered as just a big magnet.



If two bar magnets are placed with a North end and a South end as shown below, they will attract each other.



If they are placed with either the North ends or South ends together they will repel each other.



These are permanent magnets and are made out of hard steel. Iron and steel can be magnetized. Other metals that can be magnetized slightly are nickel and cobalt. Temporary magnets are made of soft iron. Most other materials are non-magnetic and cannot be magnetized. Copper cannot be magnetized. Electromagnets are made by winding coils of wire around soft iron. When an electric current flows through the wire the soft iron will become strongly magnetized. When the current stops flowing the iron will lose its magnetism.

Magnetic Fields

Magnets exert a pull on each other even though they are not touching. The space around the magnets in which this magnetic push or pull exists is known as a magnetic field.

Lines of Force

This magnetic field may be represented by lines of force. We assume that these lines of force flow from the North end of magnet to the South end of a magnet. These lines of force are just an easy way to show on paper how a magnetic field is formed and where the magnetic field is weaker and where it is stronger. These lines of force are usually called flux of magnetic flux.

Field Strength

The number of flux lines and how close together they are shows the field strength or flux density of a magnetic field. Notice that the flux density is much higher in the iron than in the air around the magnet. This shows though the flux density can be increased if an iron path is used instead of air. Although the lines of force will go through air, cardboard or any other material, the magnetic field will be much weaker than when it is in iron.

Magnetic Fields Around Electrical Conductors

Every conductor that has an electrical current flowing through it will produce a circular magnetic field around the conductor.

How far out the field will extend and how great the flux densities will depend on how much current or how many amps are flowing in the wire. The greater the amps the greater or more intense the magnetic field will be.

A straight current carrying conductor has no poles. If the wire is formed in a coil it produces a magnetic field that looks similar to a magnet.

If a piece of soft iron is put in the center of the coil, or solenoid as it is usually called, the magnetic lines of force can travel through the iron much easier and a more intense magnetic field is formed. This is an electromagnet. The strength of the electromagnet is determined by its ampere-turns, that is the number of turns of wire times the amount of current going through the wire.

The most important application of magnetic fields is in the operation of motors and generators. If we move a conductor across a magnetic field rapidly and at right angles to the lines of flux, we will generate a voltage in the conductor. The more lines of flux that are cut per second by the conductor the greater will be the “induced voltage” in the conductor. This is the basic principle in the generation of electricity.

DIRECT-CURRENT CIRCUIT THEORY

A direct-current (d-c) circuit is the starting place for the analysis of electrical circuits since it is the most basic and most simple circuit encountered. Let us begin this discussion by considering the simple d-c circuit shown in figure 4.1.

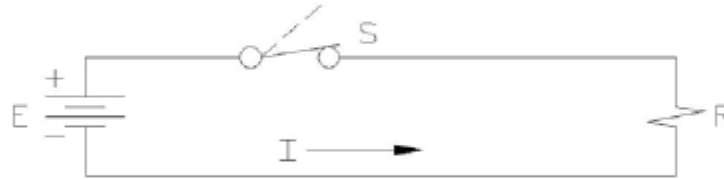


Figure 4.1. – A simple d-c circuit

The circuit consists of a source of electromotive force (voltage) –a battery in this case- that is designated by E, and a resistance (R) or load connected to the terminals of the voltage source. The resistance (R) may represent an actual resistor or some electrical device (called a load), such as a lamp, a toaster, or an electric iron, from which useful work is obtained. We also have connected a switch (S) into the circuit, to permit opening or closing the circuit.

As long as the switch is in the up or open position (shown dotted), there is no complete path for current to flow and we have what is known as an open circuit. As soon as the switch is placed in the down or closed position (shown solid), a complete, unbroken pathway (closed circuit) is formed through which an electric current (I) may flow. Electron current then flows from the negative (-) terminal of the battery, through the resistor and switch, and back to the positive (+) terminal of the battery. The switch, resistor, and connecting wires are known as the external circuit. Current also flows in an internal circuit, from the positive to the negative terminal inside the battery, thus completing the electrical path. The current flow will continue as long as the switch remains closed and as long as the voltage always flows in the same direction. The circuit is known as a direct-current (d-c) circuit. Direct current flows in only one direction and has constant magnitude.

George Simon Ohm discovered in 1827 that current (I) flowing in such a d-c circuit is directly proportional to the applied voltage (E) and inversely proportional to the resistance of the circuit. Putting this statement, known as Ohm's Law, into mathematical form, we obtain:

$$\text{Current} = \frac{\text{EMF (voltage)}}{\text{Resistance}}$$

Or using symbols:

$$I \text{ (amperes)} = \frac{E \text{ (volts)}}{R \text{ (ohms)}}$$

$$E = IR ; R = \frac{E}{I}$$

Whenever an electric current flows through a resistance, electric power is expended in the form of heat. Electric current in the d-c circuit case is numerically equal to the voltage (volts) times the

current (amperes). This relationship is expressed below using symbols. The symbol for power is P and the unit of measurement is the watt (w).

$$\text{Power} = \text{Current} \times \text{Voltage}$$

$$P \text{ (watts)} = I \text{ (amps)} \times E \text{ (volts)}$$

This equation can also be expressed in the following forms:

$$P = I^2 R$$

$$P = \frac{E^2}{R}$$

Factors Affecting Resistance

The amount of current an electrical conductor can carry is dependent on its resistance. The resistance of a wire depends upon the following:

1. Length; as the length increases, the resistance will increase proportionally.
2. Cross section; as the diameter increases, this means an increase in the area of cross section, the resistance will decrease.
3. Temperature; as the temperature increases, the resistance also increases.
4. The type of material also affects resistance.

DEFINITIONS

CURRENT

The movement of electrons through a conductor is called current. The number of electrons which passes a given point in one second determines the magnitude of the current. The unit of measurement of the current is the ampere and it is measured with an ammeter. The symbol for current is I.

RESISTANCE

Opposition to the flow of current through a conductor is called resistance. The unit of measurement of resistance is the ohm and it is measured with an ohmmeter. The symbol for resistance is the Greek letter, Omega (Ω).

ELECTROMOTIVE FORCE (POTENTIAL DIFFERENCE)

The external force which causes (or tends to cause) the current to flow through a conductor is called electromotive force (emf). The unit of measurement of electromotive force is the volt and it is measured with a voltmeter. The symbol for electromotive force is E.

OHM'S LAW

The rate of current flow (in amperes) is equal to the electromotive force (in volts) divided by the resistance in ohms.

$$I = \frac{E}{R}$$

$$R = \frac{E}{I}$$

$$E = I \times R$$

FORCE

Force is that which tends to produce motion, a change in motion, or a change in the shape of matter.

WORK

When a force overcomes a resistance and causes motion, work is done. Regardless of the force exerted, if no motion results there is no work done.

POWER

Power is the rate at which work is done. Electric power is numerically equal to the voltage in volts times the current in amperes.

$$P = E \times I$$

$$E = \frac{P}{I}$$

$$I = \frac{P}{E}$$

The unit of measurement of power is the watt. The symbol for power is P and the symbol for watt is W. One mechanical horse power is equal to 746 watts.

SERIES CIRCUIT

A series circuit is one in which the resistances or other electrical devices are connected end to end so the same current flows in each part of the circuit.

SERIES CIRCUIT LAWS

1. In a series circuit, the total resistance is the sum of the individual resistances.
2. In a series circuit, the same current flows in each part of the circuit.
3. In a series circuit, the sum of the voltage drops across each individual circuit element is equal to the applied voltage.

PARALLEL CIRCUIT

A parallel circuit is one in which the current may flow in more than one path.

PARALLEL CIRCUIT LAWS

1. In a parallel circuit the total or equivalent resistance is equal to the applied voltage divided by the total current.
2. In a parallel circuit, the voltage is the same across each branch of the circuit.

3. In a parallel circuit, the sum of the currents flowing up to a point equals the sum of the currents flowing away.

SHORT CIRCUIT

A short circuit occurs when two conductors of different potential contact each other.

SERIES - PARALLEL CIRCUIT

Consist of groups of parallel circuit elements in series with other circuit elements.

GROUND

The term ground, which actually means the earth, is used to describe a reference for voltage measurements and a point of common return from one side of circuit components to that same side of the power source.

OHM'S LAW

1. Definition:

Ohm's law states the current in a circuit is equal to the electromotive force in that circuit divided by the resistance of the circuit when the temperature is kept constant.

2. Formula:

$$I = \frac{E}{R} \quad \text{or } E = I \times R \quad \text{or} \quad R = \frac{E}{I}$$

I = Current in amps

E = Voltage drop in volts

R = Resistance in ohms

3. Basic Relationships

The current increases as the voltage drop increases, the resistance being held constant.

The current decreases as the resistance increases, the voltage drop being held constant.

SERIES CIRCUITS

In series circuits the current (I) has the same value anywhere in the circuit.

$$I = I_1 = I_2 = I_3$$

In series circuits the equivalent resistance of a group of resistors is equal to the sum of their individual resistances.

$$R_T = R_1 + R_2 + R_3 + \dots$$

PARALLEL CIRCUITS

In parallel circuits the potential drop is the same across all the resistors.

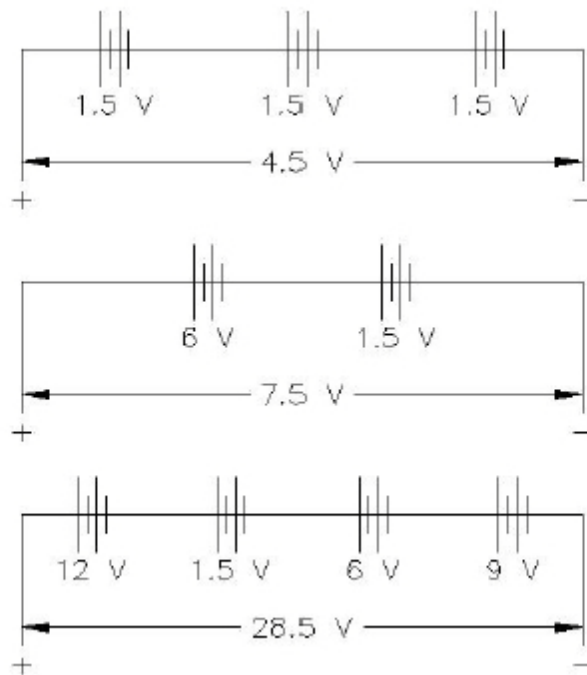
$$V = V_1 = V_2 = V_3 = \dots$$

In parallel circuits the reciprocal of the equivalent circuit resistance is equal the sum of the reciprocals of the individual resistances; therefore the group resistance of the parallel circuit is less than the smallest individual resistance in the circuit.

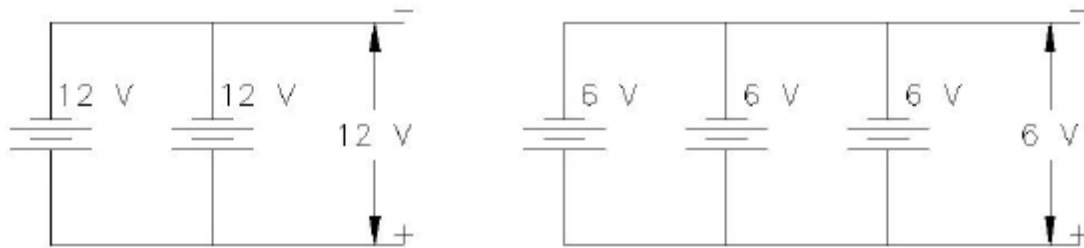
$$\frac{1}{R_{EQ}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$

BATTERY CONNECTIONS

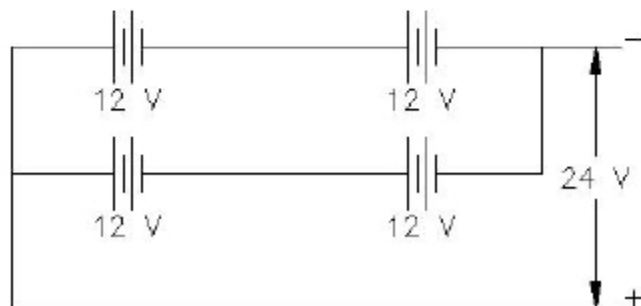
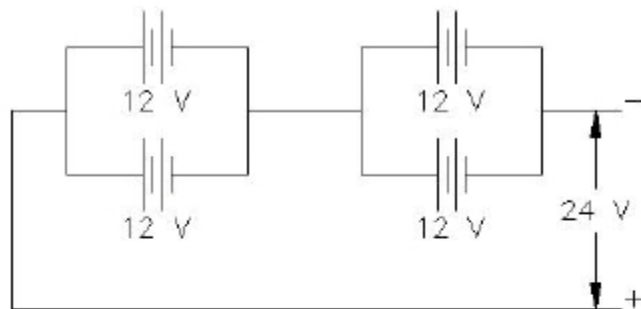
SERIES CONNECTION



PARALLEL CONNECTION



SERIES - PARALLEL CONNECTION



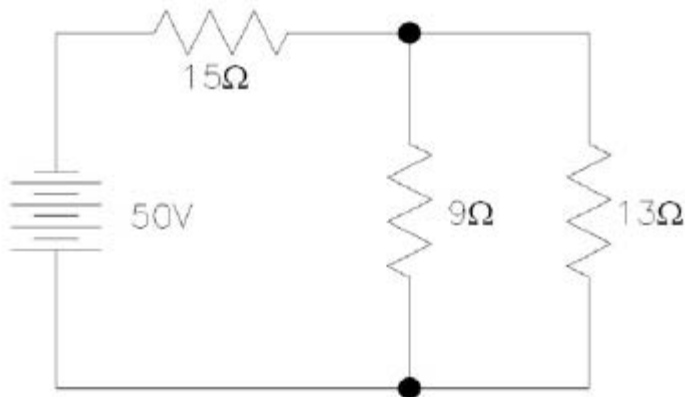
PRACTICE QUESTIONS FOR DIRECT THEORY AND APPLICATION

Direct Current Theory and Application

1. Which of the following is an incorrect form of Ohm's Law?
 - a. $E = IR$
 - b. $R = I/E$
 - c. $I = E/R$
 - d. $R = E/I$
2. The outer shell of electrons in an atom is called the:
 - a. Covalent shell
 - b. Valence shell
 - c. Negative shell
 - d. Molecular orbit
3. Which of the following is a means of producing electricity?
 - a. Friction
 - b. Heat
 - c. Magnetism
 - d. All of the above
4. Two $45\ \Omega$ resistors are connected in parallel. What is there total equivalent resistance?
 - a. $27\ \Omega$
 - b. $32\ \Omega$
 - c. $22.5\ \Omega$
 - d. $14.5\ \Omega$
5. To increase the length of a conductor would:
 - a. Increase resistance
 - b. Decrease resistance
 - c. Resistance remains the same
 - d. None of the above
6. In a parallel circuit the current is:
 - a. The same in all branches
 - b. Equal to the applied voltage
 - c. Smaller than any branch current
 - d. Divided among the parallel branches
7. In a series circuit the applied voltage is:
 - a. Equal to the sum of voltage drops
 - b. Different across each resistor
 - c. Dropped across the series resistors
 - d. All of the above

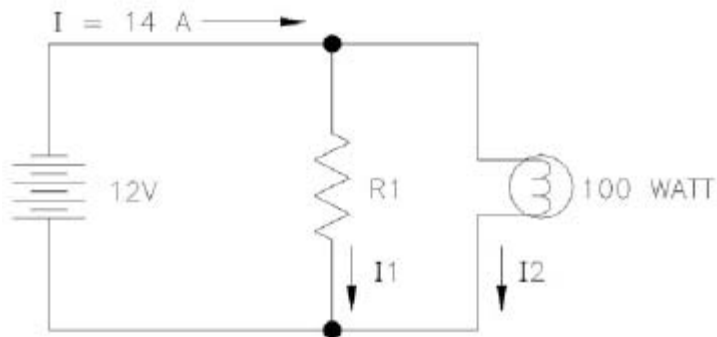
8. How much power is dissipated in a circuit containing 45 ohms resistance and drawing 3 amps?
- a. 1,200 W
 - b. 405 W
 - c. 450 W
 - d. 1,020 W
9. In a parallel circuit the total resistance is:
- a. Equal to the largest resistor
 - b. Equal to the smallest resistor
 - c. Smaller than the smallest resistor
 - d. Larger than the largest resistor

FIGURE 1



10. Total resistance in Figure 1 is:
- a. $20.32\ \Omega$
 - b. $14.11\ \Omega$
 - c. $37\ \Omega$
 - d. $3.93\ \Omega$
11. Current flow through the 15 resistor in Figure 1 is:
- a. 1.03 A
 - b. 21.3 A
 - c. 2.46 A
 - d. 11.02 A
12. Total power dissipated in Figure 1 is:
- a. 123 W
 - b. 460 W
 - c. 500 W
 - d. 98 W

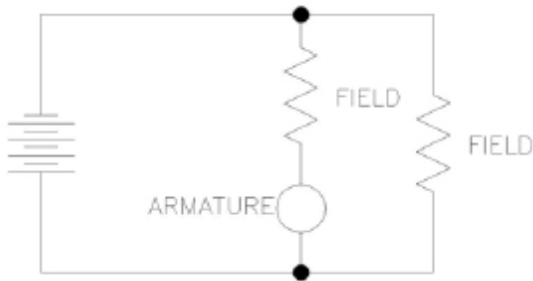
FIGURE 2



13. How many Amps flow through R1 in Figure 2?
- 16.91 A
 - 1.03 A
 - 12 A
 - 5.67 A
14. What is the Ohm value of R1 in Figure 2?
- 17 Ω
 - 2.12 Ω
 - 400 Ω
 - 102 Ω
15. What is the total power used by Figure 2?
- 420 W
 - 16.8 W
 - 168 W
 - 4.2 kW
16. A 45 Ω , a 72 Ω , and a 123 Ω , resistor are connected in series across 120V battery. How much current will flow?
- 2 A
 - $\frac{1}{2}$ A
 - 3.17 A
 - None of the above
17. Fifteen 100 Ω resistors are connected in a parallel. What is their total resistance?
- 3 Ω
 - 1,500 Ω
 - 15 Ω
 - 6.67 Ω
18. The name of the most common meter movement for DC measuring instruments is?
- Ohmic
 - Moving vane
 - D'Arsonval
 - Samson

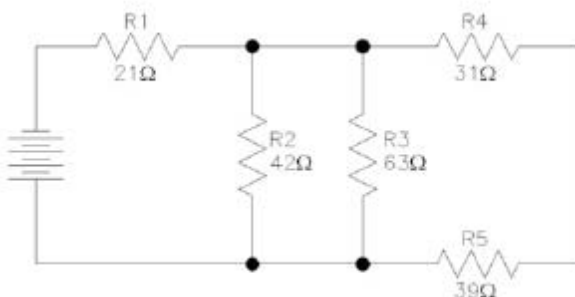
19. A series DC motor should not be operated:
- In low coal.
 - In high humidity
 - Without a load
 - In underground coal mines
20. Which of the following is not a characteristic of a DC shunt motor?
- High starting torque
 - Constant speed
 - Parallel field and armature windings
 - High starting amperages
21. A megger is used to measure:
- High voltage
 - High currents
 - Cable insulation resistance
 - Power dissipation
22. DC voltage:
- Changes direction and magnitude at regular intervals
 - May change in magnitude but never direction
 - Cannot ever change in magnitude or direction
 - Has the characteristics of sine wave

FIGURE 3



23. Figure 3 is a diagram depicting a:
- Compound DC motor
 - Series DC motor
 - Shunt DC motor
 - Three-phase DC motor

FIGURE 4



24. Total resistance for the circuit in Figure 4 is?
- a. $24\ \Omega$
 - b. $31.25\ \Omega$
 - c. $114.7\ \Omega$
 - d. $39.5\ \Omega$
25. If 3 Amps current flow through R1 in Figure 4 what is the source voltage?
- a. 118.59V
 - b. 96.3V
 - c. 12V
 - d. 144V
26. An electron has:
- a. A positive charge
 - b. A neutral charge
 - c. A negative charge
 - d. No charge
27. Copper is a good electrical conductor because
- a. It is difficult to remove electrons for copper atoms
 - b. The outer electrons are excited to zero energy very easily
 - c. The inner electrons are at a very high energy level
 - d. The free electrons are highly attracted
28. The direction of the flux lines around a current carrying conductor depends upon the:
- a. Reluctance of the surrounding medium
 - b. Permeability of the surrounding medium
 - c. Direction of the flow of electrons in the conductor
 - d. Orientation of the conductor in the earth's magnetic field
29. The amount of force associated with electrical charges depends upon:
- a. The number of electrons present
 - b. The number of protons present
 - c. The magnitude of the difference between the electrical charges
 - d. The type of conductor used
30. The device used to produce EMF by the heating of a junction of two dissimilar metals is called a:
- a. Heat-generator
 - b. Thermo-generator
 - c. Thermo-couple
 - d. Heat-processor

31. During the charging of a lead-acid cell, a dangerously high explosive gas is emitted from the cell. It is:
- Methane
 - Oxygen
 - Hydrogen
 - Nitrogen
32. The three necessary ingredients for electromagnetic induction are:
- Conductor, magnetic field, and motion
 - Generator, battery, and voltage regulator
 - Current, flux, and motion
 - Conductor, magnetic fields, and relative motion
33. The coulomb is an electrical term, which represents:
- Resistance
 - Current
 - A quantity of electrons
 - Electrons in motion
34. The direction of movement of electrons in an electrical circuit is:
- From a more negative to a less negative
 - From a more positive to a less positive
 - From more positive to more negative
 - From a less negative to more negative
35. Resistors are usually rated in:
- Ohms and current
 - Watts and voltage
 - Ohms and watts
 - Current and voltage
36. Ohm's Law may be stated in various forms; which of the following is INCORRECT:
- $E = I/R$
 - $R = E/I$
 - $I = E/R$
 - $E = IR$
37. With a 10 ohm resistance in series with a 2 ohm resistance, the total series resistance equals:
- 2 ohms
 - 8 ohms
 - 10 ohms
 - 12 ohms

38. A 36 ohm resistor and an 18 ohm resistor are in parallel with each other; their effective resistance is:
- 12 ohms
 - 18 ohms
 - 36 ohms
 - 54 ohms
39. The equivalent resistance of a parallel circuit is always:
- Greater than the resistance of the largest parallel branch
 - Less than the resistance of the smallest parallel branch
 - Equal to the resistance of the largest parallel branch
 - Equal to the resistance of the smallest parallel branch
40. If the current through a resistor is doubled, the power dissipation of the resistor becomes:
- One-fourth of the original consumption
 - One-half of the original consumption
 - Two times original consumption
 - Four times original consumption
41. The difference between power and energy is that:
- Power is the time rate of doing work, while energy does not involve time
 - Energy is the time rate of doing work, while power does not involve time
 - Energy is voltage times current without regard to time
 - Power can be measured in watt-hours but energy cannot
42. The resistance of a conductor will vary:
- Directly with length
 - Inversely with length
 - Directly with diameter
 - Inversely with temperature
43. A distinctive feature of shunt motor is that the:
- Field current flows through the armature
 - Field is connected across the armature
 - Field is constructed of relatively large wire
 - Field voltage plus armature voltage equals line voltage
44. The basic meter movement of most measuring instruments works on the principle of:
- Motor action
 - Generator action
 - The Thermocouple
 - The Wheatstone bridge
45. In using a voltmeter for trouble-shooting, how may the meter be connected in respect to the source?
- In series
 - In parallel
 - In shunt
 - In series, parallel, or shunt

**ANSWER SHEET FOR
DIRECT THEORY AND APPLICATION
PRACTICE QUESTIONS**

1. b
2. b
3. d
4. c
5. a
6. d
7. a
8. b
9. c
10. a
11. c
12. a
13. d
14. b
15. c
16. b
17. d
18. c
19. c
20. a
21. c
22. b

23. a
24. d
25. a
26. c
27. b
28. c
29. c
30. c
31. c
32. d
33. c
34. a
35. c
36. a
37. d
38. a
39. b
40. d
41. a
42. a
43. b
44. a
45. b

DC THEORY and APPLICATION

1. Q. Which of the following motors are considered to be constant or nearly constant speed?

A. Compound-wound and shunt-wound.

2. Q. The best insulator against the lines of magnetic force is:

A. Distance.

3. Q. Like poles of a magnet will:

A. Repel each other.

4. Q. Which of the following motors CANNOT be run without a load?

A. Series-wound.

5. Q. Unlike poles of a magnet will:

A. Attract each other.

6. Q. The armature of a direct current motor, when running, generates:

A. A counter-EMF.

7. Q. A triac is?

A. A bi-directional device that can pass current in either direction.

8. Q. Which of the following is NOT an electro-magnet?

A. A wire wound resistor.

9. Q. The specific gravity of the electrolyte of a fully charged battery should be:

A. 1.260 to 1.280.

10. Q. Storage battery charging stations must be provided with what kind of current protection?

A. Reverse.

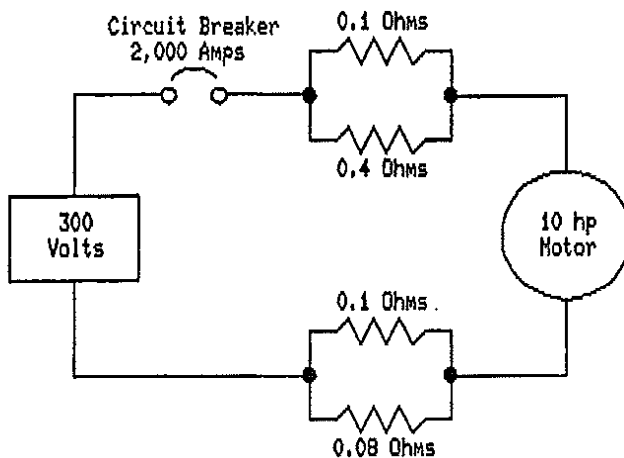
11. Q. The instrument used to check the electrolyte of a battery is a:

A. Hydrometer.

14. Q. A battery capable of producing 20 amperes steadily for 20 hours at 80 degrees Fahrenheit would have an ampere-hour rating of:

A. 400 ampere-hours.

15. Q. If a short circuit occurs at the motor terminals, does the circuit breaker open or remain closed?



A. Yes, the breaker will open because the short-circuit exceeds the setting of the breaker.

16. Q. The unit of measurement of current is:

A. Amperes.

17. Q. Power is measured with a:

A. Wattmeter.

18. Q. Resistance is measured with a:

A. Ohmmeter.

19. Q. Which of the following stays the same in all parts of a series circuit?

A. Current

20. Q. What is Ohm's Law?

A. $E=IR$.

21. Q. Define current:

A. The movement of electrons in a circuit.

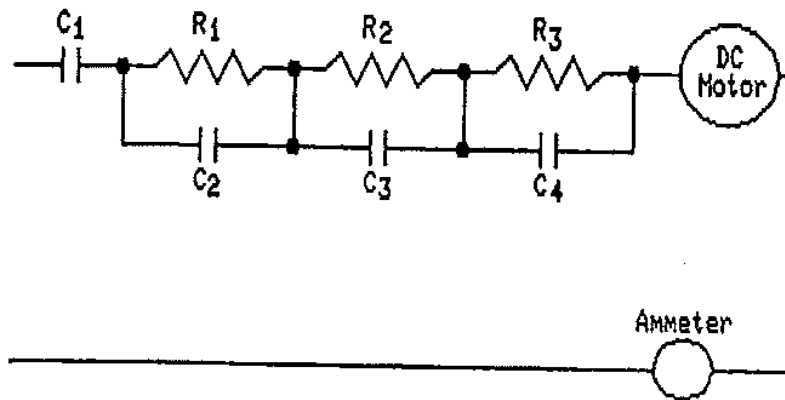
22. Q. Define direct current:

A. Current that flows in one direction only.

23. Q. What is the hazard of pouring water into battery acid "electrolyte"?

A. There is a hazard of blowing the contents back into your face, "explosive reaction".

24. Q. The instant each contactor closes, the ammeter reading should:



A. Show an increase in current.

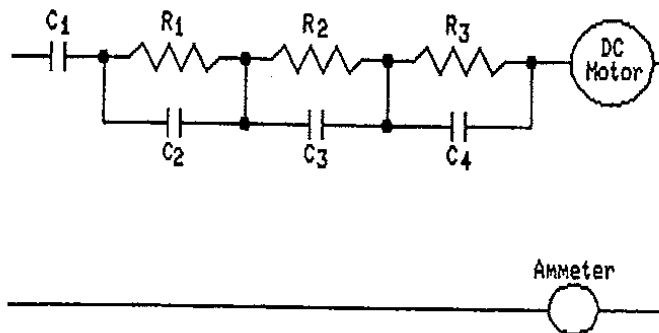
25. Q. Define direct current:

A. Current that flows in only one direction.

26. Q. The unit of measurement of resistance is?

A. Ohms.

27. Q. The contactors in this diagram close sequentially. The motor should read full voltage when contactor:



A. C4 Closes

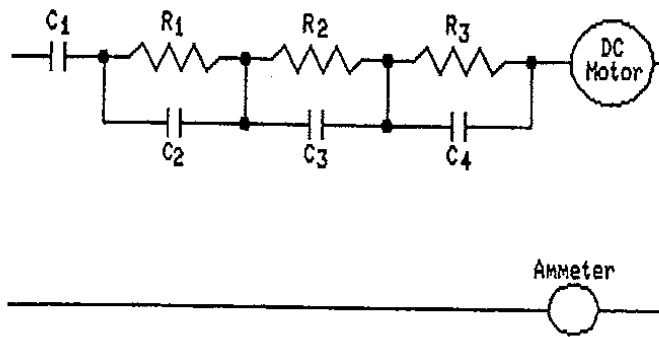
28. Q. When should water be added to a battery?

A. After charging

29. Q. What is the flow of electrons in a conductor?

A. Current.

30. Q. With each closing of a contactor, the motor voltage should:



A. Increase.

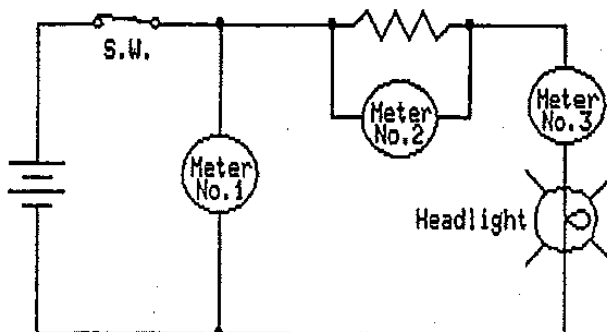
31. Q. What is the opposition to flow of electric current?

A. Resistance.

32. Q. What is the rate that work is done or heat is dissipated?

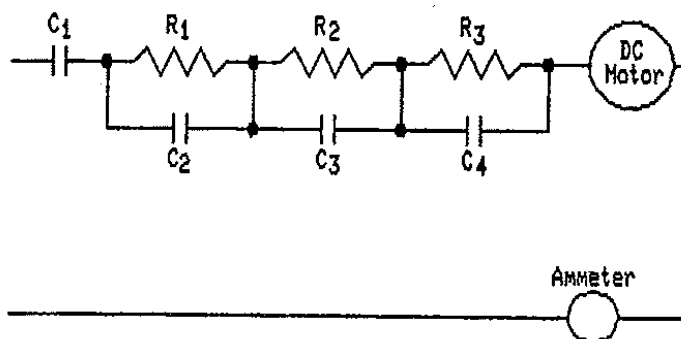
A. Power.

33. Q. Meter number 3 measures what?



A. Current

34. Q. When contactor "C1" closes, the motor will receive:

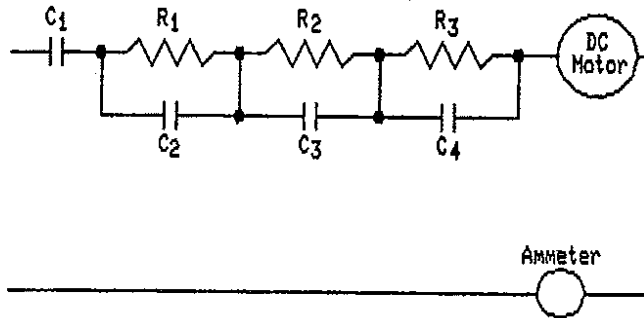


A. Partial voltage and partial current.

35. Q. Which current flows in only one direction?

A. Direct current.

36. Q. When contactor C1 is closed and C2, C3, and C4 remain open, the motor will be running at what speed?



A. Slow speed.

37. Q. What is the unit of electromotive force or electric pressure?

A. Voltage.

38. Q. The unit of measurement of power is:

A. Watts.

39. Q. Define resistance:

A. The opposition to flow of electrons in a circuit.

40. Q. Current is measured with a (an):

A. Ammeter.

41. Q. Resistors are rated in ohms and:

A. Watts.

42. Q. Voltage is measured with a:

A. Voltmeter.

43. Q. Which of the following is NOT a requirement of an explosion-proof enclosure?

A. It must prevent internal explosions.

44. Q. Which of the following is a requirement of an explosion-proof enclosure?

A. It must prevent ignition of surrounding methane atmosphere.

45. Q. Which of the following is NOT true about electrical shocks?

A. Burns will appear only at the point where contact is made to the energized circuit.

46. Q. Chemical burns caused by battery acid should be washed with clean water for at least:

A. 15 minutes.

47. Q. What should be used in treating an eye injury caused by battery acid?

A. Clean water.

48. Q. How long should treatment for shock be continued?

A. Until the victim receives medical attention.

49. Q. The first step in treating a chemical burn, such as one caused by battery acid, is to:

A. Flush thoroughly with water.

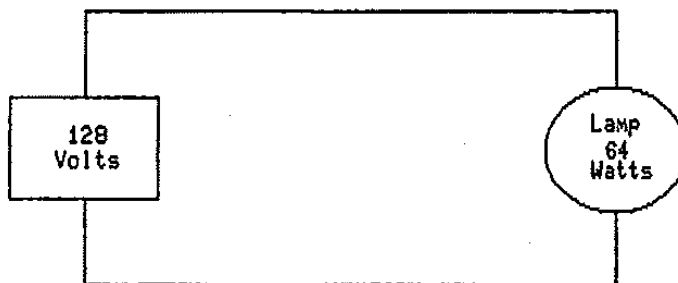
50. Q. What is the first step in treating a chemical burn of the eye?

A. Flush the burn the clean water.

51. Q. If the victim of an electrical shock has been burned while in contact with electricity, the first treatment you should apply, if the victim's heart and respiratory system are still functioning, is to:

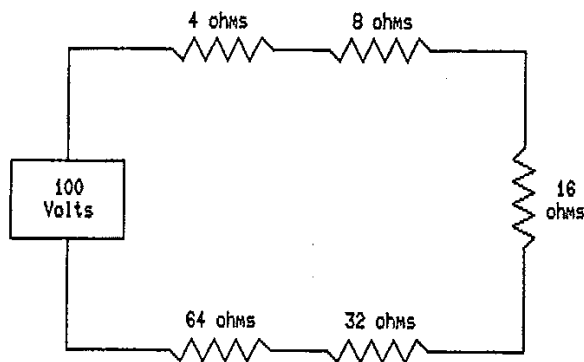
A. Treat for physical shock.

52. Q. What is the resistance of the permissible lamp shown below?



A. 256 Ohms

53. Q. What is the voltage drop across the 64-ohm resistor?



A. 51.2 Volts

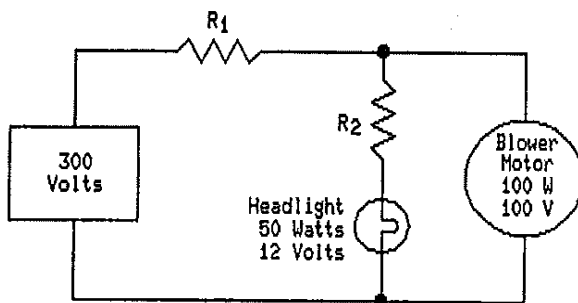
54. Q. How many watts are in one horsepower?

A. 746 watts.

55. Q. How many kilowatts are used to develop 50 horsepower?

A. 37.3 kilowatts

56. Q. What value resistor must be used as R1 in order to supply the proper voltage in the circuit shown below?

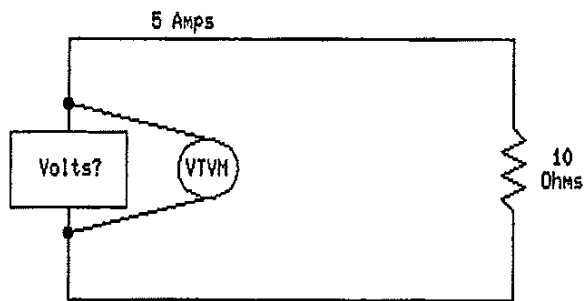


A. 38 Ohms

57. Q. You have three 9-volt batteries. How should you connect them in order to supply 27 volts?

A. In series.

58. Q. What voltage would be read on the voltmeter connected to the circuit shown below?

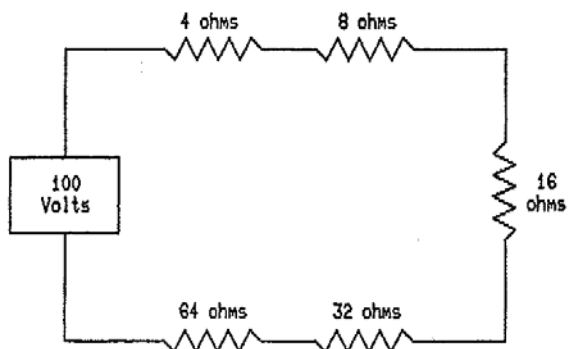


A. 50 Volts

59. Q. What voltage would be required to force 10 amps through a 50-ohm resistor?

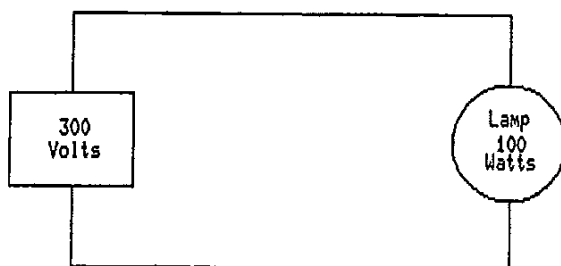
A. 500 volts.

60. Q. Find the current flow in the figure below.



A. 0.8 Amps

61. Q. What is the resistance of the lamp?

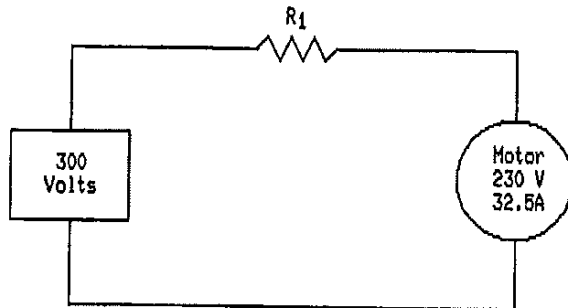


A. 909 Ohms

62. Q. What is the total voltage of eight 12-volt batteries connected in series?

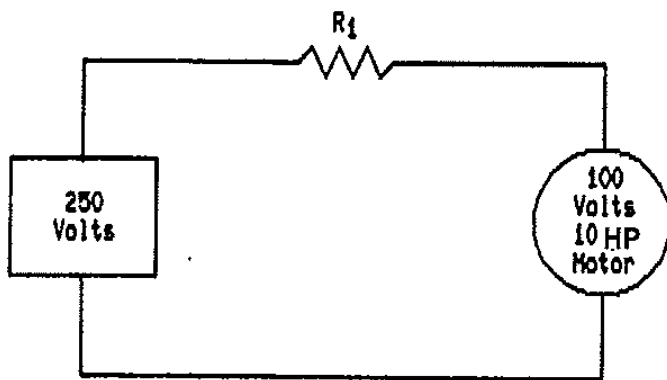
A. 96 volts.

63. Q. The motor draws 32.5 amps under full load conditions. How much voltage will the resistor R1 have to drop in order to apply proper voltage to the motor?



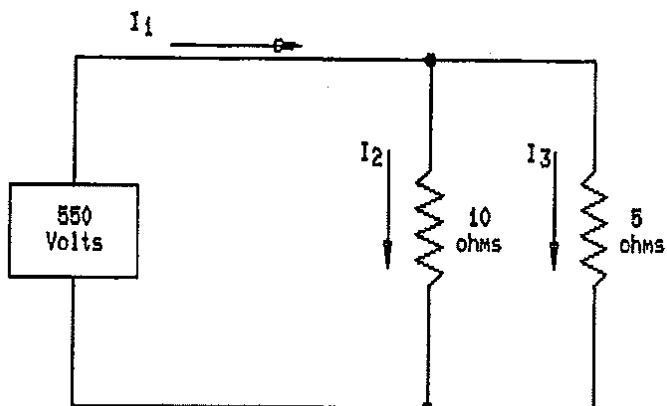
A. 70 Volts

64. Q. How much power will be consumed by R1? (Allow 746 watts per horsepower.)



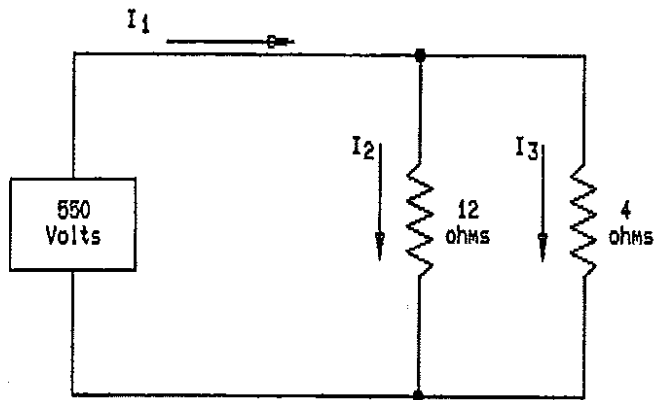
A. 11,190 watts

65. Q. What is the value of I_1 in the circuit shown below?



A. 165 Amps

66. Q. How much power will be consumed by the 4-ohm resistor in the circuit shown below?

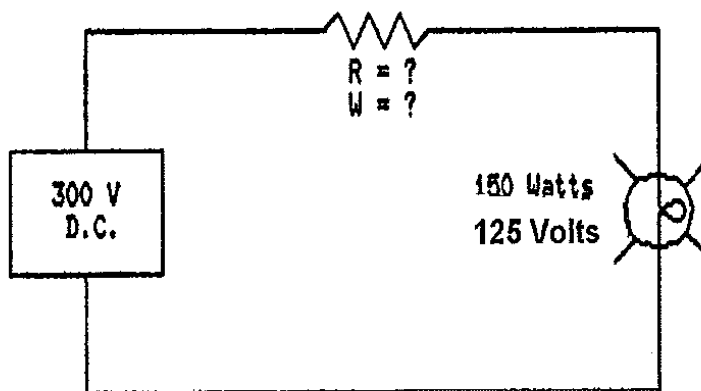


A. 75,625 watts

67. Q. Batteries connected in parallel provide:

A. Higher current with voltage remaining the same.

68. Q. Determine the ohmic resistance and wattage rating of the resistor needed to limit the voltage drop across the headlight to 125 volts. The headlight is rated at 150 watts.

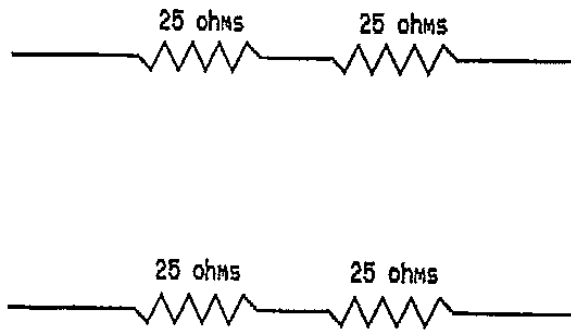


A. 146 ohms, 210 watts

69. Q. In a parallel circuit:

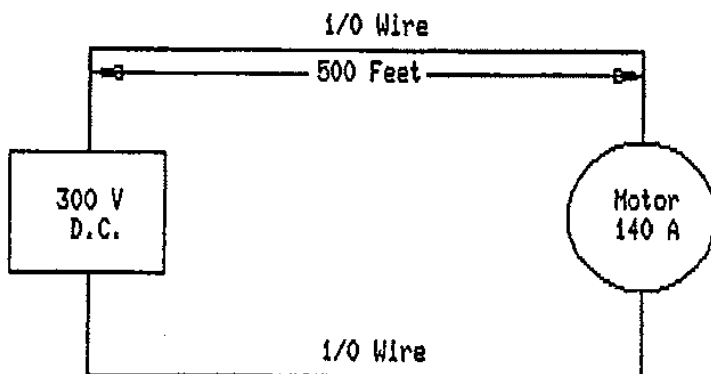
A. Total resistance is less than the smallest resistor.

70. Q. What is the total resistance of four 25-ohm resistors connected in series?



A. 100 ohms

71. Q. A 1/0, 1-conductor cable is used to feed a 140 amp motor load. The resistance of 1/0 single-conductor is 0.102 ohms per 1,000 feet. The cable is 500 feet long. What is the voltage drop in the cable?

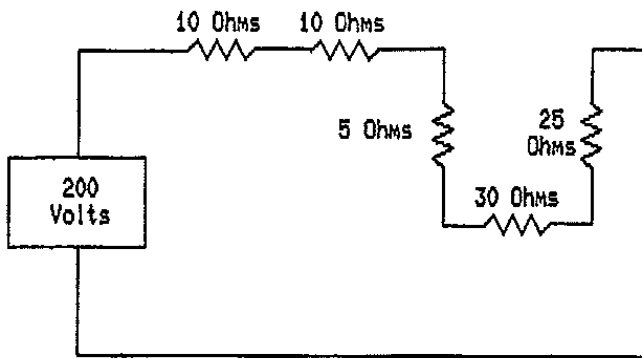


A. 14.28 volts

72. Q. The combined resistance of two resistors in parallel is:

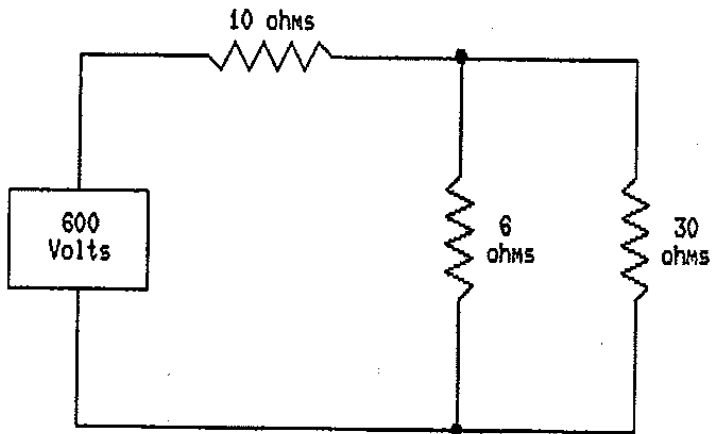
A. Less than the resistance of either resistor.

73. Q. How many amps flow through the 5-ohm resistor in this circuit?



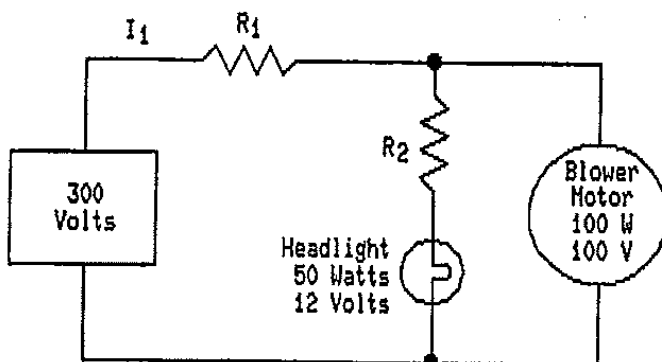
A. 2.5 amps

74. Q. How much power is consumed by the 10-ohm resistor?



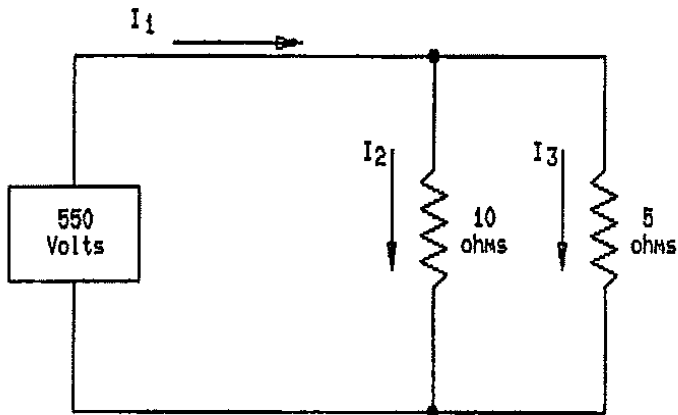
A. 16,000 watts

75. Q. What is the value of I_1 in the circuit shown below?



A. 5.2 Amps

76. Q. What is the value of I_3 in the circuit shown below?



A. 110 amps

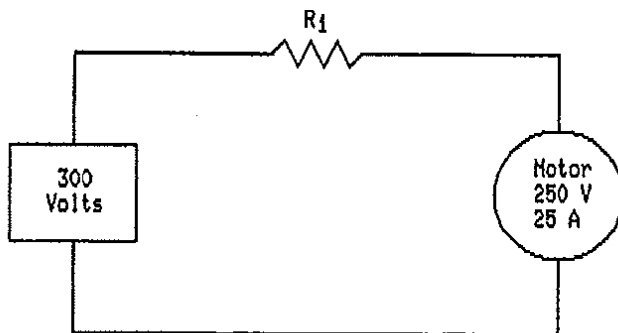
77. Q. What is the total resistance of three 16-ohm resistors connected in series?

A. 48 ohms.

78. Q. If the cross-sectional area of a conductor is increased, its resistance will:

A. Decrease.

79. Q. In the circuit shown below the resistor (R_1) must drop 50 volts. What should be the ohmic value of the resistor?

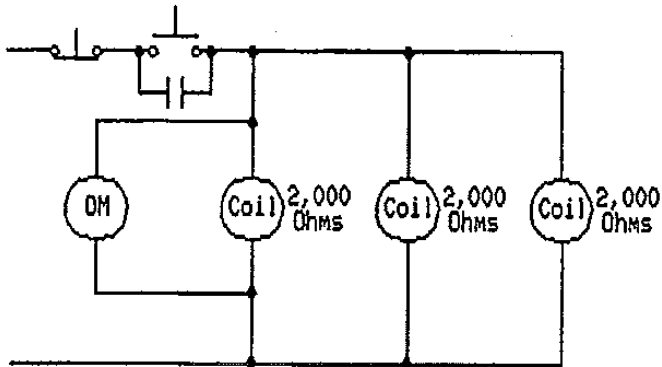


A. 2 Ohms

80. Q. The longer the conductor, the greater the:

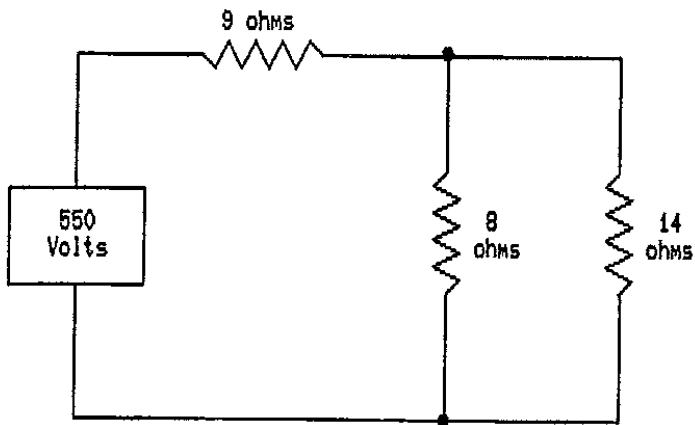
A. Resistance.

81. Q. An ohmmeter is connected as shown below. Each coil has a resistance of 2,000 ohms. What would be the approximate reading of the ohmmeter?



A. 667 ohms

82. Q. How much power is consumed by the 9-ohm resistor?

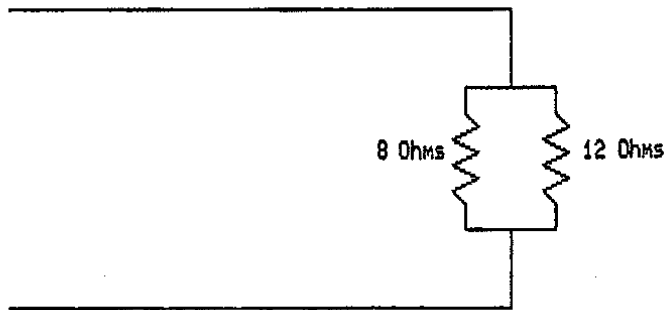


A. 13,710 watts

83. Q. How must two 12-volt batteries be connected in order to increase the current capacity?

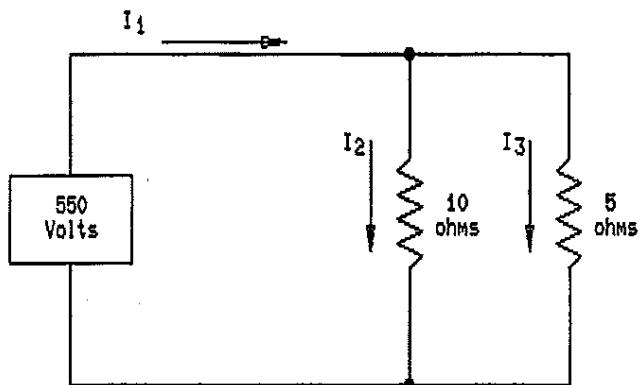
A. In parallel.

84. Q. What is the equivalent resistance of an 8-ohm and a 12-ohm resistor connected in parallel?



A. 4.8 ohms

85. Q. What is the value of I_2 in the circuit shown below?

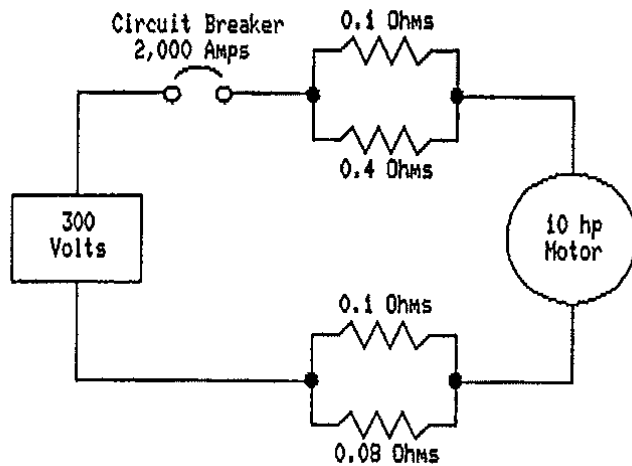


A. 55 amps

86. Q. What voltage would be required to force 10 amps through a 20-ohm resistor?

A. 200 volts

87. Q. How much voltage will be measured at the motor terminals? Allow 4 amps per horsepower:



A. 295 volts

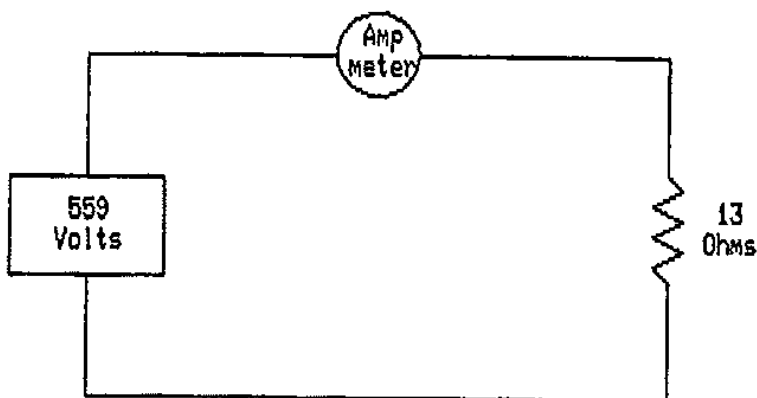
88. Q. What is the equivalent resistance of two 8-ohm resistors connected in parallel?

A. 4.0 ohms.

89. Q. What is the total resistance of four 15-ohm resistors connected in series?

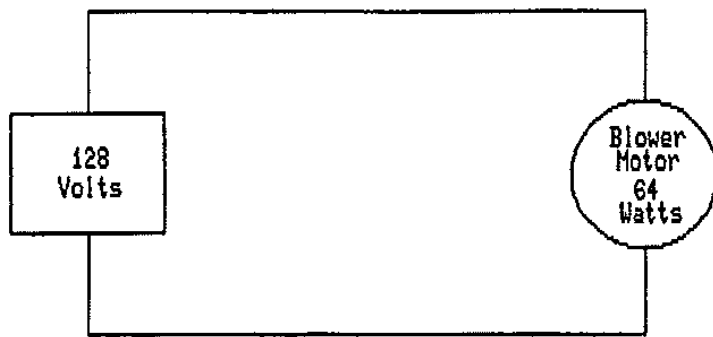
A. 60 ohms.

90. Q. What should the ammeter in this circuit read?



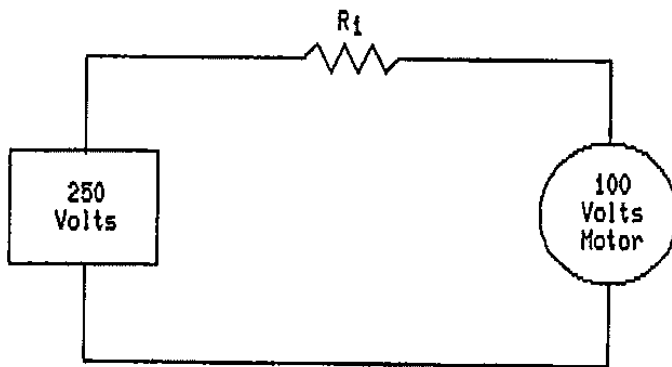
A. 43 amps

91. Q. How much current flows through the blower motor in the circuit shown below?



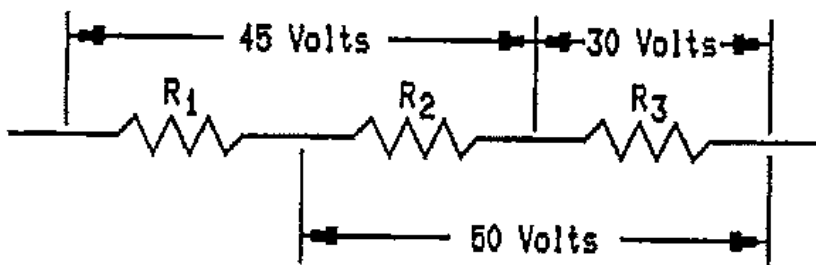
A. 0.5 amps

92. Q. The motor draws 40 amps under full load conditions. How much voltage will the resistor R1 have to drop in order to apply proper voltage to the motor?



A. 150 volts

93. Q. What is the voltage across R1?

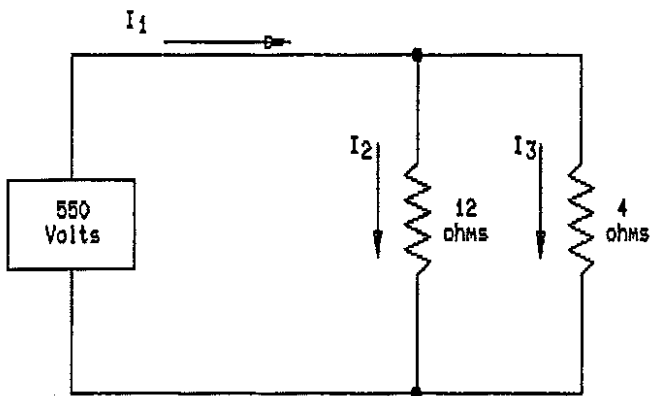


A. 25 volts

94. Q. Current in a series circuit:

A. Stays the same.

95. Q. Find the source current I_1 in the circuit diagram below.

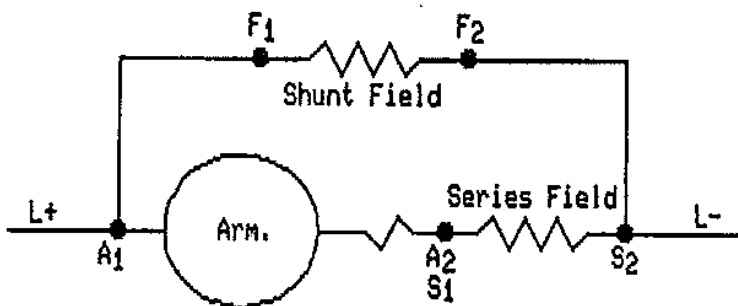


A. 183.0 amps

96. Q. Voltage in a parallel circuit:

A. Stays the same.

97. Q. How should the circuit below be changed in order to reverse the rotation of the motor?



A. Interchange A1 and A2.

98. Q. The advantage of DC over AC is that DC offers:

A. Better speed control on motors.

99. Q. Trailing cable on DC-powered mobile haulage equipment must be at least:

A. No.4 AWG.

100. Q. The minimum allowable size of trailing cable on DC-powered mobile haulage equipment is:

A. No.4 AWG.

101. Q. The most common reason that solid state devices fail is:

A. Heat

102. Q. The dangerously explosive gas emitted by charging a lead-acid storage battery is:

A. Hydrogen.

103. Q. The core of an electro-magnet should be made of:

A. Soft iron.

104. Q. The explosive gas that is generated when a battery is charging is:

A. Hydrogen.

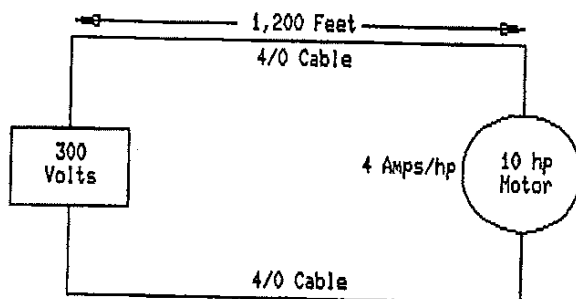
105. Q. What must be provided at underground battery charging stations?

A. Ventilation.

106. Q. What is the equivalent resistance of two 16-ohm resistors connected in parallel?

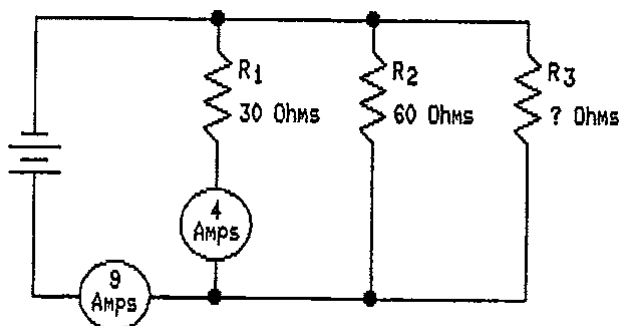
A. 8 ohms.

107. Q. A 10 hp motor is connected to a 300-volt DC source through 1,200 feet of two-conductor, number 4/0 cable. Under full load conditions, what voltage will be measured at the motor terminals? (Resistance of 4/0 wire is 0.051 per 1,000 feet)



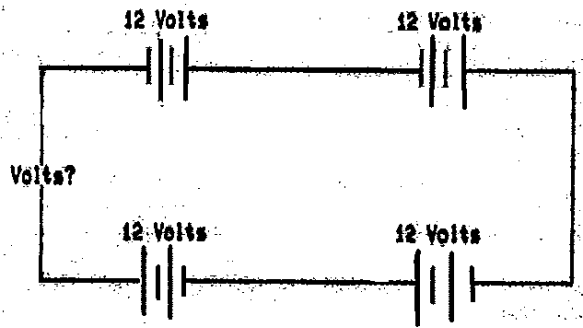
A. 295 Volts

108. Q. Find R3 in the circuit shown below.



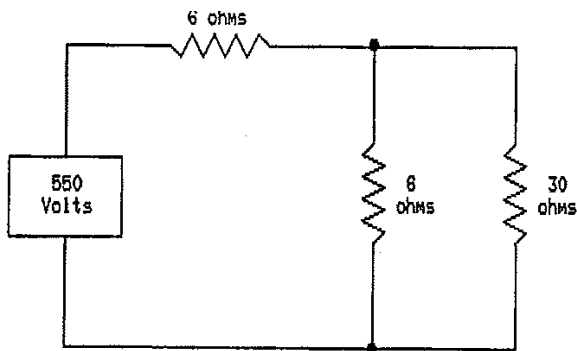
A. 40 Ohms

109. Q. What is the total voltage of four 12-volt batteries connected in series?



A. 48 volts

110. Q. How much current will flow through the 30-ohm resistor?

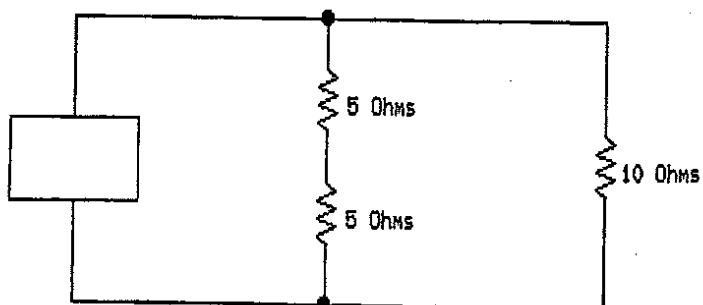


A. 8.33 amps

111. Q. What is the total voltage of four 9-volt batteries connected in a series?

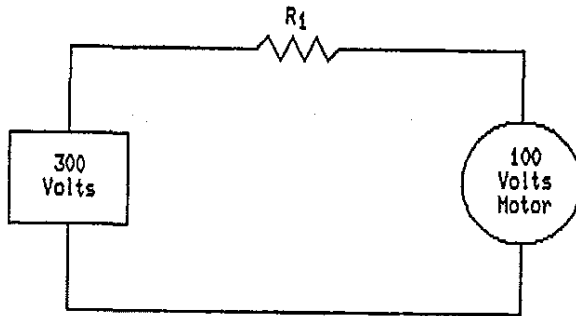
A. 36 volts.

112. Q. Find the total resistance of the parallel circuit shown below.



A. 5 ohms

113. Q. What resistance must be used for R1 on order to supply 100 volts to the motor terminals? The motor draws 40 amps under full-load conditions.



A. 5 ohms

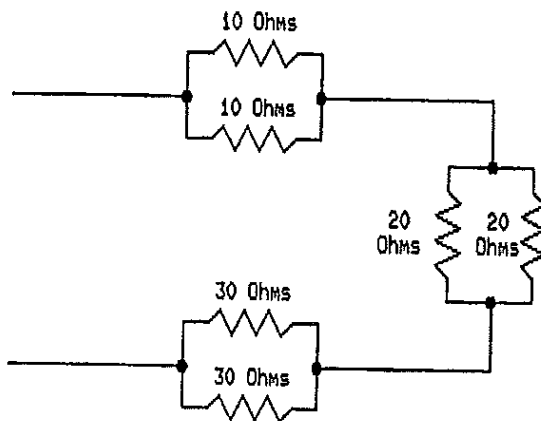
114. Q. What voltage is required to force 5 amps through a 15-ohm resistor?

A. 75 volts.

115. Q. You have three 12-volt batteries. How should you connect them in order to supply 36 volts?

A. In series.

116. Q. Find the total resistance of the circuit shown below.

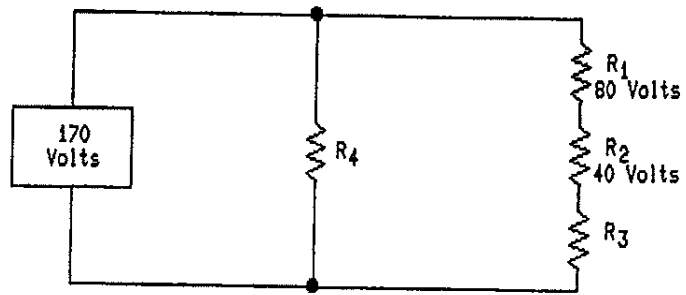


A. 30 ohms

117. Q. What is the total voltage of two 6-volt batteries connected in parallel?

A. 6 volts.

118. Q. How much voltage would be measured across R3?



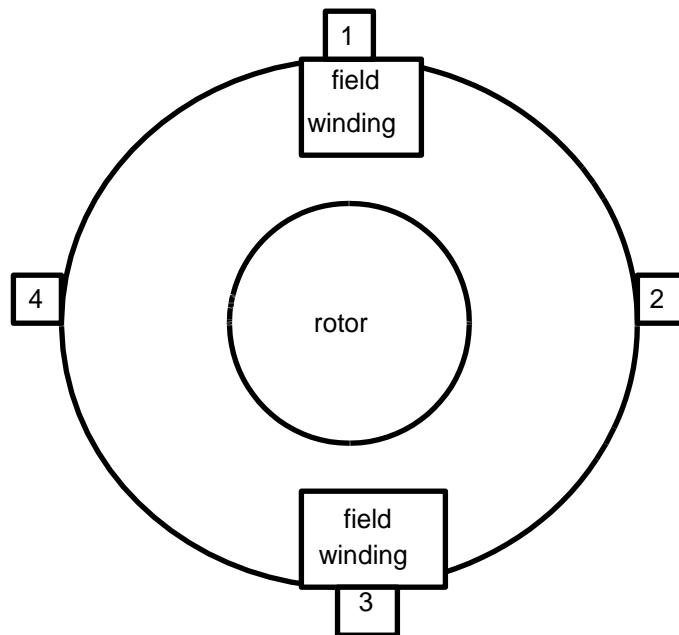
A. 50 volts

AC ELECTRICITY

We stated earlier that DC is direct current and it moves in one direction from one point to another. AC is alternating current. The current changes direction at regular intervals and the value is constantly changing.

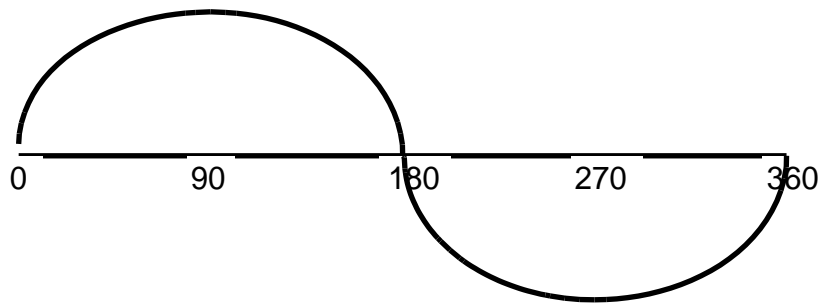
We discussed electromagnetism earlier. When a conductor moves through a magnetic field or the magnetic field moves around the conductor it cause current to flow in the conductor. Also if current is flowing in a conductor it produces a magnetic field around the conductor. This is a very significant process in AC electricity. It allows transformers to operate. We can increase the voltage to a higher level and reduce current and transform at the utilization area to the operating voltage of equipment. This is why we utilize AC instead of DC to transmit power. DC cannot be transformed because it does not produce the varying magnetic field that is constantly in motion around the winding of a transformer. If we used DC at the mines the cable would be enormous in order to maintain the voltage level from outside to the sections. Large amounts of current would be flowing and the voltage drops would be so large it isn't practical to utilize DC for the distribution system.

In order to understand how the sine wave is created that we use to describe AC electricity we must look at a simple alternator:



There is a magnetic field between the two field winding because current is flowing through the windings (exciting current). When the rotor is position with the least windings cutting the magnetic flux of the magnetic field we shall say there is no current induced into the rotor at point 1. As the rotor rotates to point 2 the amount of windings cutting the field increases until all of them are across the magnetic field. This is the maximum current being introduced at this point. When rotor turns from 2 to 3 the amount of windings cutting the magnetic field gradually decrease until we say there is no current flowing at point 3. Now when the rotor turns from point 3 to point 4 it is crossing the magnetic field in an opposite direction and current reverses. The value of current starts at zero at point 3 and increases to maximum amount at point 4 and then starts to decrease again. When it reaches point 1 it is back to zero. As long as the rotor rotates it will produce the current in this fashion. When the rotor has turned one complete turn in electricity we say it has completed one cycle.

To simplify the above electricians draw or plot the cycle out in a straight line such as below:

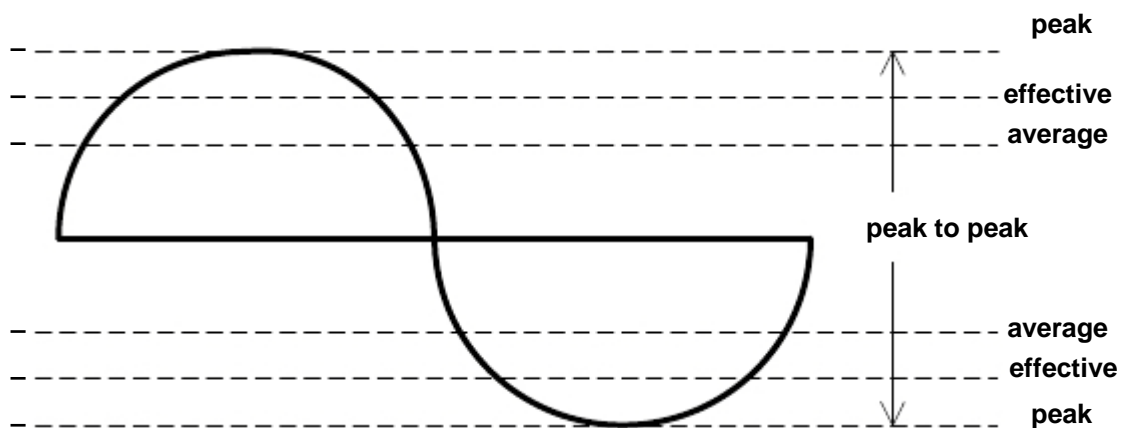


There are 360 degrees in a circle and we draw it in a straight line. You see when the rotor has turned a quarter of turn or 90 degrees the current is at its maximum value. Then it decreases to zero again. We call this one alternation (positive alternation) of current. When the windings are cutting in the opposite direction it creates the negative alternation. One complete cycle is 360 electrical degrees. One alternation is 180 electrical degrees.

If we turned the alternator at 3600 RPM it would be creating 60 of these cycles per second and we call this frequency. The frequency used in the United States is 60 cps or 60 cycles per second. Another term we use to describe frequency is Hertz. So 60 Hz is 60 cycles per second.

In a pure resistance circuit the current and voltage are on the same sine wave and rises and falls the same.

There are four different voltages on the sine wave that you will be required to know for the exam (Effective, average, peak and peak to peak voltages). The following sine wave shows where they fall on the alternations.



On the formula sheet that you will be given during the examination are the formulas you will need to convert from one voltage to another. REMEMBER THE VOLTAGE YOU READ WITH A VOLTMETER IS EFFECTIVE VOLTAGE OF THE CIRCUIT. In normal mining you do not deal with the above voltages only the effective voltage is used. However you need to know about peak voltages, etc

because if you install a diode or someother device it must be rated for the peak voltage of the circuit. If not the surges will short out the diode.

Formulas:

Effective voltage = $.707 \times \text{Peak Voltage}$

Average voltage = $.637 \times \text{Peak Voltage}$

Peak voltage = $1.414 \times \text{Effective Voltage}$

Peak to Peak = $2 \times \text{Peak Voltage}$

THREE PHASE CURRENT

In the above we have mostly discussed single phase current. Three phase AC is used mostly in the mines today. Components are smaller in size, less current, and less heat. If a continuous miner was single phase the motors would be humongous for the amount of horse power needed. In single phase we discussed the rotor turning 360 degrees and it produced on sine wave. Three phase picture three pairs of poles. When rotor turns inside it produces three sine waves 120 electrical degrees apart. An easy way to remember the 120 is that there are 360 degrees in a circle and divide by three will give you 120 degrees.

Single phase has two current carrying wires. Three phase has three current carrying wires. Remember that it takes 746 watts of power for each horsepower regardless of voltage, phasing, etc. So each of the three phase wires will carry less current.

Another reason we use three phase is because of motor starting. A three phase motor is easily started because of the phasing and rotating magnetic field. A single phase motor must have a starting capacitor with run/start winding or be a split phase motor etc. Some device must be installed usually a centrifugal device to drop out the start winding. Three phase motor do not require this and are simpler to maintain. This is why almost all large motors are three phase.

All three phase formulas use 1.732 as a constant. This is derived from the square root of 3. (Three Wires).

Remember that there are three different sine waves 120 degrees apart current is constantly changing in value and reversing direction at regular periodic intervals. In a balanced three phase circuit what current is flowing one direction the same amount of current is flowing in the reverse direction either on one or two wires. This is why on a Wye type winding a neutral is automatically derived because the current at the neutral has the same value in both polarity. We will discuss this further when we get into three phase transformers.

SINGLE PHASE TRANSFORMERS

In order to understand transformers let's review electromagnetism. We said that when current flows through a wire it creates a magnetic field around the wire. We also stated that if a wire is moved in a magnetic field it will produce a current. Also if we move the magnetic field across the wire it will produce current.



In the coil above if we connect DC to it the current will start at zero and build up to the full nominal DC current. While this current is building up to full current a magnetic field is building up around the wire. This is the same as moving a magnetic field across a wire. It produces current, however the current that is induced into the wire is opposite the current that is applied to the wire from the DC source. In other words it bucks it or holds it back. Once the applied current reaches the maximum a field is created around the wire but it is no longer moving so the Counter Electromotive Force that was created when current was rising disappears and the coil is the same as a wire in the circuit. However any changes in the applied current will once again produce the CEMF effect. We use these coils in DC as choke coils to protect devices in the circuit such as solid state drive units, etc.

Now if we apply AC to the coil the magnetic field is constantly changing. If we take another coil of wire and wrap around this coil it induces current into the second wire because of the magnetic field expanding and collapsing around the first wire. This is how we create a transformer. The primary and secondary coils are totally separated from each other and only affected by the magnetic field around the coils of wire. This is known as transformation. When AC is applied to the transformer primary it induces a current into the secondary. When no load is applied to the secondary the only power that is used in the system is what is needed to keep the transformer windings excited or energized. This current is very low and we just ignore it in calculations. However if a load is applied to the secondary windings current starts to flow and we pull current from the source to the primary windings. How much current will flow and the output voltage is determined by the Coil winding ratio of the transformer. There are three types of transformers Step up, Step down, and isolation transformers. Step up transformers increase the voltage on the output side according to the turns ratio. Step down transformers decrease the output voltage. Isolation transformers are used mostly for grounding isolation purposes and the input voltage is the same as the output voltage (Ratio 1 : 1).

A step down transformer has more windings in the primary than secondary. If it is a Ratio of 4 : 1 this means there are 4 coils of wire in the primary for every one coil of wire in the secondary. Step down means the voltage is decreased by four times on the output side.

A step up transformer has more windings in the secondary than the primary. If it is a Ratio of 1 : 4 this means there are 4 coils of wire in the secondary for every one coil in the primary. Step up means the voltage is increased by four times on the output side.

An isolation transformer has a ratio of 1 : 1. The input and output voltages are the same.

The primary and secondary windings are wires that are insulated and the wire are wound around an iron core. The cores are laminated and normally not one piece of steel or iron. If they are one piece it allows current to flow in the core and creates eddy currents or hysteresis which in turn creates a lot of heat in the transformer.

In a transformer the power that is used on primary side is the same as on the output side. You only use what you need from the utility supplying the power. Remember that power is watts which is a relationship of voltage and current ($P = E \times I$). So if we step up or down the voltage we change the current to keep the power the same on both sides. When we increase the current we must increase the wire size to keep the transformer from burning out. In a step down transformer the secondary windings are larger in wire size than the primary and reverse in a step up transformer. Normally the H marked terminals are the high side and the X marked terminals are the low side. Almost all the transformers we utilize underground are step down so the primaries are H and secondaries are X.

The output voltage of a transformer is directly related to the Ratio. If it is a 480 volt input with a 4:1 ratio the output is 120 volts. You can calculate the ratio of a transformer if you know the input and output voltages by dividing the lower voltage into the higher voltage. You must remember the power remains the same on both input and output side of the transformer so the current is in reverse. You can figure the currents on input or output by reversing the ratio. If the transformer is a 4:1 step down with a 480 volt input the output voltage is 120 volts however the secondary is pulling 4 times the amount of current that is flowing in the primary.

Transformers are rated by KVA, frequency and voltage.

In AC we use the term VA instead of Watts. VA is known as apparent power and watts is true power. We will discuss this later when we talk about power factor. In your calculations volts times amps VA is the same as EI. Remember KVA is 1000 VA. Also remember in your exercises following that the power is the same on input and output sides of transformer.

Another area of transformers you must learn is how to figure short circuit value of a transformer (SC). When a short on the secondary of a transformer occurs a large amount of current will flow. Before the protective device has time to operate it will be subjected to all the current that the transformer can produce. The short circuit device must be able to safely interrupt this large amount of current. This is stated as the interrupting capacity of the device. Many workers have been seriously burned or killed by the protective device exploding when it is not capable of interrupting this current.

When you think about a transformer winding it is just a long continuous wire that is coiled around an iron core. Why doesn't it cause a short when a voltage is connected across it? Remember that we talked about how the effect of a coil when placed into an AC circuit. The rising and collapsing of the magnetic field produces a CEMF that holds the current back and the wire itself has a lot of resistance. This creates impedance in the transformer. Impedance of a transformer is expressed in percentage. To calculate how much current a transformer can produce during a short you will use the following formula: $SC = I$ (full load current of transformer) divided by the percentage of Impedance of the transformer. $SC = I / \%Z$

The following formulas can be used to complete exercises and they will be given to you as a handout during the state electrical exam:

Single phase formulas:

TO FIND:

$$\text{Amps when KVA is known} = \frac{\text{KVA} \times 1000}{E}$$

$$\text{Amps when HP is known} = \frac{\text{HP} \times 746}{E}$$

$$\text{Amps when KW is known} = \frac{\text{KW} \times 1000}{E}$$

$$\text{Kilowatts} = \frac{IXE}{1000}$$

$$\text{KVA} = \frac{IXE}{1000}$$

$$\text{HP} = \frac{IXE}{746}$$

$$SC = \frac{I}{\%Z}$$

Let's do the following exercises to familiarize yourself with ratios, voltage, current, and short circuit values in single phase transformers:

No.	E(Primary)	Turns/Ratio	E(Secondary)
1.	480	4:1	_____
2.	240	1:2	_____
3.	_____	4:1	120
4.	_____	1:4	480
5.	120	_____	480
6.	480	_____	240

Answers:

1. 120
2. 480
3. 480
4. 120
5. 1:4
6. 2:1

No	E(Primary)	Turns/Ratio	E(Secondary)
1.	12,470	5:1	=====
2.	7200	2:9	=====
3.	_____	13:1	12,470
4.	_____	5:12	7200
5.	4160	_____	7200
6.	8360	_____	440

Answers:

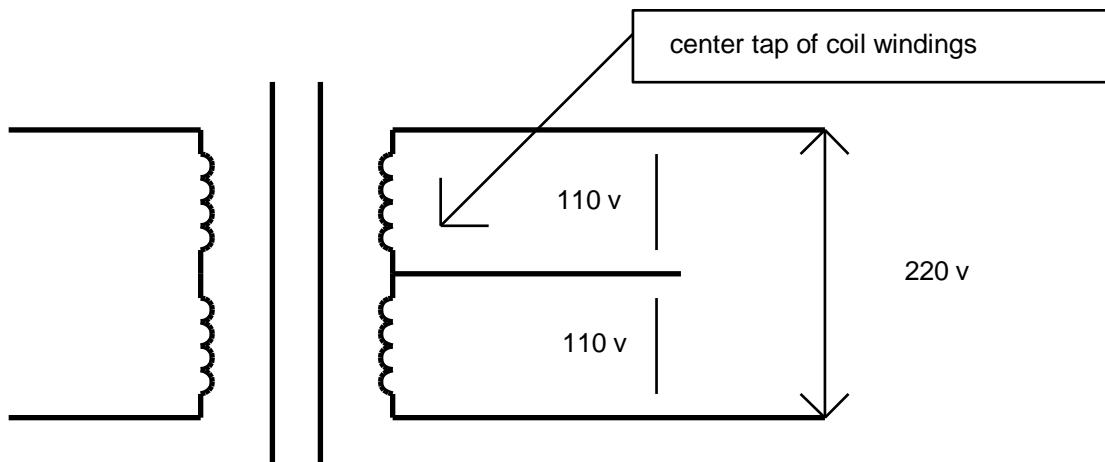
1. 2494
2. 32,400
3. 162,110
4. 3000
5. 1:1.73
6. 19:1

No	KVA	%Z	E(pri)	I(pri)	E(sec)	I(sec)	S/C
1.	50	5	480	_____	120	_____	_____
2.	75	8	240	_____	300	_____	_____
3.	_____	2.5	120	16.67	32	_____	_____
4.	_____	7	48	_____	240	2.08	_____
5.	_____	4	990	_____	480	_____	5208.3

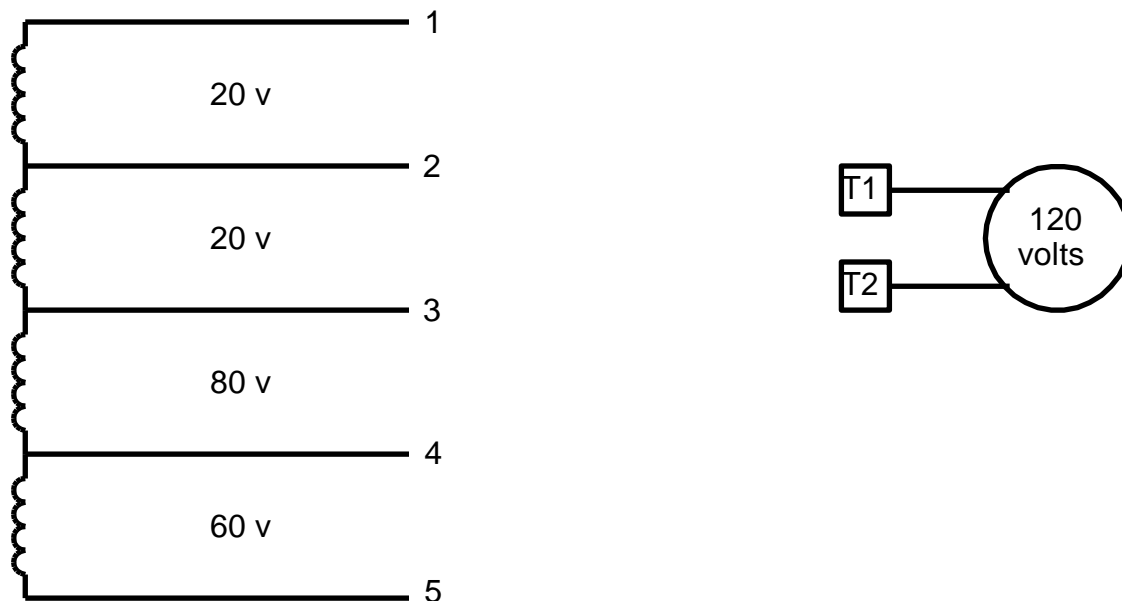
Answers:

1.	104.17	416.67	8333
2.	312.5	250	3125
3.	2	62.5	2500
4.	.5	10.4	29.7
5.	100	101	208.3

The output voltages of a transformer is directly related to the turns ratio of the transformer. By tapping into the transformer at different places on the windings we can get multiple voltages. Probably the one you are most familiar is in your own home. The transformer feeding your house circuit is 220 volts on the secondary side and center tapped at the middle to get 110 volts.

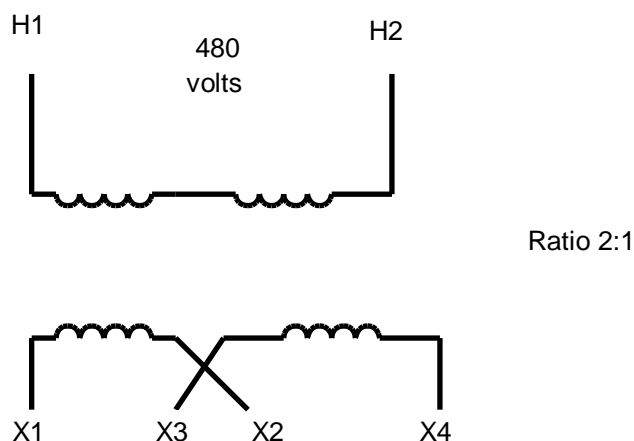


On the exam some times you will have to look at a diagram and select the terminals you would hook to motor leads to obtain proper voltage to operate the motor. It is very simple just add up the voltage between taps to obtain correct voltage. Below is an example:



Hook T leads up on motor to correct terminals to obtain 120 volts to operate the motor. The voltage between terminals 1 and 4 equals 120 volts and the motor leads should be tied to terminals 1 and 4.

As an electrician you will be required to replace a lot of control transformers in electrical circuits. Particular attention should be placed on the diagram of the transformer. Applying the input voltage to wrong terminals could create extremely high voltages and incorrectly wiring the output side can cause damage and danger to equipment and personnel.

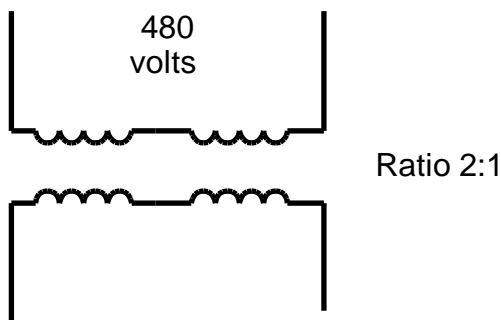


In the above transformer if terminals X3 and X2 are tied together and load is hooked at X1 and X4 the load will receive a voltage of 240 volts. If X1 and X3 are

tied together and X2 and X4 are tied together then the output voltage at these two points is 120 volts.

Probably the most confusing thing they ask on the exam about single phase transformers is if a portion of primary winding or secondary winding shorts out how does it affect the voltage on the output side. Once again use ratios to figure it out. Always draw you a simple diagram and short out the side they refer to and see how it affects output voltage.

Example:



In the above transformer with no winding shorted out the output voltage would be 240 volts.

Now lets short out half of the primary windings this will change the ratio to 1:1, now the output voltage is 480 volts.

If we short out half of the secondary winding the ratio will change to 4:1 and output voltage will decrease to 120 volts.

Simply stating that if we short out or take away primary windings the output-transformer voltage will increase., and if we take away or short out the secondary winding output voltage will decrease. Most of the time on the exam if a person does not draw a simple diagram, such as above and use the ratios, he will miss this question.

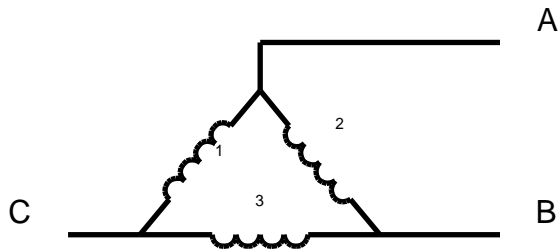
Another way many people miss questions on the exam is not reading the question correctly. Many times they will write out the question and state transformer is single phase and person taking the exam will use the three phase formulas. READ THE QUESTION CAREFULLY

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THREE PHASE TRANSFORMERS

Three phase transformers are three single phase transformers hooked up in a configuration to produce three phase power. We have already stated the advantages of three phase current. The ways we hook the single transformers are delta and wye. Another term electricians use for a wye connected transformer is star.

Delta hooked transformer:

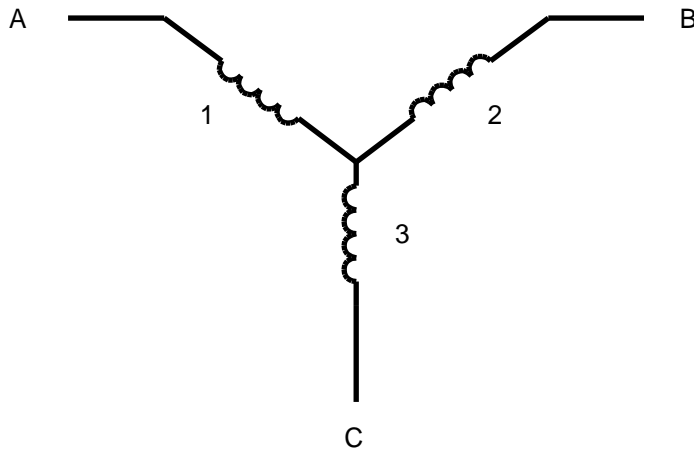


The lines A, B, and C are the phase wires of the three phase system. Another term used on exam is the lines and they are what we think of as the red, black, and white wires. 1,2,and 3 represent the coil windings of three single phase transformers either primary or secondary side hooked in a delta configuration.

If we take a look at the current coming into the transformer bank on lines a, b, or c it has two paths to flow (through the coil windings of two transformers). We have two different currents line current and phase current (coil winding current). We still use 1.732 as a constant to calculate the currents. $I_{line} = I_{phase} \times 1.732$ or $I_{phase} = I_{line}$ divided by 1.732.

The voltage potential between phase wires is the same potential applied across the phase windings or coil windings. The phases are hooked directly across the coil windings. So: Phase to phase voltage on a delta hookup is equal to phase voltage or coil winding voltage.

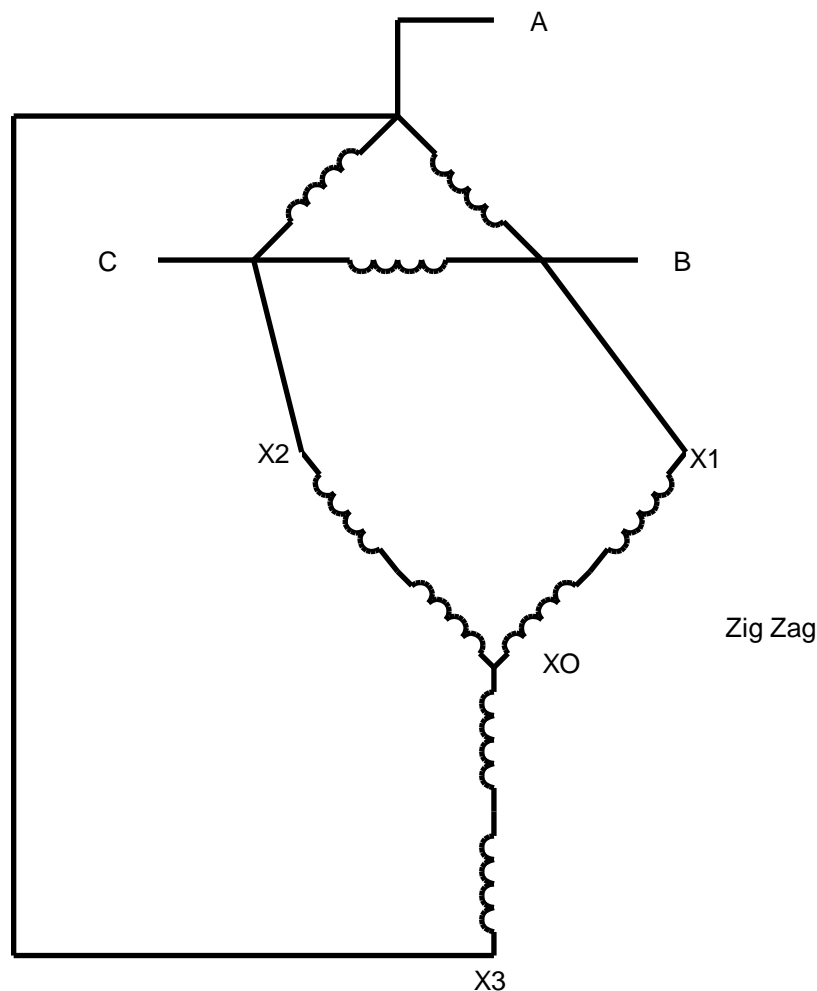
Wye or Star hooked transformer:



The current flowing into the transformers from the lines A, B, and C must go through a phase winding or coil winding. It has only one path to flow. So in a wye configuration the $I_{\text{Line}} = I_{\text{Phase}}$

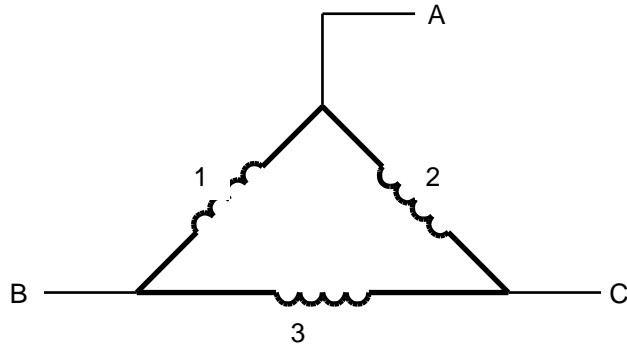
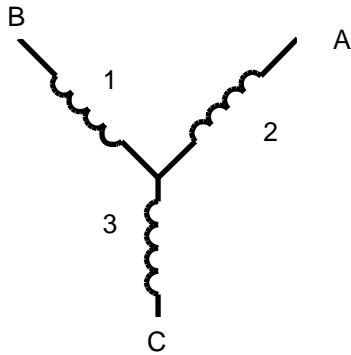
If we look at phase to phase voltage there are two coil winding between the phases. The point where all the coils are tied is called the neutral point. The voltage between the neutral and phase line is called the neutral voltage. Phase to phase voltage = phase to neutral X 1.732
And phase to neutral = phase to phase divided by 1.732.

We can wire the transformers in the configuration that gives us the proper voltages we need on the output side. The neutral point is derived by the nature of the wiring on the wye. Where the leads of each coil windings are tied together gives us this point. However on a delta as shown on page 61 there is no neutral point at the transformer. We must use another device to derive this neutral. Underground we use what we call a Zig Zag Transformer. The zig zag transformer is wound to derive a neutral point and is connected to the transformer to conduct current back to the transformer if a ground fault occurs. Without the zig zag we would have an ungrounded delta system which is not allowed underground. A zig zag is hooked as shown below:

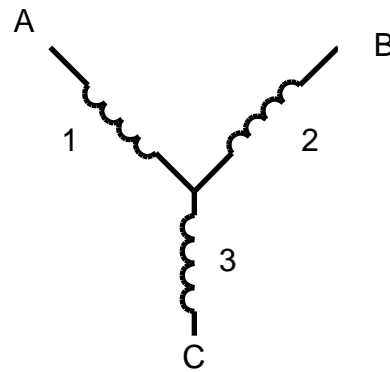
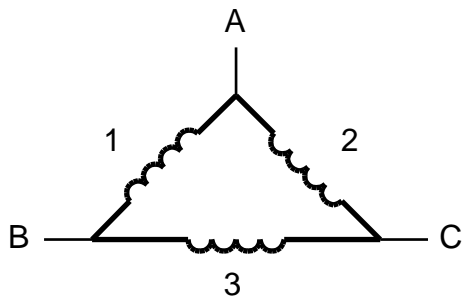


X1, X2, and X3 of the zig zag transformer are tied to a phase. XO is the derived neutral point. The voltage from any of the phase lines A, B, or C to XO is the phase to neutral voltage of the delta transformer. It is calculated the same way using the same formulas that you used above on the wye transformer.

Remember that the transformers are single phase connected to produce three phase current. The ratios are fixed and can not be changed. Ratios in three phase work the same way as they did in single phase calculations for transformers. When the three transformers are hooked Delta – Delta or Wye – Wye you can use the ratio direct to calculate voltage and inversely to calculate current. Where the problems arise are when the transformer primary is hooked wye and secondary delta or primary delta and secondary wye. If you look at where the coils lie in the hook up it makes it easier to find voltages. Look at diagrams below:

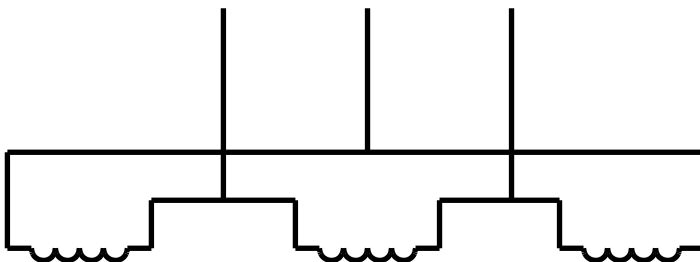


The primary side of each transformer is hooked from phase to neutral on the primary side. So the voltage applied is phase to neutral voltage. On the secondary side the coil windings or secondary winding is phase to phase. If we use phase to neutral voltage on primary and apply the ratios it gives us the phase to phase voltage on secondary.

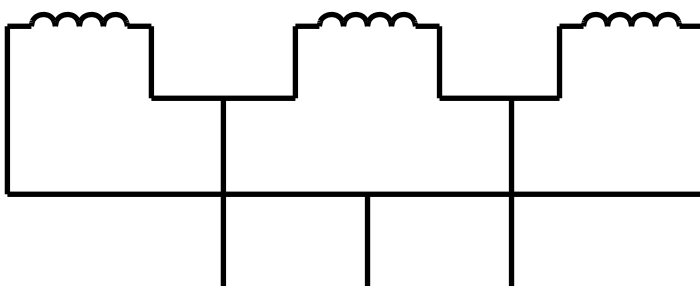


In the above drawing the primary windings of the transformer are hooked across phase to phase. The secondary windings of the transformer are hooked from phase to neutral. If you look at where the coil windings are located on each side of the transformer and apply the ratio it makes it must easier to work transformer problems on the exam.

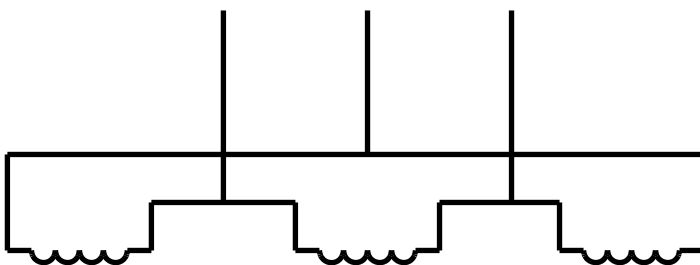
Identify the 3 phase transformer connections:



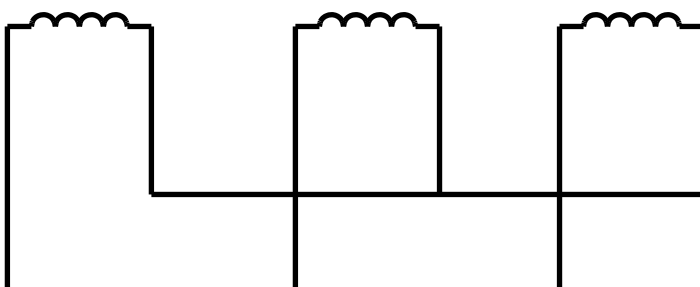
1. DELTA / DELTA



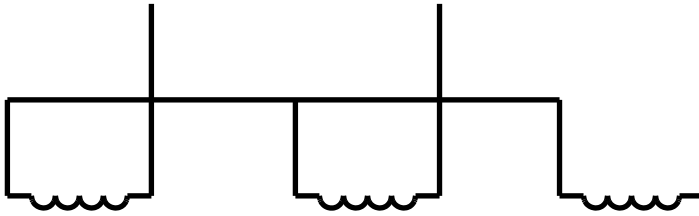
1.



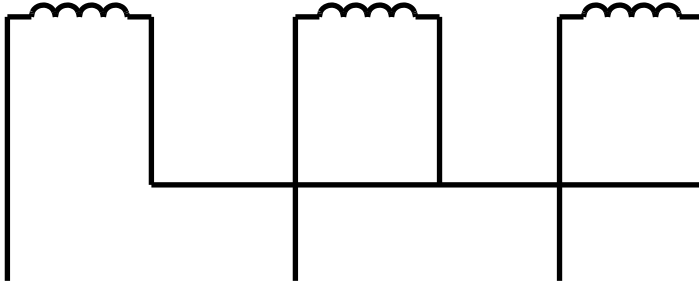
2. DELTA / WYE



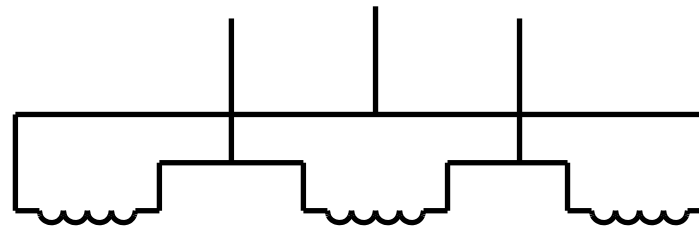
2.



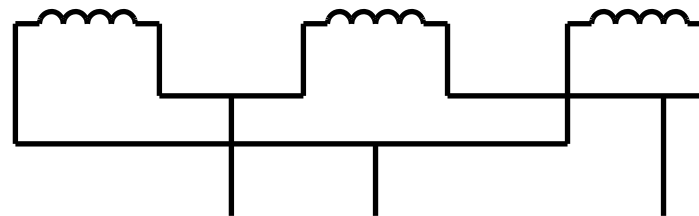
3.WYE / WYE



3.

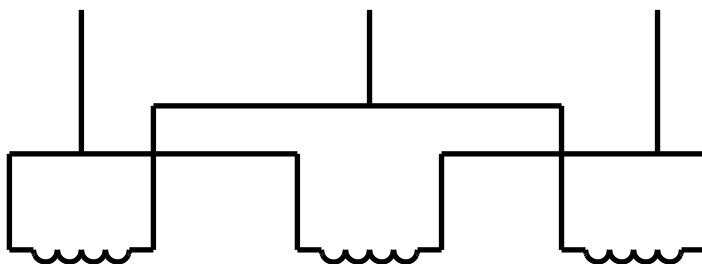


4.DELTA / DELTA

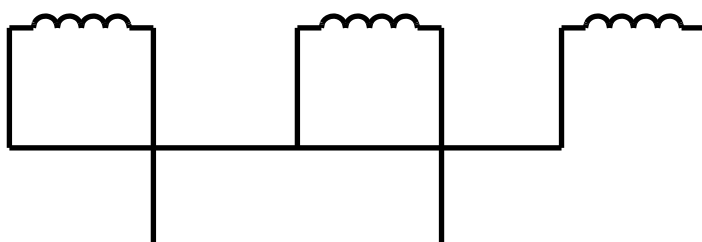


4.

1.
2.

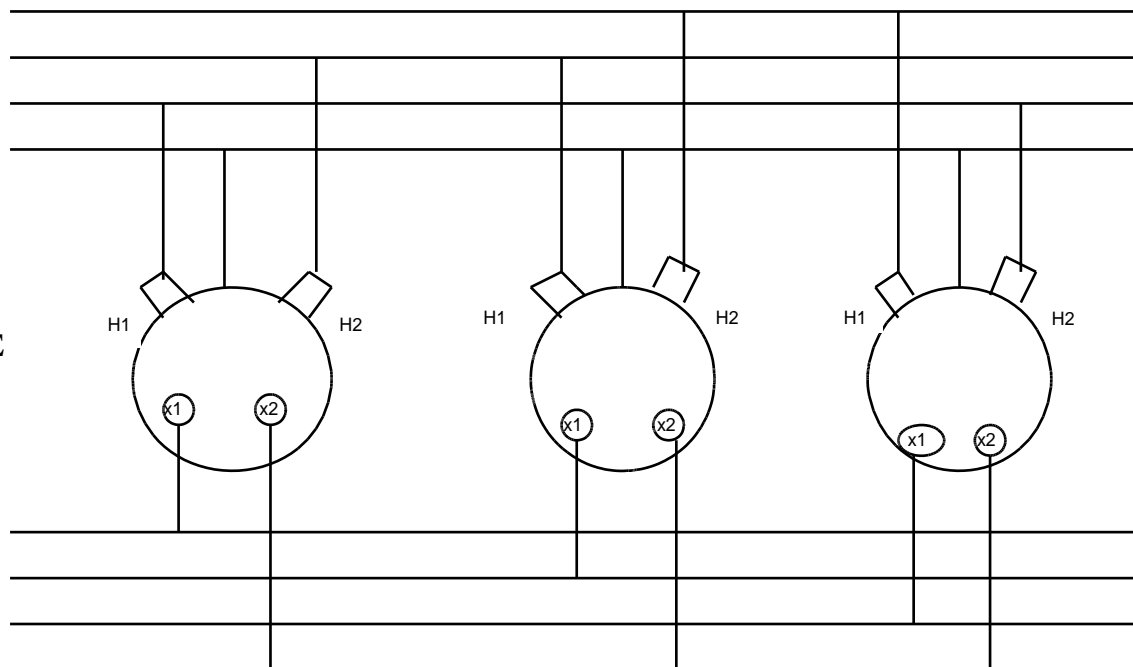


5. DELTA / WYE



5.

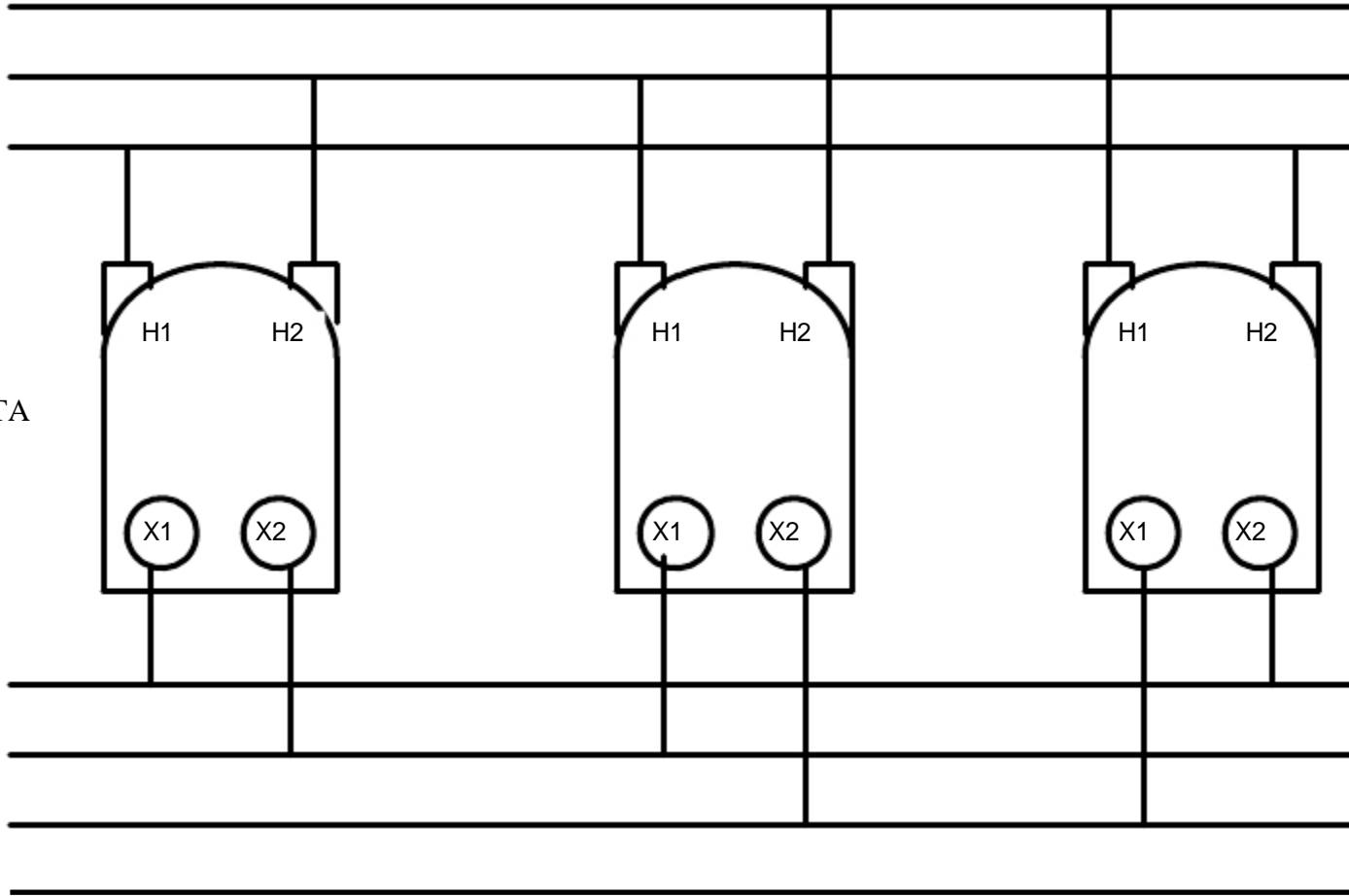
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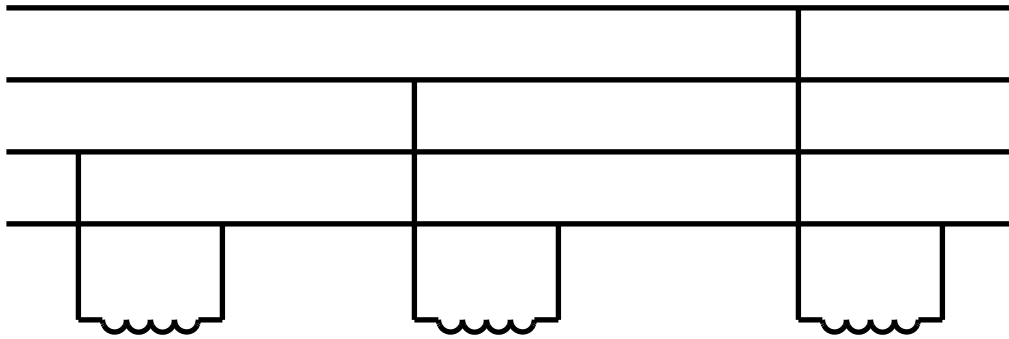


6. DELTA / WYE

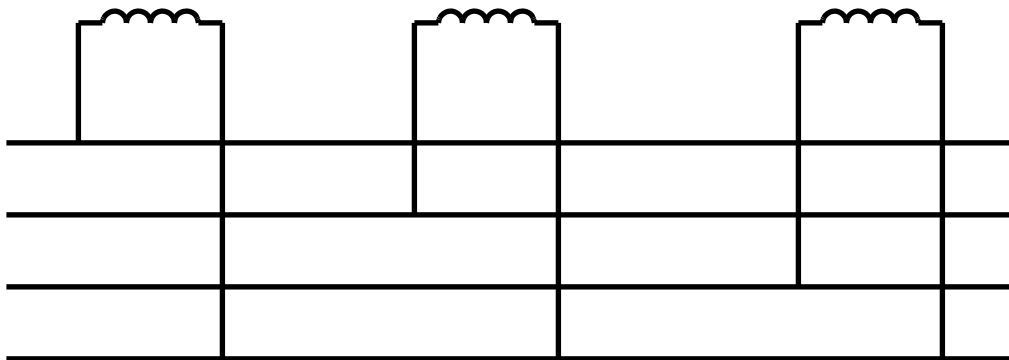
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7. DELTA / DELTA



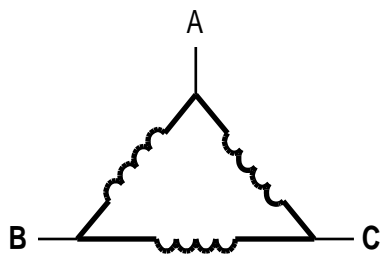


8. WYE /WYE

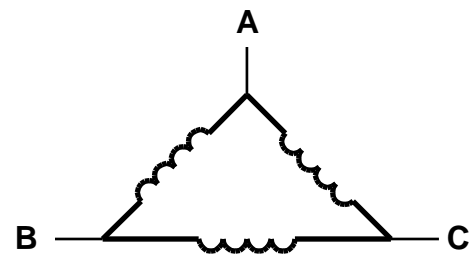


8.

Let's work a few voltage problems to familiarize our self with three phase transformer calculations:



Primary

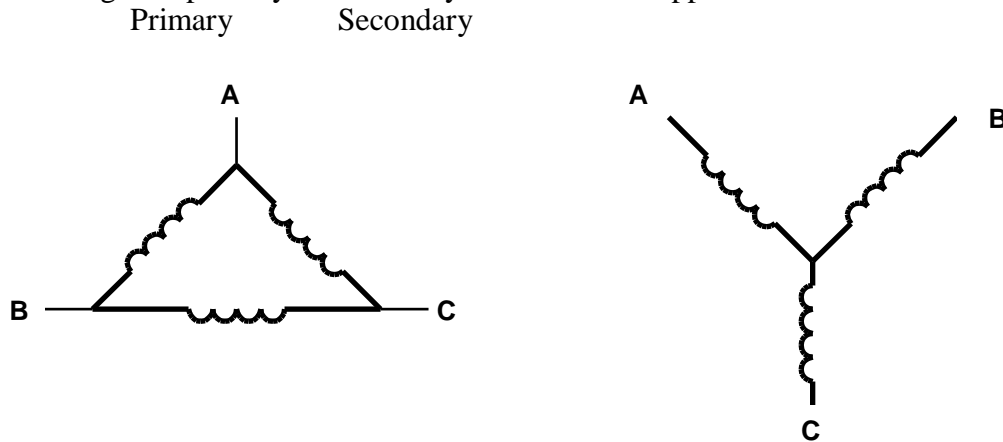


Secondary

Let us say the primary voltage of the above transformer is 7200 volts phase to phase. The ratio of the transformer is 15 : 1. $7200/15 = 480$ volts This is the phase to phase on the secondary side. The phase to neutral on primary $7200 / 1.732 = 4160$
The phase to neutral on secondary side is $480 / 1.732 = 277$ volts.

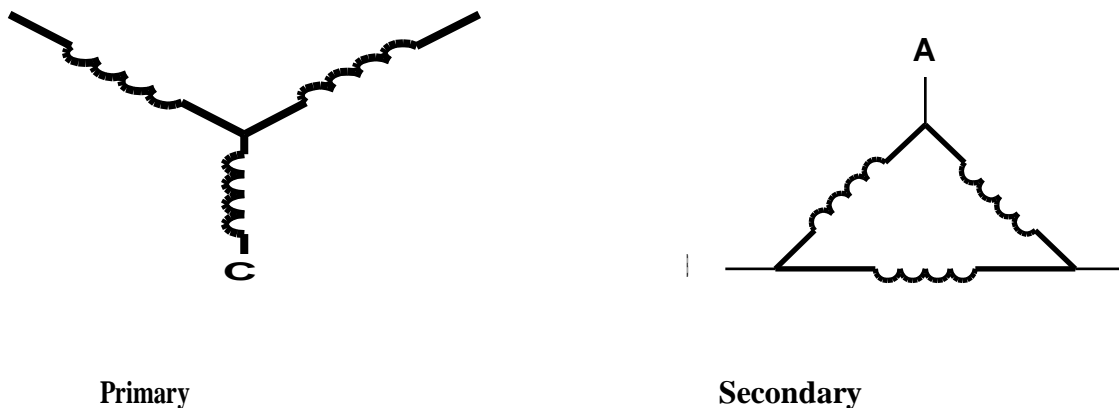
If the above transformer was hooked wye wye the voltages are figured the same.

Lets change the primary or secondary and see what happens:



Lets use the same voltage as before 7200 volts phase to phase on the primary with a 15 : 1 Ratio.

$7200 / 15 = 480$ The secondary windings are phase to neutral on the wye secondary so the phase to neutral voltage of the secondary is 480 volts. Phase to phase is $480 \times 1.732 = 831$ volts. The phase to neutral on the primary is still 4160.



Lets use the same voltage 7200 volts phase to phase on the primary with a 15 : 1 Ratio. Now with the 7200 volts applied phase to phase on primary the coil winding only sees a phase to neutral voltage. $7200 / 1.732 = 4160$ volts

The secondary coil windings see a voltage potential of $4160 / 15 = 277$ volts and this is phase to phase on the secondary. The phase to neutral of the secondary is $277 / 1.732 = 160$ volts.

Now you can see we can get different voltages on the output of the transformers by changing the hookup of the primary and secondary.

The following formulas are used to calculate current, KVA, and short circuit values for three phase transformers:

<u>TO FIND</u>	<u>THREE PHASE</u>
AMPS (If you know HP)	$\frac{HP \times 746}{E \times 1.732}$
AMPS (If you know KW)	$\frac{KW \times 1000}{E \times 1.732}$
AMPS (If you know KVA)	$\frac{KVA \times 1000}{E \times 1.732}$
KW (If you know amps and volts)	$\frac{I \times E \times 1.732}{1000}$
KW (If you know HP)	$\frac{HP \times 746}{1000}$
KVA (If you know Amps and Volts)	$\frac{I \times E \times 1.732}{1000}$
HP (If you know amps and volts)	$\frac{I \times E \times 1.732}{746}$
SHORT CIRCUIT AMPS	$\frac{I_{(Full Load)}}{\%Z}$

500 KVA
 7200 Volts phase to phase
 primary
 5% Z
 Ratio 15:1



Calculate the following:

1. $I_{(Line)}$ on primary
2. Phase to neutral voltage on primary
3. Phase-phase voltage secondary
4. Phase-neutral voltage secondary
5. $I_{(Line)}$ on secondary
- 6.. Short Circuit value on secondary

Solutions:

$$1. I = \frac{KVA \times 1000}{E \times 1.732}$$

$$I = \frac{500 \times 1000}{7200 \times 1.732}$$

$I = 40$ amps on primary at full load

1. Phase to neutral = $7200 / 1.732 = 4160$ volts
2. Phase to phase on secondary
 $7200 / 15 = 480$ volts
4. Phase to neutral = $480 / 1.732 = 277$ volts
5. $I = \frac{KVA \times 1000}{E \times 1.732}$

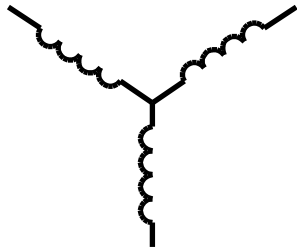
$$I = \frac{500 \times 1000}{480 \times 1.732}$$

$I = 601$ amps

$$7. SC = I / \%Z$$

$$SC = 601 / 5\% = 12020 \text{ amps}$$

500 KVA
 7200 Volts phase to phase
 primary
 5% Z
 Ratio 15 :1



Calculate the following:

1. Phase-neutral voltage on primary
2. $I_{(Line)}$ on primary
3. Phase to phase voltage on secondary
4. Phase to neutral voltage on secondary
5. $I_{(Line)}$ on secondary
6. SC value on secondary

Solutions:

1. phase to neutral = phase to phase / 1.732
 Phase to neutral = $7200 / 1.732 = 4160$ volts

$$2. I = \frac{Kva \times 1000}{E \times 1.732}$$

$$I = \frac{500 \times 1000}{7200 \times 1.732}$$

$$I = 40 \text{ amps}$$

3. The primary side of the transformer or phase voltage is the phase to neutral voltage on primary side which is 4160 volts. Now use your ratio to determine the secondary voltage of transformer (Delta connected so phase voltage of secondary side of transformer is the same as phase to phase)

$$4160 / 15 = 277 \text{ volts}$$

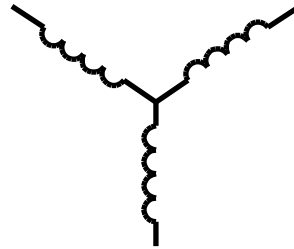
4. Phase to neutral on secondary is $277 / 1.732 = 160$ volts

$$5. \quad I = \frac{500 \times 1000}{277 \times 1.732}$$

$$I = 1042 \text{ amps}$$

$$5. \text{ SC} = 1042 / 5\% = 20844 \text{ amps}$$

500 KVA
7200 Volts phase to phase
primary
5% Z
Ratio 15 :1



Calculate the following:

1. Phase to neutral primary side
2. $I_{(Line)}$ on primary side
3. Phase to phase on secondary
4. Phase to neutral on secondary
5. $I_{(Line)}$ on secondary
6. SC value on secondary

Solutions:

$$1. 7200 / 1.732 = 4160 \text{ volts}$$

$$2. I = \frac{500 \times 1000}{7200 \times 1.732}$$

$$I = 40 \text{ amps}$$

3. The primary side of the transformer is connected phase to phase so $7200 / 15 = 480$ volts. When we look at the secondary side of the same transformer it is connected phase to neutral. So the phase to neutral voltage is 480 volts.

Phase to phase is $480 \times 1.732 = 831$ volts.

4. We already calculated the phase to neutral as 480 volts.

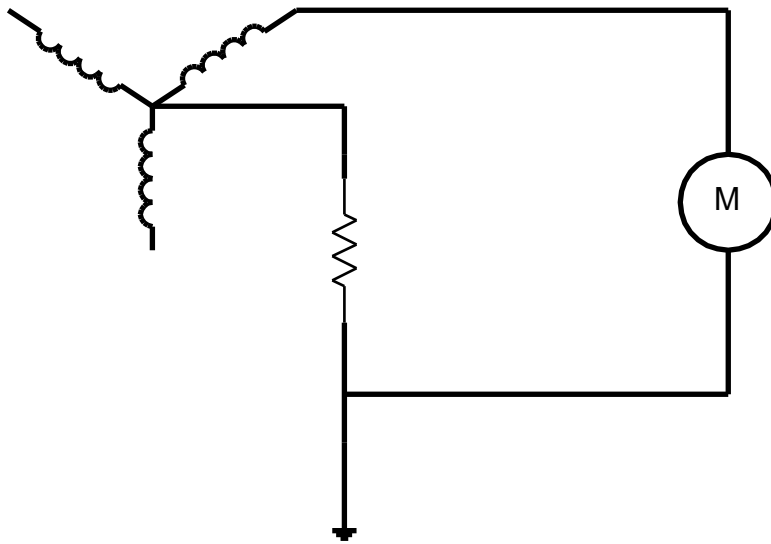
$$5. I = \frac{500 \times 1000}{831}$$

$$831 \times 1.732$$

$$I = 347 \text{ amps}$$

$$6. \text{ Short circuit} = 347 / 5\% = 6948 \text{ amps}$$

Now let us add one other step to the above problems. We must be able to calculate the resistance of a grounding resistor to limit the current to 25 amps. The grounding resistor only sees the phase to neutral voltage of the transformer. Look at the following problem:



If we only use one phase and it goes to ground at the motor and you trace the circuit it is a series circuit with one resistor in it and it sees the phase to neutral voltage of the circuit. Ideally all the voltage would be dropped at the resistor with no voltage on the frame of the motor.

If we must limit the current under a ground fault to 25 amps the minimum resistance value of the resistor will depend upon the amount of voltage it sees across the resistor (phase-neutral).

We will give the motor an operating voltage of 480 volts. The phase to neutral voltage of the source will be 277 volts.

$$E = I \times R \text{ or } R = E / I$$

Minimum resistance allowed by law in this circuit is $R = 277 / 25 = 11 \text{ ohms}$.

You can be assured there will be a grounding resistor problem on the exam.

When taking exam be sure to look at question and see if single phase or three phase transformer and you are using the correct formulas.

While we are on the subject of grounding resistors let's discuss them further. The main purpose of a grounding resistor is to limit the voltage on the frame of a piece of equipment to protect the operator from electrical shock. The CFR requires that the maximum voltage that can appear on the frame is 40 volts, when the voltage is low or medium voltage. We said earlier that under ideal conditions the grounding resistor dropped all the voltage. In real life this is impossible due to connections of the ground wire and the resistance of the ground wire itself. We call any voltage drops outside the resistor as external voltage drops from the resistor. External voltage drops cause voltage on the frame of the equipment. When using ground wire monitors to continuously monitor the grounding wire the external resistance must be kept below a certain resistance. If we use ohms law and say it must be kept at 40 volts or below on the frame we can calculate the maximum external resistance according to the size of the grounding resistor. If the grounding resistor is 25 amps then $40 / 25 = 1.67$ ohms. If the grounding resistor is 15 amps then $40 / 15 = 2.67$ ohms. If the ohms increase above these values the voltage rises in proportion on the frames of equipment under a ground fault.

The law requires on high voltage the maximum amount of voltage that can appear on the frames of equipment under a ground fault is 100 volts. If the high voltage grounding resistor is 25 amps then the maximum external resistance is limited to 4 ohms or less.

Grounding resistors must be located at the source transformer. Although grounding resistors only see phase to neutral voltage they must be isolated from ground equal to the phase to phase voltage of the system they are connected.

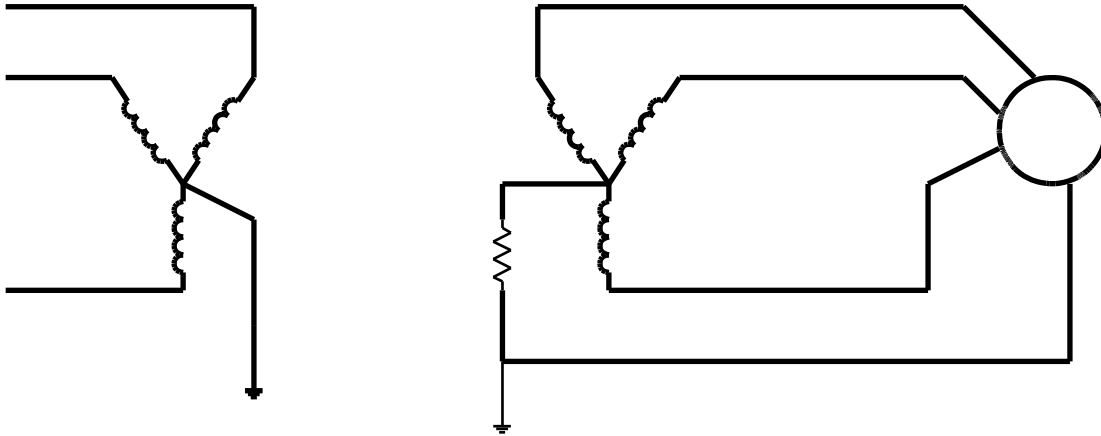
Another way they may present a transformer problem on exam is to hook a motor to secondary side and ask you to calculate both full loads of transformer and the actual current that is being pulled by motor on primary and secondary. Below is an example from the Ky study guide:

80 KVA

5% Z

Ratio
7.56 : 1

Sec. Voltage Phase-Phase = 550 volts
10 Horsepower Three Phase Motor



1. This is what type of transformer connection? Wye – Wye
2. Find sec. voltage phase to neutral: $550 \text{ volts} / 1.732 = 317.55 \text{ volts}$.
3. Find pri. Voltage phase – phase: $550 \times 7.56 = 4158 \text{ volts}$
4. Find primary voltage phase – neutral: $4158 \text{ volts} / 1.732 = 2400.69 \text{ volts}$.
5. Find the resistor rating in ohms (25 ampere rating): $317.55 \text{ volts} / 25 \text{ amps} = 12.7 \text{ ohms}$.
6. Find sec full load line current rating: $80 \text{ KVA} \times 1000 / 550 \times 1.732 = 83.98 \text{ amps}$.
7. Find sec. short circuit current: $83.98 / 5\% = 1679.6 \text{ amps}$.
8. Find actual sec. line current: $10 \times 746 / 550 \times 1.732 = 7.83$.
9. Find actual sec. total current: $7.83 \times 1.732 = 13.56 \text{ amps}$.
10. Find actual sec. total power: $10 \text{ HP} \times 746 = 7460 \text{ watts}$.
11. Find actual pri. Power: $10 \text{ HP} \times 746 = 7460 \text{ watts}$
12. Find actual pri. Total current: $7460 \text{ watts} / 4158 \text{ volts} = 1.79 \text{ amps}$.
13. Find actual pri. Line current: $1.79 \text{ amps} / 1.732 = 1.03 \text{ amps}$.
14. Find the minimum recommended wattage rating for the above resistor:
 $25 \text{ amps} \times 317.55 = 7938.75 \times 150\% = 11908.125 / 1000 = 11.9 \text{ KVA}$

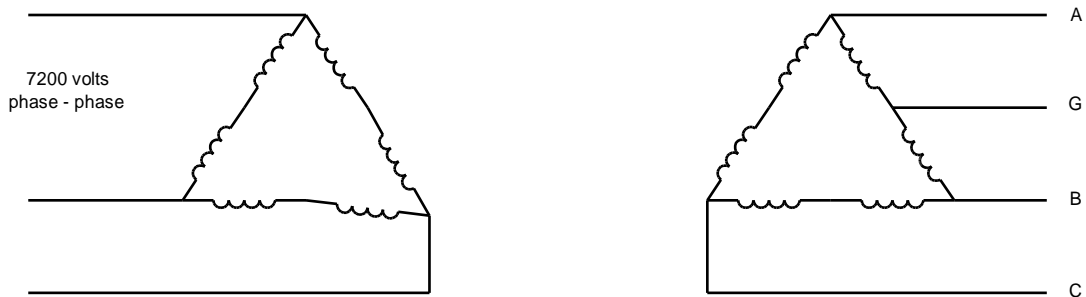
Another way to calculate the actual primary line current is:

$10 \text{ HP} \times 746 / 4158 \text{ volts} \times 1.732 = 1.03 \text{ amps}$.

This is one of the formulas given to you on your handout.

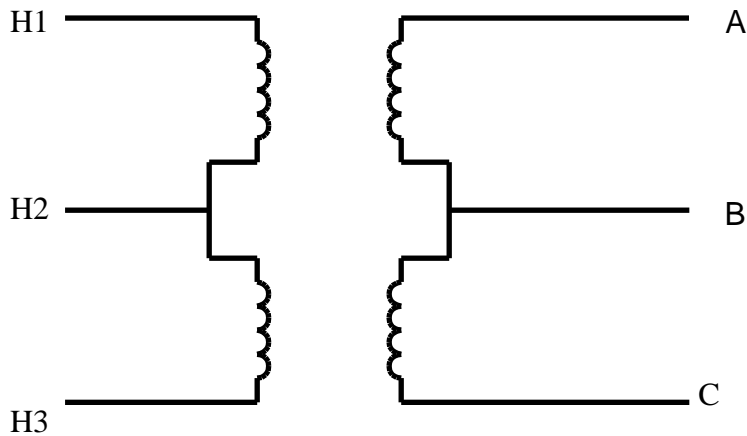
There are other transformer configurations you will need to become familiar with and they are shown below:

Ratio
15 : 1



1. This is what type of transformer connection? Delta – Delta.
2. Find secondary voltage phase to phase: $7200 \times 1/15 = 480$ volts.
3. Find secondary voltage from phase A to G: $480/2 = 240$ volts.
4. Find secondary voltage from phase B to G: $480/2 = 240$ volts.
5. Find secondary voltage from phase C to G: $240 \times 1.732 = 415.68$ volts.
6. A transformer which is grounded in this fashion is commonly referred to as what type of system? High-Leg Delta, Wildcat System, or a Red-Leg system.
7. Some advantages of this type of system are two different single phase voltages are available as well as three phase system.
8. A disadvantage is mistakes are often made causing damage to single phase loads and it is not resistant grounded.
9. This type of system is only allowed on stationary equipment on the surface.
10. According to the NEC, Phase C above must be identified in what fashion? Durably and permanently marked by an outer finish that is orange or by other effective means 384-3(e). Phase conductor and bus bar must be marked the same way.

Sometimes on the surface you have three individual transformers wired three phase. If one transformer fails you can rewire with two transformers to obtain a three phase supply. This is called an Open-Delta. The new arrangement with only two transformer will only supply 58% of the original KVA. Below is an example:



Another type of transformer is the auto-transformer. This type of transformer taps into the windings for different voltages. When used with resistance grounded systems with two grounding resistors it allows more fault current than allowed by law.

Do the following exercises to help you on transformer calculations (fill in the blanks):

No.	CONNECTIONS	E_{p-n} Pri.	E_{p-p} Pri.	RATIO	E_{p-n} Sec.	E_{p-p} Sec
1	Y-Y		480	1:6		
2	Delta-Delta	138.57		3:2		
3	Delta – Y			3:1		7200
4	Y – Delta		990	7:3		
5	Delta – Y	240		9:7		
6	Y – Delta		34,500			7200
7	Y – Delta		550	1.323:1		240

Answers:

1.	277.14				1662.84	2880
2			240		92.38	160
3	7200.42	12471.12			4157.04	
4	571.59				141.44	244.97
5			415.68		323.31	559.97
6	19919.17			2.77:1	4157.04	
7	317.55				138.57	

MORE PROBLEMS:

NO	KVA	%Z	$E_{(P-P) Pri.}$	$I_{line Pri}$	$E_{(P-P) Sec.}$	$I_{LINE Sec.}$	$I_{S/C}$
1	100	4	240		120		
2	300	6	4160		480		
3		3	480	180.43	550		
4		2	4160		990	437.4	
5		5	7200		1040		5551.6

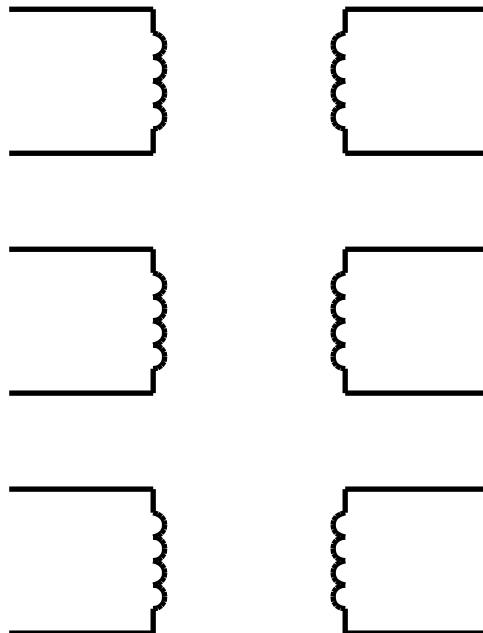
ANSWERS:

1	240.57	481.14	12028.5
2	41.64	360.85	6014.17
3	150	157.46	5248.67
4	750	104.09	21870
5	500	40.09	277.58

CONNECT THE TRANSFORMERS BELOW TO OBTAIN 160 VOLTS phase to phase:

15 : 1

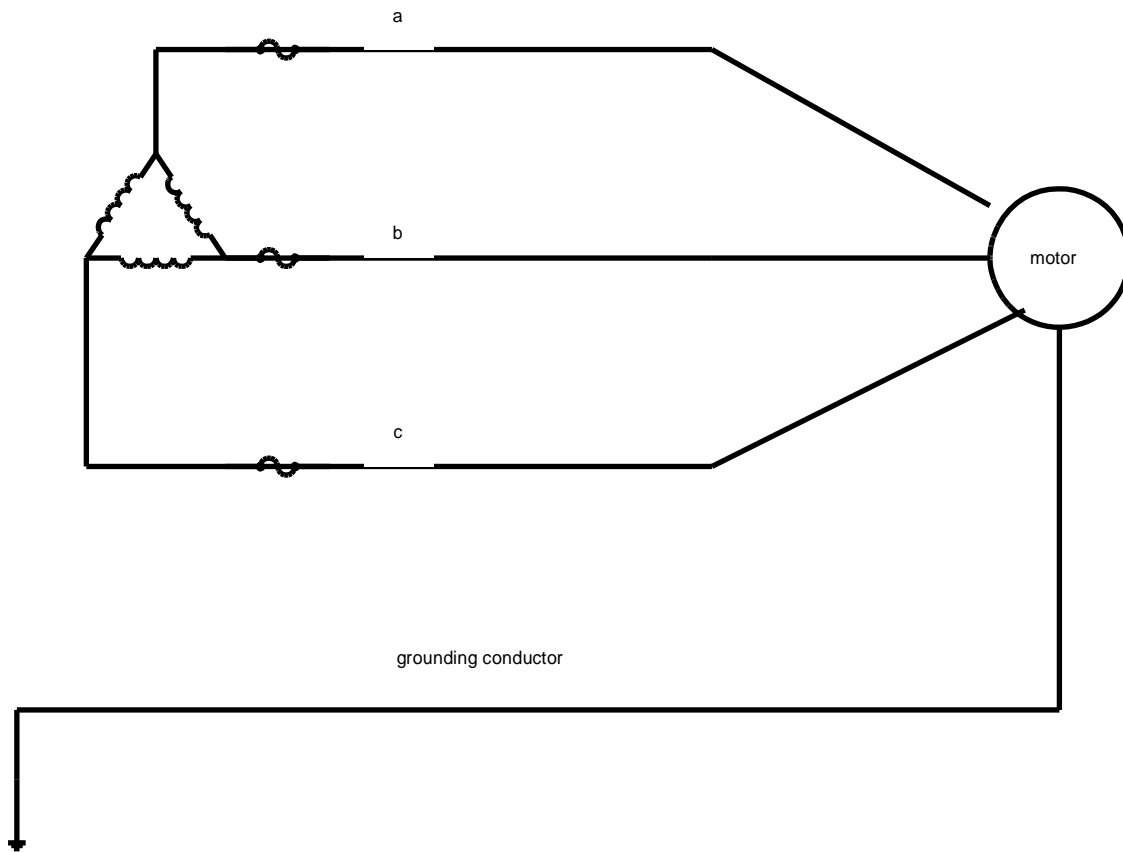
4160 volts
phase to phase



CORRECT ANSWER IS WYE – DELTA

There are two types of grounding systems used on surface of coal mines: System and Equipment Grounding. System grounding is resistance grounding and only one phase grounded will cause the breaker to trip.

The following is an example of equipment grounding (Ungrounded Delta).



The fuses in the phase lines are the ground fault protection. There is no physical connection to the delta transformer from ground. If we read voltage from any phase to ground it will read 277 volts if system is 480 volts three phase. Now let us say that phase a is grounded at the motor. The motor will continue to run the same as before even with a phase grounded because there is no current flow back to transformer or leakage to ground. If voltage is read from phase a to ground it will read zero because it is the same potential. Voltage read from phases b and c to ground will read 480 volts because it is reading same as phase to phase because phase a and ground are the same potential. The system will continue to operate until a ground is developed in either b or c phase. This will cause a phase to phase short and blow the fuses.

Ungrounded Delta systems are only allowed on the surface and used with stationary equipment only. A System Grounding System (Resistance Grounding) is required everywhere underground and for mobile and portable on the surface. Indicating lights on each phase should be used with this ungrounded delta system that light goes out when the phase has a ground. This provides a quick reference if a ground occurs in a phase and can be repaired before another phase grounded causes the phase to phase condition.

AC Theory and Application

1. Q. What type of 3-phase AC motor is used most often around a mine?

A. Squirrel-cage induction motor.

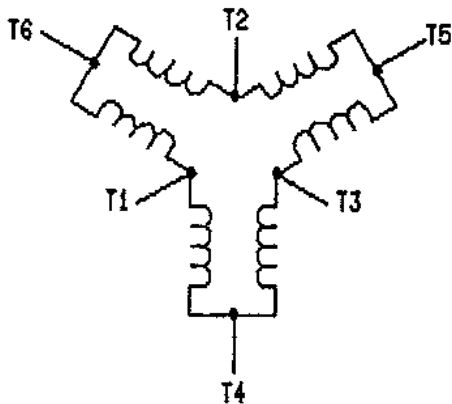
2. Q. Which of the following is not needed when using an ohmmeter to determine if a motor is grounded?

A. Disconnect the frame-grounding conductor.

3. Q. A wound-rotor induction motor has all the following EXCEPT:

A. Squirrel-cage rotor.

4. Q. A 3-phase, 2 speed, constant torque motor is running at fast speed. The motor windings are connected wye for fast speed. Motor leads T4, T5 and T6 are connected to the line leads. Motor leads T1, T2 and T3 should be:



A. Tied together

5. Q. What type motor is a wound-rotor induction motor?

A. A.C.

6. Q. When troubleshooting a circuit with a bank of capacitors, what precautions must be taken?

A. The capacitors should be discharged.

7. Q. The property of an electrical circuit that opposes any change in voltage is called:

A. Capacitance.

8. Q. What is the danger when working around capacitors?

A. An electrical shock hazard may exist.

9. Q. What is a capacitor?

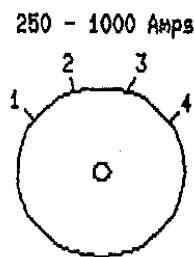
A. A device used to store electrical energy.

10. Q. The combined capacitance of two capacitors in parallel is:

A. The sum of the two capacitors.

11. Q. If the adjustable breaker provides an instantaneous trip protection for a No.4 cable, at what point would the electrician set the trip value?

- a. Point 4.
- b. Point 3.
- c. Point 2.
- d. Point 1.



A. Point 2

APPENDICES	
1. Table taken from 30 CFR 75.601-1	
Conductor size AWG or MGM	Maximum allowable circuit breaker instantaneous setting (amperes)
14	50
12	75
10	150
8	200
6	300
4	500
3	600
2	800
1	1,000
1/0	1,250
2/0	1,500
3/0	2,000
4/0	2,500
250	2,500
300	2,500
350	2,500
400	2,500

12. Q. Three-phase AC underground cables must be provided with overcurrent protection using a:

A. Circuit Breaker.

13. Q. Why is 440-volt, three-phase power more commonly used in mining than 220-volt, three-phase power?

A. Because 440-volt power draws less current so cables and control circuit wiring can be smaller.

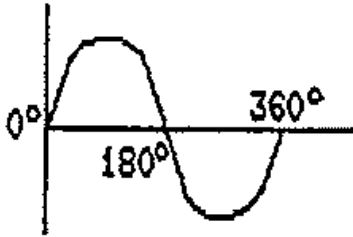
14. Q. Current that changes periodically in direction is:

A. Alternating current.

15. Q. Define alternating current:

A. Current changing constantly in magnitude and periodically in direction.

16. Q. The wave form shown below is a:



Sine wave of single-phase AC voltage.

17. Q. The property of an electric circuit that opposes any change in current is called:

A. Inductance.

18. Q. What position of a selector switch using a voltmeter would you select to check a 120-volt AC circuit to obtain the most accurate reading?

A. 200 volts AC.

19. Q. Operating coils, motors, transformers, relays and solenoids depend upon:

A. Electro-magnetism for their operation.

20. Q. Alternating current may be defined as:

A. Current that changes constantly in magnitude and periodically in direction.

21. Q. Current in an AC circuit may be measured by:

A. Clamp-on ammeter.

22. Q. The most reliable method to use to determine whether or not the heart has stopped is by checking the:

A. Carotid pulse, which is located in the neck next to the Adam's apple.

23. Q. What is the first step to be followed in aiding a victim of electrical shock?

A. Check to make sure that the victim is not still in contact with the electricity.

24. Q. Which of the following is NOT a symptom of electrical shock?

A. Hyperventilation.

25. Q. At what rate should mouth-to-mouth resuscitation be applied?

A. 12 to 15 times a minute.

26. Q. A burn causing a blister is classified as a:

A. Second-degree burn.

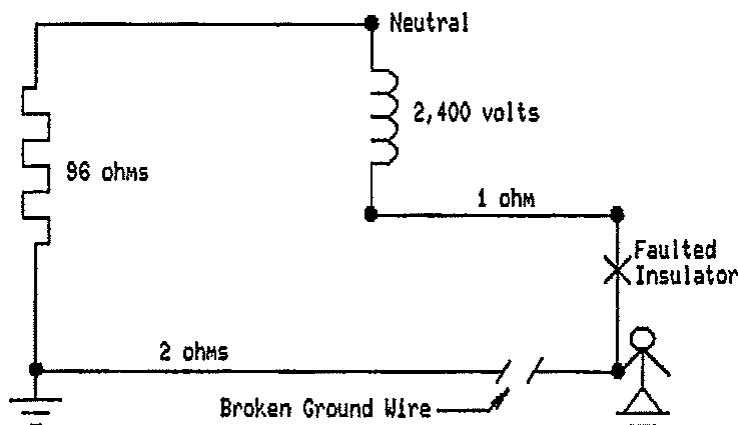
27. Q. How can you tell if a victim receiving mouth-to-mouth resuscitation is getting air into the lungs?

A. The chest should rise or inflate.

28. Q. How should clothing be removed from a burn?

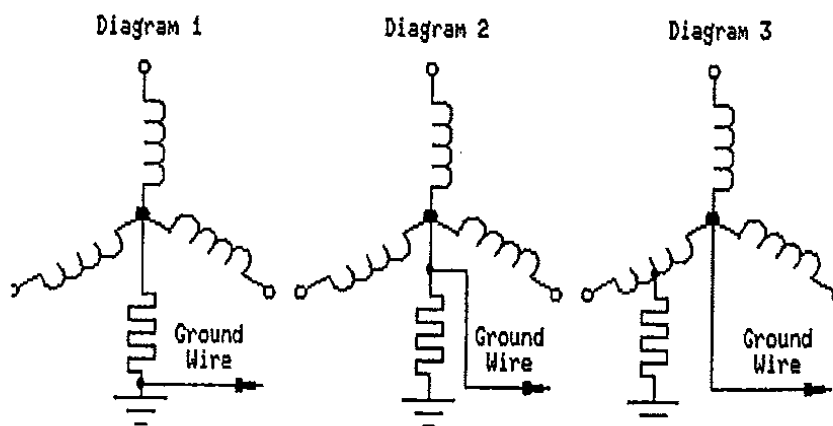
A. Cut around clothing that has adhered to the burned area.

29. Q. No current flows through the ground wire. If a miner touches a power center mounted on rubber tires, what, if any, voltage does the miner feel?



A. 2,400 Volts

30. Q. Which illustration shows a properly installed grounding resistor?



A. Diagram 1

31. Q. Under fault conditions, the grounding resistor in a high voltage circuit limits the voltage drop in the grounding circuit external to the resistor to not more than:

A. 100 volts.

32. Q. What should the duty rating of a grounding resistor be?

A. Continuous.

33. Q. If current were flowing through a grounding resistor in a 440-volt, resistance-grounded system, this would probably be because:

A. Grounded phase and ground fault devices were not operating.

34. Q. Where should grounding resistors be located?

A. At the source transformer.

35. Q. Should a ground fault occur, what device can be installed to limit the current in the neutral of a three-phase AC system?

A. A grounding resistor.

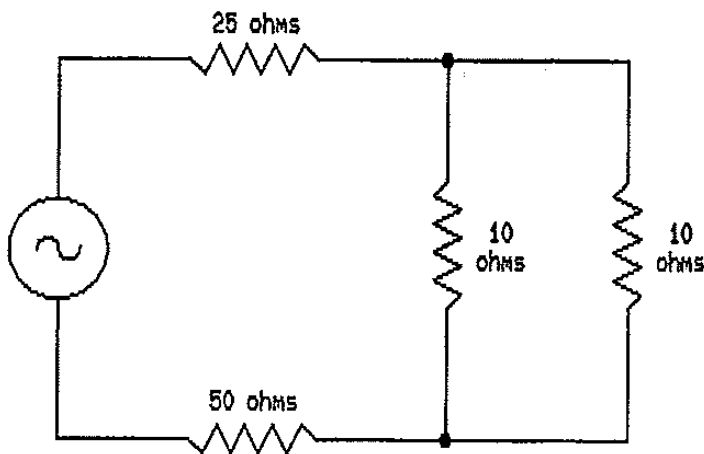
36. Q. High voltage is used to transmit power over long distances:

A. Because less current flowing at high voltage causes less line loss per kilowatt.

37. Q. The neutral ground-bed electrical power system of an underground mine should be separated from the lightning arrestor grounds by at least:

A. 25 feet.

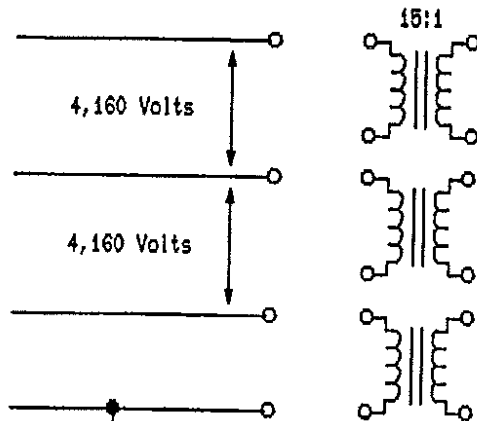
38. Q. What is the equivalent resistance of the circuit?



A. 80 Ohms

- 39. Q. Which of the following does a squirrel cage induction motor have?**
- A. Stator windings.
- 40. Q. How do you change the direction of a 3-phase AC motor?**
- A. Reverse any two-phase leads.
- 41. Q. The following motor leads are brought out of a 3-phase motor (T1, T2, T3, T4, T5, T6). This motor is probably for:**
- A. Two speeds.
- 42. Q. The speed of an alternating current, squirrel-cage induction motor is:**
- A. Nearly constant.
- 43. Q. What happens to a motor that is connected to a three-phase cable when two of the cable's leads are reversed?**
- A. The motor rotation is reversed.
- 44. Q. If any two-phase wires are reversed on a three-phase motor, the motor will:**
- A. Reverse its rotation.
- 45. Q. Which of the following is NOT true about AC power?**
- A. It provides good speed control.
- 46. Q. A solenoid coil is:**
- A. An electromagnet.
- 47. Q. The standard frequency of power supplied by the power company is:**
- A. 60 cycles per second (60 Hertz).
- 48. Q. The standard frequency of alternating current used at a mine is:**
- A. 60 Hertz
- 49. Q. The minimum allowable size for trailing cables for mobile haulage equipment powered by alternating current is:**
- A. No.6 AWG.
- 50. Q. A transformer has 2,000 turns in the primary and 500 turns in the secondary. The primary voltage is 3,200 volts. What is the secondary voltage?**
- A. 800 volts.

51. Q. How should the 3 transformers be wired to obtain 480 volts, phase-to-phase, in the secondary?



A. Delta-Wye

52. Q. When not connected to a load, the secondary leads of a current transformer should be:

A. Shunted and taped.

53. Q. The primary leads of a single-phase transformer should be connected to the:

A. H terminals.

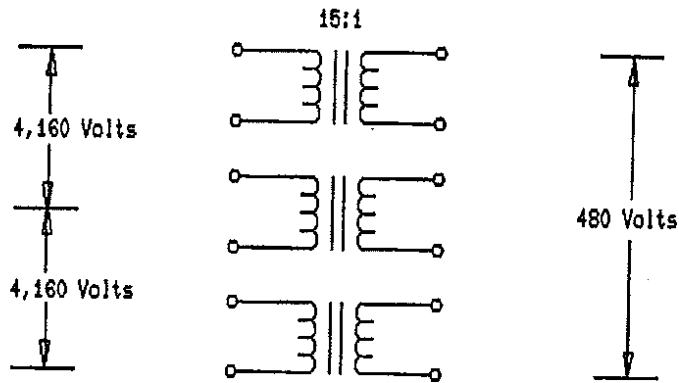
54. Q. Two 10-hp induction motors are operating on 460 volts AC. One motor is connected by single- phase; the other is connected in three-phase. The three-phase will:

A. Draw less current.

55. Q. To protect against over-current in a three-phase circuit over-current protection must be provided for:

A. At least two phases.

56. Q. How would you connect the power transformers to obtain the secondary voltage shown below?



A. Delta-Wye

57. Q. Compared to the secondary of a loaded, step-down transformer, the primary has:

A. Lower current and higher voltage.

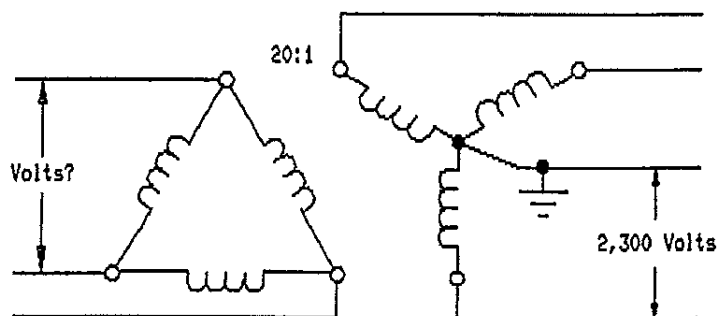
58. Q. If a voltmeter were placed between two phase leads of a three-phase 480-volt system, the meter would read:

A. 480 volts.

59. Q. A transformer with 10 turns on the primary coil and 100 turns on the secondary is classified as:

A. A step-up transformer.

60. Q. In the figure below, the secondary phase-to-neutral voltage is 2,300 volts. What is the primary line voltage?



A. 46,000 Volts

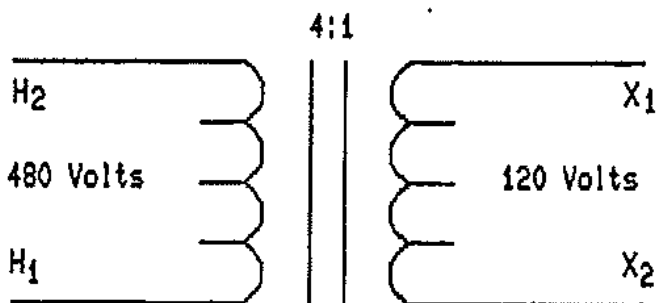
61. Q. A transformer has a primary voltage of 2,800 volts and a secondary reading of 140 volts. If there are 2,000 turns on the primary, how many turns are on the secondary?

A. 100 turns.

62. Q. If 13,200 volts are measured from phase-to-phase across a wye-connected secondary, what is the phase-to-ground voltage?

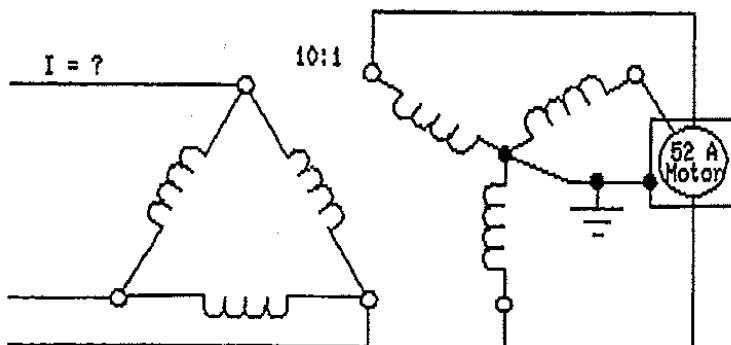
A. 7,630 volts.

63. Q. Shown below is a single-phase transformer with a turns ratio of 4:1. If the electrician were to connect 480 volts to X1 and X2 terminals, what voltage would be measured across the H1 and H2 terminals?



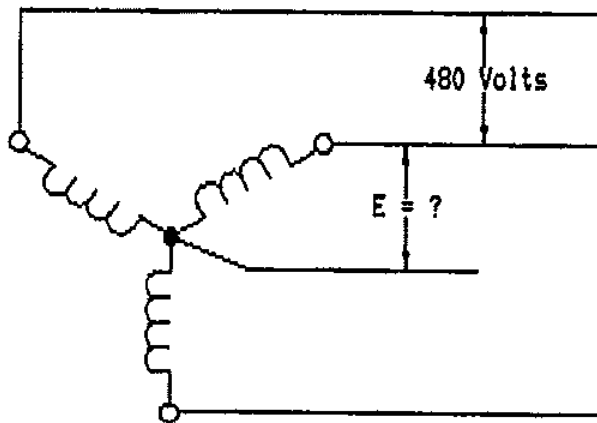
A. 1920 Volts

64. Q. Under full load conditions the motor draws 52 amps. What is the line current of the primary?



A. 9 Amps

65. Q. Shown below is a 3-phase wye connected circuit. If the line-to-line voltage is 480 volts; what is the line-to-neutral voltage?

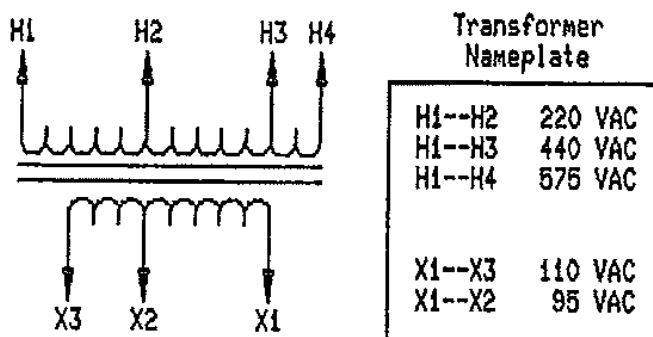


A. 277 Volts

66. Q. The current on the primary side of a step-down transformer with a 4:1 ratio will be:

A. Four times less than that of the secondary.

67. Q. If a 440 VAC power source was to be used to supply the transformer below, to what terminals on the transformer would one connect the line leads to obtain a 110 VAC secondary voltage?



A. H1-H3

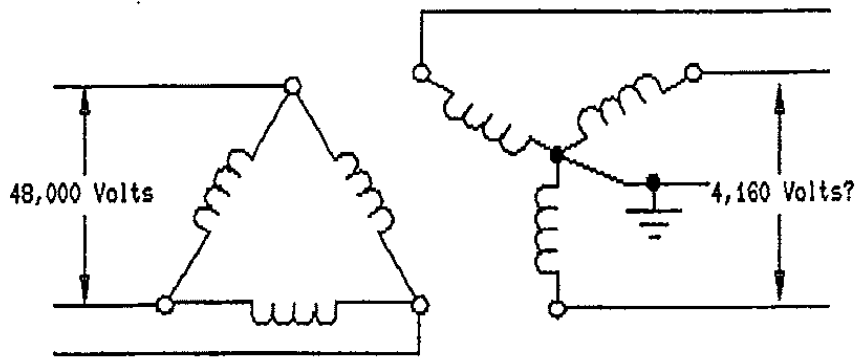
68. Q. What steps up or steps down AC voltage?

A. Transformer.

69. Q. Surface transformer installations, unless constructed to eliminate shock hazards, must be installed at least:

A. 15 feet off the ground.

70. Q. What would be the ratio of the transformers shown?



A. 20:1

71. Q. The load to which the secondary winding of a current transformer was connected has opened. The secondary leads should be:

A. Short-circuited after power has been removed.

72. Q. The primary function of a power transformer is to provide:

A. Full-load, three-phase voltage.

73. Q. What value of voltage will be measured from phase-to-phase, in a wye-connected secondary, if 2,300 volts is measured from phase-to-ground?

A. 3,979 Volts.

74. Q. A current transformer has a ratio of 350:5. If the phase current is 70 amperes, what would be the secondary current?

A. 1 amp.

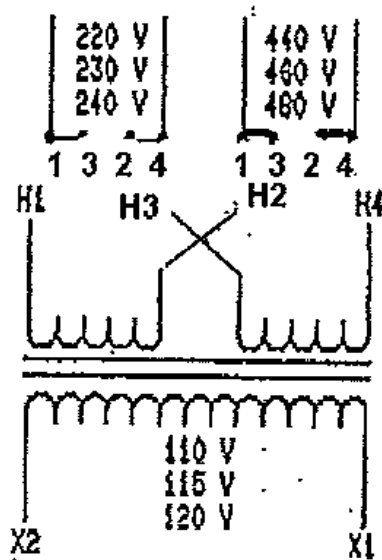
75. Q. The size of a transformer is measured in:

A. Kilovolt ampere (KVA).

76. Q. If a voltmeter is connected between a phase lead and the ground of a three-phase 480-volt system, the meter will read:

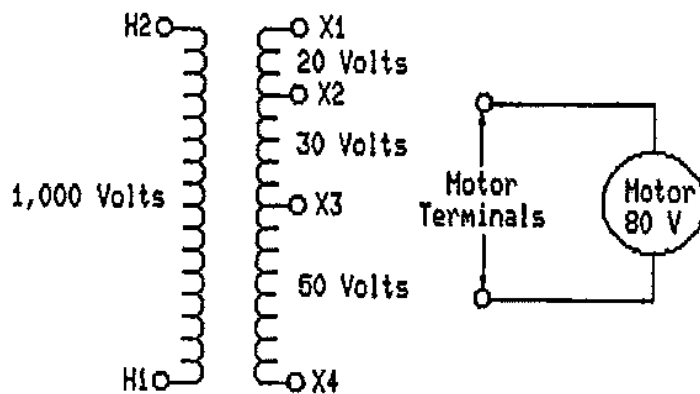
A. 277 volts.

77. Q. How should the transformer shown below be connected to obtain 115 volts on the secondary side if the input voltage is 460 volts?



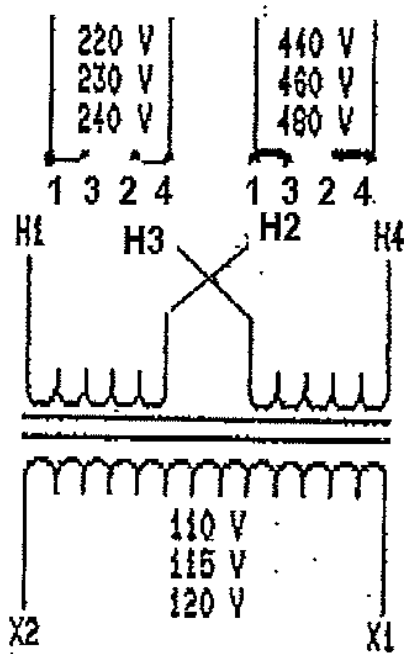
A. H2 and H3 jumpered together-Input on H1 and H4

78. Q. Which terminals should be connected to the motor terminals to provide the correct motor voltage?



A. X2 and X4.

79. Q. The transformer shown below has two primary windings. If 240 volts is applied to the primary terminals H1 and H4, what will be the secondary output voltage?

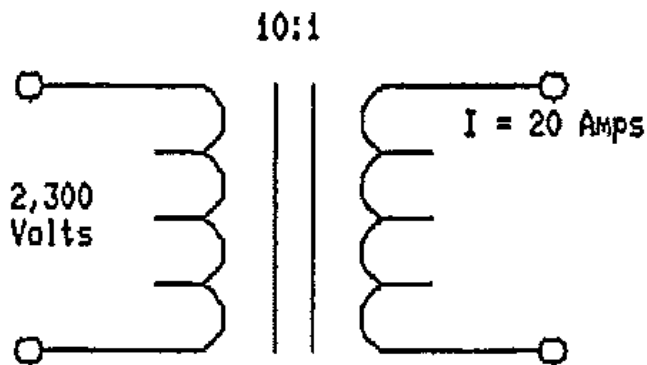


A. 60 Volts

80. Q. AC voltage is raised or lowered by means of:

A. Transformers.

81. Q. What is the current on the primary side?

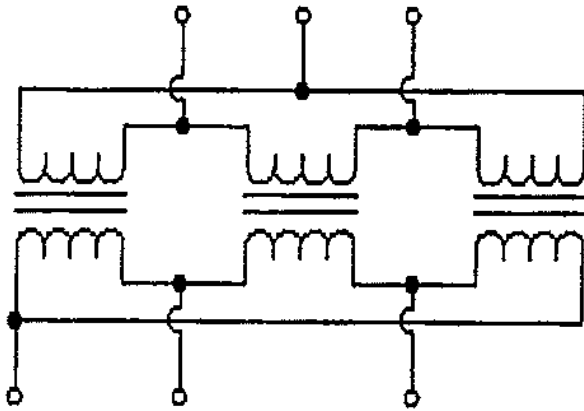


A. 2 Amps

82. Q. The main function of CT's and PT's on a main substation is to:

A. Allow for metering voltage and Current.

83. Q. The transformers in the diagram are connected:



A. Delta-Delta.

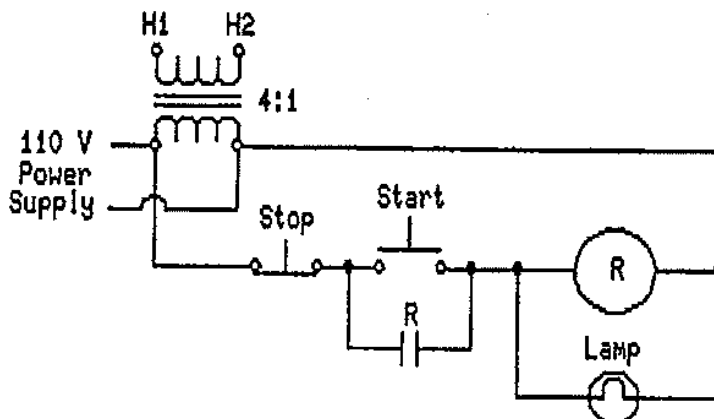
84. Q. The transformer used only to measure voltage is a:

A. Potential transformer.

85. Q. A transformer has a primary voltage of 2,400 volts and a secondary reading of 120 volts. If there are 1,500 turns on the primary, how many turns are on the secondary?

A. 75 turns.

86. Q. If a 110-volt power supply were connected to troubleshoot the control circuit in the diagram below, the voltage at H1-H2 on the primary side of the transformer would be:



A. 440 Volts

87. Q. A control power transformer:

A. Provides single-phase power to smaller loads such as lights, heaters, etc.

88. Q. A transformer has 1,600 turns in the primary and 400 turns in the secondary. The primary voltage is 2,400 volts. What is the secondary voltage?

A. 600 volts.

89. Q. Current transformers, or CT's, are used to:

A. Reduce high AC current to lower values and provide isolation between high voltage circuits and metering.

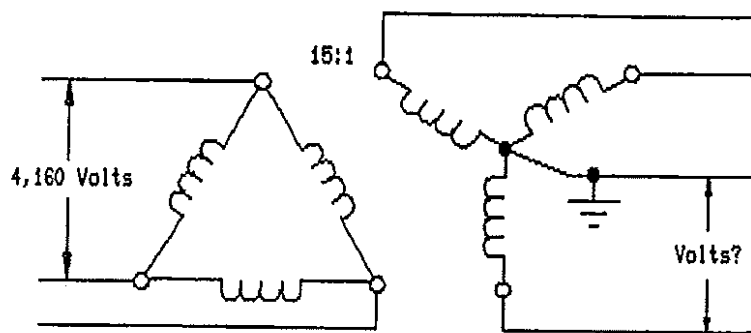
90. Q. A transformer with a 1:1 ratio is usually a (an):

A. Isolation transformer.

91. Q. All transformers step voltage up or down by:

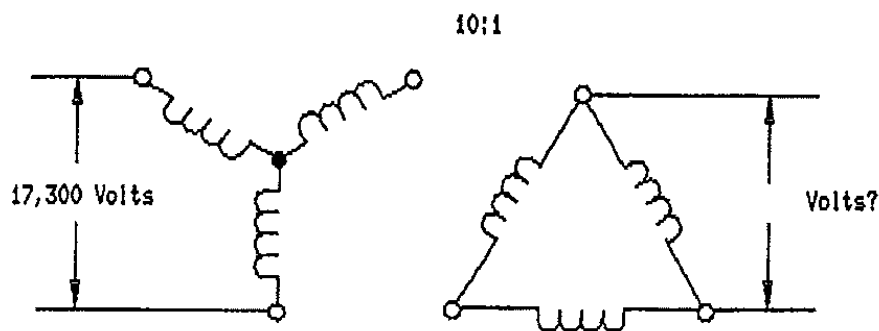
A. Inductance.

92. Q. How much voltage will be measured phase-to-ground in the figure below?



A. 277 Volts

93. Q. What is the voltage across the secondary of this transformer?

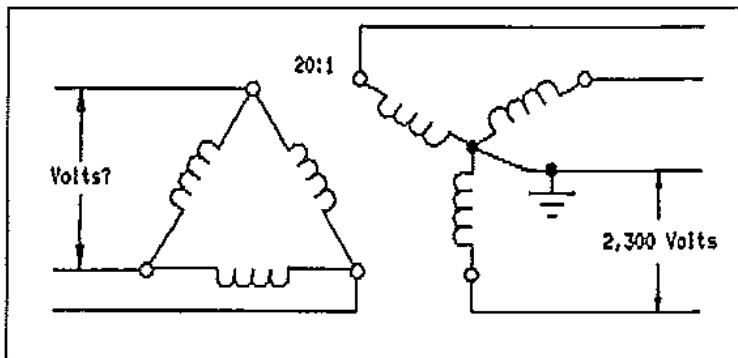


A. 1,000 Volts

94. Q. When connecting 3 single-phase transformers into a three-phase system, which of the following is NOT required for the single-phase transformers.

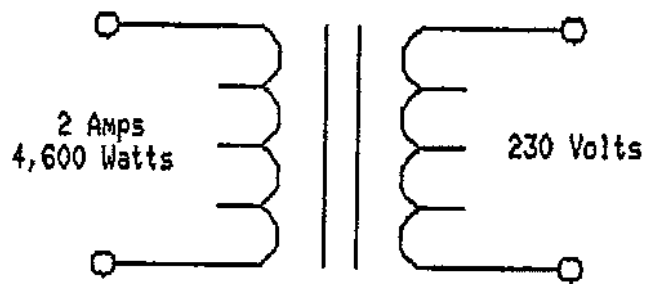
A. They should be made by the same manufacturer.

95. Q. The following transformers are connected how:



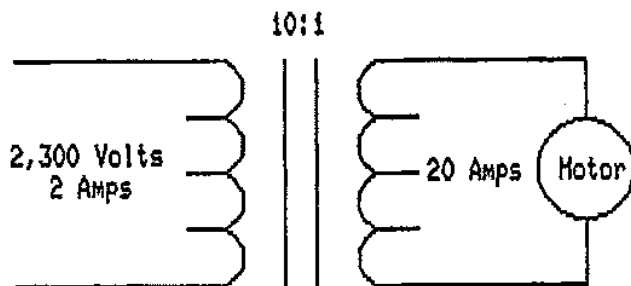
A. Delta-Wye

96. Q. What is the turns ratio of the single-phase transformer shown below?



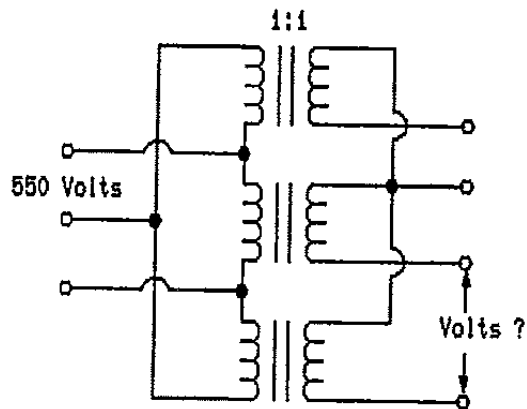
A. 10:1

97. Q. What voltage will be supplied to the motor shown below?



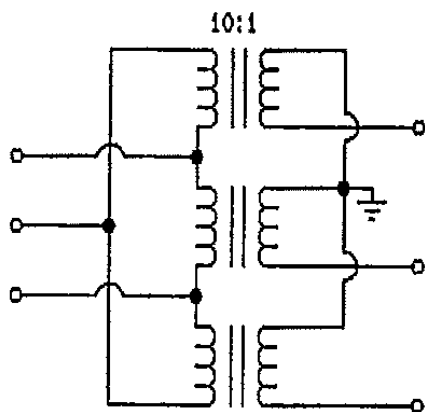
A. 230 Volts

98. Q. What would be the phase-to-phase voltage of the secondary?



A. 953 Volts

99. Q. If the line current in the primary is 34 amps, what would be the line current in the secondary?

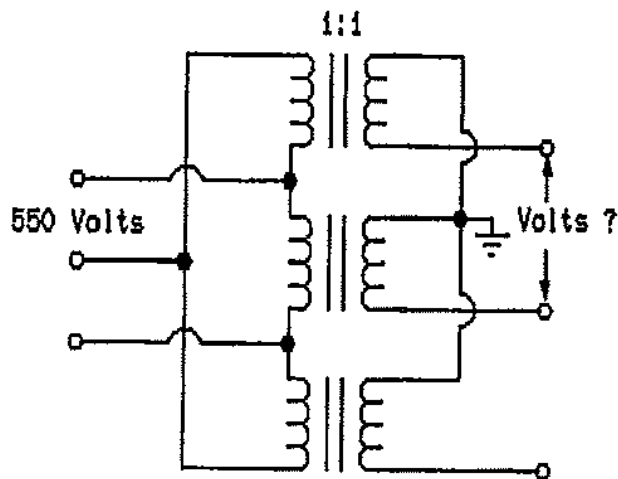


A. 196 Amps

100. Q. The secondary windings on a 10:1 step-down transformer will have a wire size:

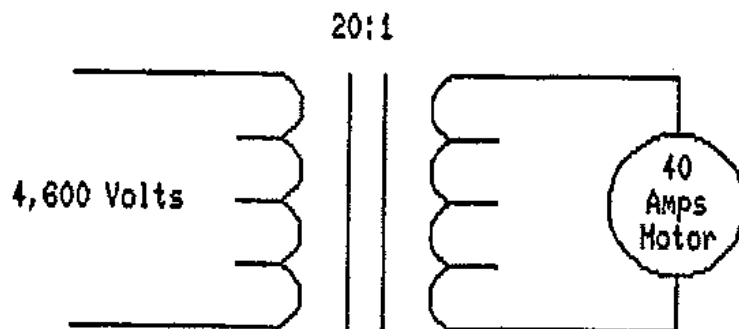
A. Larger than that found in the primary winding.

101. Q. What voltage is measured across the secondary if the primary voltage of a three-phase transformer is 550 volts?



A. About 950 Volts

102. Q. Below is a single-phase transformer with a turns ratio of 20:1. What is the primary current?



A. 2 Amps

103. Q. A transformer with 3,000 turns in the primary winding has a primary voltage of 4,800 volts and a secondary voltage of 240 volts. How many turns are in the secondary winding?

A. 150 turns.

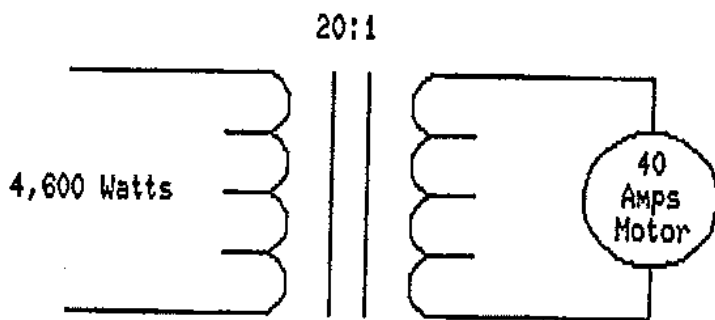
104. Q. Find the turns ratio of a single-phase transformer with the following values: Primary power of 10 KW, secondary current of 200 amps, and primary voltage of 250 volts.

A. 5:1.

105. Q. 460 volts AC is required to operate two motors, one connected in single-phase and the other connected in three-phase. The three-phase motor will:

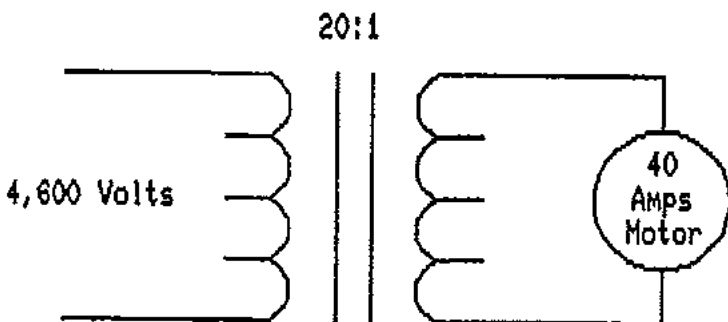
A. Draw less current.

106. Q. Shown below is a single-phase transformer with a turns ratio of 20:1. What will be the voltage measured across the motor?



A. 115 Volts

107. Q. Shown below is a single-phase transformer with a turns ratio of 20:1. How much power is used in the secondary circuit?



A. 9,200 watts

108. Q. Using a 10:1 ratio transformer, the terminals on the secondary side or lower voltage side would be marked:

A. X.

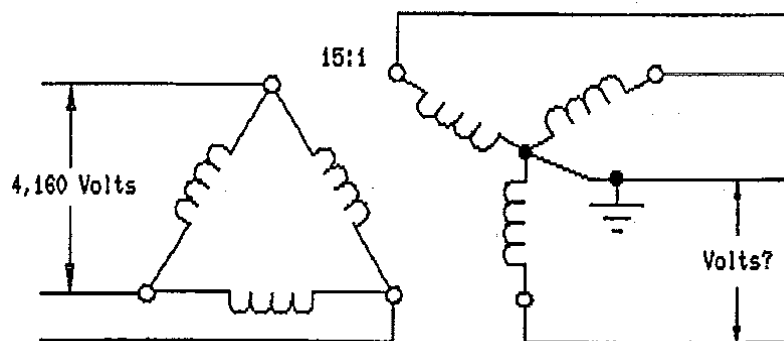
109. Q. If the conductors of a balanced, three-phase circuit pass through a current transformer, how many amps will flow in the transformer?

A. Zero amps.

110. Q. Which of the following is NOT an acceptable method for the installations of surface transformers?

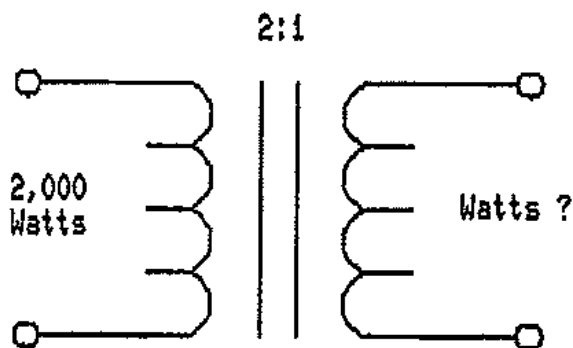
A. They must be installed at least 7 feet above the ground.

111. Q. What is the phase-to-neutral voltage in the secondary of the transformer below?



A. 277 Volts

112. Q. If 2,000 watts is read in the primary of a single-phase transformer, what is the wattage in the secondary? (Assuming no losses.)



A. 2,000 watts

113. Q. The purpose of a zig-zag transformer is to:

A. Derive a neutral for grounding purposes.

114. Q. Compared to the secondary of a loaded, step-down transformer, the primary has:

A. Lower current and higher voltage.

115. Q. Find the turns ratio of a single-phase transformer with the following values:
Primary power of 5KW, secondary current of 100 amps, and primary voltage of 250 volts.

A. 5:1

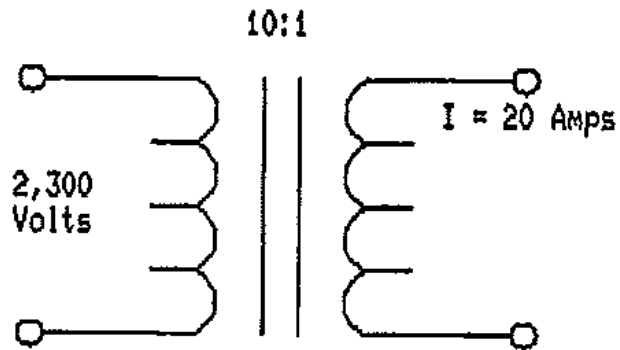
116. Q. A transformer with 1,500 turns in the primary winding has a primary voltage of 2,400 volts and a secondary voltage of 120 volts. How many turns are in the secondary winding?

A. 75 turns.

117. Q. If you use a clamp-on ammeter or tong tester around all three-phase wires of an energized three-phase circuit simultaneously:

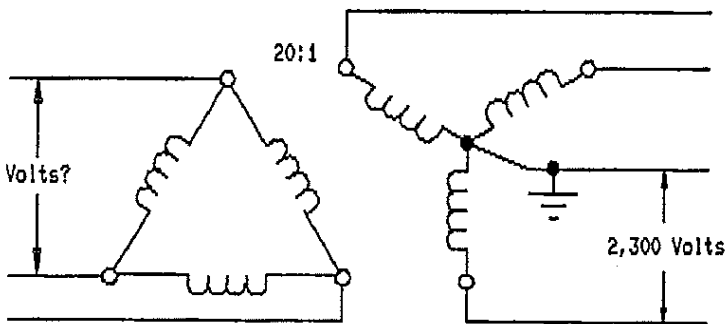
A. The current will read zero.

118. Q. The voltage in the primary side is 2,300 volts. What is the voltage on the secondary side?



A. 230 Volts

119. Q. What is the phase-to-phase voltage of the primary?



A. 46,000 Volts

ILLINOIS STUDY GUIDE
ELECTRIC CIRCUITS AND EQUIPMENT

ILLINOIS ELECTRICAL STUDY GUIDE

Electric Circuits and Equipment

- A. Recognition of schematic diagrams for
 - 1. Compound, series and shunt DC motors
 - 2. Transformer connections
- B. Shorted diode determination using an Ohmmeter
- C. Basic control circuit operation, recognition, and troubleshooting
 - 1. Push buttons – Start and stop
 - 2. Motor starter – Contacts, coil, overload
 - 3. Fuses
 - 4. Manual-OFF-Automatic selector switches
 - 5. Wire connections
- D. 3-Phase Transformer Calculations
 - 1. Turns Ratios
 - 2. Voltage Ratios
 - 3. Winding connections and applicable voltage and current relationships
- E. Grounding resistor ohmic calculations, connections, and legal criteria
- F. Phase-to-ground fault protection and indications
- G. Electrical troubleshooting methods and legal requirements
- H. Phase-to-phase or line-to-line fault protection and capability
- I. Capacitor troubleshooting safety procedures
- J. Ground monitoring requirements and function
- K. Limitations of ohmmeters for testing insulation
- L. Application of starting resistors to large DC motors
- M. Dual-element fuse description and application
- N. Three-phase, dual-voltage motor description and connections

ELECTRICAL EQUIPMENT

Direct-Current Motors

A motor that runs from a direct current power supply is called a d-c motor. A d-c motor consists of a rotating armature and one or more stationary field windings. A commutator and brushes are required to supply voltage to the armature. There are three basic types of d-c motors. The connections for each type are shown below.

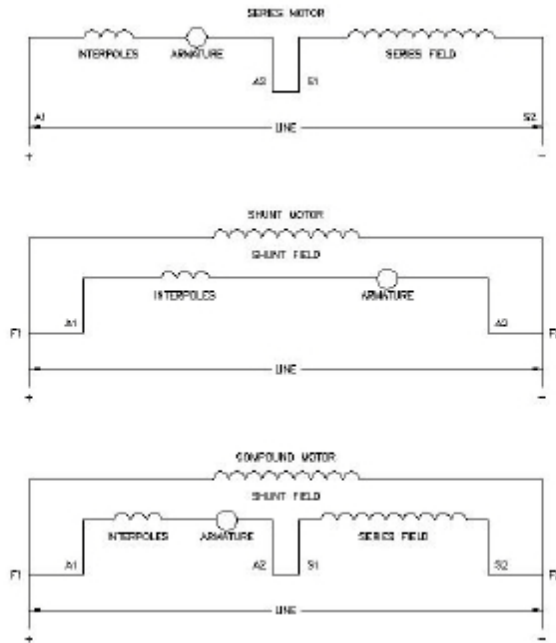


Figure 6.1 - All connections for counter-clockwise rotation facing commutator end.
For clockwise rotation interchange A1 and A2.

To reverse the rotation of any d-c motor interchange the armature leads, A1 and A2. On the shunt and compound motors the shunt field leads F1 and F2 can be interchanged to reverse the rotation. Interchanging the series field leads S1 and S2 on a series motor will also reverse the direction of that motor.

The horsepower of a d-c motor can be calculated by use of the formula below:

$$HP = \frac{EI \text{ (eff.)}}{746}$$

Where: E - voltage

I - current

eff - efficiency = .88

HP - horsepower

1 Horsepower = 746 watts

The current of a d-c motor can be calculated from the following formula:

$$I = \frac{746 \text{ HP}}{E \text{ (eff.)}}$$

The efficiency of a d-c motor is around .88.

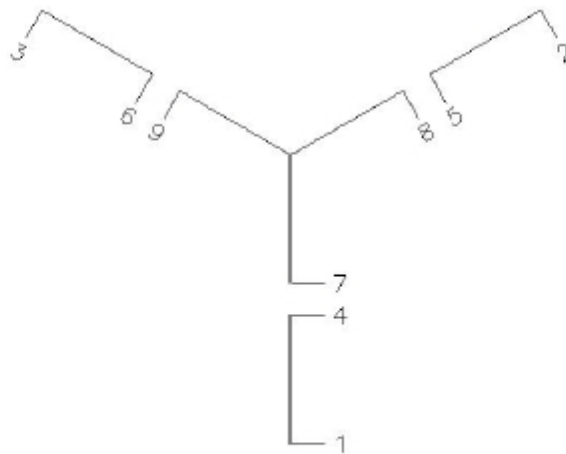
The approximation of 4 amps per horsepower is often used to calculate the current drawn by 250 volt d-c motors.

$$I = 4 \times \text{HP Amperes}$$

Three-Phase A-C Motors

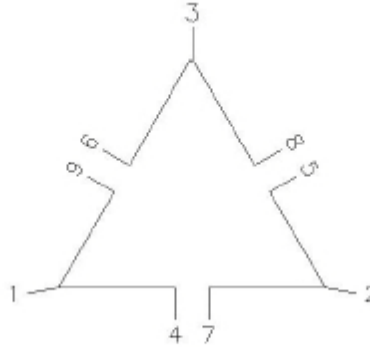
Three-phase induction motors are the most commonly used motors for high-power applications. These are the most economical motors to buy initially and also to operate. A three-phase induction motor consists of a stationary, three-phase winding called a stator and a rotating member called a rotor. A three-phase motor is typically a dual-voltage motor. This means that it can be operated from two different voltages, depending on the way the motor is connected. These motors can either be connected wye or delta. The terminal markings of these motors have been standardized and are shown below along with the voltage connections.

Wye or Star Connected



VOLTAGE	LINE 1	LINE 2	LINE 3	TOGETHER
LOW	1&7	2&8	3&9	4&5&6
HIGH	1	2	3	4&7, 5&8, 6&9

Delta Connected



VOLTAGE	LINE 1	LINE 2	LINE 3	TOGETHER
LOW	1&6&7	2&4&8	3&5&9	NONE
HIGH	1	2	3	4&7, 5&8, 6&9

Figure 6.2 – Terminal markings and connections for nine lead, three-phase motors.

The rotation of a three-phase motor is reversed by interchanging any two line leads.

The horsepower of a three-phase motor can be calculated as shown below

$$HP = \frac{\sqrt{3} I_L E_L (\cos\theta)(\text{eff})}{746} = \frac{1.732 I_L E_L (\cos\theta)(\text{eff})}{746}$$

Where: HP = horsepower
 I_L = line current
 E_L = line voltage
 $\cos\theta$ = power factor=.85
 eff = efficiency=.88

There are 746 watts in one horsepower:

$$1 \text{ HP} = 746 \text{ watts}$$

The line current, I_L , can be calculated from the following formula:

$$I_L = \frac{746 \text{ HP}}{1.732 E_L \cos\theta (\text{eff})}$$

Three-phase induction motors typically have a power factor of around .85 lagging an efficiency of near .88.

Single-Phase A-C Motors

Single-phase a-c motors are used in great multitudes for low-power applications. These motors consists of a rotating part called a rotor and a stationary part called a stator. The stator has two windings – a running winding and a starting winding. Once the motor reaches approximately 75% of full running speed, the start switch disconnects the starting winding from the circuit and the motor continues to run only on the running winding. A schematic diagram of this type of motor is shown below.

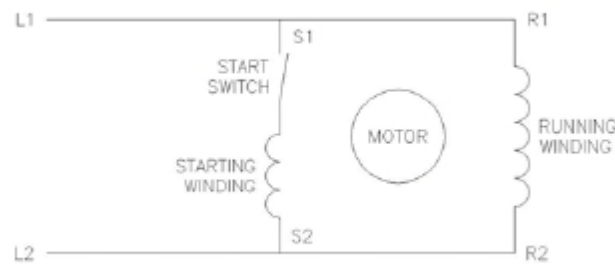


Figure 6.3 – Schematic diagram of a single-phase induction motor.

To reverse the rotation of a single-phase induction motor, interchange the starting winding leads S1 and S2, or the running winding leads R1 and R2.

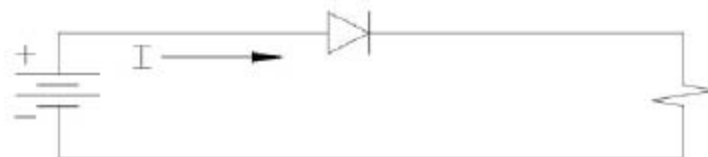
Diodes

A diode is an electronic device that conducts current in only one direction. The schematic symbol for a diode is shown below.



Figure 6.4 - Schematic symbol for a diode

A diode will conduct when it is forward biased and will not conduct when it is reverse biased. Figure 6.5 shows the forward and reverse-biased connections.



a) Forward Bias – Current is conducted. Note that conventional current is assumed when working with diodes.



b) Reverse Bias - Current is not conducted.

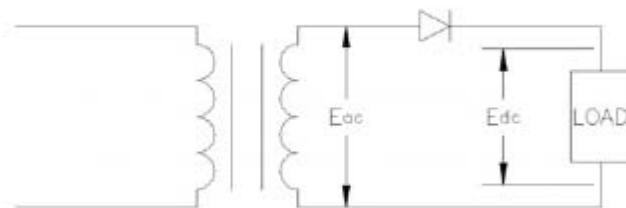
In power circuit application such as mine equipment, diodes are used for grounding and rectification. By the use of diodes to ground d-c equipment, a separate ground wire is not required. However, to use this method of grounding one conductor of the d-c system must be grounded. Rectification is the conversion of alternating current to direct current. A rectifier changes a-c to d-c. Diodes are rated for a maximum current and maximum forward and reverse peak voltages. If the current rating is exceeded the diode will over-heat and be destroyed. If the voltage ratings are exceeded, the semiconductor material that the diode is composed of will be broken down and the diode will be destroyed. The most common ways diodes are destroyed are heat and over voltage. In addition to grounding off-track d-c equipment, diodes are used to prevent the machine from operating when the polarity of the trailing cable is reversed. They are called polarizing diodes when used for this purpose.

Rectification is defined as the conversion of electrical energy from alternating current to direct current. This is shown in Figure 6.5 for simplification.



Figure 6.5 - Rectification

To describe, the power source supplies alternating current to the conversion equipment, which in turn eliminates or removes the negative or reverse cycle of the alternating current force. When this is done, although the output is pulsating (as shown), it is not alternating direction. In other words, it is not allowed to flow in the reverse direction; therefore, it becomes a direct-current output. Rectification can be accomplished in several different ways. Among these methods are: motor generator sets; dry-type rectifiers (silicon diode); rotary converters; and ignition rectifiers (mercury tube). There are various methods by which rectifiers can be connected into a circuit. The simplest type of rectifier consists of an a-c power supply with a rectifier connected in series with the load as shown in the following diagram:



This type of configuration is called a single-phase half-wave rectifier and gives an intermittent pulsating output to the load equal to one-half of the cycle. It is only used for control circuitry application in the mining industry.

Formulas:

FOR DELTA CONNECTIONS

1. Line voltage AND phase voltage:

$$E_L = E_\phi$$

2. Line current:

$$I_L = I_\phi(\sqrt{3})$$

3. Phase current:

$$I_\phi = \frac{I_L}{\sqrt{3}}$$

Where: E_L = line-to-line voltage

E_ϕ = line-to-neutral or phase voltage

I_L = line current

I_ϕ = phase current

Square Root of 3 = 1.732

Formulas:

FOR WYE CONNECTIONS

1. Line current AND phase current:

$$I_L = I_\phi$$

2. Line voltage:

$$E_L = E_\phi(\sqrt{3})$$

3. Phase voltage:

$$E_\phi = \frac{E_L}{\sqrt{3}}$$

Square Root of 3 = 1.732

Formulas:

FOR DELTA OR WYE CONNECTIONS

1. Phase Power, for a single-phase:

$$P_{\phi} = I_{\phi} E_{\phi}$$

2. Apparent Power (3-Phase):

$$P_A = I_L E_L (\sqrt{3})$$

3. True Power (3-Phase):

$$P = I_L E_L (\sqrt{3}) (PF)$$

4. Reactive Power (3-Phase):

$$P = I_L E_L (\sqrt{3}) (\sin \theta)$$

Formulas: Square Root of 3 = 1.732

ALTERNATING MACHINE SPEED

1. Synchronous Speed (SS):

$$SS = \frac{60f}{\text{Pairs of poles per phase}}$$

Where: f = frequency

Switches:

Any switch or contacts designed to start or maintain the circuit must be wired in parallel with the original start switch. Any switch or contacts designed to stop the circuit must be wired in series with the part of the circuit they will de-energize.

ELECTRICAL CIRCUIT AND EQUIPMENT

I. Three-Phase AC

- A. Essentially all large scale AC generators and distribution systems are three-phase circuits.
- B. In the work place the majority of electric motors are three-phase.
- C. Nearly all underground and surface mining installations and machines use three-phase AC.
- D. All previously mentioned AC laws and rules apply to three-phase circuits.
- E. The combination of three separate sine waves gives rise to three-phase circuits.
- F. Why use three-phase AC?
 - 1. Three-phase is more efficient in the use of conductors.
 - 2. More economical to transmit power.
 - 3. More powerful and reliable motors.
 - 4. Produces a smoother DC when rectified.
- G. How is three-phase produced?
 - 1. Three sets of poles at 120 deg. spacing.
 - 2. Generator output is three identical sine waves separated by 120°.
 - 3. There is always as much current going out to the load as there is coming back.
 - 4. Total current is shared by three conductors instead of just two for a single-phase circuit.

II. Delta Connections

- A. Windings are connected end to end, and the three line leads connect to those common points.
- B. Voltage and current produced by any phase winding of an alternator or transformer are called phase voltage (E_{ϕ}) and phase current (I_{ϕ}), and would be measured across or through any single winding.
- C. Line voltage (E_L) and line currents (I_L) would be measured across or within the output lines.
- D. Formulas:

$$1. E_L = E_{\phi}$$

$$2. I_L = I_{\phi} (\sqrt{3})$$

$$3. I_{\phi} = I_L / \sqrt{3}$$

Square Root of 3 = 1.732

III. Wye Connections

- A. Sometimes called a star connection, but usually wye since it resembles the letter Y when drawn.
- B. A wye configuration connects one end of each winding to a common point called the neutral. The other end of each winding is connected to the external line leads.
- C. Formulas: Square Root of 3 = 1.732

$$1. I_L = I_\phi$$

$$2. E_L = E_\phi (\sqrt{3})$$

$$3. E_\phi = E_L (\sqrt{3})$$

IV. Three-Phase Power Formulas

- A. Formulas for power in three-phase systems must take into account the three separate windings and the 120° phase shift.
- B. Apparent Power (PA) is the power supplied by the three-phase source.
- C. True Power (P) is the power consumed by the load resistance.
- D. Phase Power (P ϕ) is the apparent power in any single phase winding.
- E. These three formulas are the same for delta and wye connections.
- F. Formulas:

- 1. Phase Power for a single phase:

$$P_\phi = I_\phi E_\phi \text{ VA}$$

- 2. Apparent Power:

$$P_A = I_L E_L (\sqrt{3}) \text{ VA}$$

- 3. True Power:

$$P = I_L E_L (\sqrt{3}) (\text{PF}) \text{ watts}$$

- 4. Reactive Power:

$$P_R = I_L E_L (\sqrt{3}) (\sin\theta) \text{ vars}$$

V. Three-Phase Transformers

- A. Three-phase transformers in simplest form are nothing more than a bank of three single-phase transformers.
- B. Voltage can be either stepped up or stepped down.
- C. The same rules discussed about transformer input voltage and current vs. output voltage and current and still apply.
- D. Where three-phase transformers differ from single-phase is when line voltages and currents are considered, since these depend on whether the windings are connected by delta or wye.

- E. Four possible connections exist for three-phase transformers
 - 1. Delta-delta
 - 2. Wye-wye
 - 3. Delta-wye
 - 4. Wye-delta
- F. Calculate only Phase Voltage and Phase Current when using the ratio!
- G. Use the appropriate delta or wye formulas to find three-phase values after phase voltage and phase current are known for both primary and secondary.
- H. Delta Secondary characteristics
 - 1. Winding conductor size smaller than wye secondary
 - 2. Can operate at 58% of original capacity in open delta connection.
 - 3. Eliminates the possibility of phase unbalance due to single phase loads.
 - 4. Disadvantage is that there is no neutral point to ground. A zigzag transformer is usually used to derive a neutral.
- I. Wye secondary characteristics
 - 1. Direct neutral that facilitates grounding
 - 2. Higher line voltage is available than phase voltage
 - 3. Disadvantage is that phase windings must carry full line current.
 - 4. No option such as “open delta” exists. An open phase results in loss of three-phase power.
- J. Individual applications determine whether the transformer secondary will be wye or delta.

VI. Three-Phase Motors

- A. Wherever numerous large electrical motors are used, the three-phase motor plays a major role. These motors are work horses.
- B. Where single-phase motors might be a maximum of 10 HP, three-phase motors in excess of 200 HP are common.
- C. Advantages of three-phase motors are:
 - 1. They are self starting.
 - 2. They draw lower amperages than comparable single-phase motors.
 - 3. They are smoother running than single-phase motors and have excellent torque.
 - 4. They are easily reversed. Just switch any two incoming line leads to change motor rotation.
- D. The most common three-phase motor is the induction motor.
- E. Synchronous Speed (SS):

$$SS = 60 f \frac{\text{Pairs of poles}}{\text{per phase}}$$
- F. Induction motor types
 - 1. Wound Rotor
 - 2. Squirrel Cage
- G. Synchronous motors
 - 1. Constant load and low starting torque applications.
 - 2. Used where constant speed is critical.
 - 3. Can be capacitive generators.
 - 4. Not suited to rapidly changing loads.

VII. Circuit Protection

- A. All electrical equipment shall be protected against circuits and overloads.
Protective devices must be in compliance with the National Electric Code.
- B. Short Circuit
 - 1. Direct fault between two or more line leads; bypassing the normal load.
 - 2. The protection must act instantaneously to provide circuit protection.
 - 3. Protective devices must be set to allow motors to start.
 - 4. Maximum allowable instantaneous trip settings for trailing cables are specified by CFR.
- C. Overload (Running Overcurrent)
 - 1. 125% of motor full load current allowed by NEC.
 - 2. Overload devices must be slow enough to activate to allow motors to start, but sensitive to mild overcurrent surges of long duration.
 - 3. The simplest form of circuit protection is the fuse.
- D. A dual element fuse can be used to provide short circuit and overload protection. A dual element fuse has two elements-one to protect against short circuits, and the other is to protect against overloads.
- E. A circuit breaker is a switching device which automatically opens the circuit in the event of short circuit or overload; but is not destroyed in doing so.
 - 1. A circuit breaker can be reset after tripping, and is immediately ready to continue operation.
 - 2. A circuit breaker can also be operated manually if desired.
 - 3. Critical factors to be considered in the selection of a circuit breaker are:
 - a) Voltage
 - b) Amperage that must be interrupted
 - c) Type of protection being provided
 - d) Environment
 - 4. MSHA requirement for protection of underground three-phase AC mining circuits
 - a) Undervoltage
 - b) Grounded phase
 - c) Short circuit
 - d) Overcurrent
 - e) Ground monitor
 - 5. Circuit breaker instantaneous trip units provide short-circuit Protection.
 - 6. Circuit breaker thermal trip units provide overcurrent protection.
 - 7. Under voltage and grounded phase protections are normally provided by means of an auxiliary device called an Under Voltage Release (UVR).
 - a) Under voltage protection provided directly by UVR.
 - b) Grounded Phase protection requires external circuitry, but it trips the circuit breaker via the UVR. A current transformer (CT) and ground fault relay (GFR) are used to sense the fault and open the circuit breaker UVR circuit to cause the circuit breaker to trip.
 - c) Perhaps the most commonly used system for ground fault protection is the balanced flux relay system.
 - d) Types of ground fault protection systems.
 - i. Balanced flux relay systems

- ii. Direct relay systems
 - iii. Residual trip delay
 - iv. Potential relay
- 8. Ground Monitor
 - a) Continuously monitors the grounding circuit to assure continuity.
 - b) 40 V. max on low and medium voltage systems.
 - c) 96 V. max on high voltage systems.

VIII. Control Devices

A. Simplest form of control device is the switch.

- 1. SPST
- 2. DPST
- 3. SPDT (Three-way)
- 4. DPDT

B. Pushbutton Switches

- 1. Momentary
- 2. Maintained

C. Rotary Switches

D. Automatic Switches

- 1. Thermostats
- 2. Pressure
- 3. Limit

E. Electromagnetic relays

F. Contactors

G. Line Starters

H. Solenoid

I. Timing Relays

J. Motor-driven timer

IX. Solid State Theory

A. Semiconductors are those elements with four valence electrons.

B. Rectifier

- 1. A rectifier changes alternating current to direct current.
- 2. The heart of the rectifier is a diode. A diode allows current to flow freely in one direction, but block flow in the other.

C. Diode

- 1. Blocks current flow in one direction.
- 2. Diodes are made of either silicon (Si) or germanium (Ge), but because of its tolerance for high temperatures, the silicon diode is much more common.
- 3. Pure silicon is a poor conductor. Conductive properties are improved through doping.
 - a. N-type material
 - b. P-type material
- 4. When N-type and P-type materials are joined together, they form a diode. The point of juncture is called the PN junction.

5. Forward bias
6. Reverse bias
7. Avalanche or “Zener” effect
8. Zener diodes act as voltage regulators
9. Reverse breakdown voltage is usually referred to as Peak Inverse Rating (PIV). Diodes have a PIV and forward current rating.
- D. Half-wave rectifier
- E. Full-wave rectifier
 1. Ripple
 2. Filter capacitor
- F. Three-phase, full wave bridge rectifiers provide the smoothest DC available.
- G. Transistors (3 layers of semiconductors)
 1. PNP
 2. NPN
- H. Thyristor (4 layers of semiconductors) PNPN
 1. SCR

X. Electrical Diagrams

- A. Two separate circuits
 1. Power circuit
 2. Control circuit
- B. Power Circuit
 1. Heavy gauge wires
 2. Carries higher currents
 3. Usually higher voltage in three-phase AC machines.
- C. Control Circuit
 1. Small gauge wires
 2. Carries lower current
 3. Control voltage is usually lower than the power circuit and originates from a control transformer.
- D. Most common types of electrical diagrams.
 1. Elementary or schematic diagrams
 2. Wiring diagram
- E. Elementary Diagram (schematic diagram)
 1. Sometimes called a line diagram
 2. Circuit is reduced to its simplest, most understandable form.
 3. Designed to help the electrician see how the circuit operates.
 4. Makes no attempt to show exact wiring, routing, or individual connections.
 5. Devices are not shown in correct physical location; in fact, they are “exploded”, with parts scattered throughout the diagram.
 6. When reading an elementary diagram, one must locate all components having identical names. All such components are a physical part of one device.
 7. Some contactors or relays have a coil and several sets of contacts. All will be given the same identifying name, regardless of where they appear on the print.

8. Names can be a single letter or combination of letters and numbers. In many cases letters or set of initials are chosen that give a clue to the device's purpose in the circuit.

F. Wiring Diagram

1. The wiring diagram shows all devices in the circuit, their approximate physical location, and their exact wiring.
2. Every coil, contact, motor, switch, fuse, etc, is included, and the lines on the print represent actual wires.
3. A device which has several components usually is enclosed in dashed lines to isolate it from other similar devices.
4. The wiring diagram is valuable for locating wires and circuit components for repair and maintenance.

G. Control Schemes

1. Two-wire
2. Three-wire

H. Switch Connection

1. Any switch or contacts designed to start or maintain the circuit must be wired in parallel with the original start switch.
2. Any switch or contacts designed to stop the circuit must be wired in series with the part of the circuit they will de-energize.

I. Motor Reversing and Electrical Interlocks

XI MSHA Voltage Classifications

- A. Low voltage – 0 to 660 volts
- B. Medium voltage – 661 to 1,000 volts
- C. High voltage – 1,001 volts and up

PRACTICE QUESTIONS FOR ELECTRIC CIRCUITS AND EQUIPMENT

1. With two equal resistances in series across a 90 volt battery, the voltage across each resistance equals:
 - a. 30 Volts
 - b. 45 Volts
 - c. 90 Volts
 - d. 180 Volts

2. A parallel d-c circuit consists of a 10 volt battery shunted by three resistors of 3, 5, and 7 ohms. The total current equals:
 - a. 0.667 amps
 - b. 1.460 amps
 - c. 15.000 amps
 - d. 6.76 amps

3. An unknown resistor connected across a 100-volt source dissipates 200 watts. Its resistance is:
 - a. 50 ohms
 - b. 100 ohms
 - c. 200 ohms
 - d. 500 ohms

4. A 100-ohm R is in series with 100 ohms of X_L . The total impedance equals:
 - a. 70.7 ohms
 - b. 100 ohms
 - c. 141 ohms
 - d. 200 ohms

5. A 100-ohm R is in parallel with 100-ohm of X_L . The total impedance is:
 - a. 70.7 ohms
 - b. 100 ohms
 - c. 141 ohms
 - d. 200 ohms

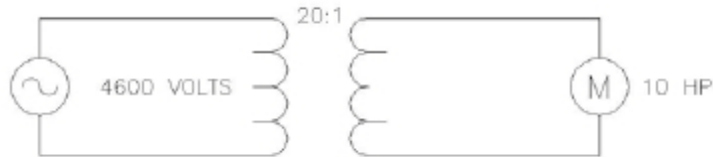
6. The total power present in an a-c circuit is referred to as:
 - a. True Power
 - b. Apparent Power
 - c. VARS
 - d. Power Factor

7. The relationship between produced power and used power is termed?
- True power
 - Apparent power
 - VARs
 - Efficiency
8. The power factor of an a-c circuit is equal to the ratio of:
- True power to VARs
 - Apparent power to VARs
 - True power to apparent power
 - Apparent power to true power
9. In a three-phase delta to delta connected transformer with a 3 to 1 step down ratio, primary line current is:
- Equal secondary line current
 - One-third secondary line current
 - Three times secondary line current
 - 1.73 times secondary line current
10. Of the four possible combinations possible with three-phase transformers, which will give the greatest current handling capacity?
- Delta to delta
 - Wye to wye
 - Delta to wye
 - Wye to delta
11. In a three-phase delta connected secondary, if one phase should open, what type power is available for use?
- Single-phase at 100% capacity
 - Single phase at 58% capacity
 - Two-phase at 100% capacity
 - Three-phase at 58% capacity
12. In a three-phase wye connected secondary, if one phase should open, what type power is available for use?
- Single-phase at 33% capacity
 - Single-phase at 58% capacity
 - Two-phase at 100% capacity
 - Three-phase at 58% capacity
13. The type AC motor which is most commonly used is the:
- Squirrel cage
 - Wound rotor
 - Shaded pole
 - Synchronous

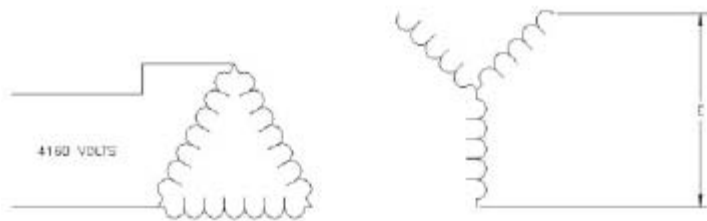
14. If two of the phase wires which supply a 3-phase motor are reversed, the motor will:
- Stop
 - Burn up
 - Run as before
 - Reverse its rotation
15. In a three-phase wye connected motor, the phase voltage is equal to:
- One-third line voltage
 - One-half line voltage
 - 1.73 time line voltage
 - .578 times line voltage
16. In the construction of a PN junction rectifier, silicon, rather than germanium, was chosen for use in the mines because:
- It is less affected by high temperature
 - It is more affected by high temperature
 - Temperature has no affect upon silicon
 - Germanium isn't used in junction rectifiers
17. In a silicon diode, when a reverse voltage is applied:
- No current flows
 - A few miliamperes flow
 - A few microamperes flow
 - The diode will break down
18. The diode ratings usually given by manufacturers are:
- Forward and reverse voltage
 - Forward and reverse current
 - Forward current and forward voltage
 - Forward current and reverse voltage
19. A calibrated conductor which is designed to burn up at a specified current is called a:
- Fuse
 - Breaker
 - Switch
 - Relay
20. A switch which is designed to control only one circuit would probably be designated as which of the following:
- DPDT
 - DPST
 - SPST
 - SPDT

21. Draw a properly grounded single-phase transformer with a current tap.

22. In the circuit shown below find the voltage of the secondary.

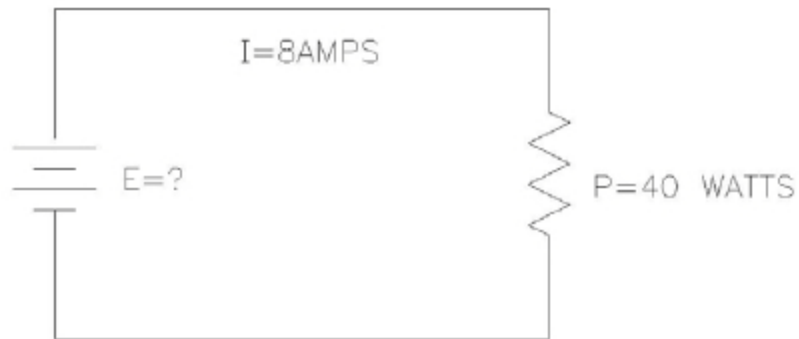


23. Three single-phase transformers with a ratio of 15:1 are connected delta-wye.
If 4160 volts is supplied to the primary side of the transformers, what is the line-to-line voltage on the secondary side?

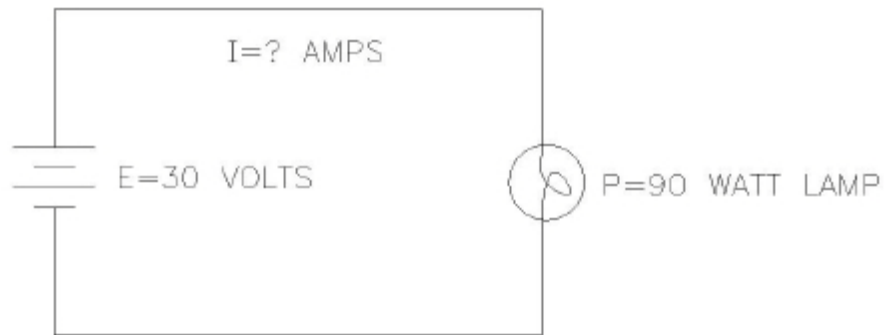


24. Draw a three-phase delta secondary with zigzag ground transformers.

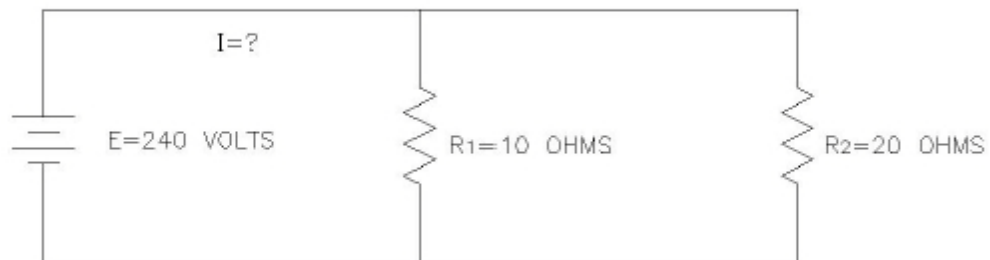
25. What is the source voltage below?

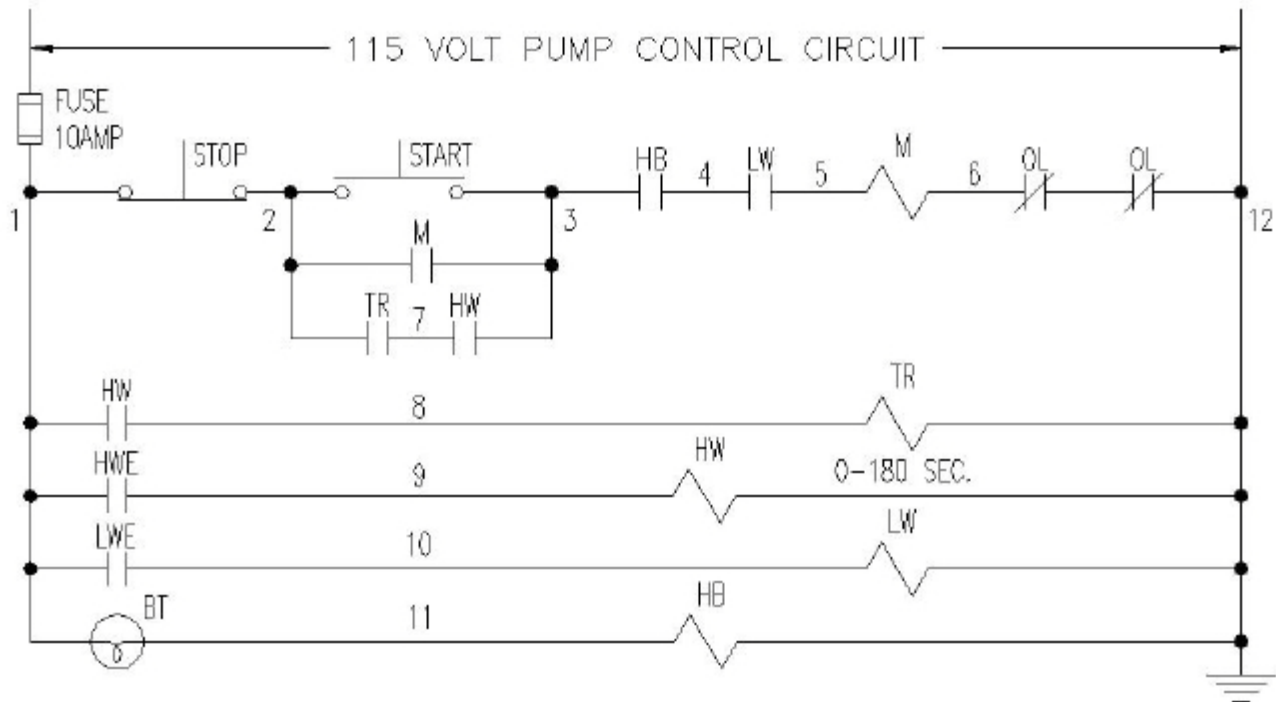


26. What is the current flow in the circuit below?



27. Calculate the total current flow in the circuit below.





M - Motor Starter Coil
 OL - overload Relay
 HW - High Water Relay
 LW - Low Water Relay
 HW - High Water Electrode
 TR - Time Delay-Relay, Time Open
 LW - Low Water Electrode
 HB - Hot Bearing Relay
 BT - Hot Bearing Thermostat
 Stop - Start on momentary contact

Note Questions No. 28 thru 32 are concerned with the above pump control circuit:

28. Give two methods of starting the pump.
29. Give two reasons to cause the pump to stop.
30. If the pump will start with the pushbutton but will not run without it what is the matter?
31. How would you check for an open in the starter coil?
32. The pump starts on high water but cuts off after 4 minutes. What is wrong?

33. A distinctive feature of a compound motor is that it has:
- Two series fields
 - Two shunt fields
 - One series and one shunt field
 - It is too complicated to determine
34. How can you reverse the rotation of a DC motor?
- Change the armature polarity
 - Change the armature and field polarity
 - Change the incoming leads
 - Use a different brush
35. During the charging of lead-acid cell, a dangerous, highly explosive gas is emitted from the cell. It is:
- Nitrogen
 - Methane
 - Oxygen
 - Hydrogen
36. The source V of a DC motor is 290V. When the motor is running, the voltage at the motor is 260V and draws 170 amp's. What is the resistance of the cable?
- 1.71 Ω
 - 1.12 Ω
 - 1.53 Ω
 - 0.18 Ω
37. Which of the following is required by all AC motors in order to operate properly?
- A rotating magnetic field
 - A phase shift capacitor
 - Two or more phases
 - A split phase
38. What is the full load secondary current of a single phase .2kVA transformer at 120V?
- 16 A
 - 1.6 A
 - 3 A
 - 24 A
39. Which 460V, 3-Phase AC motor requires the largest leads?
- 220V 40 HP
 - 220V 80 HP
 - 550V 40 HP
 - 550V 80 HP

40. Inductive reactance decreases with:

- a. An increase in frequency
- b. An increase in inductance
- c. Both A and B
- d. Neither A or B

41. Capacitive reactance decreases with:

- a. An increase in frequency
- b. An increase in capacitance
- c. Both A and B
- d. Neither A or B

42. Name four (4) things that are required to be recorded on the map of a mine electrical system.

- 1. _____
- 2. _____
- 3. _____
- 4. _____

43. Capacitors are used for:

- a. Arc reduction
- b. Correcting power factors
- c. Filtering electrical current
- d. All of the above

44. VARS is the measure of:

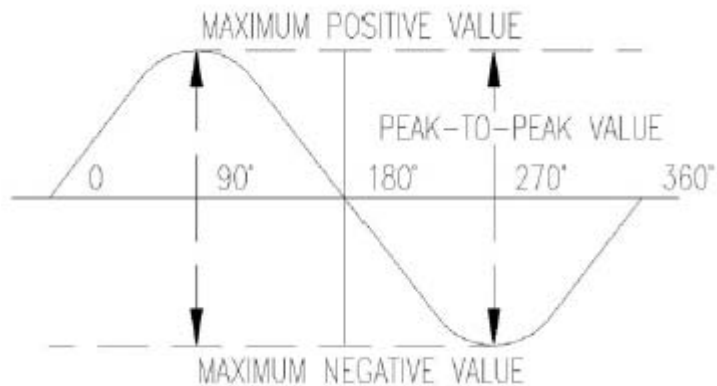
- a. Resistive power
- b. Reactive power
- c. Apparent power
- d. True power

45. A transformer has a primary voltage of 100V with 500 turns and a secondary voltage of 200V with 1,000 turns. What is the turns ratio?

- a. 1:5
- b. 5:1
- c. 1:2
- d. 2:1

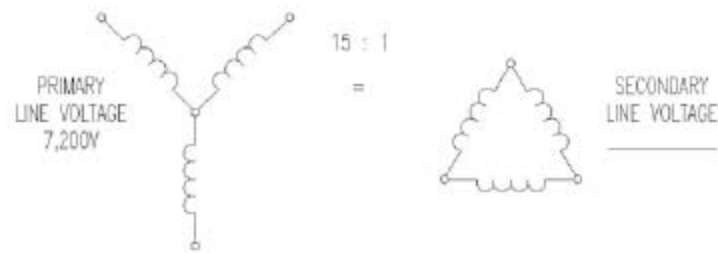
46. In a three-phase wye-connected transformer primary, the phase voltage is equal to:
- a. One-third the line voltage
 - b. One-half the line voltage
 - c. 1.73 times line voltage
 - d. 0.578 line voltage

Figure 1



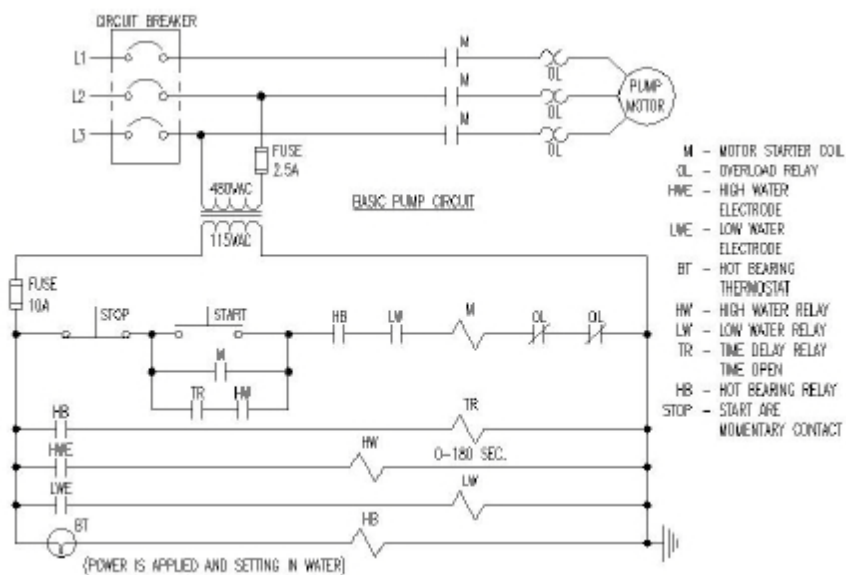
47. What is the peak-to-peak voltage when the effective voltage is 100 volts (Fig. 1)?
- a. 141.4 volts
 - b. 282.8 volts
 - c. 110.0 volts
 - d. 200 volts
48. What is the full load primary current of a 3 phase, 4,160 to 480 volt transformer with a 500kVA rating?
- a. 84
 - b. 169
 - c. 96
 - d. 69
49. If this transformer had a 4% impedance, what would the primary short circuit current be?
- a. 690
 - b. 384
 - c. 1,932
 - d. 1,725

Figure 2



50. What is the secondary line voltage (Fig. 2)?
- 480V
 - 277V
 - 550V
 - 600V
51. If the secondary line current is 200 amps, what is the primary line current?
- 7.7
 - 3,000
 - 13.3
 - 11

Figure 3



52. Give one method of starting the pump (Fig. 3).
- Push the start button
 - The low water relay starts the pump automatically
 - Close the ON contactor
 - Open the LW coil

53. Two things that will stop the pump (Fig. 3) are:
- a. ol & HW
 - b. HB & TR
 - c. LW & ol
 - d. TR & HW
54. Of the four possible combinations with three-phase transformers, which will give the greatest current handling capacity?
- a. Wye to delta
 - b. Delta to wye
 - c. Wye to wye
 - d. Delta to delta
55. Draw a Delta transformer schematic supplying a 3-phase bridge rectifier.
56. Three single-phase transformers with a ratio of 15:1 are connected delta-wye. If 4,160V is supplied to the primary side of the transformers what is the line-to-line voltage on the secondary side?
- a. 160V
 - b. 480V
 - c. 2,405V
 - d. 7,197V
57. A circuit breaker directly protects:
- a. Wire
 - b. Men
 - c. Equipment
 - d. Switches

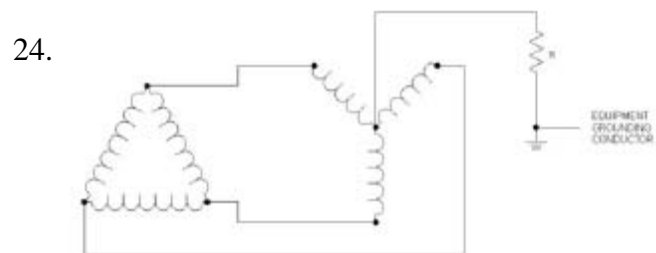
ANSWER SHEET FOR ELECTRIC CIRCUITS AND EQUIPMENT

1. b
2. d
3. a
4. c
5. a
6. b
7. d
8. c
9. b
10. d
11. d
12. a
13. a
14. d
15. d
16. a
17. c
18. d
19. a
20. c



22. $\frac{4600}{20} = 230 \text{ Volts}$

23. $E = \frac{(4160)}{15} (1.732)$
 $E = 480 \text{ Volts}$



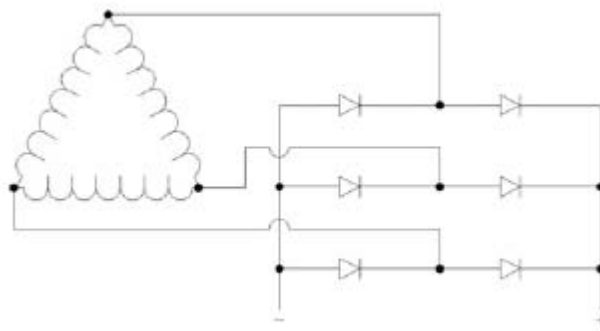
25. $E = \frac{40}{8} = 5 \text{ Volts}$

26. $I = \frac{90}{30} = 3$ amperes
27. $I_1 = \frac{240}{10} = 24$ amps
 $I_2 = \frac{240}{20} = 12$ amps
 $I_T = I_1 + I_2 = 24 + 12 = 36$ amperes
28. 1. Start Pushbutton 2. High Water Relay
29. 1. Stop Pushbutton 2. Overload 3. Hot Bearing Relay 4. Blown Fuse
 5. Low Water Relay
30. Faulty "M" holding contacts
31. 1. Remove power, lock out and tag out
 2. Check for continuity between 5 and 6 with an ohmmeter
32. 1. Hot Bearing 2. Overload 3. Blown Fuse
33. c
34. a
35. d
36. d
37. a
38. b
39. b
40. d
41. c
42. 1. Permanent Cables 2. Switchgear 3. Transformers 4. Permanent Pumps
43. d
44. b
45. c
46. d
47. b
48. d
49. d
50. b
51. c
52. a
53. c
54. a

55.

56. b

57. a



PRACTICAL EXAMINATION
WIRING DIAGRAMS AND METERS

ILLINOIS ELECTRICAL STUDY GUIDE

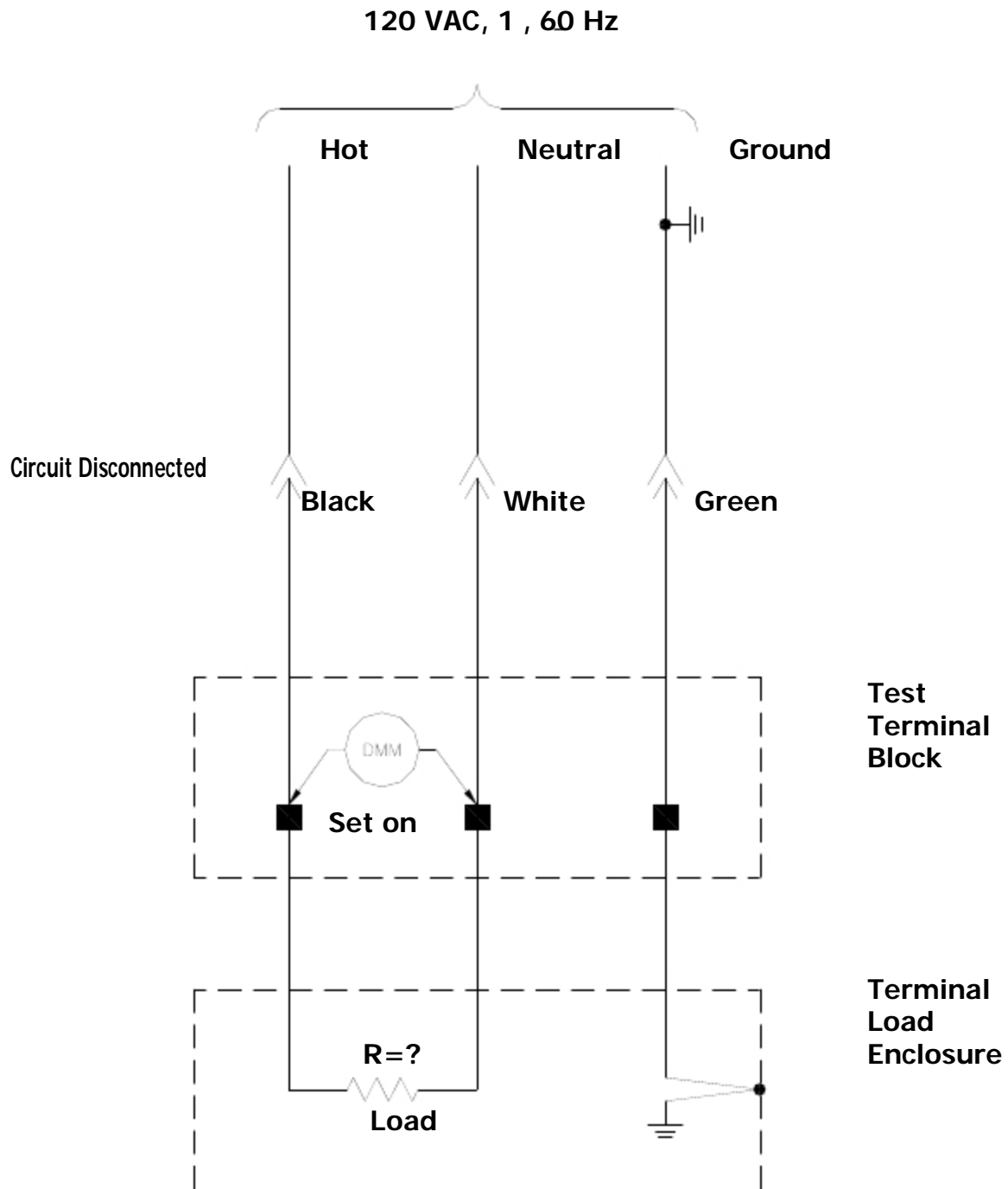
STUDY GUIDE

Wiring Diagrams and Electrical Meters Outline

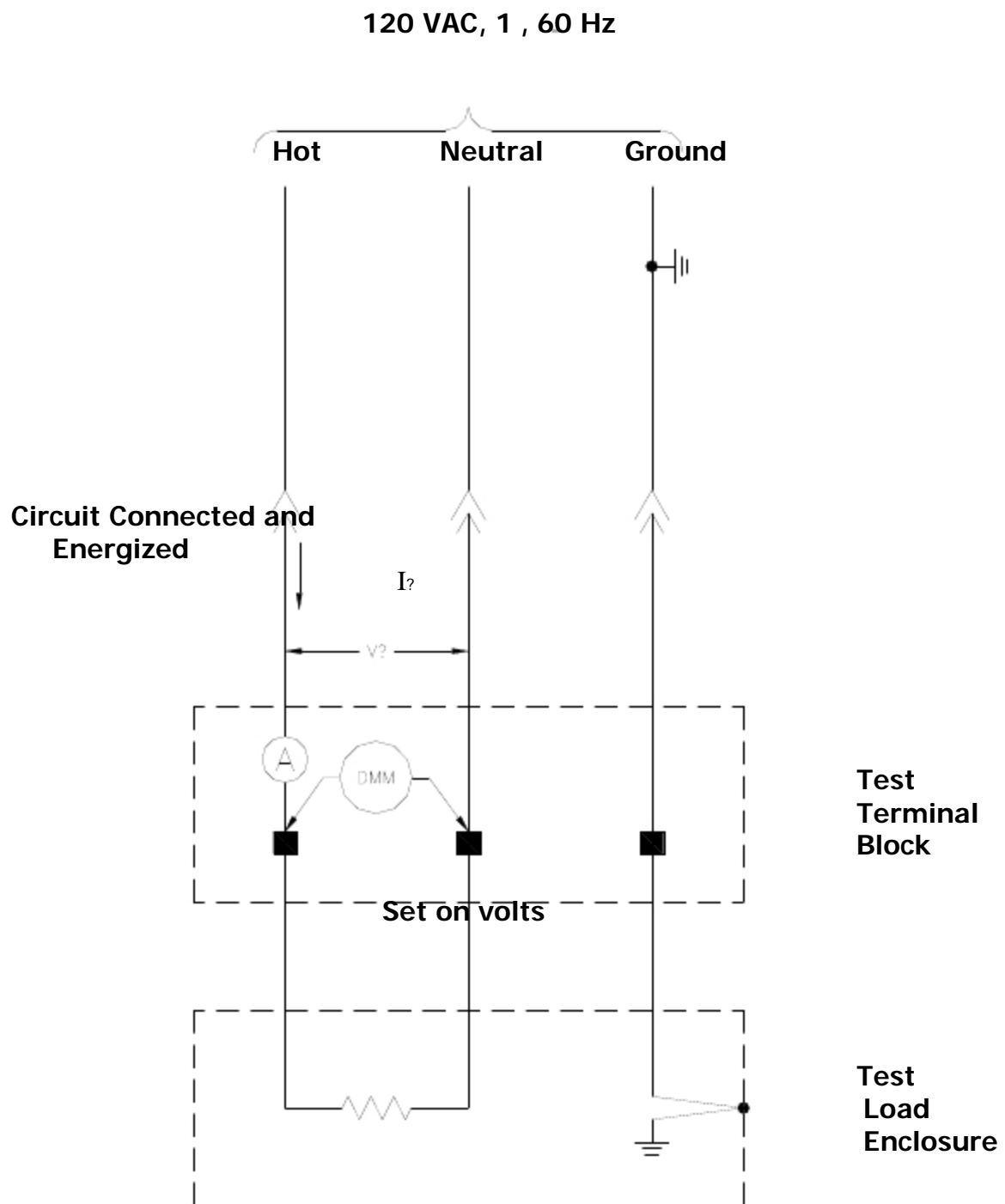
- A. Demonstrate the ability to wire electric circuits and systems from a schematic diagram
 - 1. Dual motor belt starter
 - 2. Typical substation high-voltage electrical distribution system
 - 3. Typical high-voltage electrical distribution system electrical protective device interconnections
- B. Demonstrate the ability to determine mine power feeder cable ampacity from a chart and properly set overload protection
 - 1. Current transformer ratio and connection
 - 2. Phase time overcurrent relay tap setting
- C. Particular attention must be paid to keeping substation ground field and mine ground field isolated by a minimum of 25 feet. No surface lightning arresters shall be connected to the mine ground grid
- D. Demonstrate the ability to properly use digital multimeters and clamp-on ammeters to measure circuit resistance, voltage, and current.
 - 1. All legally required and prudent safety precautions must be taken and demonstrated.
 - 2. Proper safeguards must be utilized while testing and troubleshooting energized circuits. Test circuit voltages will not exceed 120 volts.
 - 3. Properly select digital multimeter mode and range to 120 VAC nominal circuit voltage.
 - 4. Properly select digital multimeter mode and range to measure circuit load resistance.
 - 5. Properly select digital clamp-on ammeter mode and range to measure circuit current draw.

SAMPLE TEST CIRCUIT AND REQUIRED ELECTRICAL CIRCUIT MEASUREMENTS

Load Resistance Measurement



Voltage and Current Measurements



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Electrical Equipment & Circuits

1. Q. What is the effect of dust and dirt between joints of permissible equipment?

A. Joints cannot be closed tightly enough to get the required cooling action; therefore permissibility is destroyed.

2. Q. If you read an open circuit between A1 and A2 of a DC motor, it indicates that:

A. The armature circuit is open.

3. Q. What happens if the two line leads to a DC series motor are reversed?

A. Direction of rotation remains the same.

4. Q. The direction in which a motor rotates depends upon the:

A. Direction of the current flow through the armature.

5. Q. To reverse the direction of a DC motor:

A. Reverse either the armature or the series field leads.

6. Q. If you read a low resistance between leads S1 and S2 of a series motor, means that:

A. The series field is good.

7. Q. How is the rotation of a direct current, series motor reversed?

A. By changing the direction of the current flow in either the armature or series field.

8. Q. Thirty-five horsepower is equal to:

A. 26.11KW.

9. Q. Which would require the largest wiring?

A. A 15-HP, 220-volt motor.

10. Q. Five kilowatts equal how many watts?

A. 5,000 watts.

11. Q. The thermal heater element of an overload relay is generally connected in:

A .Series with the motor lead.

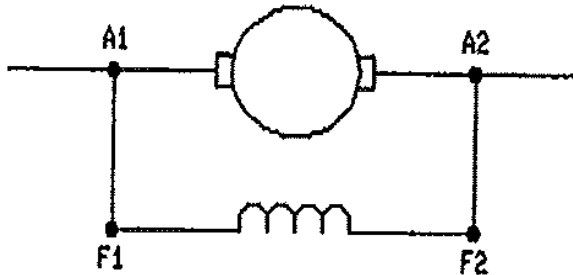
12.. Q. A hot stick shall be electrically tested:

A. Once every calendar year.

13. Q. When compared to the resistance of the series fields and armature circuit, the shunt fields of a motor will have:

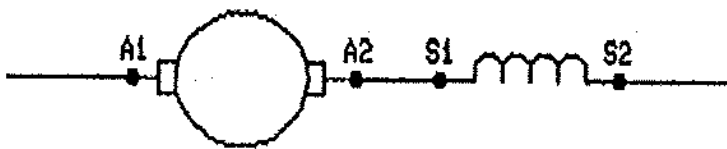
A. Higher resistance.

14. Q. The symbol below represents:



A. A Shunt motor.

15. Q. The symbol below represents:



A. A series DC motor.

16. Q. Shunt fields of a DC motor are identified by:

A. F1 and F2 leads.

17. Q. When dealing with electrical equipment, grounding:

A. Provides a return path to the earth and prevents voltage from existing on the frames of the equipment.

18. A. A ground fault is a phase-to-ground short in the output of:

A. An electrical system.

19. A. A solid state device most commonly used to control power output in a DC circuit is:

A. Silicon controlled rectifier.

20. Q. What is the purpose of a frame ground in a trailing cable?

A. To protect the operator from shock by keeping the equipment at earth potential.

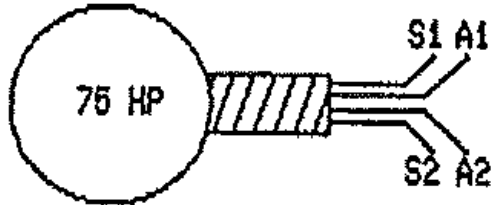
21. Q. When comparing the resistance of the shunt field of a DC motor to the series field, the shunt field resistance is usually:

A. Higher.

22. Q. If the shunt field of a compound motor opens, the motor usually:

A. Speeds up.

23. Q. What type of motor would this drawing represent?



A. Series motor.

24. Q. Series field leads of a DC motor are identified by:

A. S1 and S2.

25. Q. What purpose is served by a starting resistor in a motor circuit?

A. It limits the starting current during start-up by reducing the voltage.

26. Q. Pumps and section equipment are grounded by a:

A. A conductor connected to the system ground.

27. Q. Using a shunt motor enables you to control:

A. Both speed and direction.

28. Q. With a shunt motor, speed is controlled by:

A. A variable resistance in a separate field circuit.

29. Q. The motor better suited to control hoisting is:

A. A shunt motor.

30. Q. If the cross-sectional area (size) of a wire is decreased, its resistance will

A. Increase

31. Q. If an equipment frame grounding wire was not provided:

A. There would be a real potential for electrical shock.

32. Q. Which of the following methods is NOT recommended for removing a victim from contact with electricity?

A. Knock the victim off with a nonconductive object.

33. Q. In general, how should bandages be applied to a burn?

A. Loosely.

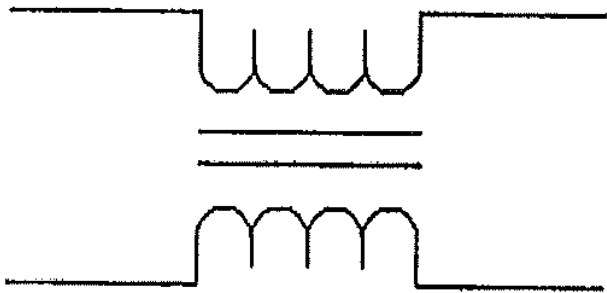
34. Q. Through what piece of equipment is alternating current fed in order to lower its voltage?

A. Transformers.

35. Q. Transformers are used to:

A. Step up or step down AC voltage.

36. Q. The following symbol would represent which of the following?

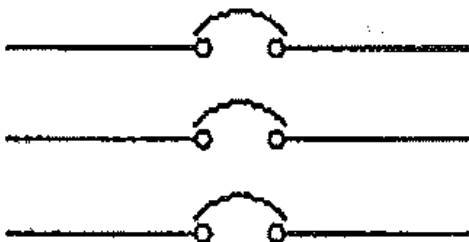


A. Transformer

37. Q. If 1,100 amps leave a rectifier on one conductor, how many amps will return to that rectifier on the other conductor?

A. 1,100 amps.

38. Q. The following symbol would represent which of the following?



A. Circuit Breaker

39. Q. Thermal overloads are used for:

A. Overload and single-phase protection on three-phase circuits.

40. Q. The function of the capacitor trip device and circuit is to:

A. Provide sufficient energy to trip the breaker, even after the power goes off.

41. Q. If the overcurrent condition continues for a long time, and at a great enough magnitude, an overcurrent device will trip the:

A. Circuit breaker.

42. Q. When a circuit breaker is tripped:

A. No current flows beyond it into the circuit.

43. Q. If circuit breakers are too small for the equipment they are protecting:

A. The circuit breaker will not stay closed.

44. Q. The instantaneous setting of a circuit breaker is:

A. The short circuit setting.

45. Q. The ampere capacity of a circuit breaker is:

A. The amount of current that a breaker can carry under normal conditions.

46. Q. Magnetic trip units of a circuit breaker provide what protection?

A. Short circuit.

47. Q. The most commonly used short-circuit protective device for trailing cables is:

A. A circuit breaker.

48. Q. When an overcurrent device detects an overload condition, the breaker should trip:

A. All three phases at the same time.

49. Q. The difference between a time delay and an instantaneous overcurrent relay:

A. Lies primarily in how quickly they trip a circuit breaker.

50. Q. A blown fuse or a tripped circuit breaker could indicate all of the following EXCEPT:

A. Overvoltage.

51. Q. The idea behind a capacitor trip device and circuit is to:

A. Provide sufficient energy to trip the breaker, even after power goes off.

52. Q. When a circuit breaker has an overload trip, what causes the circuit breaker to de-energize the circuit?

A. A thermal element heats up and actuates the contacts.

53. Q. Thermal heater strips in circuit breakers or line starters are used to provide what protection?

A. Overcurrent.

54. Q. A wire is marked "14 AWG". The number "14" refers to:

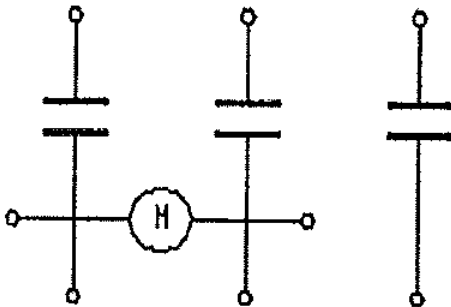
A. The size of the conductor.

55. Q. The symbol below represents:



A. A fuse.

56. Q. The following symbol would represent which of the following?

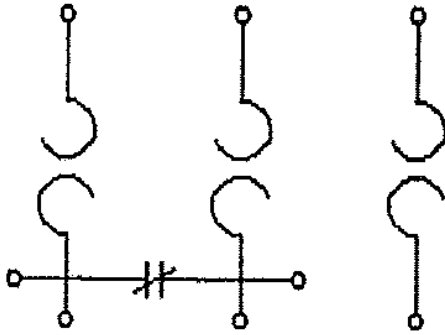


A. Line starter

57. Q. A 3-phase motor continues to operate when one lead has been severed or cut in two; then, when stopped, will not start again. The motor is said to be:

A. Single phase.

58. Q. The following symbol would represent which of the following?



A. Thermal Overload

59. Q. What does the following symbol represent?



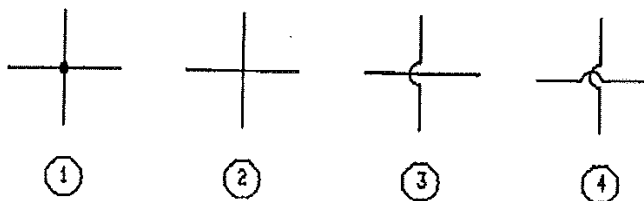
A. Silicon Controlled Rectifier (SCR).

60. Q. This symbol means:



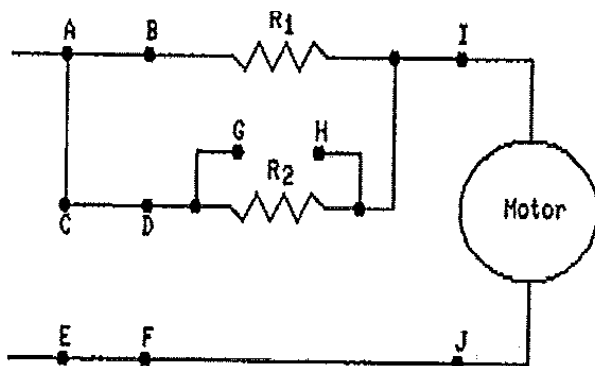
A. Fused Switch

61. Q. Which of the three diagrams below shows a wire making a physical electrical connection?



A. Diagram 1

61. Q. If you were to install a voltmeter to measure the voltage for the “R2” resistor only, you would make your connections across points:

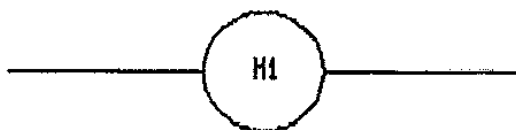


A. G and H

62. Q. If under normal load a 30-amp fuse becomes hot the most likely reason for this is:

A. The clips holding the fuse are loose.

63. Q. The symbol below represents:



A. A coil.

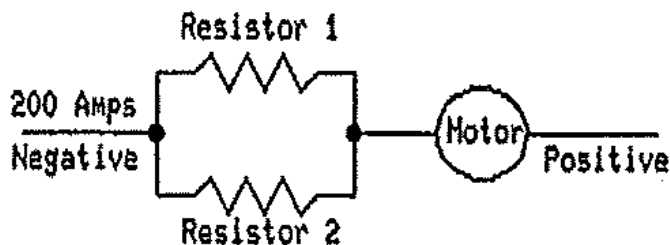
64. Q. Voltage is checked with an instrument called a (an):

A. Voltmeter.

65. Q. If a 120-volt direct current source is connected to a 10:1 step-down transformer, the output on the secondary side is:

A. Zero volts.

66. Q. Two resistors (Resistor 1 and Resistor 2) are connected in parallel and Resistor 2 burns open. What would happen?



A. Current in the circuit would be reduced.

67. Q. If an ohmmeter shows continuity across an SCR with no gate voltage applied, the SCR is probably:

A. Shorted.

68. Q. This symbol means:



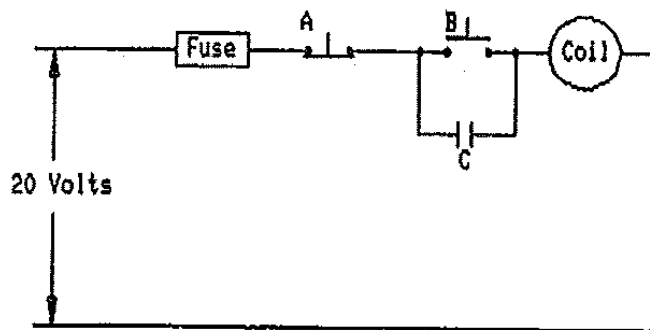
A. Fuse.

69. Q. This symbol means:



A. Circuit Breaker

70. Q. To energize this circuit you would:



A. Depress push button "B".

71. Q. The motor overload relay contacts are connected in:

A. Series with the operating coil.

72. Q. The symbol represents:



A. A normally closed instantly open mercury tube.

73. Q. If you were to shunt-out a resistor, the resistor would:



A. Not cause a voltage drop.

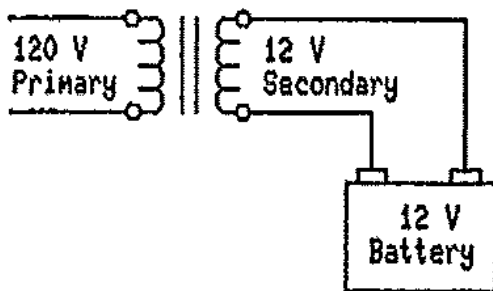
74. Q. Current is checked with an instrument called a (an):

A. Ammeter.

75. Q. Which of the following is a true statement concerning the operational characteristics of an SCR?

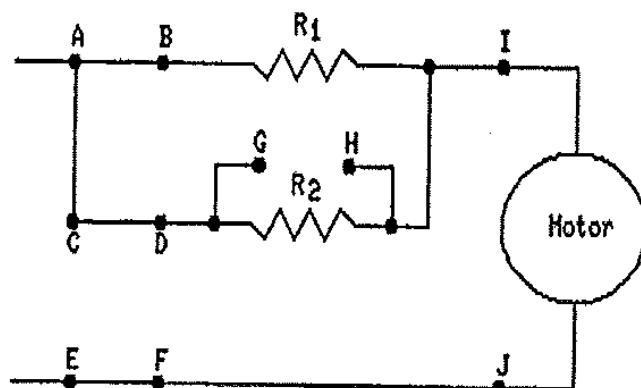
A. It will allow current flow in only one direction once it is gated.

76. Q. Charging a 12-volt battery from a 12-volt AC source will:



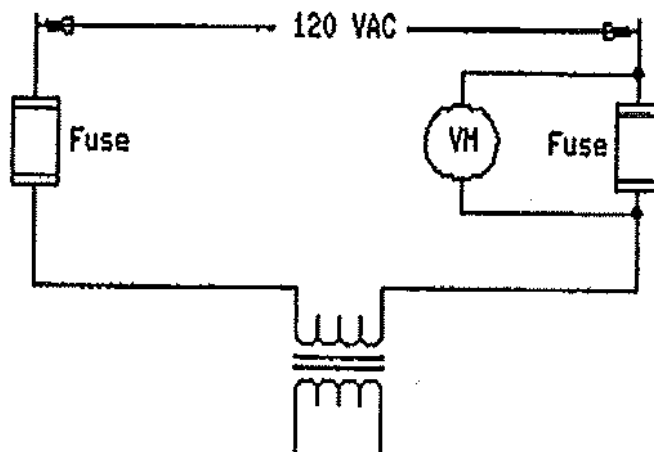
A. Not charge the battery

77. Q. If you were to install an ammeter to measure the current flowing through the 'R2' resistor you would make your connections between points:



A. C and D

78. Q. As shown below, what does a zero reading on a voltmeter indicate?



A. A good fuse

79. Q. Heat sinks on a rectifier are provided to:

A. Cool the rectifier.

80. Q. The symbol represents:



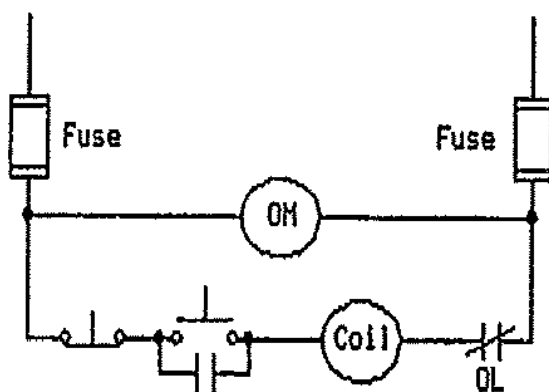
A. A diode

81. Q. The symbol below represents:



A. A resistor.

82. Q. In the following circuit, what would be the ohmmeter reading?



A. Infinity or open circuit.



84. Q. The heater element in a motor circuit overload relay is connected in:

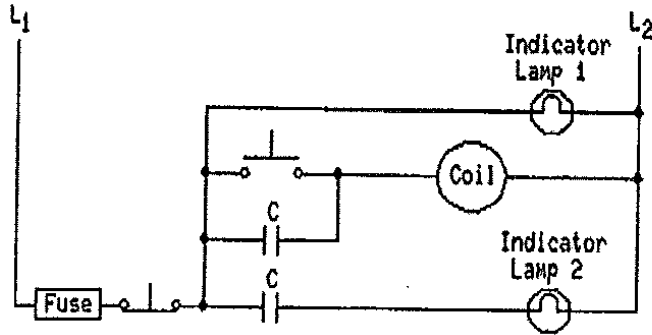
85. Q. If you were to install an ammeter to continuously monitor the current in the motor, you should connect it between points:.



86. Q. A ground monitor circuit is used to:

152

87. Q. If neither indicating light were on, and the coil would not energize, what component is most likely defective?



A. The fuse

88. Q. A dual element fuse provides:

A. Short circuit and overload protection.

89. Q. Fuses should be replaced with:

A. Proper fuses.

90. Q. What is wrong with replacing a blown fuse with a piece of copper wire?

A. The copper wire will not provide adequate overcurrent protection.

91. Q. If a system designed for a 20-amp fuse blows, and an electrician replaces it with one rated at 30 amps:

A. A fire may result or the equipment may become damaged.

92. Q. When fuses are too big for the current requirement of the equipment being protected:

A. Too much current could be allowed to pass through, overheating equipment and burning off insulation.

93. Q. A single element fuse provides:

A. Short circuit protection.

94. Q. What is used to prevent the Forward and Reverse contactors in a motor reversing control from operating at the same time?

A. Electrical and/or mechanical interlocks.

95. Q. The DC motor that uses both a series and shunt winding and combines the characteristics of both is called a:

A. Compound motor.

96. Q .What will happen to a DC shuttle car series wound motor if the chain or drive shaft would break?

A. The motor will overspeed to the point of destruction.

97. Q .To reduce the hazard of electrical shock, which of the following should be installed?

A. Frame ground conductor.

98. Q. What device may be installed in the neutral of a three-phase wye connected system to limit the current if a ground fault occurs?

A. Grounding resistor.

99. Q. When checking resistance in an AC circuit when troubleshooting, what initial precaution must be taken?

A. Disconnect the source voltage.

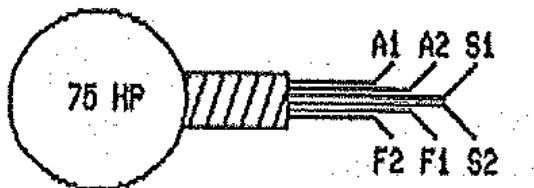
100. Q. Speed of DC motors can be controlled by:

A. Regulating the applied voltage.

101. Q. The overload relay contacts of a thermal overload are generally connected in:

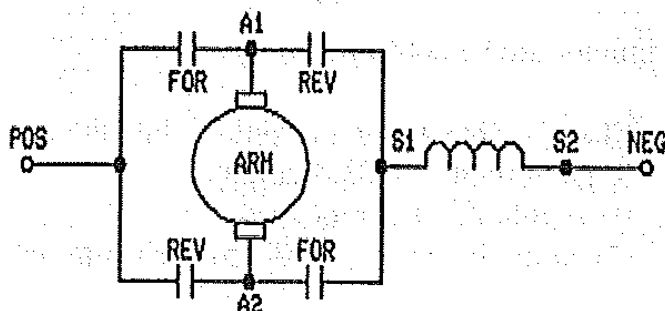
A. Series with the operating coil.

102. Q. What type of motor would this drawing represent?



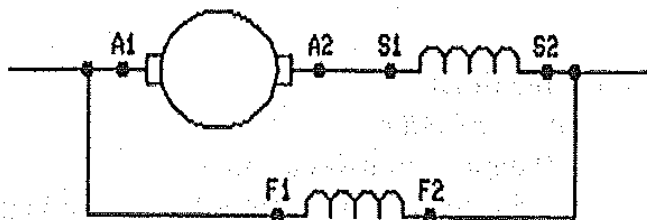
A. Compound Motor

103. Q. The following symbol represents:



A. Reversing contactors for a series motor.

104. Q. The symbol below represents:



A. A compound motor.

105. Q. Which of the following is not a characteristic of a series motor?

A. Current remains the same at all loads.

106. Q. What is used to limit the starting current of a DC motor?

A. Resistors.

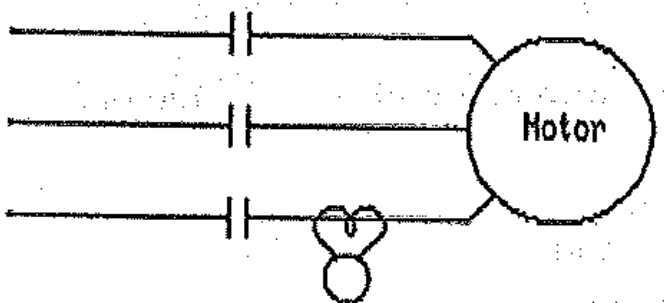
107. Q. Three-pole single-throw disconnect switches have how many knife blades?

A. Three.

108. Q. Arc chutes on contactors contain heavy copper coils that are called:

A. Blowout coils.

109. Q. The component attached to the donut coil on one phase lead, between the contactors and motor, is normally used as a (an):

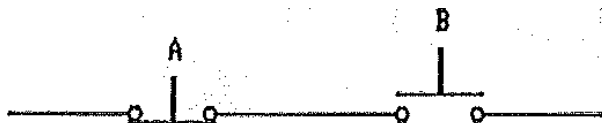


A. Ammeter

110. Q. If a thermal overload activates, causing a circuit to be de-energized, what must you do before the circuit can be re-energized?

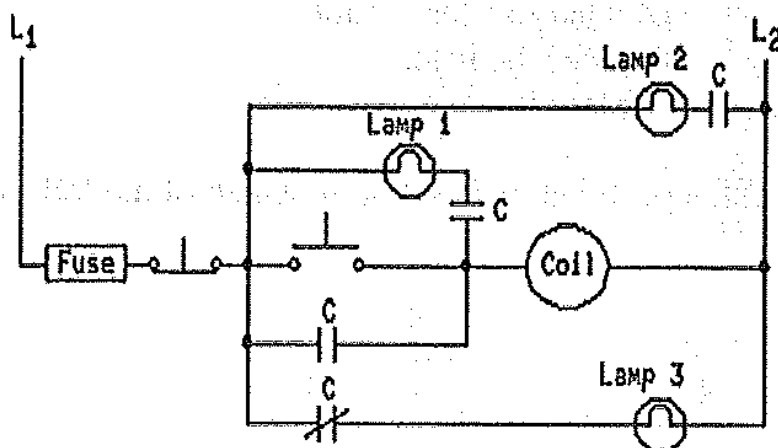
A. Allow it to cool.

111. Q. This start/stop push button is set up in which of the following manners?



A. Button "A" is for stop and "B" is for start.

112. Q. Which of the following indicating lights (No. 1, No. 2, No.3) will remain lit when the coil is NOT energized?

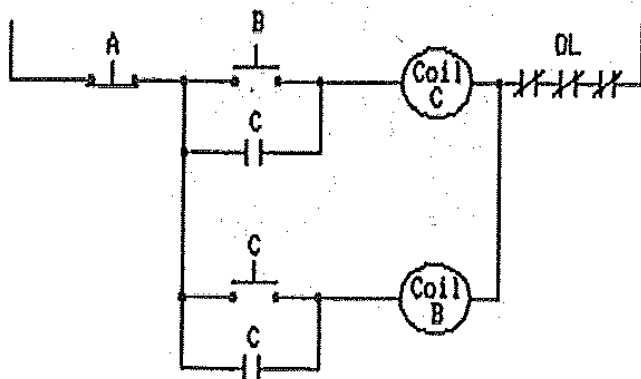


A. Light No. 3

113. Q. If you were to peel the insulation off a No. 14 AWG stranded conductor, you would expect to find:

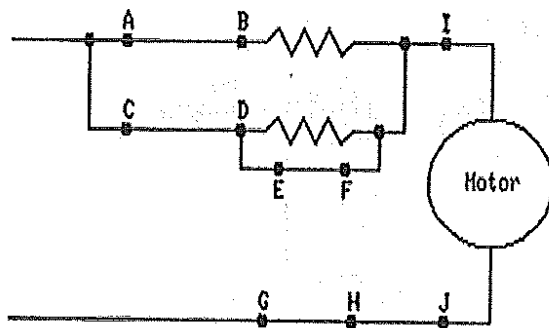
A. Smaller wires which are not insulated from one another.

114. Q. Which button, when depressed, will energize coil "B" and keep it energized after the button is released?



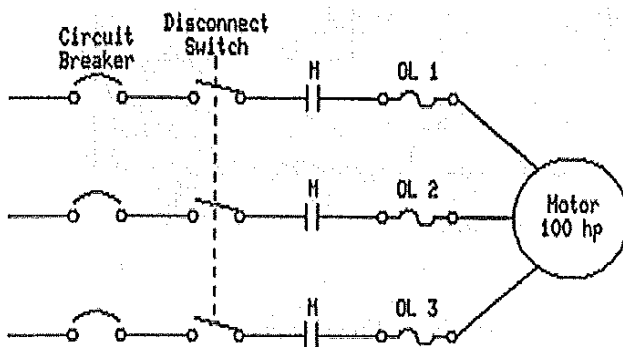
A. Push button "B".

115. Q. If you were to install a voltmeter to measure the voltage at the motor, you should connect it between points:



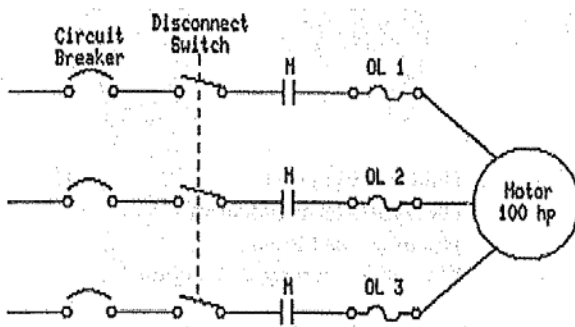
A. I and J

116. Q. The diagram indicates that the motor is operated by:



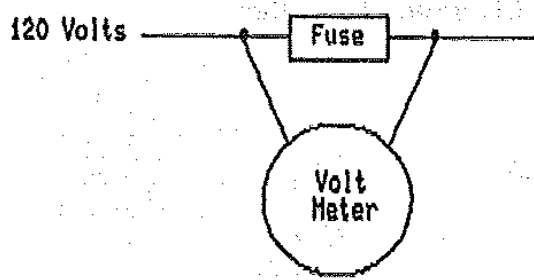
A. A three-phase power source.

117. Q. If you were to lockout and tag the motor to begin repair work, the safest and most convenient place to do this would be at the:



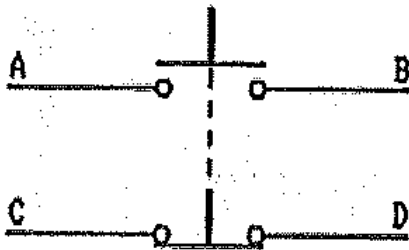
A. Disconnect switch located near the motor.

118. Q. If a voltmeter were placed across the fuse and no voltage was indicated, you could correctly assume that:



A. The fuse was good

119. Q. If a circuit is created across "AB" when the button is depressed, the circuit "CD" will:

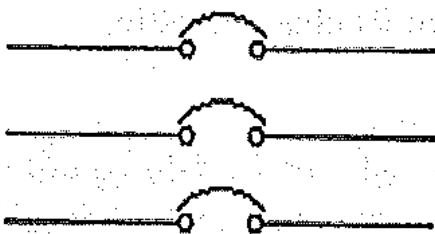


A. Open

120. Q. What is the same in all parts of a series circuit?

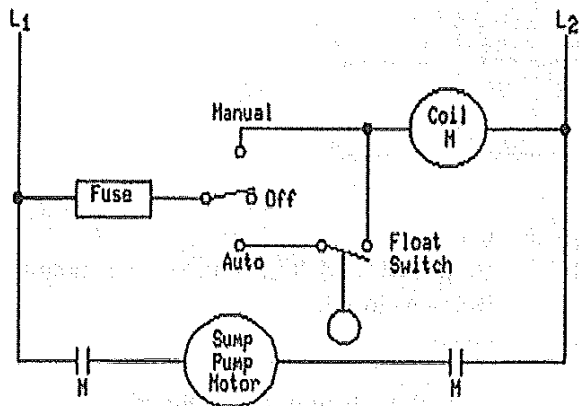
A. Current.

121. Q. This symbol stands for a:



A. Circuit Breaker

122. Q. The purpose of the float switch shown in the diagram is to:

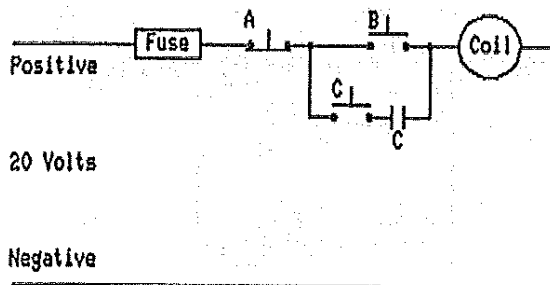


A. Start motor when the water level gets high enough to close the float switch.

123. Q. The duty cycle of a motor refers to its characteristic:

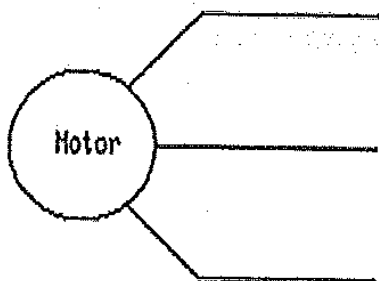
A. Maximum time period it can safely operate.

124. Q. If push buttons "B" were depressed, the coil would:



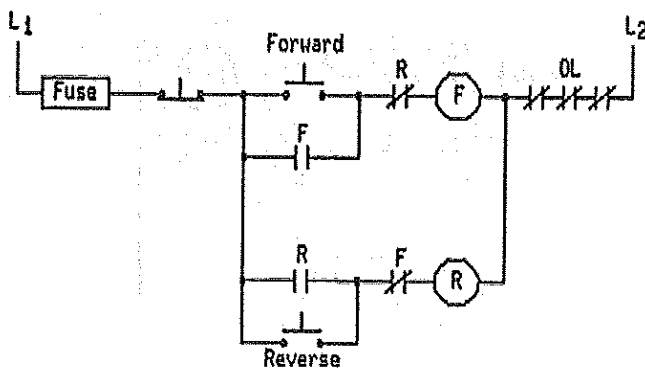
A. Remain energized as long as the button remained depressed.

125. Q. This symbol indicates:



A. A three-phase motor.

126. Q .Contact “F” is normally closed. What is its purpose?



A. To prevent coil “R” from becoming energized while coil “F” is energized.

127. Q. A solenoid operates in the same way as a:

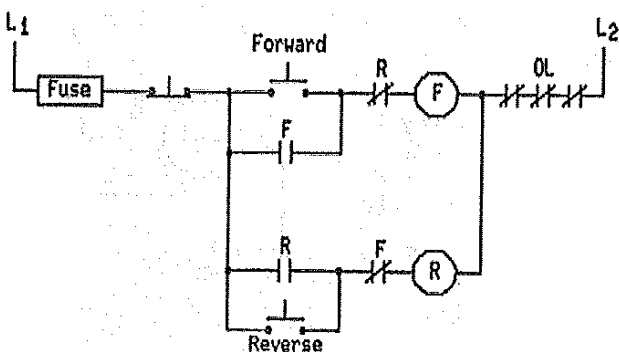
A. Relay.

128. Q. This stop switch is classified as:



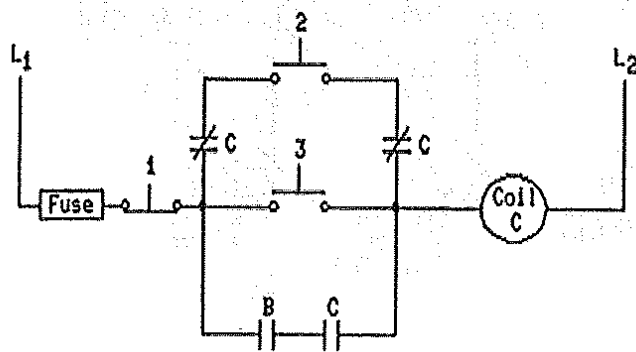
A. Momentary.

129. Q. Which of the following statements would be true if the forward push button were depressed?



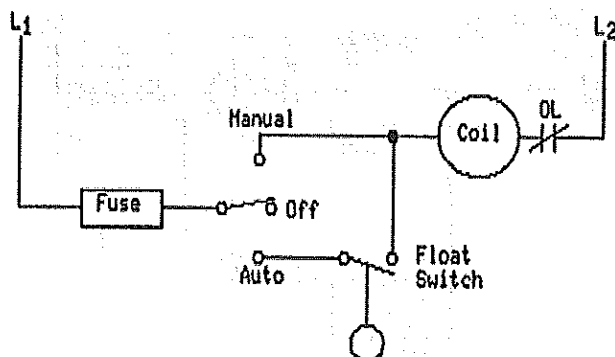
A. Coil “F” will energize and remain energized.

130. Q. Which of the following push buttons will energize coil “C” while the button is depressed and de-energize coil “C” when the push button is released?



A. Push button 3

131. Q. If you want this pump to operate only when the water level reaches a certain depth, you should set the selection switch at what position?



A. Auto position

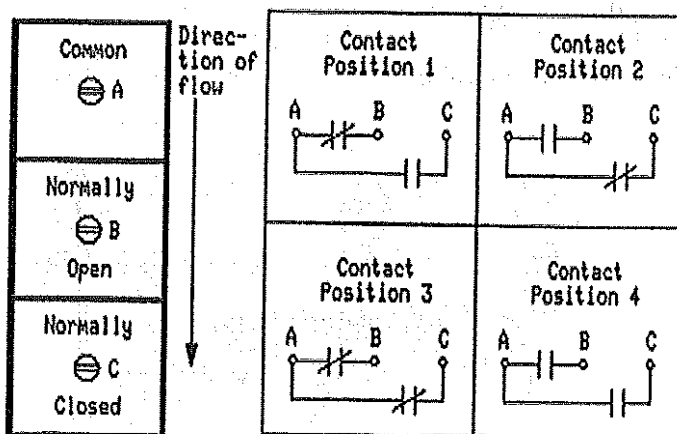
132. Q. Meggers are used to check:

A. Insulation resistance.

133. Q. The system using one ground wire and three hot wires, whose voltage is balanced 120 degrees apart is called:

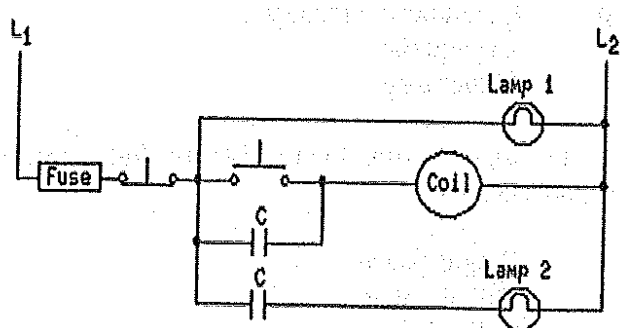
A. Three-phase.

134. Q. Which of the following contact positions match the contact position plate in the diagram below?



A. Contact position No. 2.

135. Q. In the circuit shown in the diagram, if all components were functioning properly, which light(s) would be lit if the coil were energized?

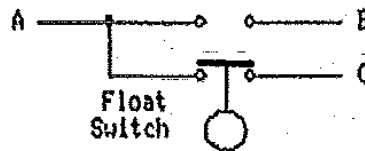


A. Both lights

136. Q. The safest way to de-energize a motor running on full load is:

A. Through the control circuit which will open the line contactors.

137. Q. If you wanted to energize a pump motor to operate when the water level got high enough to cause the float switch to close, you would connect your leads to what terminals on the float switch in the diagram below?



Common	Normally	Normally
⊖ A	⊖ B	⊖ C
	Open	Closed

A. A and B

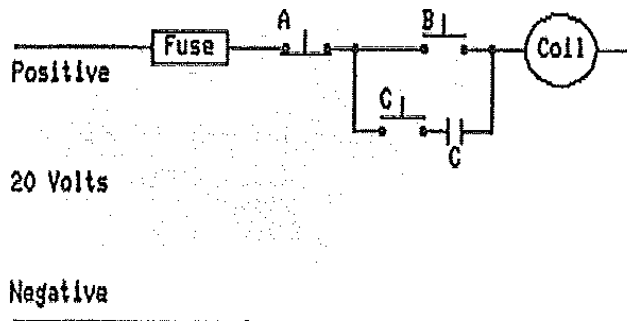
138. Q. Which system requires only two power conductors and is generally used for control, lighting, and small loads?

A. Single-phase power.

139. Q. A magnetic relay is either closed or opened by:

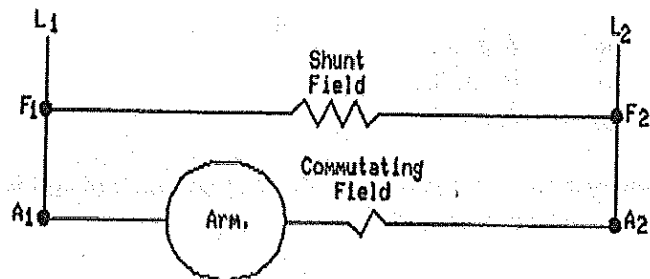
A. An electromagnetic field.

140. Q. Push button "B" would be classified as:



A. A jog push button

141. Q. This is a schematic of a:



A. Shunt motor

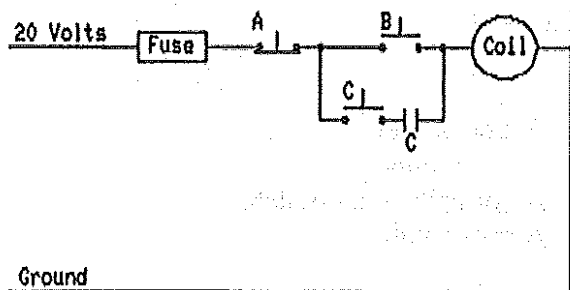
142. Q. If a float switch on a pump closes because the water level rises:

A. The pump should start because the float switch completed an electrical circuit

143. Q. The purpose of a slip switch on a belt is to:

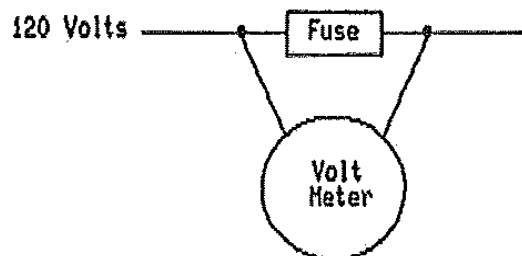
A. Stop the drive when the belt is slipping.

144. Q. Push button "A" would be classified as:



A. A stop push button

145. Q. If a voltmeter were placed across the fuse and the scale indicated 120 volts, you could correctly assume that:



A. The fuse was blown.

146. Q. Of the devices listed below, what will change single-phase AC to DC?

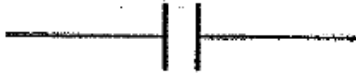
A. Rectifiers.

147. Q. The symbol below represents:



A. A stop button

148. Q. The following symbol would represent:



A. A normally open contact.

149. Q. The following symbol would represent:



A. A normally closed contact.

150. Q. The symbol below represents:



A. A start button

151. Q. A rectifier does what:

A. Changes AC current to DC current.

152. Q. What is electrolysis?

A. The action of an electrical current which carries away particles of a conductor.

153. Q. A diode blocks:

A. Current in one direction.

154. Q. When testing a diode with an ohmmeter, what will be the reading of a good diode?

A. A low resistance reading in one direction and a very high reading in the other direction.

155. Q. If a diode reads continuity in one direction and open in the other, it is probably:

A. Good.

156. Q. What purpose is served by a blowout coil used as a DC contactor?

A. It helps to extinguish the arc when the contactor opens.

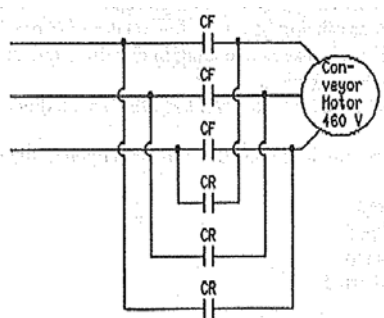
157. Q. Electrical pressure or electromotive force is defined as:

A. Voltage.

158. Q. The current used for charging storage batteries is:

A. Direct current.

159. Q. This circuit supplies power to the conveyor motor. Which of the following is NOT true?



A. All six contactors will close at once.

160. Q. This symbol represents a 5-amp:



A. Fuse

161. Q. A wire used for a temporary connection is termed a:

A. Jumper.

162. Q. A small sump pump blows a 20-amp fuse. The pump under full load draws 12 amps of current and receives its power through a No. 12 AWG cable. After repairing the problem, you discover you only have a 15-amp and a 30-amp fuse. You should:

A. Install the 15-amp fuse.

163. Q. The unit of measurement meaning “electrical pressure or force” is the:

A. Volt.

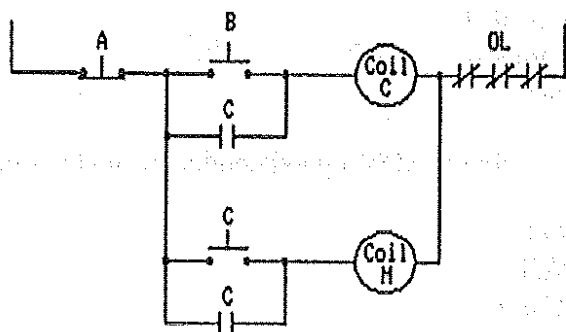
164. Q. The wires of a transformer have a 10:1 ratio. When stretched out side by side:

A. One wire would be ten times the length of the other.

165. Q. The material used to separate one electrical wire from another in a cable is called:

A. Insulation.

166. Q. If push button “C” is depressed:



A. Only coil “M” will be energized and remain energized as long as the button is depressed.

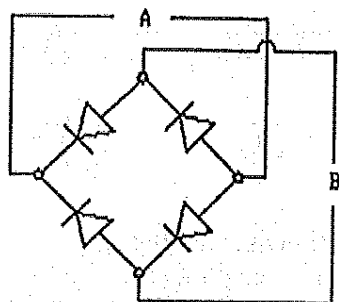
167. Q. If you checked a resistor marked 50 ohms and your meter read the resistance extremely high (your meter would not measure the amount), you would be most correct in assuming that:

A. The resistor has burned open.

168. Q. If four cables all have the same insulation and circular mil value, which cable would be the most flexible?

A. 200 strands.

169. Q. Which of the following is represented by the symbol shown?



A. Full wave rectifier.

170. Q. A shuttle car tramping up a steep grade at the feeder blows a fuse. Before knocking the power and tagging-out the circuit you must:

A. Block the machine so it doesn't move.

171. Q. The part of a disconnect switch which has metal blades that pivot at one end is called a (an):

A. Knife switch.

172. Q. The safest way to check an electrical load to see if it is an open circuit is with a (an):

A. Ohmmeter with power off.

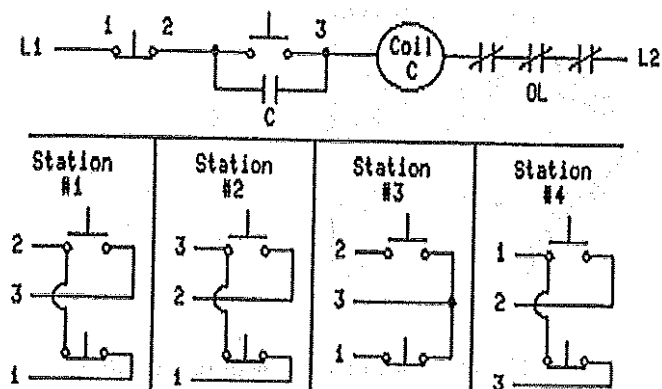
173. Q. Which of the following is a good conductor of electricity?

A. Carbon.

174. Q. If a circuit breaker with thermal overload protection has just tripped and you immediately try to re-energize the circuit and find that the breaker will not hold in, you should:

A. Wait for the thermal element in the breaker to cool sufficiently so that it will hold in the tripping mechanism.

175. Q. Which of the push button stations below is wired according to the diagram?



A. Station No. 1

176. Q. The power of a transformer is rated by its:

A. KVA rating.

177. Q. There are three types of electrical diagrams. Which of the following is NOT an electrical diagram?

A. Power diagram.

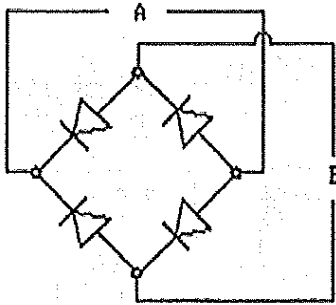
178. Q. A transformer has primary windings of 460 volts and secondary windings of 115 volts. What can you correctly assume about wire size?

A. The secondary windings would be larger in size (AWG) than those on the primary side.

179. Q. The main function of a thermal overload is to:

A. Protect the motor from overload.

180. Q. What type of current would you expect to find at the leads of Point "B"?

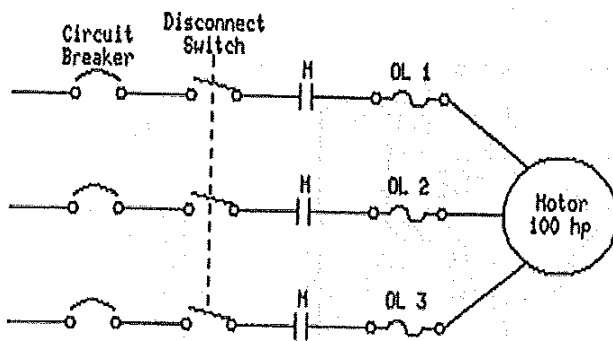


A. Alternating current.

181. Q. The device that makes or breaks a circuit feeding a load is called a:

A. Contactor.

182. Q. If the motor developed an internal "direct short" between phases, the device to de-energize the circuit would be the:

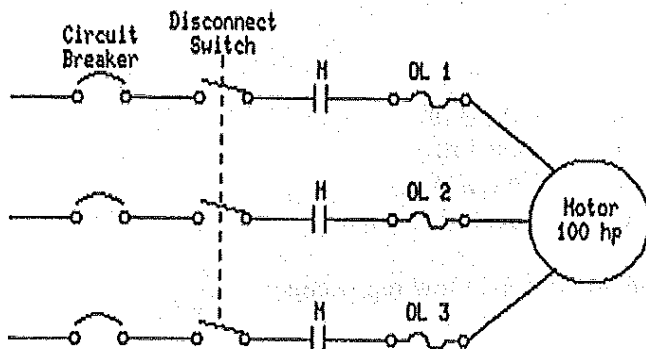


A. Circuit breaker.

183. Q. If you wanted to check the insulation on wire for damage, the instrument you would use is a (an):

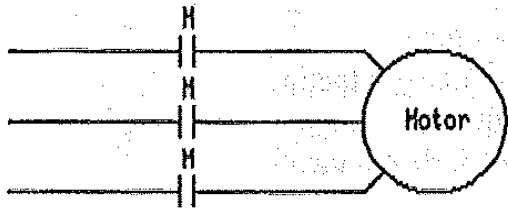
A. Megger.

184. Q. The main purpose of the overloads is to protect the:



A. Motor

185. Q. The “M” line contactors should be physically located in:

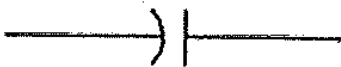


A. The starter

186. Q. If a belt conveyor loaded with coal was turned on, the starting torque would be greatest when the motor:

A. First starts

187. Q. This is a symbol for a:



A. Capacitor.

188. Q. The symbol shown below represents:

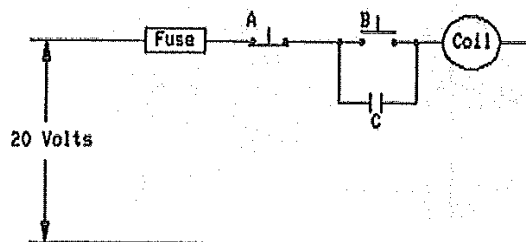


A. A single pole contactor.

189. Q. A current that changes in magnitude but not in direction is called?

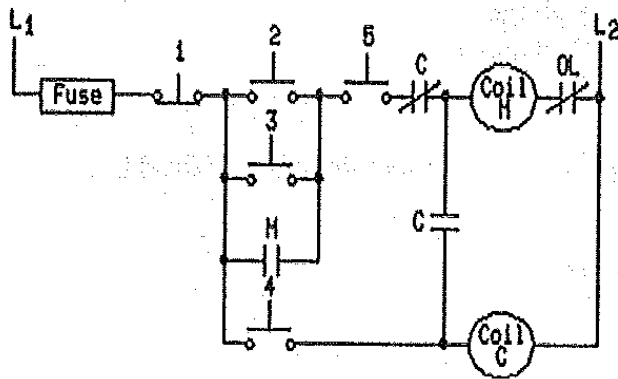
A. Pulsating current.

190. Q. To stop or de-energize this circuit in a normal manner you would:



A. Depress push button “A”.

191. Q. Which of the four push button stations will cause coil “M” to be energized only while that push button is depressed?

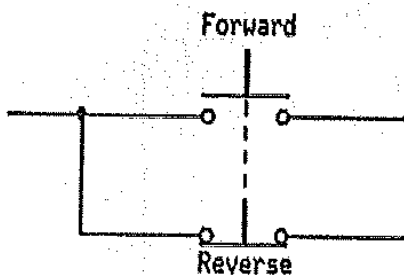


A. Push button 4

192. Q. The unit of measurement of resistance to the flow of electricity is the:

A. Ohm.

193. Q. These push buttons are:

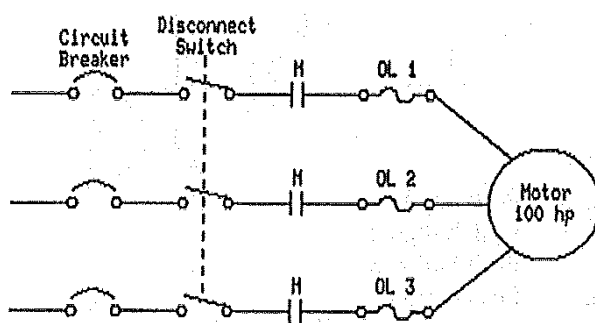


A. Mechanically interlocked.

194. Q. What is the same across each part of a parallel circuit?

A. Voltage.

195. Q. Across-the-line starting of this motor is achieved by:



A. The M contactors.

196. Q. The unit of measurement generally used when rating a capacitor is the:

A. Microfarad.

197. Q. If you wanted to find information concerning a motor's duty cycle characteristics, you could find it most easily by:

A. Looking at the tag attached to the motor housing

198. Q. Resistance is checked with an instrument called a(an):

A. Ohmmeter.

199. Q. If the continuous miner stops operating, and the only component that is energized on the miner is its methane monitor, you could do all of the following EXCEPT:

A. Jumper-out the methane monitor.

200. Q. Which will cause the power center circuit breaker for a continuous miner to trip faster?

A. The shuttle car runs over the miner cable causing two conductors to come in contact with each other.

201. Q. This is a symbol for a:



A. Resistor

202. Q. If a transformer was believed to be shorted because of a breakdown in its insulation, what instrument would you use to check it?

A. A megger.

203. Q. Electron flow in a conductor is defined as:

A. Current.

204. Q. If the cross-sectional area (size) of a wire is decreased, its resistance will:

A. Increase.

PERMISSIBILITY OF ELECTRICAL EQUIPMENT

ILLINOIS ELECTRICIAN STUDY GUIDE

Permissibility Of Electrical Equipment Outline

- A. Most questions are related to CFR, Part 18
- B. Trailing cable rating in accordance to IPCEA
- C. Hand tool safety device requirements
- D. Frame-to-ground potential limitations as per CFR, Part 18
- E. Fire protection requirements for unattended, enclosed, equipment
- F. Criteria for plugs for spare lead entrances, including radial clearance
- G. Surface temperature limitations of machine components
- H. Fastening requirements for explosion proof enclosures such as a bolt length, bolt size, studs, washers, packing nuts, stuffing boxes, and thread engagement
- I. Electrical and mechanical protection requirements for cables entering splice boxes and between machine components
- J. Slip switch requirements for conveyor belts and exemptions
- K. Trailing cable installation requirements
- L. Cable reel requirements
- M. Machine headlight requirements
- N. Allowable method of making splices in power cables between machine components
- O. Maximum allowable clearances
 - 1. Step flange
 - 2. Plane flange
 - 3. Motor end-bells
 - 4. Cylindrical switches and joints
- P. Purpose of hose conduit
- Q. Permissible machine criteria and maintenance
 - 1. Approval by MSHA
 - 2. Maintained in permissible condition
 - 3. Fire and explosions can result from inadequate maintenance
- R. Definitions
 - 1. Explosion-proof
 - 2. Intrinsically-safe
- S. Requirements for cable and wires that pass through metal walls of electrical compartments
- T. Requirements for temporary cable splices
 - 1. Low and medium voltage
 - 2. High voltage

PERMISSIBILITY

There are three main types of joints that are used most commonly on permissible enclosures. These joints are classified as plane flange joints, step flange joints, and threaded joints.

Plane Flange Joints – Refer to Figure 5

A plane flange joint is one which has to adjoining surfaces in parallel planes or a smooth metal to metal joint. A good example of the plane flange joint can be observed on most shuttle car panel covers. In order for a plane flange joint to be permissible, it must not have a clearance or tolerance greater than 0.004 inches after it is securely bolted in place. An inspector will check this clearance with a 0.005 inch feeler gauge. Plane flange joints cannot be made permissible by the use of gaskets, permatex, or epoxy. The minimum distance for the flame resistant path is 1 inch. The cover must be securely fastened with bolts and lock washers. The bolts must be located at intervals not exceeding 6 inches. If bolts of $\frac{1}{2}$ inch diameter are use then the threaded bolt stub must be at least $\frac{1}{2}$ high in length, thus a $\frac{5}{8}$ inch bolt would have to have a threaded stub of least $\frac{5}{8}$ inches in length. There must be at least $\frac{1}{8}$ inch at the bottom of the bolt hole after the bolt is securely fastened. The purpose of this is in case a lock washer was left off, the bolt would still tighten. The minimum distance between the threaded portion of the bolt holes and the inside of the box cannot be less than $\frac{7}{16}$ inch.

When the threads of bolt holes in a permissible enclosure become stripped there are 3 ways they can be repaired, which are as follows:

1. Use a heli-coil
2. Fill the whole by welding, then re-drill and tap to the original size.
3. Drill to a larger size and re-tap for larger bolt. Caution must be taken to maintain the minimum $\frac{7}{16}$ inch clearance from the edge of the bolt hole and the inside of the enclosure.

TYPICAL PLANE JOINT

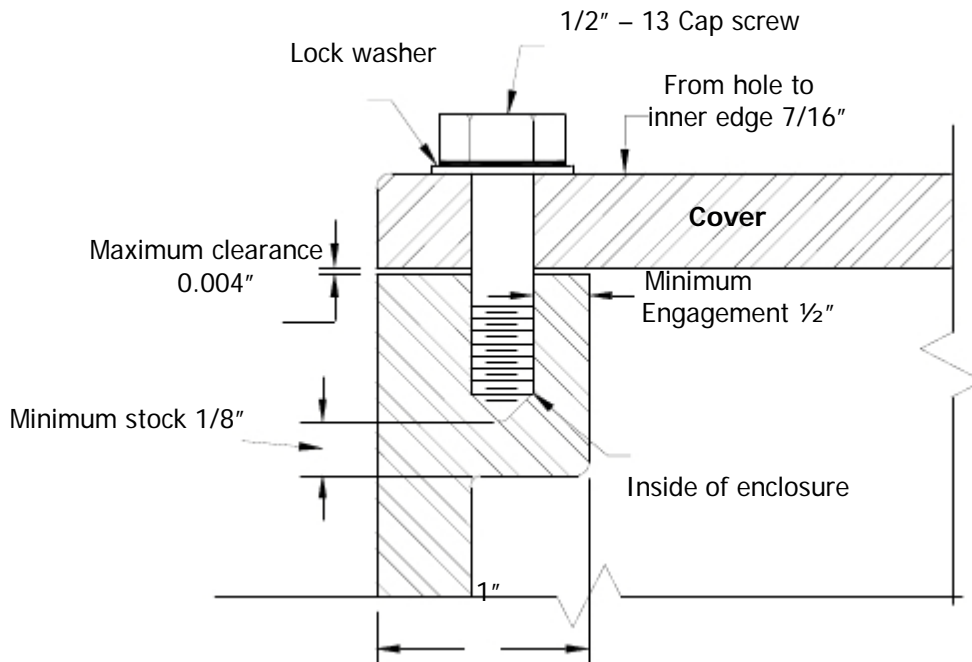


Figure 5

Step Flange Joint – Refer To Figure 6

A step flange joint means a joint comprised of two adjoining surfaces with a change in direction between its inner and outer edges. (A step flange joint may be composed of a cylindrical portion and a plane portion or two or more plane portions). The maximum permissible clearance of the step flange joint is 0.006 inch. An inspector will check this clearance with a 0.007 inch feeler gauge. The cylindrical fit of a step flange joint must extend into its hole a minimum of 1/8 inch. The maximum allowable clearance between the step and the box is 0.003 inches when the step is greater than 1/8 inch less but than 1/4 inch. If the length of the step is greater than or equal to 1/4 inches, then the maximum allowable clearance between the step and the box is 0.004 inches. If a 1/2 inch bolt is used the threads have to extend into the bolt hole a minimum of 1/2 inch. Likewise a 5/8 inch bolt has to have a minimum of 5/8 inches of threads. The flame path of the step flange joint must be at least 3/4 inches. Some examples of a step flange joint are the endbells on most motors, safe-off-reset switches on shuttle cars, and inspection boxes on motors.

TYPICAL STEP FLANGE JOINT

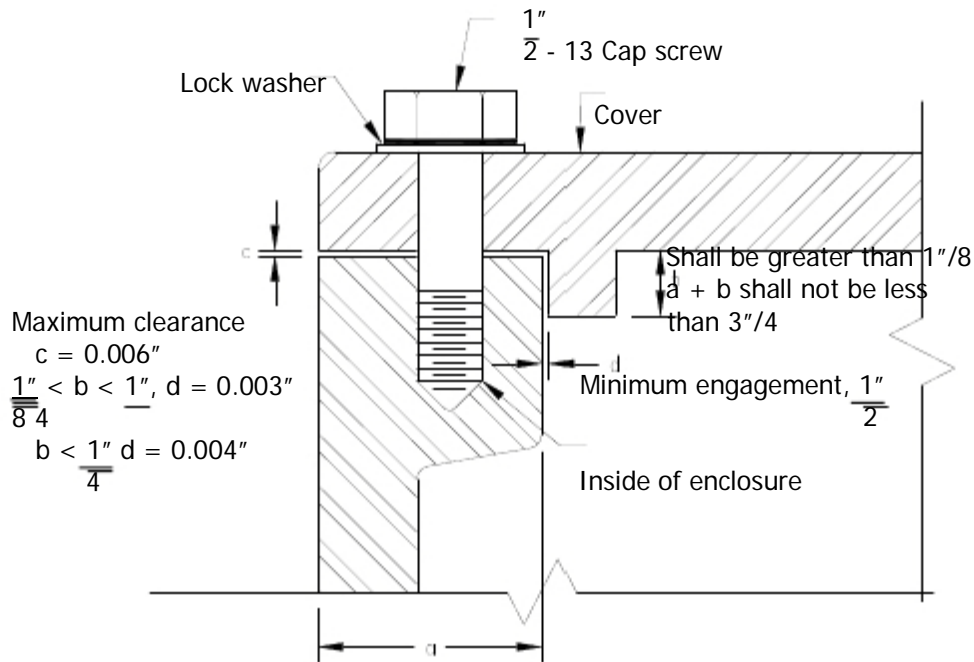


FIGURE 6

Threaded Joint – Refer to Figure 7

A threaded joint means a joint consisting of a male and a female-threaded member, both of which are of the same type and gauge. The flame path of a threaded joint is around the threads and must be a minimum of 1 inch. Threaded covers shall be designed with Class 1 (coarse, loose fitting) threads. The cover shall be tightened, locked, and wired.

Another type joint is called a cylindrical joint, which means a joint comprised of two contiguous, concentric, cylindrical surfaces. Examples of cylindrical joints are the off-on switches and safe-off-reset switches found on the machinery. The maximum allowable clearance for this type of joint is 0.010 inches for a 1 inch flame path. An inspector will use a 0.011 inch feeler gauge for checking. If the flame path is $\frac{3}{4}$ inch then the maximum clearance is 0.008 inches. An inspector will now use a 0.009 inch feeler gauge for checking.

Headlight enclosures are part of the permissible equipment on a machine, and they must be checked weekly. The headlight must burn. Proper entrance glands must be installed and locked. Fire resistant conduit must protect the headlight cables and this conduit must be clamped to the entrance gland. The headlight must be securely fastened to the machine with all bolts in place. The headlight lens must be securely locked in place and should not be cracked or broken. The headlight unit must be properly assembled.

All permissible enclosures must be bolted tightly to the frame of the machine. All wires or cables must enter an enclosure through a cable entrance gland. The compressed packing in this gland must be untreated rope asbestos or an approved alternate.

If a standard packing gland is properly packed, there will be a minimum clearance of $\frac{1}{8}$ inch between the shoulder of the nut and the top of the stuffing box. The compressed packing in this gland must extend along the cable for a minimum of $\frac{1}{2}$ inch. If the cable entrance glands or packing glands were approved by the Bureau of Mines with lock nuts, then the nuts must be locked and securely wired.

If a 1-inch diameter cable was removed from a packing gland and replaced with a $\frac{3}{4}$ inch diameter cable this would be a violation because the clearance between the outer diameter of the cable and the inner diameter of the cable and the inner diameter of the stuffing box is too large. The clearance between the stuffing box and the cable cannot exceed 75% of the diameter of the packing material. Assuming that $\frac{1}{4}$ inch packing material is used, the maximum allowable clearance would be $\frac{3}{16}$ inches. The clearance left by replacing 1-inch cable with $\frac{3}{4}$ inch cable is $\frac{1}{4}$ inch clearance, and constitutes a permissibility violation.

Hose conduit shall be provided for mechanical protection of all machine cables that are exposed to damage. Hose conduit shall be flame resistant and have a minimum wall thickness of $\frac{3}{16}$ inch. All conduit hose must have flame resistant and the Bureau of Mines identification written on it.

Any piece of underground mobile equipment that travels in excess of 2-1/2 (two and one-half) miles per hour must have a cable reel. The maximum speed of any underground equipment is 6 miles per hour. All trailing cables must be entirely insulated. All spooling devices must be oiled and kept in good condition to prevent damage to the cable. All cables must have size, type, company, and Bureau of Mines number and approval written on it.

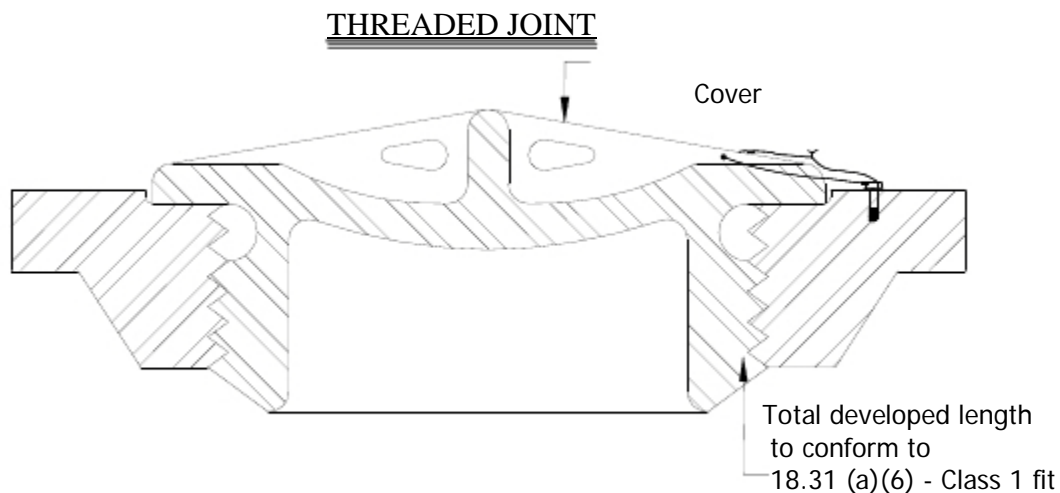


Figure 7

Volume of empty closure			
	Less than 45 cu.in	45 to 124 cu. in. inclusive	more than 124 cu. in.
Minimum thickness of material for walls	1/8"	3/16"	1/4"
Minimum thickness of material for flanges	1/4" ₁	3/8" ₂	1/2" ₂
Minimum thickness of material for cover	1/4" ₁	3/8" ₂	1/2" ₂
Minimum width of joint-all in one plane	1/2"	3/4"	1"
Maximum clearance-joint all in one plane	0.002"	0.003"	0.004"
Minimum width of joint, portions of which are in different planes cylinder or equivalent:	3/8" ₃	5/8" ₃	3/4" ₃
Maximum clearances-joint in two or more planes, cylinders or equivalent:			
a) portion perpendicular to plane	0.008" ₄	0.008" ₄	0.008" ₄
b) plane portion	0.006"	0.006"	0.006"
Maximum bolt (5) spacing-joints all in one plane	6" with minimum of 4 bolts	6" with minimum of 4 bolts	6"
Maximum bolt spacing-joints, portions of which Are in different planes	(6)	(6)	(6)
Minimum diameter of bolt (without regard to type Of joint)	1/4"	1/4"	3/8"
Minimum thread engagement (7)	1/4"	1/4"	3/8"
Maximum diametrical clearance between bolt body and unthreaded holes through which it passes (8)	1/64"	1/32"	1/16"
Minimum distance from interior of enclosure to the edge of the bolt hole: Joint-minimum width 1"			7/19" ₉
Joint-less than 1" wide	1/8"	3/16"	
Cylindrical Joints			
Shafts centered by ball or roller bearings: Minimum length of flame-arresting path	1/2"	3/4"	1"
Maximum radial clearance	0.010"	0.0125"	0.015"
Shafts through journal bearings: 10			
Minimum length of flame-arresting path	1/2"	3/4"	1"
Maximum radial clearance	0.003"	0.004"	0.005"
Other than shafts:			
Minimum length of flame-arresting path	1/2"	3/4"	1"
Maximum radial clearance	0.0015"	0.002"	0.003"

- ¹ 1/32-inch less is allowable for machining rolled plate.
- ² 1/16-inch less allowable for machining rolled plate.
- ³ If only two planes are involved, neither portion of a joint shall be less than 1/8-inch wide, unless the wider portion conforms to the same requirements as those for a joint that is all in one plane. If more than two planes are involved (as in labyrinths or tongue-and-groove joints) the combined lengths of those portions having prescribed clearances will be considered.
- ⁴ The allowable diametrical clearance is 0.008 inch when the portion perpendicular to the plane portion is 1/4 inch or greater in length. If the perpendicular portion is more than 1/8 inch but less than 1/4 inch wide, the diametrical clearance shall not exceed 0.006 inch.
- ⁵ Where the term "bolt" is used, it refers to a machine bolt or a cap screw, and for either of these studs may be substituted provided the studs bottom in blind holes, are completely welded in place, or the bottom of the hole is closed with a secure plug. Bolts shall be provided at all corners.
- ⁶ Adequacy of bolt spacing will be judged on basis of size and configuration of the enclosure, strength of materials, and explosion test results.
- ⁷ In general minimum thread engagement shall be equal to or greater than the diameter of the bolt specified.
- ⁸ Threaded holes for fastening bolts shall be machined to remove burrs or projections that affect planarity of a surface forming a flame-arresting path.
- ⁹ Less than 7/16-inch (1/4-inch minimum) will be acceptable provided the diametrical clearance for fastening bolts does not exceed 1/32 inch.
- ¹⁰ Shafts or operating rods through journal bearings shall be not less than 1/4-inch in diameter. The length of fit shall not be reduced when a push button is depressed. Operating rods shall have a shoulder or head on the portion inside the enclosure. Essential parts riveted or bolted to the inside portion will be acceptable in lieu of a head or shoulder, but cotter pins and similar devices will not be acceptable.

PRACTICE QUESTIONS FOR PERMISSIBILITY OF ELECTRICAL EQUIPMENT

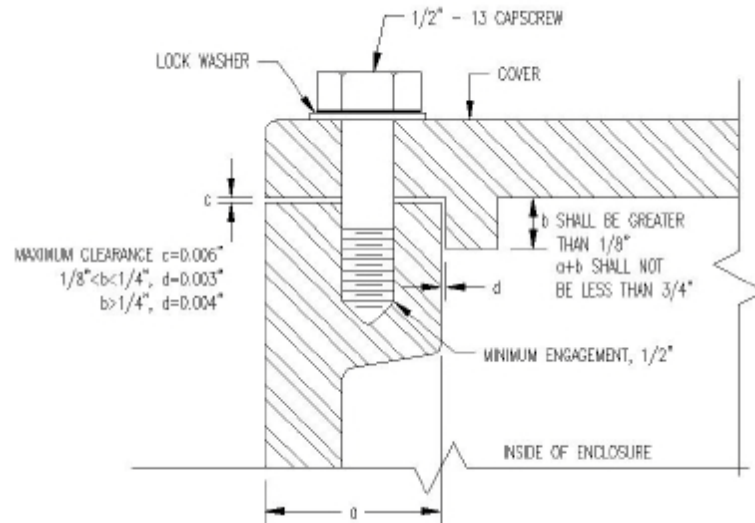
Permissibility of Electrical Equipment

1. The flame path under control panel covers on shuttle cars is a:
 - a. Step flange joint
 - b. Plane flange joint
 - c. Tongue and groove joint
 - d. Combination step flange and plane joint
2. The maximum allowable opening in flame paths of panel covers on shuttle cars is:
 - a. .004 inch
 - b. .006 inch
 - c. .010 inch
 - d. .005 inch
3. The minimum allowable length of flame path for such joints is:
 - a. 1 ¼ inch
 - b. 2 inches
 - c. 1 inch
 - d. ¾ inch
4. Changes in electrical components of permissible equipment must be:
 - a. Recorded only in the electrical equipment inspection book at the mine
 - b. Approved by State and Bureau of Mines and reported to the mine inspector during the next inspection
 - c. Made in a workman like manner and reported to the mine inspector during the next inspection
 - d. Made only by qualified persons
5. The maximum allowable surface temperature of all components on machines approved under schedule 2G is:
 - a. 150 degrees centigrade
 - b. 300 degrees centigrade
 - c. 100 degrees centigrade
 - d. 250 degrees centigrade
6. The primary purpose of a breather on explosion-proof compartment is:
 - a. To keep the parts cool
 - b. To allow harmful gases that cause corrosion to escape
 - c. To provide inspection openings
 - d. To let methane out of the compartment

7. Unused entrance glands must be:
 - a. Closed with neoprene fire resistance plugs
 - b. Left open
 - c. Closed with secured metal plugs
 - d. Plugged with short lengths of cable
8. What are some of the dangers created by the operation of electrical equipment in coal mines?
 - a. Hernia in workman from pulling cables
 - b. Stray currents blowing fuses
 - c. Fires from overheated equipment and explosions from arcs
 - d. Open overload relays due to excessive current draw of electric equipment
9. How is permissibility of equipment commonly destroyed?
 - a. By proper maintenance
 - b. By improper mining cycle
 - c. By improper maintenance
 - d. None of the above
10. What should not be permitted to accumulate in the boxes enclosing contactors and switches.
 - a. Extra parts
 - b. Stray currents
 - c. Coal dust
 - d. Methane-air mixtures
11. Where permissible power connection units are not available, how shall all power connections points out by the last open crosscut be made?
 - a. In intake air
 - b. In output air
 - c. With rigid connectors
 - d. Best method not to interfere with production
12. What is the maximum number of temporary splices permissible in trailing cables?
 - a. One
 - b. Two
 - c. Three
 - d. Four
13. How long may a trailing cable be used which has been temporarily spliced?
 - a. 12 hours
 - b. 24 hours
 - c. 36 hours
 - d. 48 hours

14. Cable reels must be installed on all equipment that receives electric power through cables and travel:
- Not over two miles per hour
 - More than 2 ½ miles per hour
 - Distances that exceed 1,000 feet
 - Grades exceeding 2 ½ percent
15. The dielectric strength of power wires and cables is required to be at least equal to the voltage of the circuit, on and after what date?
- March 30, 1970
 - March 30, 1971
 - March 30, 1972
 - March 30, 1974
16. High voltage circuits extending to mobile or portable equipment such as shovels and portable transformer shall be:
- Provided with a resistance grounded neutral and protected by dual element fuses
 - Provided with a resistance grounded neutral and protected by a circuit breaker
 - Protected by dual element fuses
 - Supplied power from a solidly grounded, wye connected bank
17. The approved method of grounding for metallic sheaths, armors, and conduits in resistance grounded systems where the enclosed conductors are a part of the system is to use:
- A solid connection to the neutral conductor
 - A #8 wire firmly connected to the earth ground rod
 - A #4 wire with permissible coupling to the trolley track
 - Any of the above fulfill the requirements of the law
18. There are four approved methods for grounding of metallic frames, casing, and other enclosures of electric equipment receiving power from D.C. power systems with one polarity grounded. Which of the following is **NOT** specified as permissible?
- A solid connection to the mine track
 - A solid connection to the grounded conductor of the system
 - Silicon diode grounding
 - Connection to any existing grounding system
19. Which of the following is **NOT** a permissible method of grounding equipment receiving power from an ungrounded delta system?
- A solid connection to a borehole casing having low resistance to earth
 - A solid connection to metal waterlines having low resistance to earth
 - A solid connection to a grounding conductor extending to a low resistance ground field located on the surface
 - A solid connection to the ground rod

20. Under fault conditions, what maximum voltage is permissible in the grounding circuit external to the grounding resistor?
- 55 Volts
 - 96 Volts
 - 100 Volts
 - 110 Volts



21. Assuming that $b = \frac{1}{2}$ ", what is the maximum clearance for d (Fig. 1)?
- .001
 - .002
 - .003
 - .004
22. What is the minimum length of a and b together (Fig. 1)?
- $\frac{1}{2}$ "
 - $\frac{3}{16}$ "
 - $\frac{3}{4}$ "
 - 1"
23. What type of washer is required (Fig. 1)?
- Regular
 - Lock
 - Flat
 - None of the above
24. Portable trailing cables for face equipment shall be:
- Longer than 1,000 feet
 - Larger than 6" in diameter
 - Flame resistant
 - Smoke tested

25. When electrical work is to be performed, the appropriate disconnecting devices shall be open, locked out and tagged by:
- The person(s) who are to perform the electrical work
 - Any miner who happens to be in the area
 - The faceboss
 - The Secretary or his authorized representative
26. Under most circumstances, who should remove locks or tags from the electrical circuits that have been de-energized, locked out and tagged?
- The Mine Foreman
 - The Secretary
 - ONLY by the person(s) who locked out and tagged the circuit(s)
 - The Maintenance Foreman
27. The maximum allowable opening in the flame paths of main panel covers on Shuttlecars is:
- .004 inch
 - .005 inch
 - .006 inch
 - .010 inch
28. What is the minimum length for a plane flange flame arresting path over 124 cubic inches?
- 1 inch
 - ½ inch
 - ¼ inch
 - Not important
29. The flame path under the main control panel covers on 10SC22 Shuttlecars is a:
- Step flange joint
 - Plane flange joint
 - Tongue and groove joint
 - Combination step flange and plane flange joint
30. What size gauge is used to check end bells on motors by Federal and State Inspectors?
- .004
 - .005
 - .006
 - .007
31. What size is used by a Federal or State Inspector to check a Joy Shuttlecar Control Box?
- .003
 - .004
 - .005
 - .006

32. The minimum allowable length of flame path for a step joint is:
- 1-1/4 inches
 - 2 inches
 - 3/4 inches
 - 1 inch
33. How often must fire equipment be inspected?
- Yearly
 - Every month
 - Every 6 months
 - Every 3 months
34. Changes in electrical components of permissible equipment must be:
- Made only by qualified persons
 - Approved by State and Bureau of Mines and reported to the Mine Inspector during the next inspection
 - Recorded only in the electrical equipment inspection book at the mine
 - Made in a workman-like manner and reported to the Mine Inspector during the next inspection
35. Unused entrance glands must be:
- Plugged with short lengths of cable
 - Closed with neoprene fire resistance plugs
 - Left open
 - Closed with secured metal plugs
36. The maximum allowable surface temperature of all components on machines approved under Schedule 2G is:
- 100° Centigrade
 - 150° Centigrade
 - 250° Centigrade
 - 300° Centigrade
37. The primary purpose of a breather on explosion-proof compartments is:
- To let methane out of the compartment
 - To keep the parts cool
 - To allow harmful gasses that cause corrosion to escape
 - To provide inspection openings
38. The minimum distance between the packing gland nut and the stuffing box of a properly installed cable assembly is:
- 1/16 inch
 - 1/8 inch
 - 1/4 inch
 - 1/2 inch

39. In order to qualify as permissible, a step flange joint must extend into its opening at least:
- a. 1/16 inch
 - b. 1/8 inch
 - c. 1/4 inch
 - d. 1 inch
40. How long may a trailing cable be used which has been temporarily spliced?
- a. 48 hours
 - b. 36 hours
 - c. Not over 24 hours
 - d. 12 hours
41. Where permissible power connection units are not available, where shall all power connection points outby the last open crosscut be made?
- a. Best method not to interfere with production
 - b. In intake air
 - c. In output air
 - d. With rigid connectors
42. The maximum allowable voltage for hand-held electric drills is:
- a. 300VAC or 300VDC
 - b. 220VAC or 110VDC
 - c. 480VAC or 480VDC
 - d. 110VAC or 220VDC
43. All hand-held electrical equipment shall be provided with:
- a. AC motors or DC motors
 - b. Two Pole Switch of the Deadman-Control Type
 - c. Three-phase power
 - d. Ground diodes
44. The minimum allowable size of trailing cables on DC powered equipment is:
- a. #8
 - b. #6
 - c. #4
 - d. #2
45. The minimum allowable size of trailing cables on AC powered equipment is:
- a. #2
 - b. #4
 - c. #6
 - d. #8

ANSWER SHEET FOR PERMISSIBILITY OF ELECTRICAL EQUIPMENT

1. b
2. a
3. c
4. b
5. a
6. b
7. c
8. c
9. c
10. c
11. a
12. a
13. b
14. b
15. a
16. b
17. a
18. d
19. d
20. c
21. d
22. c

23. b
24. c
25. a
26. c
27. a
28. a
29. b
30. d
31. c
32. c
33. c
34. b
35. d
36. b
37. c
38. b
39. b
40. c
41. b
42. a
43. b
44. c
45. c

Permissibility

1. Q. The maximum surface temperature of all components on machines approved under Schedule 2G is:

A. 150 degrees Centigrade.

2. Q. All mobile equipment that is powered by a trailing cable and travels in excess of 2.5 mph must be provided with:

A. A cable reel.

3. Q. The “dead-man” type switch on a hand-held tool functions by:

A. Closing with hand pressure and opening if pressure is released.

4. Q. Battery boxes:

A. Must be adequately ventilated.

5. Q. Each wire or cable leaving a battery box on storage battery operated equipment shall have:

A. Short-circuit protection in an explosion-proof enclosure.

6. Q. What should be provided in the bottom of each battery box?

A. Drainage holes.

7. Q. Battery box covers:

A. Must be lined with a flame-resistant insulating material preferably bonded to the inside of the cover.

8. Q. Battery-box covers must meet all of the following requirements, EXCEPT:

A. Be made of a non-sparking material.

9. Q. The purpose of hose conduit is to:

A. Provide for mechanical protection.

10. Q. How should hose conduit be marked to indicate it is flame-resistant?

A. Flame-resistant USBM - Not exceeding 3 feet.

11. Q. To meet the requirements of Schedule 2G, all conduit hose on equipment:

A. Must be flame-resistant.

12. Q. The minimum thickness of hose conduit allowed is:

A. 3/16 inch.

13. Q. Conduit hose must be marked flame resistant:

A. Every three feet.

14. Q. Conduit hose is used for:

A. The mechanical protection of a cable.

15. Q. Conductors must have current-carrying capacities that meet:

A. ICEA standards.

16. Q. To protect the trailing cable from being run over by mobile equipment, all self-propelled equipment:

A. Which moves faster than 2.5 mph must be equipped with cable reels.

17. Q. A cable reel is required on self-propelled equipment that travels at a speed exceeding:

A. 2.5 mph.

18. Q. What is the maximum tramming speed permitted for a continuous miner?

A. 2.5 MPH.

19. Q. Any underground machine traveling faster than how many MPH must be equipped with a cable reel?

A. 2.5 MPH.

20. Q. What is the minimum distance that a 1/2-inch bolt can extend into the threaded portion of the hole on a permissible enclosure?

A. 1/2 inch.

21. Q. An electric motor that is a power source for a permissible mining machine:

A. Must be explosion-proof.

22. Q. Control panels and electrical motors are equipped with access openings and inspection covers:

A. So maintenance personnel can more readily check for damaged or worn parts.

23. Q. When a bolt with a diameter larger than 3/8-inch is used, thread engagement should be:

A. Equal to or greater than the diameter of the bolt.

24. Q. What type of packing glands should be locked?

A. All glands.

25. Q. What is the maximum radial clearance that should be allowed when installing a typical plug for spare lead entrance holes?

A. .003 inch.

26. Q. To check a plane flange joint you would use what size feeler gauge?

A. 0.005 inch.

27. Q. Since certain electrical components almost always spark when in operation, they:

A. Must be placed in explosion-proof enclosures before they are considered "permissible."

28. Q. A permissible box must withstand an explosion pressure of:

A. 150 psi.

29. Q. If the threads are stripped out of the cover of an explosion-proof box, which of the following methods is NOT accepted method of repair?

A. Drill hole through and use bolt nut.

30. Q. Each bolt, stud or screw used to fasten a cover to an explosion-proof enclosure must be provided with a:

A. Lock washer to help hold it in position.

31. Q. A permissible joint that is made of a large screw with five or six threads is called a:

A. Screw type joint.

32. Q. The maximum clearance between the lid and the box of a step-flange joint is:

A. 0.006 inch.

33. Q. How far should a 1/2-inch bolt extend into the threaded portion of the hole?

A. At least 1/2 inch.

34. Q. If the cover of the permissible compartment has a step shape, it is:

A. A step flange joint.

35. Q. All unused holes in permissible compartments must be:

A. Closed with specially designed fittings or plugs.

36. Q. If there are damaged threads on a screw-type cover:

A. The cover must be replaced.

37. Q. When a bolt hole in an explosion-proof enclosure is stripped out, it:

A. Is no longer considered permissible.

38. Q. Lenses for headlights used on mining machines must be constructed of glass or other suitable material with physical characteristics:

A. 1/2-inch thick tempered glass.

39. Q. Inspection covers or screw type joints must be:

A. Threaded in snug and locked in place.

40. Q. What is the minimum thread engagement of bolts for an enclosure which is greater than 124 inches?

A. 3/8 inch.

41. Q. End bells on motors and reset switches are typical examples of:

A. Step flange joints.

42. Q. Most end bells on explosion-proof motors should be checked with a feeler gauge.

A. .007 inch.

43. Q. To check a step flange joint you should use what size feeler gauge?

A. 0.007 inch.

44. Q. If the threads in the bolt holes of a permissible enclosure are stripped out, which of the following is NOT an acceptable means of repair?

A. Drill a hole through and use a nut and bolt.

45. Q. Plane flange joints on explosion-proof enclosures cannot exceed a separation distance of:

A. .004 inch.

46. Q. The primary purpose of a breather on explosion-proof compartments is:

A. To allow harmful gases that cause corrosion to escape.

47. Q. The use of bolts with more than one lock washer in a control panel box is considered:

A. An improper assembly.

48. Q. Which of the following is allowed to be under a permissible bolt?

A. Lock washers.

49. Q. Which of the following is NOT a requirement of cables between machine components?

A. They must be less than 6 feet in length.

50. Q. What is the minimum distance a 1/2-inch bolt can extend into the threaded portion of the hole of a permissible enclosure?

A. 1/2 inch.

51. Q. Electrical components that normally arc during operation:

A. Must be properly enclosed to be considered permissible.

52. Q. What minimum clearance must be maintained between the packing gland nut and the stuffing box?

A. 1/8 inch.

53. Q. Breathers or pressure-relief devices are installed on an explosion-proof enclosure to:

A. Relieve pressure, ventilate, or drain.

54. Q. Permissible compartments are designed to be:

A. Explosion proof.

55. Q. What is the minimum distance from the interior of an enclosure to the edge of a bolt hole (more than 124 cubic inches)?

A. 7/16 inch.

56. Q. A plane flange joint has a maximum clearance between the box and the lid of:

A. 0.004 inch.

57. Q. The packing material in a stuffing box is compressed tightly against the cable by:

A. Tightening the packing gland nut.

58. Q. A flat metal to metal joint is a:

A. Plane Flange Joint.

59. Q. Stuffing boxes are drilled into the walls of the explosion-proof enclosures in such a way that:

A. There's space for packing material to be placed around the cable.

60. Q. A screw type joint cannot be used if:

A. The threads are damaged.

61. Q. Because of the electrical wiring inside headlights, the lens rings:

A. Should be mechanically tight and sealed or padlocked.

62. Q. Plane flange joints and step flange joints are the types of joints formed:

A. When two pieces of metal come together.

63. Q. All bolts in a permissible enclosure must have:

A. Lock washer.

64. Q. The maximum clearance of a plane flange joint allowed for permissibility is:

A. 0.004 inch.

65. Q . When a bolt hole in an explosion-proof enclosure is stripped out, and re-tapping it to the next larger size:

A. 7/16 of an inch of metal from the interior of the enclosure to the closest edge of the hole must be maintained.

66. Q. When a standard packing gland is properly packed, the minimum clearance permitted between the shoulder of the packing nut and the top of the stuffing box is:

A. 1/8 inch.

67. Q. What is the minimum size of asbestos packing material allowed?

A 3/16-inch diameter if round and 3/16 x 3/16-inch if square.

68. Q. What is the maximum-sized clearance of a plane flange joint on a shuttle car allowed by law?

A. .004 inch.

69. Q. Insulated wires should pass through metal walls of electric compartments only through:

A. Insulated bushings.

70. Q. What size feeler gauge should be used to check plane flange joints?

A. .005 inch.

71. Q. A .007-inch feeler gauge is used by an inspector to check:

A. Step flange joints.

72. Q. Permissible electrical equipment is equipment which:

A. Is similar in all respects to that which has been approved by the USBM.

73. Q. When 1/4-inch packing is used in a stuffing box, the maximum allowable diametrical clearance between the cable and the holes in the stuffing box and the packing nut is:

A. 3/16 inch.

74. Q. Packing material used in stuffing boxes should be:

A. An approved packing material.

75. Q. Cast or welded enclosures should be designed to withstand a minimum internal pressure of:

A. 150 PSI.

76. Q. What is the maximum-sized opening permitted for a plane flange joint?

A. .004 inch.

77. Q. How thick must lenses for headlights be?

A. 1/2 inch.

78. Q. What is the maximum-sized spacing permitted for bolts securing enclosure covers with joints all in one plane?

A. 6 inches.

79. Q. A .005-inch feeler gauge is used to check:

A. Plane flange joints.

80. Q. What size feeler gauge should be used to check end bells on most motors?

A. .007 inch.

81. Q. The minimum clearance between the shoulder of the nut and the top of a stuffing box in a properly packed, standard packing gland is:

A. 1/8 inch.

82. Q. The minimum amount of packing that should be in a packing gland along a conductor is:

A. 1/2 inch.

83. Q. Before electric face equipment is deemed permissible, the equipment must meet the:

A. Specifications set forth by the Secretary.

84. Q. All electric equipment used in return air outby the last open crosscut:

A. Must be permissible.

85. Q. The maintenance required to keep equipment in permissible condition is the responsibility of the:

A. Mine operator.

86. Q. Permissibility is required for electrical equipment and components:

A. Inby the last open crosscut and in return air.

87. Q. Permissible electric face equipment is defined as:

A. Equipment which has been tested and approved.

88. Q. Headlights used on permissible mining machines to provide illumination in the direction of travel:

A. Must be permissible.

89. Q. What is the minimum distance from combustible material that unattended enclosed motors, rectifiers, and transformers may be placed?

A. 2 feet.

90. Q. Cable grips or insulated clamps shall be provided on:

A. Portable trailing cables.

91. Q. When mounting ground wires:

A. Always use terminals or clamps.

92. Q. All trailing cables and drop cables must have:

A. A restraining clamp in permissible condition.

93. Q. The primary function of a strain clamp is to:

A. Transfer most of the strain from the trailing cable to the frame of the equipment it feeds.

94. Q. In low-and medium-voltage, three-phase AC systems, the maximum ground-fault tripping current should not exceed:

A. 25 amps.

95. Q. The frame to ground potential of any off-track machine must not exceed:

A. 40 volts.

96. Q. A tool or switch that is held in an operator's hand or supported against an operator's body will NOT be approved if the nameplate rating on the tool or switch exceeds:

A. 300 volts DC or AC.

97. Q. The term "intrinsically safe circuits" refers to circuits that:

A. Do spark but will not ignite a methane-air mixture.

98. Q. Tools or switches held in the operators hand or supported against his body:

A. Cannot have a nameplate voltage rating of more than 300 volts.

99. Q. Material that will burn when held in a flame but will cease burning when the flame is removed is defined as:

A. Flame-resistant.

100. Q. What is the most violent explosive percent of methane?

A. 10%.

101. Q. "Flame-resistant," as applied to trailing cables and conduit hose, means:

A. Cables and hose will burn when held in a flame, but will cease burning when removed from flame.

102. Q. The maximum operating temperature of the external surface of a machine is:

A. 150 Centigrade or 302 Fahrenheit.

103. Q. What is the explosive range of methane?

A. 5% to 15%.

104. Q. The maximum speed of travel of a machine receiving power from a trailing cable.

A. 6 MPH.

105. Q. Which of the following is a requirement of a temporary splice?

A. It must be mechanically strong and well-insulated.

106. Q. Which of the following is NOT a requirement of a permanent splice?

A. It must be more than 25 feet from the machine (except cable reel).

107. Q. Which of the following is a requirement of a permanent splice?

A. It must be mechanically strong with adequate conductivity.

108. Q. The number of temporary splices permitted in a single length of trailing cable is:

A. One.

109. Q. Which of the following is NOT a requirement of a temporary splice made in a trailing cable?

A. It must be vulcanized.

110. Q. What is the maximum allowable speed of travel of a machine that receives power through a trailing cable?

A. 6 mph.

111. Q. The minimum-sized trailing cable permitted for direct current powered mobile haulage units is:

A. No.4 AWG.

112. Q. The maximum length permitted for trailing cables (4/0 and larger) is:

A. 1,000 feet.

113. Q. When a trailing cable is used to power an underground mining machine, that machine must not move faster than:

A. 6 mph.

114. Q. What is the minimum-sized trailing cable permitted for AC-powered mobile haulage units?

A. No.6 AWG.

115. Q. If trailing cables are run over by mobile face equipment:

A. Arcing or sparking could result which, in turn, could set off an explosion or cause a fire.

116. Q. Flame resistant as applied to trailing cables and hose conduit means:

A. It will burn when held in a flame but will cease when the flame is removed.

117. Q. All trailing cables used to conduct electrical energy to face equipment shall conform to the following EXCEPT:

A. Have at least 3 power wires and one ground wire.

118. Q. In most cases, the length of a portable cable should not exceed:

A . 500 feet.

119. Q .Trailing cables must be marked:

A. Flame-resistant.

120. Q. A No. 6 AWG trailing cable should be no longer than:

A. 550 feet

30 CFR, PART 75 (UNDERGROUND)

ILLINOIS ELECTRICIAN STUDY GUIDE

CFR 30 75 & 77

- A. Electrical Protection Requirements
 - 1. Trailing cables
 - 2. Three-phase electrical motors
 - 3. Lightning arresters
 - 4. Underground high-voltage circuits
- B. Grounding Requirements
 - 1. High-voltage electrical equipment
 - 2. Minimum ground conductor sizes of circuits and cables
 - 3. Minimum size of internal and external ground check conductors
- C. Trailing cable temporary splice time and distance limitations
- D. High-voltage circuit breaker application and testing requirements
- E. Lockout requirements prior to performing electrical work
 - 1. Disconnect switches
 - 2. Locked and tagged out
- F. Ground fault current and voltage limitations
 - 1. Low-and-medium-voltage limitations, three-phase circuits
 - 2. High-voltage, three-phase circuits
- G. Minimum distance between lightning ground (substation ground grid) and neutral ground (mine ground grid)
- H. Definition of voltage classification
 - 1. Low voltage (0-660 Volts)
 - 2. Medium voltage (661-1000 Volts)
 - 3. High voltage (1001 Volts and Above)
- I. Requirements for cables and wires entering metal frames or electrical equipment
- J. Ground monitor circuit criteria
 - 1. Low-and-medium-voltage circuits
 - 2. High-voltage circuits
- K. Danger sign requirements for electrical installations on the surface (Part 77)
- L. Troubleshooting and testing exemptions, requirements, limitation, and comparison to performance of electrical work
- M. High-voltage cable protection and guarding requirements
 - 1. Regular work areas
 - 2. Minimum height to prelude guarding
- N. Requalifications requirements for qualified (certified) electricians
- O. Work may never be performed on energized underground high-voltage circuits
- P. Protective equipment requirements for:
 - 1. Disconnecting energized surface high-voltage lines
 - 2. Handling energized low, medium, and high-voltage trailing cables
 - 3. Troubleshooting and testing

- Q. Grounding resistors
 - 1. Voltage and current required ratings
 - 2. Theory of operation and personnel safety enhancement
 - 3. Criteria regarding current and voltage limitations
 - A. High-voltage circuits
 - B. Low and Medium-voltage circuits
- R. High-voltage circuits entering the underground area of any coal mine shall be protected with a circuit breaker located on the surface to provide protection against the following:
 - 1. Undervoltage
 - 2. Grounded phase
 - 3. Short circuit
 - 4. Overcurrent

PRACTICE QUESTIONS FOR 30 CFR PART 75&77

1. Federal regulations require operators to provide training and retraining for:
 - a. Each miner working in a mine
 - b. Each certified person in a mine
 - c. Each qualified person in a mine
 - d. Persons required to carry out the mine Act.
2. The maximum elapsed time between training courses for qualified persons is:
 - a. Annually
 - b. Semi-annually
 - c. Every six months
 - d. Every two years
3. Which of the following is **NOT** required to be included in the “Coal Operators’ Electrical Survey?”
 - a. Equipment being used
 - b. Equipment being repaired
 - c. Equipment on order
 - d. Equipment stored for future use
4. A map of the mine electrical system is required to be made available to whom?
 - a. The mine superintendent
 - b. The mine foreman
 - c. The mine owner
 - d. The miners in the mine
5. When trolley tracks are used as conductors, the size of the track must be included in the electrical system map. This track size must be expressed in:
 - a. Pounds per yard
 - b. Pounds per foot
 - c. Square inches
 - d. Square feet
6. Normally, all power shall be removed when work is done on circuits or other equipment, what is the exception to this rule?
 - a. When the breaker is stuck in the on position
 - b. When the foreman says leave it on
 - c. When troubleshooting
 - d. There is no exception

7. What is the frequency of examination of electrical equipment?
 - a. At least daily
 - b. At least weekly
 - c. At least monthly
 - d. At least yearly
8. Within how many feet from where the main power circuits enter the mine shall lightning arrestors be provided?
 - a. 100 feet
 - b. 300 feet
 - c. 500 feet
 - d. 700 feet
9. There is one approved method for grounding of metallic frames, casings and other enclosures of electric equipment receiving power from a single-phase 110/220 volt circuit. Which of the following is permissible?
 - a. A solid connection to a borehole casing having low resistance to earth
 - b. A solid connection to metal water lines having low resistance to earth
 - c. A solid connection to a grounding conductor extending to a low-resistance ground field located on the surface
 - d. A separate grounding conductor which establishes a continuous connection to a grounded center top of the transformer
10. Work may be performed on energized high voltage lines underground under which of the following conditions?
 - a. When authorized by the Superintendent
 - b. When authorized by the Secretary
 - c. When necessary for troubleshooting
 - d. Never, it is prohibited by law
11. Which of the following best describes how a grounding resistor is used to protect high voltage circuits?
 - a. By connection from equipment frame to ground
 - b. By connection from a derived neutral to ground
 - c. By connection across the fused circuit to ground
 - d. By connection to the hot line to reduce the voltage
12. What is the deadline date for incorporation of fail safe ground check circuits on high voltage resistance grounded systems?
 - a. March 30, 1970
 - b. September 30, 1970
 - c. March 30, 1971

13. The statutory provisions for the connection of single-phase high voltage loads states that they shall be connected:
- Wye-to-wye
 - Delta-to-delta
 - Line-to-line
 - Phase-to-phase
14. Who may authorize the movement of high-voltage power centers while they are energized?
- The Superintendent
 - The Secretary
 - The Mine Foreman
 - No one has this authority
15. The areas where circuit breakers are used to protect low-and-medium-voltage circuits underground are required to have all of the following, except:
- A safe roof
 - Clear of moving equipment
 - Accessible for testing
 - Adequate illumination
16. Under which of the following conditions is grounding of three-phase medium-voltage circuit neutral not required?
- If the circuit is steel armored
 - If it is on stationary equipment only
 - If it is used on portable equipment only
 - Under no conditions may the neutral be ungrounded
17. Trailing cables for mobile equipment shall contain an insulated conductor for the ground continuity check circuit no later than:
- March 30, 1970
 - Sept. 30, 1970
 - March 30, 1971
 - March 30, 1974
18. What is the minimum distance from pillar workings that trolley wires may be kept?
- 100 feet
 - 150 feet
 - 200 feet
 - 250 feet
19. Trolley wires are required to be provided with cutout switches at intervals of not more than:
- 500 feet
 - 1000 feet
 - 1500 feet
 - 2000 feet

20. Bare signal wires are required to be insulated at which of the following points?
- a. At points where men are required to work
 - b. On both sides of all doors
 - c. At man trip stations
 - d. Where they cross other cables.
21. A distribution center is an example of:
- a. Portable equipment
 - b. Trailing equipment
 - c. Stationary equipment
 - d. Mobile equipment
22. What is the frequency of examination of electrical equipment?
- a. At least daily
 - b. At least monthly
 - c. At least weekly
 - d. At least yearly
23. Metal conduit between two explosion-proof enclosures shall be:
- a. Approved by M.S.H.A
 - b. Provided with loose fitting threads
 - c. Welded to the enclosure it connects
 - d. None of the above
24. The grounding resistor of Low and Medium three-phase circuits must limit the fault current to _____ amps.
- a. 25A
 - b. 96A
 - c. 18A
 - d. 100A
25. A temporary electrical installation is intended for use not more than:
- a. 12 months
 - b. 6 months
 - c. 60 days
 - d. 30 days
26. A circuit is considered to be “intrinsically safe” if in the course of testing:
- a. The circuit protector opens
 - b. It operates correctly
 - c. It doesn't explode
 - d. No ignitions occur

27. The purpose of testing battery boxes is to determine the adequacy of all but which of the following?
- a. Ventilation
 - b. Insulation
 - c. Explosibility
 - d. Clearances
28. Single-phase loads must be connected phase-to-phase for:
- a. Low voltage
 - b. Medium voltage
 - c. High voltage
 - d. All of the above
29. Couplers for three-phase low voltage cables shall be designed so that:
- a. The ground conductor breaks last
 - b. The ground check conductor breaks last
 - c. The ground conductor breaks first
 - d. The phase conductors break first
30. The areas where circuit breakers are used to protect low and medium voltage circuits underground are required to have all the following except:
- a. Adequate illumination
 - b. Accessible for testing
 - c. Clear of moving equipment
 - d. A safe roof
31. Within how many feet from where the main power circuits enter the mine shall lightning arrestors be provided?
- a. 100 feet
 - b. 300 feet
 - c. 500 feet
 - d. 700 feet
32. The maximum current between the frames of two pieces of equipment must not exceed:
- a. 1A
 - b. 10A
 - c. 0.1A
 - d. 0.01A
33. Which of the following is **NOT** required to be included in the “Coal Operators’ Electrical Survey?”
- a. Equipment being used
 - b. Equipment being repaired
 - c. Equipment on order
 - d. Equipment being stored for future use

34. The ground wire used with conductors smaller than #6 AWG must be:
- Half of conductor
 - Fourth of conductor
 - Solid wire
 - Same as conductor
35. Low and medium underground three-phase circuits must be protected against:
- _____
 - _____
 - _____
 - _____
36. What fire protection is required at temporary electrical installations?
- Two portable fire extinguishers
 - 480 pounds of rock dust
 - One portable fire extinguisher and 240 pounds of rock dust
 - Two portable fire extinguishers and 480 pounds of rock dust
37. How far apart are water outlets required for belt conveyors?
- Every 100 feet
 - Every 300 feet
 - Every 500 feet
 - Every 1,000 feet
38. Fire hoses installed for use underground shall have a burst pressure equal to:
- Twice the pressure at the hose inlet with valve closed
 - Twice the pressure at the hose inlet with valve open
 - Four times the pressure at the hose inlet with the valve closed
 - Four times the pressure at the hose inlet with the valve open
39. At locations where welding, cutting, or soldering is to be done with an arc or flame, the following items must be available:
- Two portable fire extinguishers
 - 280 pounds of rock dust
 - One portable fire extinguisher or 240 pounds of rock dust
 - Two portable fire extinguishers and 240 pounds of rock dust
40. Fire fighting material such as water containers, rock dust and chemical extinguishers shall be examined how often?
- Every 6 months
 - Every 3 months
 - Every 9 months
 - Yearly

41. Welding is not permitted in a mine atmosphere when the percentage on methane reaches:
- a. 0.5%
 - b. 2.0%
 - c. 1.0%
 - d. 1.5%
42. In deluge-type water systems, two or more branch lines of nozzles shall be installed. The maximum permissible distance between nozzles is:
- a. 12 feet
 - b. 10 feet
 - c. 8 feet
 - d. 6 feet
43. The primary purpose for automatic fire sensors is to:
- a. Provide an audible signal
 - b. Provide a visual signal
 - c. Provide both audible and visual signals that
 - d. None of the above
44. The maximum voltage allowed for low and medium ground check circuits is;
- a. 25V
 - b. 100V
 - c. 96V
 - d. 40V
45. Water discharge rate from a sprinkler system nozzle shall be not less than 0.25 gallons per minute and shall be directed at:
- a. The top surface of the belt only
 - b. The top surface of the belt and the top surface of the bottom belt only
 - c. The top surface of the top belt, the bottom surface of the top belt, and the top surface of the bottom belt
 - d. The top and bottom surfaces of the top belt
46. Circuit breakers protecting high voltage circuits going underground must be located:
- a. 500 ft. or less underground
 - b. On the surface
 - c. 8 ft. high
 - d. In an insulated box
47. Disconnect switches of high voltage circuits must be located within _____ feet of where it goes underground.
- a. 100
 - b. 500
 - c. 150
 - d. 200

48. Ground check relays can be used for under voltage protection if they trip when voltage reaches _____% of normal.
- a. 40 to 80
 - b. 30 to 70
 - c. 40 to 60
 - d. 50 to 70
49. A ground check conductor inside a high voltage cable cannot be smaller than # _____ AWG.
- a. 6
 - b. 8
 - c. 10
 - d. 12
50. What is the maximum number of temporary splices in a trailing cable?
- a. One
 - b. Two
 - c. Five
 - d. No limit
51. What type of electrical work is permitted on energized equipment?
- a. None
 - b. All types of work
 - c. Cable slices only
52. What must be done when a hazardous condition is found on a piece of electrical equipment?
- a. Operator warned to be careful
 - b. Machine removed from service until repairs are made
 - c. Mine power de-energized until equipment is repaired
 - d. Foreman informed of hazardous condition
53. When a phase-to-ground short circuit occurs in a resistance grounded system, which of the following relays causes the circuit breaker to open?
- a. Undervoltage relay
 - b. Ground monitor relay
 - c. Ground fault relay
 - d. Overcurrent relay
54. Which of the following would be classified as medium voltage?
- a. 550V
 - b. 660V
 - c. 1,000V
 - d. 1,250V

55. What is **NOT** an approved method of testing circuit breakers?
- a. Smoke test of ground wire
 - b. Visual
 - c. Break ground check conductor
 - d. Activate auxiliary protective relays
56. Disconnecting devices for high-voltage circuits shall be located:
- a. At the individual piece of equipment
 - b. At the beginning of each branch line
 - c. Within 50 ft. of any substation utilizing 69,000V or more
 - d. Within 50 ft. of any resistance grounding system
57. Circuit breakers must be tested at least:
- a. Weekly
 - b. Yearly
 - c. Daily
 - d. Monthly
58. On three-phase couplers, which conductor must break contact first?
- a. Ground check
 - b. Ground conductor
 - c. Any phase conductor
 - d. All three-phase conductors simultaneously
59. Where shall the grounding resistor always be located?
- a. On the machine
 - b. Somewhere in the trailing cable
 - c. At the source transformers
 - d. Within an explosion-proof enclosure
60. Before moving portable substations or transformers they must be:
- a. Free of dirt and debris
 - b. Placed on wheeled trailers
 - c. De-energized
 - d. Cleaned and painted on exposed metal surfaces
61. Who is permitted to work on and examine electrical equipment?
- a. The Mine Superintendent
 - b. Qualified persons
 - c. The machine operator
 - d. Interested persons
62. Rubber gloves shall be worn when handling trailing cables having a voltage:
- a. Above 440V
 - b. Above 660V
 - c. Above 480V
 - d. Above 240V

63. What is the approved method for connecting single-phase loads on three-phase systems?
- Across one phase winding of the transformer
 - On one lead of a portable trailing cable
 - Phase-to-phase
 - Phase-to-ground

ANSWER SHEET FOR MINE LAW 30 CFR, PART 75 (UNDERGROUND)

- | | | |
|-------|--|-------|
| 1. a | 22. c | 43. c |
| 2. b | 23. c | 44. d |
| 3. c | 24. a | 45. c |
| 4. d | 25. b | 46. b |
| 5. a | 26. d | 47. a |
| 6. c | 27. c | 48. c |
| 7. b | 28. d | 49. c |
| 8. a | 29. a | 50. a |
| 9. d | 30. a | 51. a |
| 10. d | 31. a | 52. b |
| 11. b | 32. a | 53. c |
| 12. b | 33. c | 54. c |
| 13. d | 34. d | 55. a |
| 14. b | 35. undervoltage, grounded phase, short circuit, and overcurrent | |
| | 56. b | |
| 15. d | 36. c | 57. d |
| 16. a | 37. b | 58. a |
| 17. b | 38. c | 59. c |
| 18. b | 39. c | 60. c |
| 19. d | 40. a | 61. b |
| 20. d | 41. c | 62. b |
| 21. a | 42. c | 63. c |

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MINE LAW – 30 CFR, PART 77 (SURFACE)

ILLINOIS MINE ELECTRICIAN STUDY GUIDE

Mine Law 30 CFR, Part 77 (Surface)

- A. Electrical Protection Requirements
 - 1. Trailing cables
 - 2. Three-phase electrical motors
 - 3. Lightning arresters
 - 4. Underground high-voltage circuits
- B. Grounding Requirements
 - 1. High-voltage electrical equipment
 - 2. Minimum ground conductor sizes of circuits and cables
 - 3. Minimum size of internal and external ground check conductors
- C. Trailing cable temporary splice time and distance limitations
- D. High-voltage circuit breaker application and testing requirements
- E. Lockout requirements prior to performing electrical work
 - 1. Disconnect switches
 - 2. Locked and tagged out
- F. Ground fault current and voltage limitations
 - 1. Low-and-medium-voltage limitations, three-phase circuits
 - 2. High-voltage, three-phase circuits
- G. Minimum distance between lightning ground (substation ground grid) and neutral ground (mine ground grid)
- H. Definition of voltage classification
 - 1. Low voltage (0-660 Volts)
 - 2. Medium voltage (661-1000 Volts)
 - 3. High voltage (1001 Volts and Above)
- I. Requirements for cables and wires entering metal frames or electrical equipment
- J. Ground monitor circuit criteria
 - 1. Low-and-medium-voltage circuits
 - 2. High-voltage circuits
- K. Danger sign requirements for electrical installations on the surface (Part 77)
- L. Troubleshooting and testing exemptions, requirements, limitation, and comparison to performance of electrical work
- M. High-voltage cable protection and guarding requirements
 - 1. Regular work area
 - 2. Minimum height to prelude guarding
- N. Re-qualifications requirements for qualified (certified) electricians
- O. Work may never be performed on energized underground high-voltage circuits
- P. Protective equipment requirements for:
 - 1. Disconnecting energized surface high-voltage lines
 - Handling energized low, medium, and high-voltage trailing cables
 - 2. Troubleshooting and testing
- Q. Grounding resistors
 - 31. Voltage and current required ratings

2. Theory of operation and personnel safety enhancement
3. Criteria regarding current and voltage limitations
 - a. High-voltage circuits
 - b. Low and Medium-voltage circuits
- R. High-voltage circuits entering the underground area of any coal mine shall be protected with a circuit breaker located on the surface to provide protection against the following:
 1. Undervoltage
 2. Grounded phase
 3. Short circuit
 4. Overcurrent

SAMPLE QUESTIONS FOR SURFACE ELECTRICIAN

30 CFR Part 77 – (Surface)

1. High voltage power lines must be installed a minimum of:
 - a. 30 feet above ground
 - b. 100 feet above ground
 - c. 15 feet above ground
 - d. 50 feet above ground
2. Where high voltage power lines are installed over driveways, haulage ways and railroad tracks they must be installed a minimum of:
 - a. 30 feet above ground
 - b. 15 feet above ground
 - c. 50 feet above ground
 - d. 100 feet above ground
3. When operating equipment having a boom or mast, the minimum distance allowed between the boom or mast and a 69,000 to 114,000 volt power line must be:
 - a. 12 feet
 - b. 20 feet
 - c. 35 feet
 - d. 6 feet
4. Ground wires used to ground metallic sheaths, armors, conduits, frames, casing and other metallic enclosures shall be:
 - a. Equal in cross sectional area to that of the conductor
 - b. Equal to $\frac{1}{2}$ of the cross sectional area of the power conductor if the power conductor is #6 AWG or larger
 - c. No smaller than the #6 AWG
5. Circuit breakers for high voltage circuits of surface distribution systems for mobile equipment:
 - a. Must provide short circuit and overcurrent protection
 - b. Must provide grounded phase protection
 - c. Must provide under-voltage protection
 - d. All of the above

6. Preparation plants, dryer plants, tipples, draw-off tunnels, shops, and other surface installations shall be equipped with which of the following lists of fire fighting equipment:
 - a. Two fire extinguishers and 240 lbs. Of rock dust
 - b. Two portable fire extinguishers, and one additional fire extinguisher for each 10,000 cubic feet volume in the structure
 - c. One portable fire extinguisher for each room in the building
 - d. Complete fire sprinkler system
7. When welding, cutting or soldering with arc or flames:
 - a. One portable fire extinguisher must be provided at the location
 - b. Precautions shall be taken to make sure that smoldering metal or sparks do not result in a fire
 - c. In areas likely to contain methane, a methane check must be made
 - d. All of the above
8. When moving portable substations and transformers:
 - a. They must be de-energized before they are moved
 - b. They may be moved while energized if special precautions are taken
 - c. They must be completely disconnected
 - d. They may be moved energized since the frames are grounded
9. High voltage circuit breakers and disconnect switches:
 - a. Must be located close to the equipment they control
 - b. Must be labeled to show which circuits they control, unless identification can be made readily by location
 - c. May not be used to protect more than one circuit
 - d. None of the above
10. Grounding resistors where required in low and medium voltage circuits shall be of an ohmic value to limit the fault current to:
 - a. 15 amps
 - b. 50 amps
 - c. 25 amps
 - d. 100 amps
11. Power circuits and electric equipment shall be de-energized before work is done on such circuits and equipment, except:
 - a. When given permission by the Mine Superintendent
 - b. When troubleshooting or testing
 - c. When given permission by the Electrical Inspector
 - d. There is no exception

12. Who may perform electrical work on electric distribution circuits or equipment?
 - a. By any Journeyman or Master Electrician
 - b. By a Graduate of an Accredited Electrical School
 - c. Only by a qualified person by definition of the Act or by a person trained to perform electrical work under the direct supervision of a qualified person
 - d. A person designated by the Mine operator
13. What is the proper procedure prior to performing work on electric equipment?
 - a. The power must be removed by turning the circuit breaker off
 - b. The Foreman must remove the power
 - c. The power must be removed by means of an approved visible disconnect and locked or tagged out by the person who performs such work
 - d. The power must be removed by means of an approved visible disconnect and locked or tagged out by any qualified electrician
14. Who may remove locks or tags from electrical equipment?
 - a. The Mine Superintendent
 - b. The Electrical Inspector
 - c. Any qualified electrician
 - d. Only by the persons who installed them, or if such persons are unavailable, by persons authorized by the operator or his agent
15. What is the frequency of examination of surface electrical equipment?
 - a. At least daily
 - b. At least weekly
 - c. At least monthly
 - d. At least yearly
16. Which of the following is not a requirement of electric conductors on the surface?
 - a. Sufficient in size and have adequate current-carrying capacity for the load
 - b. Constructed such that a rise in temperature resulting from a normal operation will not damage the insulating materials
 - c. Meet the minimum requirements for ampacity provided in the National Electric Code 1968
 - d. Possess a MSHA approval number
17. The ampacity of trailing cables for surface equipment shall meet the minimum requirements set forth in:
 - a. National Electric Code 1968
 - b. Current National Electric Code
 - c. Schedule 2G
 - d. Insulated Cable Engineers Association – National Electric Manufacturers Association standards in effect when cables are purchased

18. Cables shall enter metal frames of surface electric equipment only through:
- Cable glands
 - Proper fittings
 - Junction boxes
 - Pot heads
19. All surface electric equipment and circuits shall be provided with what type of protection:
- Short circuit and overload
 - Overvoltage and overload
 - Grounded phase and overload
 - Undervoltage and overload
20. Electrical protective devices shall conform to what standards?
- ICEA – NEMA
 - National Electric Code 1968
 - IEEE
 - Underwriters Laboratory
21. Where shall lightning arrestors protecting exposed telephone wires entering buildings be located?
- Within 100 feet of the point where they enter the building
 - At the point where they enter the building
 - At the main terminal block for the telephone system on mine property
 - None of the above
22. Which of the following is not a requirement for the installation of a surface transformer?
- Transformer shall be of the totally enclosed type, or shall be placed at least 8 feet above the ground, or installed in a transformer house, or surrounded by a substantial fence at least 6 feet high and at least 3 feet from any energized parts, casings, or wiring
 - Transformer stations shall be enclosed to prevent persons from unintentionally or inadvertently contacting energized parts
 - Transformers shall be housed in fireproof enclosures
 - Transformer enclosures shall be kept locked against unauthorized entry
23. What is the maximum allowable voltage for bare signal or control wires?
- 24 volts
 - 40 volts
 - 96 volts
 - 100 volts

24. What requirements must be met by all electric wiring and equipment installed after June 30, 1971?
- Comply with National Electrical Code 1968
 - Comply with National Electrical Code 1971
 - Comply with National Electrical Code in effect at the time of installation
 - Comply with Schedule 2G
25. What is the proper method of grounding metallic sheaths, armors, and conduits in resistance-grounded systems where the enclosed conductors are a part of the system?
- A solid connection to metal waterlines having low resistance to earth
 - A solid to a grounding conductor, other than the neutral conductor of a resistance-grounded system, extending to a low-resistance ground field
 - A solid connection to the AC neutral ground conductor of the resistance-grounded system
 - None of the above
26. Which of the following is not an approved method of grounding metallic sheaths, armors, and conduits in all systems other than neutral resistance-grounded systems?
- A solid connection to metal waterlines having low resistance to earth
 - A solid connection to a grounding conductor, other than the neutral conductor of a resistance-grounded system, extending to a low-resistance ground field
 - A solid connection to the AC neutral ground of a resistance-ground system
 - Any other method of grounding approved by an authorized representative of the Secretary
27. Which of the following does not satisfy requirements for the minimum size and capacity of grounding wires?
- Where the power conductor used is No. 6 AWG or larger, the cross-sectional area of the grounding wire is at least one-half the cross-sectional area of the power conductor
 - Where the power conductor used is less than 6 AWG, the cross-sectional area of the grounding wire is equal to the cross-sectional area of the power conductor
 - A No. 6 AWG ground conductor is adequate in all cases
 - When more than one grounding conductor is used, the sum of the cross-sectional areas of all wires is considered for the total grounding conductor cross-sectional area
28. Low-and-Medium voltage circuits supplying power to portable or mobile three-phase alternating current equipment shall be protected by circuit breakers equipped with devices to provide protection against:
- Overvoltage, grounded phase, short circuit, and overcurrent
 - Undervoltage, grounded phase, short circuit, and overcurrent
 - Undervoltage, grounded phase, single phase, and short circuit
 - Overvoltage, undervoltage, single phase and grounded phase

29. What is the frequency of examination of circuit breakers protecting low-and-medium voltage circuits serving surface portable or mobile three-phase alternating current equipment?
- At least daily
 - At least weekly
 - At least monthly
 - At least annually
30. Low-and-Medium voltage circuits supplying power to portable or mobile three-phase alternating equipment shall contain:
- Either a direct or derived neutral grounded through a suitable resistor at the power source
 - A grounding circuit originating at the grounded side of the grounding resistor which extends along with the power conductor for the frames of all the electric equipment supplied power from the circuit
 - Neither A or B
 - Both A and B
31. Low-and-Medium voltage circuits supplying power to three-phase alternating current stationary electric equipment shall comply with:
- Schedule 2G
 - IEEE Standards
 - NEMA Standards
 - National Electrical Code
32. Grounding resistors, where required, shall be of ohmic value which limits the ground fault current to a maximum of:
- 5 amperes
 - 15 amperes
 - 20 amperes
 - 25 amperes
33. Which of the following are grounding resistors not required to comply with?
- Rated for maximum fault current continuously
 - Rated for a voltage equal to the phase-to-phase voltage of the system
 - Shall meet the “extended time rating” set forth in AIEE Standard No. 32
 - Shall comply with Schedule 2G
34. The maximum voltage used for ground check circuits for low-and-medium voltage alternating current circuits shall not exceed:
- 24 volts
 - 40 volts
 - 96 volts
 - 100 volts

35. Which of the following is **NOT** a requirement of ground check circuits used on surface low-and-medium voltage resistance grounded systems to portable and mobile equipment?
- a. Shall be of fail-safe design
 - b. Shall monitor continuously the grounding circuit to assure continuity
 - c. Shall cause the circuit breaker to open when either the ground or pilot check wire is broken
 - d. Shall comply with Schedule 2G
36. How must single-phase loads be connected in resistance grounded systems?
- a. Phase-to-phase
 - b. Phase-to-neutral
 - c. Phase-to-ground
 - d. Line-to-ground
37. You are working on a piece of surface electric equipment and you can not locate the fasteners to an electrical panel cover plate. Which of the following procedures should be followed?
- a. Leave the cover off and make a note to replace it later
 - b. Wire the cover in place
 - c. Remove the machine from service until the cover can be properly installed
 - d. Notify the equipment operator that the cover is off
38. Energized medium-and high-voltage trailing cables shall be handled:
- a. Only by Certified Electricians
 - b. Only by persons wearing protective rubber gloves
 - c. Only by the machine helper
 - d. Only by persons wearing protective leather gloves
39. Rubber protective gloves should be inspected for defects:
- a. Once each month
 - b. Daily
 - c. Before use on each shift and at least once thereafter during the shift when used for extended periods
 - d. Once every three months
40. Where must danger signs be installed on the surface?
- a. At all major electrical installations
 - b. Only at substations
 - c. Only at motor control centers
 - d. Only at high-voltage electrical installations
41. The frequency of examination and testing of surface electrical equipment shall be:
- a. Daily
 - b. Weekly
 - c. Monthly
 - d. Semi-annually

42. The ampacity of trailing cables for surface equipment shall meet the minimum requirements sent forth in:
- a. Insulated Cable Engineers Association; National Electric Manufacturers Association in effect when cables are purchased (ICEA)
 - b. National Fire Protection Agency
 - c. Current National Electrical Code
 - d. National Electric Code 1968
43. Surface electrical equipment and circuits require which of the following types of protection for mobile or portable equipment?
- a. Short circuit and overload
 - b. Over voltage
 - c. Under voltage and grounded phase
 - d. All of the above
44. Part 77 applies to:
- a. Auger coal mines
 - b. Surface areas of underground coal mines
 - c. Surface coal mines
 - d. All of the above
45. You are going to operate a disconnect switch that has a wooden platform to stand on; however it is raining, what special precautions should you take?
- a. None
 - b. Operate the switch with insulated tongs or other suitable device
 - c. Don't operate the switch
 - d. Have your helper operate the switch
46. Rubber protective gloves should be inspected for defects:
- a. Once each month
 - b. Daily
 - c. Before use on each shift and at least once thereafter during the shift when used for extended periods
 - d. Once every three months
47. The grounding resistors shall have a _____ rating.
- a. 100 Watt
 - b. Extended time
 - c. 500 Watt
 - d. 15 Minute
48. Low voltage is from 0 to _____ volts.
- a. 500
 - b. 1,000
 - c. 660
 - d. 690

49. Circuit breakers and their auxiliary devices shall be tested and examined at least:
- Daily
 - Monthly
 - Weekly
 - Semi-annually
50. Bare signal or control wires on the surface shall not exceed _____ volts.
- 30
 - 40
 - 25
 - 50
51. Single-phase loads shall be connected:
- Phase-to-phase
 - Phase-to-ground
 - Phase-to-neutral
 - Any of the above
52. One of the protections provided by the thermal overload relays in the line starter of an AC circuit is:
- Short circuit
 - Undervoltage
 - Single-phase
 - Overvoltage
53. The approved method of grounding for metallic sheathes, armors and conduits in resistance grounded systems where the enclosed conductors are a part of the system is to use:
- A solid connection to the neutral conductor
 - A #8 wire firmly connected to the earth ground rod
 - A #4 wire with permissible coupling to the trolley track
 - Any of the above fulfill the requirements of the Law
54. The maximum elapsed time between training courses for qualified persons is:
- Annually
 - Semi-annually
 - Every six months
 - Every two years
55. Areas surrounding flammable liquid storage tanks and electric substations and transformers shall be kept free from grass (dry), weeds, underbrush, and other combustible material such as trash, rubbish, leaves and paper for at least:
- 25 feet
 - 50 feet
 - 100 feet
 - 500 feet

56. Energized medium and high voltage trailing cables shall be handled:
- a. Only by Certified Electricians
 - b. Only by persons wearing protective rubber gloves
 - c. Only by the machine helper
 - d. Only by the persons wearing protective leather gloves
57. Normally, all power shall be removed when work is done on circuits or other equipment; what is the exception to this rule?
- a. When the breaker is stuck in the ON position
 - b. When the Foreman says leave it on
 - c. When troubleshooting
 - d. There is no exception
58. Heater strips for motor overload relays shall be:
- a. 95% to 120% motor full load current
 - b. 115% to 140% motor full load current
 - c. 125% to 150% motor full load current
 - d. 105% to 130%
59. Federal requirements for persons to become qualified to do electrical work for surface requires a minimum experience of:
- a. 6 Months
 - b. 12 Months
 - c. 18 Months
 - d. 24 Months
60. Which of the following would be classified as medium voltage?
- a. 550V
 - b. 660V
 - c. 1,000V
 - d. 1,250V
61. Who shall maintain a written record of circuit breaker tests and repairs?
- a. Person making them
 - b. Operator
 - c. Inspector
 - d. Safety Committee

**ANSWER SHEET FOR
MINE LAW 30 CFR, PART 77
(SURFACE)**

- | | | |
|-------|-------|-------|
| 1. c | 22. c | 43. d |
| 2. b | 23. b | 44. d |
| 3. a | 24. c | 45. b |
| 4. b | 25. c | 46. c |
| 5. d | 26. c | 47. b |
| 6. b | 27. c | 48. c |
| 7. d | 28. b | 49. b |
| 8. a | 29. c | 50. b |
| 9. b | 30. d | 51. a |
| 10. c | 31. d | 52. c |
| 11. b | 32. d | 53. a |
| 12. c | 33. d | 54. a |
| 13. c | 34. b | 55. a |
| 14. d | 35. d | 56. b |
| 15. c | 36. a | 57. c |
| 16. d | 37. c | 58. b |
| 17. d | 38. b | 59. b |
| 18. b | 39. c | 60. c |
| 19. a | 40. a | 61. b |
| 20. b | 41. c | |
| 21. a | 42. a | |

Illinois Coal Mining Act

ARTICLE 18.

ELECTRICITY REGULATIONS.

(225 ILCS 705/18.01) (from Ch. 96 1/2, par. 1801)

Sec. 18.01. After the effective date of this Act, overhead power lines on the surface, carrying greater than 600 volts potential, shall be installed on insulators and shall be supported and guarded against contact with other circuits.

(Source: Laws 1953, p. 701.)

(225 ILCS 705/18.02) (from Ch. 96 1/2, par. 1802)

Sec. 18.02. Power circuits on the surface shall be protected against lightning.

(Source: Laws 1953, p. 701.)

(225 ILCS 705/18.03) (from Ch. 96 1/2, par. 1803)

Sec. 18.03. Electric wiring shall be installed so as to present minimum fire and contact hazards in buildings on the surface.

(Source: Laws 1953, p. 701.)

(225 ILCS 705/18.04) (from Ch. 96 1/2, par. 1804)

Sec. 18.04. Permanent surface transformers shall be elevated eight feet or more above the ground, or be enclosed in a transformer house, or be surrounded by a fence at least 6 feet high.

(Source: Laws 1953, p. 701.)

(225 ILCS 705/18.05) (from Ch. 96 1/2, par. 1805)

Sec. 18.05. Transformers containing flammable oil and installed on the surface, if the transformers are located within 10 feet of mine openings, shall be provided with a drain, or catch basin, to confine the oil.

(Source: Laws 1953, p. 701.)

(225 ILCS 705/18.06) (from Ch. 96 1/2, par. 1806)

Sec. 18.06. The operator of every mine where motor generator sets or transformers are installed underground shall designate or cause to be designated on the map provided for in this Act, the location of transformer stations and motor generator stations and said stations shall be of fireproof construction. A sufficient amount of sand or rockdust shall be kept in a suitable place convenient to motor generator stations and transformer stations for the purpose of extinguishing any fire starting from short circuiting or otherwise. In addition thereto two suitable chemical fire extinguishers shall be kept in a convenient place.

(Source: Laws 1953, p. 701.)

(225 ILCS 705/18.07) (from Ch. 96 1/2, par. 1807)

Sec. 18.07. "DANGER-HIGH VOLTAGE" signs shall be posted conspicuously on all transformer stations, high-voltage switchboards and other installations.

(Source: Laws 1953, p. 701.)

(225 ILCS 705/18.08) (from Ch. 96 1/2, par. 1808)

Sec. 18.08. Pull switches, circuit breakers, and other power controls shall be mounted on slate or other insulating material of equal or superior insulating qualities.

(Source: Laws 1953, p. 701.)

(225 ILCS 705/18.09) (from Ch. 96 1/2, par. 1809)

Sec. 18.09. All wires carrying electric current passing through curtains or flammable material, shall be properly protected so as not to ignite said curtains or flammable material.

(Source: Laws 1953, p. 701.)

(225 ILCS 705/18.10) (from Ch. 96 1/2, par. 1810)

Sec. 18.10. When the main line track is used as a return conductor, both rails shall be well-bonded at every joint, and one rail on secondary haulage roads, when used as a return conductor, shall be bonded, unless other equally efficient methods are used.

(Source: Laws 1953, p. 701.)

(225 ILCS 705/18.11) (from Ch. 96 1/2, par. 1811)

Sec. 18.11. All trolley and positive feed wires crossing places where persons or animals are required to travel, shall be safely guarded or protected from such persons or animals coming in contact therewith.

(Source: Laws 1953, p. 701.)

(225 ILCS 705/18.12) (from Ch. 96 1/2, par. 1812)

Sec. 18.12. Casings of transformers shall be grounded effectively.

(Source: Laws 1953, p. 701.)

(225 ILCS 705/18.13) (from Ch. 96 1/2, par. 1813)

Sec. 18.13. All main power circuits entering the mine from the outside shall have disconnecting switches above and below ground.

(Source: Laws 1953, p. 701.)

(225 ILCS 705/18.14) (from Ch. 96 1/2, par. 1814)

Sec. 18.14. Electric light wires shall be supported by suitable insulators. Electric lights shall be installed so that they cannot come in contact with combustible materials.

(Source: Laws 1953, p. 701.)

(225 ILCS 705/18.15) (from Ch. 96 1/2, par. 1815)

Sec. 18.15. Dry wooden platforms, rubber mats, or other electrically non-conductive material shall be kept in place at each switchboard and power-control switch; and at stationary machinery where shock hazards exist.

(Source: Laws 1953, p. 701.)

(225 ILCS 705/18.16) (from Ch. 96 1/2, par. 1816)

Sec. 18.16. Trolley wires or other exposed electrical wires shall not carry more than 275 volts. Terminal ends of all positive wires shall be guarded against persons coming in contact therewith.

(Source: Laws 1953, p. 701.)

(225 ILCS 705/18.17) (from Ch. 96 1/2, par. 1817)

Sec. 18.17. In a gassy mine, permissible junction or distribution boxes shall be used for making multiple-power connections in working places or other places where dangerous quantities of methane may be present or may enter the air current, except that where nonpermissible junction or distribution boxes are in use, or on order, on the effective date of this section or the date such mine became a gassy mine, whichever is later, their use may be continued until such time as replacements are made.

(Source: Laws 1953, p. 701.)

(225 ILCS 705/18.18) (from Ch. 96 1/2, par. 1818)

Sec. 18.18. In all mines, trolley and feeder wires shall not extend beyond the last open crosscut and shall be kept at least 150 feet from pillar workings.

(Source: Laws 1957, p. 2413.)

Section 220.50 Electrical Equipment-General

- a) Electric power circuits and electric equipment; deenergization. Power circuits and electric equipment shall be deenergized before work is done on such circuits or equipment, except when necessary for trouble-shooting or testing. Disconnecting devices shall be locked out and suitably tagged by the persons who perform such work, except that in cases where locking out is not possible, such devices shall be opened and suitably tagged by such persons. Locks and tags shall be removed only by the persons who installed them, or, if such persons are unavailable, by persons authorized by the operator or his agent.

- b) Electric circuits and equipment; repair.

No electrical work shall be performed on electric circuits or equipment except by a person qualified to perform electrical work and to maintain electrical equipment, or by a person trained to perform electrical work and to maintain electrical equipment at the direction of a qualified person. When such work is done by a trained person, the circuits or equipment shall be examined by a qualified person to assure safe operating condition before such circuits or equipment are energized.

- c) Electric equipment; examination, testing, and maintenance.

Electric equipment shall be frequently examined, tested and properly maintained by a person qualified to perform electrical work and to maintain electrical equipment to assure safe operating conditions. When a potentially dangerous condition is found on electric equipment, such equipment shall be identified and be removed from service until such condition is corrected. A record of such examinations shall be kept in an approved book, and shall include all dangerous conditions found, corrective actions taken, and the signature of the qualified person conducting the examination or testing. The record of examinations shall be signed by the person responsible for maintaining the equipment in safe operating condition, who shall also be a person qualified to perform electrical work and maintain electrical equipment, and records shall be made available for inspection by an authorized representative of the Department and the authorized representative of miners of such mine.

- d) Electric equipment; examination and testing.

A potentially dangerous condition within the meaning of Section 220.50(c) shall include without limitation, exposed conductors, improper frame grounding, missing guards, missing inspection covers, poorly-made splices in conductors, improper terminations, improper overload or short circuit protection, broken conduit, missing or malfunctioning safety devices, inoperative indicating lights, inoperative ground fault protection, defective monitoring circuits, and inadequate ground fields.

e) Qualified person.

A qualified person within the meaning of Sections 220.50(b), 220.50(c), 220.60(b), 220.80(b) and Section 220.90 of this Part is an individual who has been qualified as a coal miner electrician under 30 CFR 77.103, or anyone who may be so qualified in the future as a coal miner electrician by the Department, if and when such Department adopts rules affecting coal miner electrician certification.

f) Electric equipment; frequency of examination and testing.

The examinations and test required under the provisions of Section 220.50(c) shall be conducted as interpreted in the Mining Enforcement Safety Administration (MESA) Inspector's Manual at least monthly or more often if necessary to assure safe operating conditions. State Mine Inspectors shall be presented evidence of qualifications upon request.

g) Electric conductors; capacity and insulation.

Electric conductors shall be sufficient in size and have adequate current-carrying capacity and be of such construction that a rise in temperature resulting from normal operation will not damage the insulating materials.

h) Electric Conductors.

Electric conductors, installed inside surface buildings and structures, shall be sufficient in size to meet the minimum current-carrying capacity provided for in the National Electrical Code in effect at the time of installation.

i) Electric conductors; mobile and portable equipment.

Trailing cable, portable cables, and electric conductors installed in mobile or portable equipment shall have ampacities and construction in accordance with the specifications of Insulated Power Cable Engineers Association-National Electrical Manufacturers Association in effect at time of purchase and the conductors shall be sufficient in size so that a rise in temperature resulting from normal operation will not damage the insulating material.

j) Electrical connections or splices; suitability.

Electrical connections or splices in electric conductors shall be mechanically and electrically efficient, and suitable connectors or approved splicing methods shall be used. All electrical connections or splices in insulated wire and cable shall be reinsulated at least to the same degree of protection as the remainder of the wire or cable.

k) Cable fittings; suitability.

Cables shall enter metal frames of motors, splice boxes, and electric compartments only through proper fittings and shall be secured to prevent chaffing of the insulation. When insulated wires, other than wiring installed in conduit, pass through metal frames, the holes shall be substantially bushed with insulated bushings and the wires be secured.

- l) Electric equipment and circuits; overload, short-circuit, and ground fault protection.

Automatic circuit-breaking devices or fuses of the correct type and capacity shall be installed so as to protect all electric equipment and circuits against short circuit and overloads. Ground fault protection shall be provided for equipment, powered by solidly or resistance grounds' systems.

- m) Electric equipment and circuits; overload and short-circuit protection; minimum requirements.

Devices providing short-circuits and overload protection shall conform to the minimum requirements for protection of electric circuits and equipment of the National Electrical Code in effect at the time of installation except that motors and circuits used in specially designed electrical systems, such as those used on some excavators, hoists and elevators, shall be considered as being provided with overload protection if the design of the system prevents the motors and associated circuits from being subjected to harmful overloads.

- n) Electric equipment-switches.

All electric equipment contracted for after the effective date of this regulation shall be provided with switches or other controls that are safely designed, constructed, and installed. The voltage of alternating current remote control circuits that are installed external to the controller enclosure shall not exceed one hundred twenty (120) volt.

- o) Lightning arresters; ungrounded, exposed power conductors, and telephone wires.

All ungrounded, exposed power conductors, control lines, and communication wires shall be equipped with suitable lightning arresters which are adequately installed and connected to a low resistance grounding medium in accordance with Section 220.70(f).

- p) Lightning arresters; circuits entering or leaving buildings.

Lightning arresters protecting circuits entering or leaving buildings shall be provided at a point near where each such circuit enters or leaves the building.

- q) Transformers and high-voltage equipment; installation and guarding; minimum vertical clearance.

- 1) Transformers and other high-voltage equipment shall be of the enclosed type, or installed in a transformer house, or surrounded by a substantial fence at least six (6) feet high and at least three (3) feet from any energized parts, casings, or wiring.

- 2) Enclosures of high-voltage equipment shall be kept locked against unauthorized entry.

- 3) Electric equipment energized at more than one thousand (1,000) volts and containing unguarded live parts, shall be installed with a minimum vertical clearance above the surfaces where a person would normally stand, as follows:

Voltage between Phases		Minimum Vertical Clearance of Unguarded Parts:	
		Feet	Inches
1,000 –	6,600	8	0
6,601 –	11,000	9	0

11,001 –	22,000	9	3
22,001 –	33,000	9	6
33,001 –	44,000	9	10
44,001 –	66,000	10	5
66,001 –	88,000	11	0
88,001 –	110,000	11	7
110,001 –	132,000	12	2

r) Resistors; location and guarding.

Resistors, heaters, and rheostats shall be located so as to minimize fire hazards and, where necessary, provided with guards to prevent personal contact.

s) Danger signs at high-voltage electrical installations.

Danger signs shall be posted at the entrance to all high-voltage electrical installations.

t) Inspection and cover plates.

Inspection and cover plates on electrical equipment shall be kept in place at all times except during testing or repairs. Equipment designed with exposed energized parts shall be properly guarded to prevent accidental contact.

u) Insulated platforms at power switches.

Insulated mats or platforms, insulated for the phase-to-phase voltage of the system, shall be kept in place at all switchboards and power control switches where shock hazards exist. However, metal plates on which a person normally would stand and which are kept at the same potential as the grounded, metal noncurrent-carrying parts of the power switches to be operated, may be used.

v) Switchboards; enclosures, passageways, and clearance.

Switchboards in stationary installations which require back access shall be provided with passageways or lanes of travel which permit access to the back of the switchboard from both ends for inspection, adjustment, or repair. Openings permitting access to the rear of any switchboard shall be guarded, except where they are located in buildings which are kept locked. Enclosures containing switchboards motor generators sets, transformers, oil circuit breakers, and resistance panels shall not be used for the storage of material.

w) Bare signal or control wires; voltage.

The voltage on bare signal or control wires accessible to personal contact shall not exceed forty (40) volts.

x) Electric Wiring and equipment; Installation and maintenance.

Except as otherwise provided in this Part, all wiring and electrical equipment installed after effective date of this regulation shall meet the requirements of the National Electric Code in effect at the time of installation.

y) Hazardous locations, surface facilities; bituminous and lignite mines.

- 1) All electrical circuits and equipment installed after effective date of this regulation with a coal preparation plant or other enclosure housing coal-handling facilities, except in sections where only wet coal is handled or in sections so maintained as to be free from dangerous amounts of coal dust, shall be of the type designed for hazardous locations, Class II, Group F, and installed in accordance with the requirements in Article 501 of the National Electrical Code.
- 2) Enclosed areas where methane may accumulate and is not prevented from accumulating by an adequate ventilation system shall have electric circuits and equipment of the type designed for hazardous locations, Class I, Group D, and installed in accordance with the requirements in Article 501 of the National Electrical Code.
- 3) An adequate ventilation system within the meaning of paragraph (b) above is a system in which:
 - A) The enclosed area is monitored continuously in accordance with the provisions of Section 220.20(n); and
 - B) The provisions of Section 220.20(a) are complied with.

z) Approved permissible equipment.

Permissible electrical equipment which is maintained in a permissible condition may be used in lieu of equipment required in Section 220.50(y).

aa) Minimum wiring requirements for stationary structures and buildings; general.

- 1) All wiring shall be installed so as to be adequately protected from physical damage;
- 2) Raceways, cable assemblies, boxes, cabinets, and fittings shall be securely fastened in place;
- 3) Cables, conductors, metal raceways, cable armor, boxes, fittings, supports, and other wiring hardware shall be of proper construction and material for the environment in which they are installed;
- 4) Power cables within surface structures shall closely follow the surface of the building or the other continuous support and shall be secured at intervals not exceeding four and one-half (4 1/2) feet and within one (1) foot from every box fitting; and
- 5) All open conductors within surface structures shall closely follow the surface of the building and be installed on proper insulators which support the wires at least every four and one-half (4 1/2) feet.

bb) Equipment marking.

All electrical equipment purchased or rebuilt after the effective date of these rules shall be provided with a plate which indicates the manufacturer's name, rated voltage, current, horsepower, frequency, number of phases, and duty cycle.

cc) Protection of power cables.

All power cables and wiring shall be adequately protected against mechanical damage. If a cable is damaged to the extent that the outer jacket will not exclude moisture, or if the conductors or

metallic shielding are exposed, the cable jacket shall be repaired to the same degree of protection as the remainder of the cable.

dd) Identification.

Circuit breakers, disconnects, control switches, and push buttons shall be marked to show which circuit they control, unless identification can be made readily by location

Section 220.60 Trailing Cables

a) Trailing cables; ampacity.

All trailing cables shall meet the minimum requirements for construction and ampacity provided in the Standards of the Insulated Power Cable Engineers Association – National Electric Manufacturers Association in effect when such cables are purchased.

b) Trailing cables; short-circuit, grounded phase protection, and disconnecting devices.

Short-circuit protection for trailing cable shall be provided by a circuit breaker or other no less effective device of adequate current-interrupting capacity in each ungrounded conductor. One (1) breaker may protect multiple cables if the amperage setting on the breaker is set to the lowest amperage setting of the smallest circuit. Disconnecting devices shall be installed in conjunction with each circuit breaker and within three thousand (3,000) feet of each mobile machine. Such disconnecting devices used to connect power from trailing cables shall be plainly marked and identified and such devices shall be equipped or designed in such a manner that it can be determined by visual observation that the power is disconnected.

c) Short-circuit protection; ratings and settings of circuit breakers.

Circuit breakers providing short-circuit protection for trailing cables shall be set at not more than eighty (80) percent of the short-circuit capability of the system. The maximum time for clearing a short circuit shall not exceed that cable time current rating specified by the Insulated Power Cable Engineers Association higher settings may be permitted by an authorized representative of the Department when he has determined that higher settings are justified.

d) Design of trailing cable for low and medium voltage three (3) phase equipment.

All trailing cables supplying power to equipment from low and medium-voltage systems purchased after effective date shall contain two (2) or more grounding conductors having a total cross-sectional area of not less than one-half ($\frac{1}{2}$) the power conductor and grounded metallic shields around each power conductor. The metallic shielding shall meet the requirements for shielding provided by the Standards of the Insulated Power Cable Engineers Association-National Electrical Manufacturers Association for type SH or SHD portable power cables. Such trailing cables shall include an insulated conductor for the ground continuity check circuit except in circuits in which a no less effective device for ground check monitoring approved by the Department is being utilized.

e) Splicing of trailing cables.

1) When splices in trailing cables are made, they shall be:

- A) Mechanically strong with adequate electrical conductivity,
- B) Effectively insulated and sealed so as to exclude moisture, and
- C) Vulcanized or otherwise made with suitable materials to provide good bonding to the outer jacket.

2) Splices made in trailing cables shall provide continuity of all components including the grounded metallic shielding.

3) Trailing cables or portable cables with exposed wires or splices that heat or spark under load shall not be used.

f) Securing of Trailing Cables to equipment.

Trailing cables shall be secured to machines in a manner to protect the cables from damage and to prevent strain on the electrical connections.

- g) Protection of trailing cables.
Trailing cables shall be adequately protected to prevent damage by mobile equipment and placed to afford protection against rock slides and other falling objects. Surplus trailing cable to shovels, draglines, drills, and similar equipment shall be stored on reels mounted on the equipment or otherwise protected from mechanical damage. Damaged outer jackets of trailing cables shall be repaired to the same degree of protection as the remainder of the cable.
- h) Breaking trailing cable and power cable connections.
 - 1) Plugs and connectors in trailing cables and power cables shall not be connected or disconnected while the circuit is energized.
 - 2) No power cable or electric circuit supplying power in excess of two hundred forty (240) volts will be energized or deenergized, hooked up or unhooked except by a person qualified under Section 220.50(e) of this Part to perform electrical work, or by a person trained to perform electrical work at the direction of a qualified person.
 - 3) This requirement shall not be construed to include the energizing or deenergizing of a simple "on-off" switch on standard equipment, when such switch or equipment is located outside of any high-voltage switch house.
- i) Trailing Cables; Movement.
Trailing cables shall not be moved with mobile equipment unless cable slings, sleds, or equivalent protection is provided.
- j) Energized trailing cables, handling.
Energized trailing cables, where the phase-to-ground voltage is one hundred fifty (150) volts or more, shall be handled only by persons wearing protective gloves. Protective gloves must be worn while using insulated hooks or tongs.
- k) Protective gloves; minimum requirements.
 - 1) Protective gloves worn while handling high-voltage trailing cables shall be rated at least for the phase-to-ground voltage of the system and shall be used and tested in accordance with the provisions of Section 220.80(aa), (bb) and (cc).
 - 2) Protective gloves worn while handling low-voltage and medium-voltage trailing cables shall be rated for a minimum of the phase-to-ground voltage of the circuit.
 - 3) Protective gloves shall be inspected for defects before each use. Protective gloves which contain defects shall not be used.

Section 220.70 Grounding

- a) Grounding, metallic shielding, armors, conduit enclosing power conductors, metallic frames, casings, and other metallic enclosures of electric equipment and circuits.
Metallic shieldings, armors, conduits enclosing power conductors, metallic frames, casings, and other metallic enclosures of electric equipment and circuits that can become "alive" through failure of insulation or by contact with energized parts shall be grounded by methods approved by an authorized representative of the Department.
- b) Approved grounding methods; three (3)-phase systems.
 - 1) Resistance Grounded Systems. A grounding circuit consisting of a grounding wire that meets the requirements of Section 220.70(f), originating at the grounded side of the grounding resistor, shall extend along with the power conductors and serve as the grounding conductor for all metallic shielding, armors, conduit enclosing power conductors, metallic frames, casings, and other metallic enclosures of electric equipment and circuits that receive power from the circuit. The grounding resistor shall be located

at the power source. The grounded side of the grounding resistor shall be connected to a low resistance ground field.

- 2) Solidly Grounded Systems. The grounded point of three (3)-phase systems shall be grounded to a low resistance ground field and to the cases of the source transformers. A grounding circuit that meets the requirements of Section 220.70(b)(1) shall originate at the grounded point of the circuit and extend along with the power conductors and serve as a grounding circuit for the frames, casings, and other metallic enclosures of all circuits and equipment receiving power from that circuit. The grounded point shall be located at the power source. In three (3)-phase, four (4)-wire systems in which the neutral is a power conductor, the neutral shall also be grounded to a low resistance ground field at the service entrance to building or at the utilization locations.
- 3) Ungrounded Systems. A grounding circuit, consisting of a grounding conductor that meets the requirements of Section 220.70(i) and originating at the grounded case or frame of the power source, shall extend along with the power conductors and serve as the grounding conductor for all metallic casings and other metallic enclosures of electrical equipment and circuits receiving power from that circuit. The grounded case or frame of the power source shall be connected to a low resistance ground field.

- c) Grounding method; single-phase system.
- Single phase systems shall be grounded in such manner so that the minimum amount of voltage will exist between the ungrounded conductors and earth. A conductor that meets the requirements of Section 220.70(i) shall originate at the grounded point in the circuit and extend along with the power conductors and serve as a grounding medium for the frames of all equipment receiving power from that circuit and such conductor shall also be grounded to a low resistance ground field at the service entrance or utilization points.

- d) Grounding methods; direct-current systems.

- 1) Direct-current systems having one (1) grounded polarity. In direct-current systems having one polarity grounded to a low resistance ground field the grounded feeder wire or track rail shall be approved grounding medium. A grounding circuit meeting the requirements of Section 220.70(f) shall originate at the grounded feeder wire or track rail and extend along with the power conductors and serve as a grounding conductor for the frames, casing, and metallic enclosures of all circuits and equipment receiving power from that circuit.
- 2) Direct current systems having a grounded neutral point. The grounded neutral point shall be the approved grounding medium. A grounding circuit meeting the requirements of Section 220.70(f) originate at the grounded neutral point and extend along with the power conductors and serve as a grounding conductor for the frames, casings, and metallic enclosures of all circuits and equipment receiving power from that circuit.
- 3) Ungrounded direct-current circuits. In ungrounded direct-current circuits the grounded frame or casing of the power source shall be the approved grounding medium. In the event the power source is a direct-current generator, the frame of the generator power source is a direct-current generator, the frame of the generator shall be connected to a low resistance ground field. A grounding circuit meeting the requirements of Section 220.70(f) shall originate at the grounded frame or casing of the power source and extend along with the power conductors and serve as a grounding conductor for the frames, casings, and metallic enclosures of all circuits and equipment receiving power from that circuit.

- e) Low resistance ground field; interpretation.

- 1) A low resistance ground field as referred to in Section 220.90 of this Part is interpreted to mean: made electrodes, buried metallic piping system, metal building framework, well or borehole casing, steel piling, and other underground metal structures installed for purpose other than grounding which have a resistance to ground of not more than five (5) OHMS. Grounding fields shall be measured at the time of installation and at least annually thereafter to insure a sufficiently low resistance ground field has been

established and is being maintained and such measurements shall be recorded and kept at the installation.

- 2) An authorized representative of the Department may allow higher resistance to ground values if an investigation has revealed that such greater values of resistance will not pose a hazard to the miners.

f) Grounding wires; capacity.

Where grounding wires are used to ground metallic shielding, armors, conduits, frames, casings, and other metallic enclosures, such grounding wires will be approved if:

- 1) Where the power conductor used is No. 6 A.W.G., or larger, the cross-sectional area of the grounding wire is at least one-half ($\frac{1}{2}$) the cross-sectional area of the power conductor; or
- 2) Where the power conductor used is less than No. 6 A.W.G., the cross-sectional area of the grounding wire is equal to the cross-sectional area of the power conductor.

g) Protection other than grounding.

Methods other than grounding which provide no less effective protection may be permitted by the Department or its authorized representative. Such methods shall not be used unless so approved.

h) Grounding circuit; criteria.

The grounding circuit for equipment and conductor enclosures shall:

- 1) Be permanent and continuous;
- 2) Have ample current-carrying capacity to conduct safely any currents liable to be imposed on it; and
- 3) Have impedance sufficiently low to facilitate the operation of the ground overcurrent devices in the circuit during fault conditions.

i) Approved grounding conductors.

Any of the following conductors when properly installed shall be acceptable for grounding equipment to the ground field:

- 1) A properly-sized copper or other corrosion-resistant conductor which meets the requirements of Section 220.70(f);
- 2) Rigid metal conduit;
- 3) Electrical metallic tubing; and
- 4) The structural metal frame of buildings.

j) Use of grounding connectors.

If ground wires are attached to grounded power conductors, separate clamps, suitable for such purpose, shall be used and installed to provide a solid connection.

k) Guy wire; grounding.

Guy wires from poles supporting power lines shall be securely connected to the system ground or be provided with insulators installed near the pole end.

Section 220.80 Surface High-Voltage Distribution

a) High-voltage circuits; protective devices.

- 1) Circuit breakers protecting high-voltage circuits supplying power to portable or mobile equipment must:
 - A) be properly tested and maintained in accordance with this Section;
 - B) have adequate interrupting capacity for the circuit application as rated by the manufacturer;
 - C) be equipped with devices for protection against;
 - i) short circuit,
 - ii) overload,

- iii) grounded phase, and
 - iv) undervoltage unless protection against undervoltage is provided on board the portable or mobile equipment receiving power from the circuit. A magnetic starter, which opens upon and must be reset manually following a loss of power, satisfies the undervoltage requirement.
 - 2) High-voltage circuits supplying power to stationary equipment must be protected from an overload or short circuit by a circuit breaker or fuses of the correct type and capacity. Circuit breakers must, in addition, on solidly grounded or resistance grounded systems, deenergize the circuit on the occurrence of a phase-to-ground fault.
 - 3) Circuit breakers and fuses must have adequate interrupting capacity rated to clear the short circuit current of the system. All electrical components and devices must be rated for the normal voltage and current of the system.
- b) Monthly testing, examination, and maintenance of circuit breakers; procedures; high-voltage. Circuit breakers and auxiliary devices located on the surface protecting surface or underground circuits, or both, must be examined and tested at least once (1) each month by a person qualified to perform testing and calibration, or qualified to perform electrical work under Section 220.50(e).
- 1) The examination must include observations of all readily accessible components of the circuit breaker and its auxiliary devices, and the manual activating of any of the auxiliary devices causing circuit breakers to operate. Examination of oil circuit breakers must include visual observation of all external components of the circuit breaker, including excessive oil spillage and/or the oil level of the tank. Repairs or adjustments as are indicated by such tests and examinations must be carried out immediately.
 - 2) Tests must include:
 - A) Breaking continuity of the ground check conductor where ground check monitoring is used, and
 - B) Actuating any auxiliary protective relays.
 - C) Actual system trips during the inspection interval may be used in place of the test specified in subsections (b)(2)(A) and (B) where such actual operations are maintained as part of the records.
 - 3) The operator must maintain written records of each test, examination, repair, or adjustment of all circuit breakers protecting high-voltage circuits. Such records must be kept in a book containing the following information:
 - A) The name of the person making the inspection;
 - B) The equipment inspected;
 - C) The inspected equipment's location;
 - D) The date of inspection;
 - E) The problems discovered and their corrections;
 - F) The signature of the supervisor of the person inspecting the equipment.
- c) Annual testing, examination, and maintenance of circuit breakers; procedures; high-voltage. Circuit breakers and auxiliary devices located on the surface protecting surface or underground circuits, or both, must be tested and calibrated at the time of installation and at least annually thereafter by a person qualified to perform testing and calibration or qualified to perform electrical work under Section 220.50(e).
- 1) The annual test and examination must include:
 - A) In resistance grounded systems:
 - i) Operation of the circuit breaker by passing a sufficient amount of current through the ground fault current sensing circuit to trip the circuit breaker. The ground resistor must be checked for continuity and ohmic value,
 - ii) If ground check monitoring is used, tripping the circuit breaker by breaking continuity of the ground check conductor, or using the manufacturer's recommended test,
 - iii) Verifying all current transformer secondary circuits,
 - iv) Verifying the operation and calibration of all over-current trip devices or relays,

- v) Verifying the operation of the circuit breaker trip system, and
 - vi) Verifying the operation of under-voltage devices where their use is required under subsection (a)(1).
- B) In ungrounded and solidly grounded systems:
 - i) If ground check monitoring is used, tripping the circuit breaker by breaking continuity of the ground check conductor, or using the manufacturer's recommended test,
 - ii) Verifying the operation of all current transformer secondary circuits,
 - iii) Verifying the operation and calibration of all over-current trip devices or relays,
 - iv) Verifying the operation of the circuit breaker trip system, and
 - v) Verifying the operation of under-voltage devices where their use is required under subsection (a)(1).
- 2) Repairs, calibrations, or adjustments indicated as necessary by the examination and test required in subsection (c) must be carried out before being returned to service.
- 3) Calibrations must include adjusting all relays and associated components according to manufacturer's specifications.
- 4) An authorized representative of the Department may require additional testing or calibration of circuit breakers and auxiliary devices when it is necessary to protect the health, safety and welfare of the miners. Examples of conditions for which the Department may require additional testing or calibration include the finding of any present or repeated dangerous conditions or malfunctions, incomplete or inadequate recordkeeping, or any indication that procedures have not been followed.
- 5) The operator must maintain written records of each test, examination, repair, or adjustment of all circuit breakers protecting high-voltage circuits. Such records must be kept in a book containing the following information:
 - A) The name of the person making the inspection;
 - B) The equipment inspected;
 - C) The inspected equipment's location;
 - D) The date of inspection;
 - E) The problems discovered and their corrections;
 - F) The signature of the supervisor of the person inspecting the equipment.
- d) Grounding resistors.
 The grounding resistor, where required must be of the proper ohmic value to limit the voltage drop in the grounding circuit external to the resistor to not more than one hundred (100) volts underground fault conditions. The grounding resistor shall be rated for maximum fault current continuously and insulated from ground for a voltage equal to the phase-to-phase voltage of the system.
- e) Grounding resistors; continuous current rating.
 The ground fault current rating of grounding resistors must meet the "extended time rating" set forth in Institute of Electrical and Electronics Engineers, Inc., 345 E. Forty-Seventh Street, New York City, New York 10017, Standard No. 32 (1972, reaffirmed in 1984) (The reference does not include any later amendments or editions.)
- f) Protection of high-voltage circuits; neutral grounding resistors.
 - 1) High-voltage circuits supplying portable or mobile equipment must contain either a direct or derived neutral which must be grounded through an extended time grounding resistor at the source transformers.
 - 2) A grounding circuit, originating at the grounded side of the grounding resistor, must extend along with the power conductors and serve as a grounding conductor for the frames of all high-voltage equipment supplied power from that circuit.
 - 3) The grounding circuit conductor must conform to Section 220.70(c).
 - 4) High-voltage stationary equipment may be served from impedance grounded, solidly grounded or ungrounded systems.
 - 5) Grounding transformers, where used to derive a neutral, must:

- A) be rated for continuous phase-to-ground fault current operation; and
- B) be located at the transformers supplying power to the circuit.

g) High-voltage cables; minimum design requirements.

- 1) Cables used in high-voltage systems must be equipped with metallic shielding around each power conductor with one (1) or more grounding conductors having a total cross-sectional area of not less than one-half ($\frac{1}{2}$) the power conductor. The metallic shielding must completely enclose each individual conductor or must meet the requirements for shielding set forth in Standard WC8 of the Insulated Cable Engineers Association-National Electrical Manufacturers' Association, 2101 L. Street, N.W., Washington, D.C. 20037 for type SH or SHD portable power cables (The reference to Standard WC8 is as revised July 1987 and does not include any later revisions or amendments). Cables used as trailing cables must contain an insulated conductor for the ground continuity check circuit if the circuit requires a conductor.
- 2) All high-voltage cables must be rated for the intended current and voltage. Splices made in such cables must provide continuity of all components and must meet the requirements of Section 220.60(e).

h) Cable couplers and connection boxes; minimum design requirements.

- 1) Cable couplers; requirements.
 - A) Couplers that are used in medium or high-voltage power circuits must be of the three (3)-phase type and enclosed in a full metallic shell.
 - B) Cable couplers must be rated for the intended current and voltage.
 - C) The metallic shell of cable couplers must be grounded to the grounding conductor in the cable.
 - D) Couplers must be constructed in such manner so that the ground check monitoring conductor when required will break first and the grounding conductor will break last when being uncoupled.
- 2) Connection Boxes
 - A) Cable connection boxes must be designed and constructed to guard all energized parts from personal contact.
 - B) The box lid/plate/ door must be interlocked so that the circuit will be deenergized when opened.
 - C) The current-carrying parts must be deenergized and discharged before performing any work inside such boxes, unless the particular load carrying cable is in an isolated compartment from the rest of the connection box. In this case, only the load carrying cable need be deenergized to be worked on or removed. While deenergizing and discharging the box, protective gloves must be worn.

i) Connection of single-phase loads.

Single-phase loads must be connected phase-to-phase in resistance grounded systems.

j) Installation of high-voltage transmission cables.

High-voltage transmission cables must be installed or placed so as to afford protection against damage. They must be placed to prevent contact with low-voltage or communication circuits.

k) High-voltage power lines; clearances above ground.

High-voltage power lines located above driveways, haulageways, and railroad tracks must be installed so as to provide the minimum vertical clearance as specified in Rule 232 of the National Electrical Safety Code published by the Institute of Electrical and Electronics Engineers, Inc., 345 E. 47th Street, New York, New York 10017 (1981). (The reference does not include any later amendments or editions.); provided, however, that in no event shall any high-voltage power line be installed less than fifteen (15) feet above ground, walkways, or working areas.

l) Booms and masts; minimum distance from high-voltage lines. The booms and masts of equipment operated on the surface of any coal mine must not be operated within ten (10) feet of an energized overhead powerline. Where the voltage of overhead powerlines is sixty-nine

thousand (69,000) volts, or more, the minimum distance from the boom or mast must be as follows:

Nominal Powerline Voltage (In 1,000 volts)	Minimum Distance Feet
69-114	12
115-229	15
230-499	25
500 or more	35

- m) Movement of equipment: minimum distance from high-voltage lines.
When any part of any equipment operated on the surface of any coal mine is required to pass under or by any energized high-voltage power line and the clearance between such equipment and powerline is less than that specified in subsection (l) for booms and masts, such power lines must be deenergized or other precautions must be taken.
- n) Operating of rear dump trucks under powerlines.
In cases where dump trucks are operated under powerlines, the minimum vertical clearance that must be maintained over dumping areas, must be five (5) feet more than the maximum height of the truck bed measured with the truck bed in the extreme raised position.
- o) Disconnecting devices.
Disconnecting devices must be installed at the beginning of each branch line in high-voltage circuits, except disconnecting devices in high-voltage transmission lines, which must be accessible and located as near as practicable to the entrance to the high-voltage stationary installations supplied from the overhead powerlines, and must be equipped or designed in such manner that it can be determined by visual observation that the circuit is deenergized when such devices are open.
- p) Identification of circuit breakers and disconnecting switches.
Circuit breakers and disconnecting switches must be labeled to show which units they control, unless identification can be made readily by location.
- q) High-voltage equipment grounding.
Low resistance ground fields used in high-voltage systems serving portable or mobile equipment must be separated from the other ground fields by twenty-five (25) feet or more.
- r) Movement of portable substation and transformers.
Portable substations, transformers, and high-voltage switch gear must be deenergized before they are moved from one location to another, and must be examined by a qualified person under Section 220.50(e) to assure safe operating condition prior to reenergization.
- s) Performing work in proximity to energized high-voltage circuits.
Work must not be performed within four (4) feet of any exposed energized high-voltage conductor unless the provisions of subsections (v) through (dd) have been complied with, with respect to guarding of all energized conductors; except that, a person qualified under Section 220.50(e) and wearing protective lineman's gloves rated for the phase-to-phase voltage of the system, may disconnect and connect conductors to the load side of opened fused cutouts or disconnecting switches.
- t) Work on high-voltage line; deenergizing and grounding.
High-voltage lines must be deenergized and grounded before work is performed on them, except that repairs may be permitted on energized high-voltage line if:
 - 1) Such repairs are made by a qualified person under subsection (ff) in accordance with procedures and safeguards set forth in subsection (u) through (dd) as applicable; and
 - 2) The operator has tested and properly maintained the protective devices necessary in making such repairs.

- u) Work on high-voltage line.
- 1) A high-voltage line is not regarded as deenergized for the purpose of performing work on it, until it has been determined by a qualified person under subsection (ff) that such high-voltage line has been deenergized and grounded. Such qualified person must by visual observation:
 - A) Determine that the disconnecting devices on the high-voltage circuit are in open position; and
 - B) Insure that each ungrounded conductor of the high-voltage circuit upon which work is to be done is properly connected to the system grounding medium. In the case of resistance grounded or solid wye-connected systems, the neutral wire is the system grounding medium. In the case of an ungrounded power system, either the steel armor or conduit enclosing the system or a surface grounding field is a system grounding medium.
 - 2) Work must not be performed on any high-voltage line which is supported by any pole or structure which also supports other high-voltage lines until:
 - A) All lines supported on the pole structure are deenergized and grounded in accordance with all of the provisions of this Part which apply to the repair of deenergized surface high-voltage lines; or
 - B) The provisions of subsections (v) through (dd) have been complied with, with respect to the energized lines which are supported on the pole or structure.
 - 3) Work must not be performed on energized surface high-voltage lines except in accordance with the provisions of subsection (u) through (dd) inclusive.
- v) Repairs to energized high-voltage lines.
An energized high-voltage line may be repaired only when:
- 1) The operator has determined that:
 - A) Such repairs cannot be scheduled during a period when the power circuit could be properly deenergized and grounded;
 - B) Such repairs will be performed on power circuits with a phase-to-phase nominal voltage no greater than fifteen thousand (15,000) volts;
 - C) Such repairs on circuits with a phase-to-phase nominal voltage of five thousand (5,000) volts or more will be performed only with the use of live line tools; and
 - D) Weather conditions will not interfere with such repairs or expose those persons assigned to such work to an imminent danger.
 - 2) The operator has designated a qualified person under subsection (ff) as the person responsible for carrying out such repairs and such person, in order to insure protection for himself and other qualified persons assigned to perform such repairs from the hazards of such repairs, has prepared and filed with the operator:
 - A) A general description of the nature and location of the damage or defect to be repaired;
 - B) The general plan to be followed in making such repairs;
 - C) A statement that a briefing of all qualified persons assigned to make such repairs was conducted informing them of the general plan, their individual assignments, and the dangers inherent in such assignments;
 - D) A list of the proper protective equipment and clothing that will be provided; and
 - E) Such other information as the person designated by the operator feels necessary to describe properly the means or methods to be employed in such repairs.
 - 3) Work performed on power lines energized at more than fifteen thousand (15,000) volts must be done in accordance with a plan submitted to and approved by the State Mine Inspector.
- w) Work on energized high-voltage surface line; reporting. Any operator designating and assigning qualified persons to perform repairs on energized high-voltage surface lines under the provisions of subsection (v) must maintain a record of such repairs. Such record must contain a notation of the time, date, location, and general nature of the repairs made, together with a copy of the information filed with the operator by the qualified person designated as responsible for performing such repairs.

- x) Simultaneous repairs.
When two (2) or more persons are working on an energized high-voltage surface line simultaneously, and any one of them is within reach of another, such person must not be allowed to work on different phases or on equipment with different potentials.

y) Installation of protective equipment.

- 1) Before repair work on energized high-voltage surface lines is begun, protective equipment must be used to cover all bare conductors, ground wires, guys, telephone lines, and other attachments in proximity to the area of planned repairs. Such protective equipment must be installed from a safe position below the conductors or other apparatus being covered. Each rubber protective device employed in making repairs must have a dielectric strength of twenty thousand (20,000) volts or more and must comply with the provisions of the American Society for Testing and Materials (ASTM) 655 Fifteenth Street N.W.; Washington, D.C. 20005 as follows:

ITEM	ASTM STANDARD	DATE OF ADOPTION
Rubber Insulating gloves	D120-87	July 31, 1987
Rubber matting for use around electrical apparatus	D178-88	Nov. 29, 1987 Feb. 26, 1988
Rubber insulating blankets	D1048-88	Feb. 26, 1988
Rubber insulating hoods	D1049-83	June 24, 1983
Rubber insulating line hose	D1050-85	August 30, 1985
Rubber insulating sleeves	D1051-87	July 31, 1987

AGENCY NOTE: The standards do not include any later amendments or editions.

- 2) Protective equipment of material other than rubber must provide equal or better electrical and mechanical protection.
- 3) Only live line tool poles having a manufacturer's certification to withstand the following minimum tests shall be used:
- A) One hundred thousand (100,000) volts per foot of length for five (5) minutes when the tool is made of fiberglass;
- B) Seventy-five thousand (75,000) volts per foot of length for three (3) minutes when the tool is made of wood; or
- 4) Measuring tapes or measuring ropes containing metal must not be used when working on or near energized parts.

z) Protective clothing; use and inspection.

- 1) All persons performing work on energized high-voltage surface lines must wear protective rubber linemen's gloves, sleeves, and climber guards if climbers are worn. Protective rubber gloves must not be worn wrong side out or without protective leather gloves. Protective devices worn by a person assigned to perform repairs on high-voltage surface lines must be worn continuously from the time he leaves the ground until he returns to the ground and such person must visually inspect the equipment assigned him for defects before each use.
- 2) All rubber protective equipment used for work on energized high-voltage surface lines must be electrically tested in accordance with the American National Standards Institute and the American Society for Testing and Materials Standards (ASTM), 655 Fifteenth Street N.W.; Washington, D.C. 20005 as follows:

ITEM	ASTM STANDARD	DATE OF ADOPTION
Rubber Insulating gloves	D120-87	July 31, 1987

Rubber insulating blankets	D1048-88	Feb. 26, 1988
Rubber insulating hoods	D1049-83	June 24, 1983
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Rubber insulating sleeves	D1051-87	July 31, 1987

AGENCY NOTE: The references do not include any later editions or references.

- aa) Protective equipment; inspection.
Each person must visually inspect protective equipment and clothing provided him in connection with work on high-voltage surface lines before using such equipment and clothing and any equipment or clothing containing any defect or damage must be discarded and replaced with proper protective equipment or clothing prior to the performance of any electrical work on such lines.
- bb) Protective equipment; testing and storage.
 - 1) All rubber protective equipment used on work on energized high-voltage surface lines must be electrically tested by the operator in accordance with subsection (z)(2) and such testing must be conducted in accordance with the following schedule:
 - A) Rubber gloves, once each month(except that gloves previously tested under Section 220.80(z)(2) that are not in use and have been kept in a storeroom or warehouse may be treated the same as new gloves);
 - B) Rubber sleeves, once every three (3) months;
 - C) Rubber blankets, once every six (6) months;
 - D) Insulator hoods and line hose, once a year;
 - E) Aerial lift arm current test, before each use; and
 - F) Other electric protective equipment, once a year.
 - 2) Rubber gloves must not be stored wrong side out.
 - 3) Blankets must be rolled when not in use, line hose and insulator hoods must be stored in their natural position and shape.
- cc) Operating disconnecting or cutout switches.
Disconnecting or cutout switches on energized high-voltage surface lines must be operated only with insulated sticks, fuse tongs, or pullers which are adequately insulated and maintained to protect the operator from the voltage to which he is exposed. When such switches are operated from the ground, the person using such devices must wear protective rubber lineman's gloves except where switches are bonded to a metal mat as provided in subsection (t).
- dd) Tying into energized high-voltage surface circuits.
If the work of forming an additional circuit by tying into an energized high-voltage surface line is performed from the ground any person performing such work must wear and employ all the protective equipment and clothing required and tested under the provisions of subsections (z), (aa), and(bb). In addition, the insulated stick used by such person must have been designed for such purpose and must be adequately insulated and be maintained to protect such person from the voltage to which he is exposed.
- ee) Use of grounded messenger wires; ungrounded systems.
Solely for purposes of grounding ungrounded high-voltage power systems, grounded messenger wires used to suspend the cable of such systems may be used as a grounding medium.
- ff) Repair of energized surface high-voltage line; qualified person.
An individual is a qualified person for the purpose of repairing energized surface high-voltage lines, under subsections (t) through (ee) only if such person:
 - 1) has had at least two (2) years experience in electrical maintenance, and
 - 2) has had at least two (2) years experience in the repair of energized high-voltage lines located on poles and structures.

Section 220.90 Low and Medium-Voltage Alternating Current Circuits

- a) Low-voltage and medium-voltage circuits serving portable, mobile and stationary, three (3)-phase alternating-current equipment; protective devices.
 - 1) Low and medium-voltage circuits supplying power to portable or mobile three (3)-phase alternating-current equipment shall be protected by suitable circuit breakers of adequate interrupting capacity, which are properly tested and maintained and equipped with devices to provide protection against grounded phase, short circuit, and overload.
 - 2) Low and medium-voltage circuits supplying power to stationary equipment shall be deenergized with the occurrence of an overload or, short circuit, by a circuit breaker, or fuses of the correct type and capacity. Such devices shall, in addition, on solidly grounded or resistance grounded systems deenergize the circuit on the occurrence of a phase-to-ground fault. Ungrounded low and medium-voltage circuits supplying power to stationary equipment shall be provided with ground detectors to indicate visually the presence of a grounded on any phase. Other no less effective devices may be approved by an authorized representative of the Department.
- b) Testing, examination, and maintenance of circuit breaker; procedures.
 - 1) Circuit breakers and their auxiliary devices shall be tested and examined at least once each month by a qualified person.
 - 2) In performing such tests, the circuit breaker auxiliaries or control circuits shall be actuated in any manner which causes the circuit breaker to open. In the absence of auxiliaries or control circuits, the breaker will be operated manually. All components of the circuit breaker and its auxiliary devices shall be visually examined and such repairs or adjustments as are indicated by such tests and examinations shall be carried out immediately.
- c) Testing, examination, and maintenance of circuit breakers; record.

The operator shall maintain a written record of each test, examination, repair, or adjustment of all circuit breakers protecting low and medium-voltage circuits serving three (3)-phase alternating-current equipment and such record shall be kept in an approved book.
- d) Low-voltage and medium-voltage three (3)-phase circuits; system grounding.
 - 1) Low-voltage and medium-voltage circuits supplying power to portable or mobile three (3)-phase alternating-current equipment shall contain:
 - A) Either a direct or derived neutral grounded through a suitable resistor as the power source; or
 - B) A grounding circuit originating at the grounded side of the grounding resistor which extends along with the power conductors and serves as a grounding conductor for the frames of all the electric equipment supplied power from the circuit.
 - 2) Grounding resistors shall be connected to a low resistance ground field, and shall be of an CHMIC value which limits the ground fault current to no more than twenty-five (25) amperes. Such grounding resistors shall be rated for maximum fault current continuously and provide insulation from ground for a voltage equal to the phase-to-phase voltage of the system.
- e) Grounding resistors; continuous current-rating.

The ground fault current rating of grounding resistors shall meet the "extended time rating" set forth in American Institute of Electrical Engineers Standard No. 32.
- f) Low-voltage and medium-voltage ground check circuits.

Present technology does not provide for a fail safe ground monitor system. In the event such technology becomes available, The Mining Board has the authority to adopt rules requiring such systems.
- g) Systems grounding.

Three (3)-phase low-voltage and medium-voltage circuits of more than two hundred forty (240) volts phase-to-phase extending to stationary equipment shall be grounded in one of following ways:

- 1) Solidly grounded through a direct or derived neutral;
- 2) Contain a direct or derived neutral grounded through a suitable resistor located at the power source; or
- 3) Ungrounded Delta.

h) Disconnecting devices.

Disconnecting devices shall be installed at the beginning of each branch line supplying power to each piece of portable or mobile equipment and shall provide visual evidence that the power is disconnected.

i) Connection of single-phase loads.

Single-phase loads shall be connected phase-to-phase in resistance grounded systems.

j) Qualified person.

An individual is a qualified person within the meaning of this Section 220.90 of this Part, if such person is a qualified person under Section 220.50(e) of this Part.

Federal & Law

1. Q. High-voltage equipment in use underground, including supporting structures, must be grounded to:

A. A high-voltage neutral.

2. Q. When electrical equipment is powered by a single-phase, 110-volt or 220-volt circuit:

A. Only one grounding method is used-a separate grounding conductor to the grounded center tap.

3. Q. What should be provided at storage battery charging stations to prevent the storage batteries from energizing the power circuits in the event of a power failure?

A. Reverse current protection.

4. Q. Diode grounding can be used on:

A. DC machinery with one polarity permanently grounded.

5. Q. When electrical equipment is operated in by the last open crosscut, a test for methane shall be taken at intervals not to exceed:

A. 20 minutes.

6. Q. If a DC power system is feeding an off-track DC machine, the grounded polarity of the power system:

A. Is an approved grounding medium for the frame.

7. Q. If the power conductor is smaller than No. 6 AWG, the cross-sectional area of the grounding wire must be:

A. Equal to that of the power conductor.

8. Q. How far from the portal must a disconnecting device that is serving a high-voltage circuit be located?

A. Within 100 feet.

9. Q. All metallic frames, casing or enclosures of electrical equipment:

A. Must be grounded to ensure no difference of potential between the equipment and the earth.

10. Q. The fence surrounding all surface transformer installations should be at least:

A. 6-feet high.

11. Q. If a piece of electrical equipment has the approval plate missing, it:

A. Is not permissible.

12. Q. The connection of lightning arrestors to the surface grounding must be located:

A. At least 25 feet from the neutral grounds entering the mine.

13. Q. Which of the following is NOT true concerning movement of energized power centers and transformers?

A. Power centers and transformers can never be moved while energized.

14. Q. Before work is performed on any power circuit, what precaution should be taken?

A. Open and lockout visible disconnects.

15. Q. When grounding diodes, over current devices, and polarizing diodes are installed on permissible equipment, they should be placed in:

A. Explosion-proof compartments.

16. Q. Mobile equipment with two conductor cables and grounding diodes should be checked weekly by the following method EXCEPT:

A. Checking the value of the current flow through the diodes.

17. Q. Where should lightning arrestors be provided for underground mine phones?

A. At the point of entry.

18. Q. Why must only permissible equipment be used at the face?

A. To prevent explosive gases from being ignited.

19. Q. Sheaths, armors, and conduits which are made of metal and which enclose power conductors:

A. Must be grounded because it is the law and also for safety reasons.

20. Q. In which one of the following may gaskets be used between two surfaces forming a flame-arresting path?

A. Headlights.

21. Q. Before any welding or cutting is performed in by the last open crosscut:

A. An examination for methane must be made.

22. Q. All circuits supplying power to underground three-phase portable or mobile equipment must contain a grounding circuit. This circuit must:

A. Begin at the grounded side of the grounding resistor.

23. Q. All underground electrical equipment should be examined:

A. Weekly.

24. Q. All electrical equipment must be equipped with:

A. A frame ground.

25. Q. Electrical conductors should be joined together by:

A. Suitable connectors.

26. Q. The entire electric system of a mine:

A. Must be indicated on a mine map according to the law.

27. Q. The purpose of the grounding circuit in a portable or mobile equipment circuit is to:

A. Serve as a grounding conductor for the frames of the equipment receiving power from that circuit.

28. Q. All single-phase loads must be connected:

A. Phase-to-phase

29. Q. When changes in the electrical system are made, those changes must be made on the mine map:

A. No later than the end of the workday following completion of the change.

30. Q. Which of the following would NOT create a safety hazard when charging batteries?

A. Battery-box covers were lined with a flame-resistant insulating material.

31. Q. What type of resistor is provided with power-factor capacitors?

A. Bleed-off resistors.

32. Q. Each ungrounded, exposed power conductor that leads underground must be equipped with lightning arrestors that are located within:

A. 100 feet of where the circuit enters the mine.

33. Q. Frame grounds and return grounds of direct current powered equipment:

A. Should be separated.

34. Q. The current-carrying capacity of a conductor found in an underground mine must be determined by the standards set by the:

A. National Electrical Code.

35. Q. The cross-sectional area of any grounding wire must be at least:

A. One-half the cross-sectional area of the power conductors.

36. Q. An electrician is to perform work underground on an idle day. What must be done within three hours before the electrician can enter the mine?

A. The area must be declared safe by a fire boss.

37. Q. When telephone wires cross over or under power lines, they must:

A. Be properly insulated.

38. Q. A de-energization device, required on self-propelled electric face equipment, is used to:

A. Stop the motor immediately when necessary.

39. Q. If insulated wires other than cables are used, the entry holes to metal frames:

A. Must have insulated bushings to protect the wires from friction.

40. Q. Which of these power wires must be supported on insulators?

A. Ordinary cables to power non-mobile equipment.

41. Q. A polarizing diode is used on DC equipment:

A. To prevent the machine from being operated with the trailing cable leads reversed.

42. Q. When insulated wires, other than cables, pass through metal frames, the holes:

A. Must be substantially bushed with insulated bushings.

43. Q. When not in use, power circuits underground should be de-energized on idle days and idle shifts, EXCEPT those used on:

A. Rectifiers and transformers

44. Q. If an electrician observes an electrical hazard, that electrician should first:

A. De-energize the circuit.

45. Q. All power wires-with some exceptions:

A. Will be supported on well-installed insulators and must not contact combustible material, roof or ribs.

46. Q. If in some special situations where energized power centers and portable transformers must be moved, relocation must be done under the direct supervision of a:

A. Qualified person.

47. A. All of the following are required electrical devices on belts, EXCEPT:

A. Belt alignment switches.

- 48. Q. The panic bar or lever on self-propelled electric face equipment, which actuates the emergency stop switch, must extend a sufficient distance in each direction to permit:**
- A. A quick de-energization of tramming motors.
- 49. Q. All ungrounded exposed power conductors and telephone wires must be equipped with:**
- A. Suitable lightning arrestors that are properly installed and grounded.
- 50. Q. The panic bar or lever on self-propelled electric face equipment must be reachable from:**
- A. All locations from which the equipment can be operated.
- 51. Q. Underground power circuits must:**
- A. Be de-energized on idle days and idle shifts.
- 52. Q. In most instances, before power centers and portable transformers are moved they:**
- A. Must be de-energized.
- 53. Q. Protection devices that do not meet NEC requirements would:**
- A. Not be considered adequate under the law.
- 54. Q. Self-propelled electric face equipment that is equipped with a substantially constructed cab:**
- A. Must be equipped with a de-energization device.
- 55. Q. When adjusted to provide protection to the smallest conductor, one circuit breaker may be used to protect:**
- A. Two or more branch circuits.
- 56. Q. When can one circuit breaker be used to protect two or more branch circuits?**
- A. When the circuit breaker is adjusted to afford protection for the smallest conductor.
- 57. Q. Circuit breakers and their components and auxiliary devices:**
- A. Must be visually inspected.

58. Q. From the following charts listed in the Code of Federal Regulations, what would be maximum allowable circuit breaker setting that could be used for providing short-circuit protection using a No. 6 AWG single conductor?

Conductor size	Maximum allowable circuit breaker
AWG or MCM	Instantaneous setting (amperes)
14	50
12	75
10	150
8	200
6	300
4	500
3	600
2	800
1	1,000
1/0	1,250
2/0	1,500
3/0	2,000
4/0	2,500
250	2,500
300	2,500
350	2,500
400	2,500
450	2,500
500	2,500

Conductor size	Single Conductor cable		Two Conductor cable	
AWG or MCM	Ampacity	Max fuse rating	Ampacity	Max fuse rating
14	..	..	15	15
12	..	..	20	20
10	..	..	25	25
8	60	60	50	50
6	85	90	65	70
4	110	110	90	90
3	130	150	105	110
2	150	150	120	125
1	70	175	140	150
1/0	200	200	170	175
2/0	235	250	195	200
3/0	275	300	225	225
4/0	315	350	260	300
250	350	350	285	300
300	395	400	310	350
350	445	450	335	350
400	480	500	360	400
450	515	600	385	400
500	545	600	415	450

A. 300

- 59. Q. All electric equipment and circuits must be protected from a short circuit by:**
- A. Automatic circuit breakers or fuses.
- 60. Q. What must be provided on a power unit having different sized circuit breakers?**
- A. Means to prevent the connections of wrong sized cable to wrong sized circuit breaker.
- 61. Q. Underground low- and medium-voltage alternating current, serving portable or mobile three- phase alternating current equipment, must be protected by:**
- A. Circuit breakers.
- 62. Q. One circuit breaker used to protect two or more branch circuits:**
- A. Must provide overcurrent protection for the smaller conductor.
- 63. Q. Three-phases motors must be equipped with overload protection that de-energizes:**
- A. All three phases when any phase is overloaded.
- 64. Q. Automatic circuit-breaking devices or fuses of the correct type and capacity must be installed to:**
- A. Protect equipment and circuits against overloads and short circuits.
- 65. Q. Circuit breakers used in low- and medium-voltage AC circuits, must be tested at least:**
- A. Once a month by a qualified person.
- 66. Q. Circuits that are used to power portable or mobile equipment must protected against overcurrent by:**
- A. Circuit breakers only.
- 67. Q. Who should change the adjustment on a circuit breaker for a continuous miner?**
- A. An electrician.
- 68. Q. Circuit breakers and disconnecting switches that protect high-voltage circuits:**
- A. Must be labeled to show which equipment they control.
- 69. Q. Cable couplers must be designed so that when they are uncoupled, the:**
- A. Ground check continuity conductor is broken first and the ground conductor last.
- 70. Q. Couplers used in medium or high-voltage circuits must be of the:**
- A. Three-phase type and be enclosed in a full metallic shell.

71. Q. Since couplers must carry the same load as the cables with which they are used:

A. They must be adequate for the voltage and current of the circuit.

72. Q. Couplers that are used with medium or high-voltage power circuits must be adequate for the voltage and current expected as well as being:

A. Three-phase.

73. Q. Disconnecting devices used to disconnect trailing cables should be designed or equipped so that you can tell by:

A. Visual observation when the power is disconnected.

74. Q. When main power circuits enter the underground mine through a shaft or a borehole, the disconnecting device is installed:

A. Underground, within 500 feet of the bottom.

75. Q. During an electrical work session, disconnecting devices should be locked-out, if possible, and tagged by:

A. Only the person performing the electrical work.

76. Q. Disconnecting switches or cutout switches on energized lines can be opened:

A. Only with insulated sticks, fuse tongs or pullers.

77. Q. Disconnecting devices used to disconnect power from trailing cables should be:

A. Plainly marked and identified

78. Q. Disconnecting devices should be installed in conjunction with the circuit breaker in order to provide:

A. Visual evidence that the power is disconnected.

79. Q. When underground, the disconnecting device must be located within:

A. 500 feet of the bottom of the shaft or borehole.

80. Q. When a main power circuit enters the underground mine the disconnecting switch is installed:

A. On the surface within 100 feet of the entry point.

81. Q. How often should main mine fans be checked for mechanical and electrical reliability?

A. Daily.

82. Q. Records of daily fan inspection must be kept for at least:

A. 1 year.

83. Q. Electrically operated main mine fans should be equipped with all of the following EXCEPT:

A. A fan slippage alarm.

84. Q. How often should automatic closing doors on main mine fans be checked?

A. Once a month.

85. Q. Who should make the daily inspection of ventilation fans?

A. A certified electrician or a competent person.

86. Q. What fire-fighting equipment must be located at each temporary electrical installation of an underground coal mine?

A. One portable fire extinguisher and 240 lbs. of rock dust.

87. Q. When examining fire extinguishers, the date of such examinations should be recorded:

A. On a permanent tag attached to the extinguisher.

88. Q. The minimum fire fighting protection that must be provided where welding or cutting is being performed is:

A. One portable fire extinguisher and water.

89. Q. Permanent electrical installations must be provided with at least:

A. Two portable fire extinguishers.

90. Q. All unattended loading points where electrically driven hydraulic systems are used must utilize:

A. Fireproof oil or emulsion

91. Q. How often must fire extinguishers be examined?

A. At least once every six months.

92. Q. What fire protection must be provided at all temporary electrical installations?

A. One portable fire extinguisher and 240 pounds of rock dust.

93. Q. Which of the following types of power wire need not be supported on well installed insulators and prevented from coming in contact with combustible material, roof, or ribs?

A. Special high-voltage cables.

94. Q. Insulated power cables used along belt conveyors can be suspended by insulated J-hooks for:

A. 6 months.

95. Q. How long can insulated power wires remain on insulated J-hooks?

A. 6 months.

96. Q. To protect trailing cables from damage and to prevent strain on electrical connections:

A. The cable should be clamped to the machine.

97. Q. What should be done to trailing cables in order to protect them from damage, and to prevent strain on the electrical connections?

A. They should be clamped to machines.

98. Q. Communication cables:

A. Must be supported on insulated hangers or on insulated J-hooks.

99. Q. What must be done to protect a trailing cable from damage and to prevent strain on the electrical connection?

A. The cable should be clamped to the machines.

100. Q. Telephone lines and cables should be:

A. Carried on insulators and installed on the opposite side from power or trolley wires.

101. Q. How long may insulated control cables such as those used along belt conveyors be installed on insulated J-hooks?

A. Permanently.

102. Q. Most fail-safe monitoring devices, that assure continuity, will NOT cause the circuit breaker to open if:

A. Power line is broken.

103. Q. Ground check relays used to provide undervoltage protection must be designed to trip when the line voltage decreases:

A. 40 percent to 60 percent.

104. Q. Ground check circuits:

A. Assure the continuity of the grounding conductor.

105. Q. Power conductor cables, monitored by impedance monitors, must have at least:

A. One insulated ground check conductor.

106. Q. What is the maximum voltage that may be used for ground check circuits on high-voltage, resistance-grounded systems?

A. 96 volts.

107. Q. The fail-safe ground check monitor should cause the circuit breaker to open when:

A. Either the ground or ground check wire opens.

108. Q. Underground low and medium-voltage ground check circuits should not exceed:

A. 40 volts.

109. Q. When used with high-voltage power cables, external ground check conductors must be no smaller than:

A. 8 AWG.

110. Q. In high-voltage circuits, the voltage used for ground check circuits has a:

A. Maximum of 96 volts.

111. Q. Which of the following is NOT true concerning a ground check circuit?

A. It can detect an imbalance in phases that will cause the circuit breaker to open.

112. Q. What is the purpose of ground check circuits?

A. To assure the continuity of the grounding conductor.

113. Q. In underground low and medium-voltage systems, the voltage for ground check circuits must never exceed:

A. 40 volts.

114. Q. Ground continuity protection for resistance grounded systems is provided by:

A. A fail-safe ground check circuit.

115. Q. Any ground check circuit used in a resistance grounded system:

A. Should use some type of fail-safe device that will open circuit breakers when ground continuity is interrupted.

116. Q. The maximum voltage permitted for ground check circuits in a high-voltage system:

A. Cannot exceed 96 volts.

117. Q. Most ground check circuits cannot:

A. Detect an imbalance in phases which will cause the circuit breaker to open.

118. Q. The maximum voltage for a high-voltage ground check circuit is:

A. 96 volts.

119. Q. The purpose of a fail-safe ground check circuit is to:

A. Continuously monitor the grounding circuit to assure continuity.

120. Q. When line voltage decreases by 40% of the rated voltage:

A. It causes the ground check relay to drop out..

121. Q. Metal borehole casings or other substance that has low resistance to earth can:

A. Be used as a method of grounding when a solid connection is assured.

122. Q. What are two methods of preventing voltage from appearing on the frame of off-track direct current equipment?

A. Grounding conductor and grounding diodes.

123. Q. 550-volts, three-phase, alternating current equipment used underground must be grounded to:

A. The grounded side of the resistor at the source transformer.

124. Q. What method of grounding will be approved where single-phase 110-220 volt circuits feed electrical equipment?

A. A separate conductor connected to the center-tap of the transformer.

125. Q. Which of the following words means “to connect with the ground to make the earth part of the circuit?”

A. Grounding.

126. Q. Ground-fault voltage should be limited to what value in a circuit external to the resistor in high-voltage circuits extending underground?

A. 100 volts.

127. Q. High-voltage circuit grounding resistors should be designed to limit fault voltage to:

A. 100 volts.

128. Q. The voltage drop, external to the high voltage grounding resistor, cannot be more than:

A. 100 volts under fault conditions.

129. Q. Where must the grounding resistor be located?

A. At the source transformer.

130. Q. Low and medium-voltage, three-phase, alternating current circuits extending underground must be provided with a grounding resistor in the grounding circuit to limit ground-fault current to a maximum of:

A. 25 amps.

131. Q. The total cross-sectional area of ground conductors for trailing cables and all power cables must be:

A. No less than one-half the cross-sectional area of the power conductor.

132. Q. According to mining laws, if a three-phase high-voltage system is powered by three 2/0 conductors, the minimum-sized ground check wire must be:

A. No. 10 AWG or larger.

133. Q. What is the minimum size of an insulated internal ground check conductor that may be used for the ground continuity check circuit?

A. No. 10 AWG.

134. Q. The minimum distance from a mine opening that compressed or liquefied gas, oil, gasoline or other petroleum products can be stored is:

A. 100 feet.

135. Q. When working on equipment:

A. Make sure all circuits feeding power to that equipment are de-energized.

136. Q. For testing and trouble shooting purposes only, power circuits:

A. Can be energized.

137. Q. All permissibility checks must be conducted by a qualified person:

A. Weekly.

138. Q. It is important to when welding or cutting.

A. Wear clothing free from excessive oil and grease.

139. Q. Lubricating machinery while in motion:

A. Is permitted if machinery is equipped with extended fittings or cups.

140. Q. All persons performing work on energized high-voltage surface lines should wear:

A. Protective rubber gloves, sleeves, and climber guards if climbers are worn.

141. Q. Stop and start control switches should be installed on belt conveyors that do not transport miners. These switches should not be farther apart than:

A. 1,000 feet.

142. Q. Disconnecting devices should be locked out and tagged by:

A. The person doing the work.

143. Q. Locking out and tagging should be done by:

A. The person doing the work.

144. Q. Safety rules have been made:

A. For your own protection.

145. Q. All electrical work (underground or surface) shall be performed by:

A. A Certified Electrician or an electrical trainee under direct supervision.

146. Q. When performing testing procedures on power circuits, the circuits:

A. Can be energized.

147. Q. Inspection or cover plates on electrical equipment:

A. May be removed for testing or repair and must be replaced when such work is completed.

148. Q. Exposed moving machine parts that may be contacted by and cause injury to persons should be:

A. Guarded as required by law.

149. Q. Transformer stations:

A. Must be posted with "Danger High Voltage" signs and must be enclosed to prevent contact with energized parts.

150. Q. The examination tests required for surface electrical equipment must be conducted:

A. Monthly.

151. Q. The testing, maintenance and repair of electrical equipment must be performed by:

A. A qualified person.

152. Q. Power must be removed from electric equipment before work is performed on such equipment EXCEPT when:

A. Troubleshooting and testing.

153. Q. Electrical circuits must be de-energized, locked out, and tagged, while repairs are performed except for what?:

A. Troubleshooting and testing.

154. Q. Low voltage rubber gloves, in use, must be tested electrically:

A. Every six months.

155. Q. Insulated platforms must be placed:

A. At all stationary machinery where shock hazards may exist.

156. Q. Before working on electrical equipment the power should be removed, except when:

A. Troubleshooting and testing.

157. Q. When electrical equipment is tagged and locked-out, who should remove the tag and lock?

A. The person who installed the tag and lock.

158. Q. Guards that protect persons from exposed moving machine parts must be:

A. In place except when testing the machine.

159. Q. Dry insulating platforms of rubber or other suitable nonconductive material are required on all of the following, EXCEPT:

A. Mobile equipment.

160. Q. Where should insulated platforms be placed?

A. At stationary machinery where shock hazards may exist.

161. Q. You should protect yourself and the equipment you're working on by:

A. Locking out and tagging the visible disconnect device at the power source.

162. Q. During repair on energized surface high-voltage lines the regulations for rubber gloves inspection is:

A. Before the shift begins and at least once during the shift.

163. Q. Who is permitted to perform electrical work on low, medium, or high-voltage distribution circuits or equipment?

A. A qualified person.

164. Q. Where should “Danger: High-Voltage” signs be posted?

A. At all high voltage installations.

165. Q. Switches or other controls that are safely designed, constructed, and installed should be provided for:

A. All electrical equipment.

166. Q. If inadequate conductors were used:

A. The insulation could be damaged and result in a short circuit.

167. Q. Switchboard access openings:

A. Shall be guarded except when located in locked buildings or locked rooms.

168. Q. The minimum distance from a mine opening that any combustible material OTHER THAN compressed or liquefied gas, oil, or other petroleum products may be kept is:

A. 25 feet.

169. Q. If a defect is found in protective equipment, it must be:

A. Immediately discarded and replaced with proper equipment before work is continued.

170. Q. Persons who perform welding, cutting, or burning operations should:

A. Wear clothing free from excessive oil and grease.

171. Q. According to federal law, actuating of at least two of the auxiliary protective relays for a high-voltage circuit breaker must be done:

A. Once a month.

172. Q. The purpose of the polarizing diode in diode-grounding installations is:

A. To prevent the machine from being operated when the polarity of the trailing cable is reversed.

173. Q. Even though off-track equipment can be moved into active working areas the equipment:

A. Must be examined by a certified person.

174. Q. In addition to de-energizing, what other precaution must be observed when maintenance or repair work is to be performed on machinery?

A. The machinery must be blocked against motion.

175. Q. If a potentially dangerous condition is found on a piece of electric equipment, what shall be done?

A. It shall be removed from service until it can be repaired.

176. Q. Electric equipment must be examined and tested weekly by:

A. A qualified person.

177. Q. How many turns of cable should remain on the cable reel when the cable of a hoist is extended to its maximum working length?

A. At least 3 full turns.

178. Q. While performing work in or over shafts, miners should wear:

A. Safety belts.

179. Q. Fans and hoisting equipment for personnel use must be checked:

A. Daily.

180. Q. Define high voltage:

A. More than 1000 volts.

181. Q. Define low voltage:

A. From 0 to 660 volts.

182. Q. Which of the following equipment may remain energized on idle days and idle shifts even when not in use?

A. Transformers, rectifiers, and automatically controlled pumps.

183. Q. "An integral part of an electrical machine or accessory that is essential to the functions of the machine or accessory" defines a (an):

A. Component.

184. Q. Each mine map showing the mine electrical system must show all of the following, EXCEPT:

A. Telephones.

185. Q. 1,000 volts is classified as:

A. Medium voltage.

186. Q. “Low voltage” means any voltage:

A. Up to and including 660 volts.

187. Q. Permanent splices in trailing cables must be:

A. Vulcanized or treated with suitable material.

188. Q. How many temporary splices are allowed in a trailing cable?

A. One, for a twenty-four hour production period.

189. Q. Semi-conducting electrical tape has been designed specifically to:

A. Reduce dielectric stress under cable shields.

190. Q. Splices in conductors on cables should be reinsulated at least to the same degree of protection as:

A. The remainder of the wire.

191. Q. What procedures should be followed when a potentially dangerous condition is found in electrical equipment?

A. The equipment must be removed from service until such condition is corrected.

192. Q. No temporary splices are allowed:

A. Within 25 feet of a machine without a reel.

193. Q. How many temporary splices may be used in the same cable for the “next” 24-hour period?

A. One.

194. Q. A temporary splice may be used in a trailing cable for:

A. 24 hours.

195. Q. How many permanent splices are allowed in a trailing cable?

A. No limit.

196. Q. One of the most frequent safety errors found on mine sites is:

A. Improper splices of cables or conductors.

197. Q. Temporary splices may not be made on low or medium-voltage trailing cables within of where the cable enters the machine, if the machine does not have a cable reel.

A. 25 feet.

198. Q. A temporary splice within 25 feet of the reel on a low- or medium-voltage cable cannot be left in place for more than:

A. 24 hours.

199. Q. A splice on a low or medium-voltage cable is within 25 feet of the reel. This splice:

A. Can be temporary.

200. Q. If a low or medium-voltage trailing cable were pulled apart 15 feet from where it entered the machine, and the machine does not have a cable reel, an electrician must NOT:

A. Make a temporary splice.

201. Q. A permanent splice can be made:

A. Anywhere in a cable.

202. Q. Which of the following is NOT required when using tape to insulate existing power wire?

A. The tape should be fireproof

203. Q. A temporary splice in a drag cable may not be made within:

A. 25 feet of operating equipment.

204. Q. Allowing a trailing cable to trail in water may:

A. Result in a very dangerous condition.

205. Q. Any underground trailing cable, regardless of cable size, can be a length of:

A. 500 feet long.

206. Q. Trailing cables that supply power to both low and high-voltage equipment must have:

A. One or more ground conductors.

207. Q. At an intersection where other vehicles pass, a trailing cable can best be protected from damage by:

A. Suspending the cable from the roof.

208. Q. Cables without shields maybe used on reel equipment for medium voltage if the insulation has a rating of:

A. 2000 volts or more.

209. Q. Before unplugging a trailing cable:

A. The cable should be de-energized.

210. Q. To protect trailing cables from damage by moving equipment, the cables:

A. Should be positioned to prevent damage from moving equipment.

211. Q. Trailing cables:

A. Must always be protected from damage.

212. Q. Permanent pumps, battery charging stations, underground shops, and transformer stations must:

A. Be housed in fireproof structures or areas.

213. Q. Permanent pumps, battery charging stations, underground shops, and transformer stations must:

A. Be vented directly into the return.

214. Q. When lightning strikes a transmission line, causing a sudden surge of voltage into the system, circuit protection is provided by:

A. A surge arrestor.

215. Q. The main substation, which provides power for the entire pit:

A. May be fixed or portable.

216. Q. The voltages provided by the various substations are:

A. Dependent upon the needs of that part of the system.

217. Q. Insulated tools:

A. Can provide an extra measure of protection when working on equipment.

218. Q. The type of grounding system that involves drilling a hole to a level below the coal seam, then extending a heavy ground wire to the bottom of the hole is a:

A. Borehole ground system.

219. Q. Main substations are:

A. Either fixed or portable.

220. Q. Circuit protection against a tremendous surge of additional voltage through a distribution system is provided by:

A. Surge arrestors.

221. Q. Transmission lines provided by an electrical utility company often carry as much as:

A. 138,000 volts.

222. Q. The objective of grounding is to provide a constant electrical connection between:

A. Equipment frames and the earth.

223. Q. The grounding system stipulated in the Mine Safety and Health Act for both surface underground mines is the:

A. Resistance (impedance) grounded system.

224. Q. To further reduce the voltage provided by the various substations:

A. Another step-down transformer is used.

225. Q. The voltages provided by the utility are:

A. Changed to meet the system requirements.

226. Q. A capacitor, after it is disconnected from a circuit:

A. Will hold a dangerous charge.

227. Q. How often must circuit breakers be tested and examined?

A. Once a month.

228. Q. Circuit breakers, protecting high-voltage circuits entering an underground area of a coal mine:

A. Must be located on the surface.

229. Q. A high-voltage circuit, which supplies power to portable or mobile equipment, must be protected by:

A. A circuit breaker.

230. Q. High-voltage circuits to stationary equipment must be protected against overload by:

A. Circuit breakers or fuses.

231. Q. Molded case, and oil or oil blast are two types of:

A. Circuit breakers.

232. Q. A high-voltage circuit, which supplies power to stationary equipment on the surface, must be protected by:

A. Either a circuit breaker or fuses.

233. Q. Circuit breakers at disconnect switches which protect high-voltage circuits:

A. Must always be labeled to show what equipment is being controlled by which circuit.

234. Q. Circuit breakers serving high-voltage circuits to portable or mobile equipment must be tested:

A. At least once a month.

235. Q. Where should circuit breakers, protecting high-voltage circuits entering an underground area of any coal mine, be located?

A. On the surface.

236. Q. Circuit breaker and disconnecting devices underground are to be:

A. Marked for identification.

237. Q. Circuit breakers for high-voltage circuits entering an underground mine should provide protection for all of the following EXCEPT:

A. Over voltage.

238. Q. If high-voltage circuit is equipped with a circuit breaker, and if this circuit supplies power to portable or mobile equipment, then the circuit breaker must be tested and examined by a qualified person at least:

A. Once each month.

239. Q. Circuit breakers and disconnecting switches underground should be:

A. Marked for identification.

240. Q. Circuit breakers protecting high-voltage lines entering an underground area of any coal mine must provide all of the following EXCEPT:

A. Single-phase protection.

241. Q. To protect against a short circuit or overcurrent situation, there's a:

A. Circuit breaker at the output end of each substation.

242. Q. Cable couplers should be constructed so that the conductor which "breaks" first when the coupler is being uncoupled is the:

A. Ground check conductor.

243. Q. Cable couplers should be constructed in the following manner:

A. Ground check conductor should be broken first.

244. Q. A stress cone is used in high-voltage cable termination to:

A. Reduce electric field concentrations.

245. Q. Cables couplers should be constructed so that the conductor which “breaks” last when the coupler is being uncoupled is the:

A. Ground conductor.

246. Q. High-voltage cable couplers with any metal exposed should be:

A. Grounded to the ground conductor in the cable.

247. Q. All exposed metal on metallic couplers should be grounded to:

A. The ground conductor in the cable.

248. Q. Disconnecting or cutout switches on energized high-voltage surface lines should be operated only with:

A. Insulated sticks or fuse tongs.

249. Q. The beginning of each high-voltage branch circuit must be equipped with:

A. A disconnecting device.

250. Q. Under a full load, air switches:

A. Are usually not intended to be opened.

251. Q. One function of the main sub is to provide protection to both the system and the mine personnel by the use of:

A. Air switches and circuit breakers.

252. Q. Where high-voltage circuits enter the underground portion of a mine, disconnecting devices should be installed:

A. Within 100 feet of the mine entrance.

253. Q. An air switch is:

A. A visible disconnect.

254. Q. Disconnecting devices shall be installed at:

A. The beginning of each branch line in underground high-voltage circuits.

255. Q. High-voltage disconnecting devices must be installed:

A. At the beginning of all branch lines.

256. Q. An air switch located between the utility’s transmission and the main substation is used to isolate:

A. The entire mine’s underground power distribution system.

257. Q. A manually operated air switch:

A. Should not be opened under load.

258. Q. All branch lines in underground high-voltage circuits:

A. Must have disconnecting devices designed so that you can tell by visual observation that a line is de-energized.

259. Q. The maximum voltage used for ground check circuits in high-voltage systems should never exceed:

A. 96 volts.

260. Q. The grounding method that involves burying a network of conductors and connecting this network to the system is called:

A. Ground field grid.

261. Q. If a window-type current transformer is used for ground-fault detection on a high-voltage cable, the following conductors must pass through the opening:

A. The three phase conductors.

262. Q. A high-voltage, ground-monitoring system:

A. Opens the breaker whenever either the ground or pilot check wire is broken.

263. Q. If a high-voltage circuit utilizes resistance grounding, then the system must include:

A. A fail-safe ground check circuit or another device that is at least as effective.

264. Q. The insulation rating, for ground check conductors used with high-voltage trailing cables, must be at least:

A. 600 volts.

265. Q. The component which continuously checks the ground wires in trailing cables is the:

A. Ground monitor.

266. Q. What is the maximum voltage that can be used for high-voltage ground check circuits?

A. 96 volts.

267. Q. How must electrical enclosures of stationary, portable, or mobile underground AC equipment and frames supporting these structures be grounded?

A. Grounded to high-voltage ground.

268. Q. On a resistance-grounded power system, single-phase loads should be connected:

A. Phase-to-phase.

269. Q. Underground high-voltage cables used in resistance grounding should be equipped with:

A. A metallic shield around each power conductor.

270. Q. If a high-voltage circuit includes a grounding resistor, under fault condition it must limit the voltage drop in the grounding circuit external to the resistor to not more than:

A. 100 volts.

271. Q. If resistance grounding is used in a high-voltage circuit, then the grounding resistor must be rated for:

A. Maximum fault current continuously.

272. Q. In impedance and resistance grounding systems, an important part, which functions by limiting the ground-fault current from one phase of the system to the ground, is the:

A. Grounding resistor.

271. Q. On low and medium voltage circuits when a ground-fault occurs, if both the grounding transformer and the resistor in the impedance-grounded system are good, the maximum ground fault tripping current shall not exceed:

A. 25 amps.

272. Q. The grounding circuit of a high-voltage circuit extending underground must:

A. Originate at the grounded side of the grounding resistor.

273. Q. High-voltage circuits that supply power to portable or mobile equipment should:

A. Contain either a direct or a derived neutral that is grounded through a resistor.

274. Q. The neutral grounding resistor in a high-voltage circuit must be insulated from ground for a voltage equal to:

A. The phase-to-phase voltage of the system.

275. Q. Can messenger wire that is to be used to suspend high-voltage cable also be used as a grounding medium in an ungrounded system?

A. Yes, if the messenger wire is grounded.

276. Q. What is the minimum size of an insulated internal ground check conductor that may be used for the ground continuity check circuit?

A. No. 10 AWG

277. Q. According to federal law, if a high-voltage cable does not contain an insulated conductor for the ground continuity check circuit, an external conductor may be used if it is:

A. Not smaller than No. 8 AWG.

278. Q. The total cross-sectional area of the ground conductor in a high-voltage trailing cable must be:

A. Not less than one-half of the cross-sectional area of a power conductor.

279. Q. Flexible steel conduit as protection for high-voltage circuits:

A. May never be used.

280. Q. When handling high-voltage trailing cables:

A. Rubber or lineman's gloves (rated to at least 20,000 volts) must be worn.

281. Q. Rubber gloves used to work on high-voltage lines for extended periods should be visually inspected for defects by the person using them no less than:

A. Twice each day.

282. Q. Each rubber protective device employed in making repairs to energized high-voltage lines must have a dielectric strength of at least:

A. 20,000 volts.

283. Q. A boom or a mast may not be operated within:

A. 10 feet of an energized power line.

284. Q. If work is to be done on energized high-voltage lines, it must be done by:

A. A specially qualified person.

285. Q. Rubber gloves used to work on energized high-voltage surface lines must be electrically tested:

A. Once each month.

286. Q. When equipment must be moved or operated near energized surface high-voltage power lines, minimum clearance must be:

A. 10 feet.

287. Q. Which of the following is NOT an acceptable way to store high-voltage rubber gloves?

A. Wrong side out.

288. Q. When two persons are working on an energized high-voltage line at the same time within reach of each other, they:

A. Cannot work on different phases or on equipment with different potentials.

289. Q. How often must rubber sleeves be tested for use with high voltage?

A. Every 3 months.

290. Q. High-voltage lines are considered safely de-energized for maintenance when so determined by:

A. A qualified person.

291. Q. Energized high-voltage surface lines may be repaired:

A. By qualified persons in accordance with procedures and safeguards.

292. Q. Work on energized high-voltage lines underground is:

A. Prohibited by law.

293. Q. What precautions must be taken when two or more persons are working within reach of each other on energized high-voltage lines?

A. They must not work on equipment with different potentials.

294. Q. Before performing work on high-voltage lines on the surface or underground, the lines should be:

A. De-energized and grounded.

295. Q. The person responsible for making out the special report concerning the repair of high-voltage lines is the:

A. Person who made the repairs.

296. Q. Must a record be kept of repair work done on energized high-voltage surface lines?

A. Yes.

297. Q. In no event should any high-voltage power line be installed above ground at a height less than:

A. 15 feet.

298. Q. Where the voltage of overhead power lines is less than 69,000 volts, the booms and masts of equipment operated on the surface should be operated no closer to the power lines than:

A. 10 feet.

299. Q. A requirement for working on energized high-voltage surface lines is:

A. The mine operator must provide, test, and maintain protective devices used in making such repairs.

300. Q. The term “high voltage” means that the voltage is:

A. More than 1,000 volts.

301. Q. How high must unguarded, high-voltage cables be from the mine floor and rail where people pass under them?

A. 6 1/2 feet.

302. Q. When splices are made in high-voltage cables:

A. They must be made in accordance with the manufacturer's specifications.

303. Q. Which of the following is the only acceptable method of splicing a copper wire to an aluminum wire?

A. By using a special connector that prevents contact of dissimilar conductors.

304. Q. A 1,200-volt trailing cable can have how many temporary splices?

A. None.

305. Q. May temporary splices be used in high-voltage trailing cables?

A. No.

306. Q. Each power conductor of high-voltage trailing cables must be surrounded by:

A. A metallic shield.

307. Q. When high-voltage cables are used as trailing cables:

A. They can have no temporary splices.

308. Q. An air switch is:

A. A visible disconnect.

309. Q. Where may high-voltage cables be installed underground?

A. Only in regularly inspected air courses.

310. Q. High-voltage cables should be installed in:

A. Regularly inspected air courses.

311. Q. All high-voltage transmission cables used underground must be installed:

A. Only in regularly inspected air courses and haulage ways.

312. Q. Why must a power center be located outby the last open crosscut in intake air?

A. So it does not ignite explosive gases which could be found inby the last open crosscut.

313. Q. Most transformers used in mining situations are:

A. Delta- wye wired.

314. Q. Which of the following is NOT a requirement of transformers enclosed by a 6-foot fence:

A. The enclosed unit must be well lighted.

315. Q. Which device will detect the smaller current under fault conditions:

A. Potential transformer.

316. Q. Before portable substations and transformers are moved from one location to another, they should be:

A. De-energized.

317. Q. A donut current transformer on the neutral grounding conductor will detect a grounded phase condition even if:

A. The neutral grounding resistor is shorted.

318. Q. A “derived neutral” on a transformer with a delta-connected secondary can be obtained through the use of:

A. A zigzag transformer.

319. Q. If an unbalanced condition occurs, the donut CT will detect the condition and cause the:

A. Ground relay to open the circuit.

320. Q. With a potential relay ground fault system, a potential transformer takes the remaining voltage and steps it down to 120 volts, it can use this voltage to

A. Activate its own voltage-sensitive relay to trip the oil circuit breakers.

321. Q. Alternating current is changed to direct current by means of a:

A. Rectifier.

NATIONAL ELECTRICAL CODE

ILLINOIS MINE ELECTRICIAN STUDY GUIDE

National Electrical Code

- A. A copy of the 1968 NEC is provided for use while taking the test. All questions pertain to provisions of the 1968 NEC.
- B. Pertinent cable ampacity charts are also provided
- C. The following exercises must be performed using the 1968 NEC:
 - 1. Determine the size of motor branch circuit conductors for an individual motor
 - 2. Determine the size of feeder conductors supplying power to multiple motors
 - 3. Determine maximum allowable instantaneous trip setting for motor branch circuit protection for an individual motor
 - a. Normal (standard) Maximum setting = $7 \times \text{FLA}$
 - b. Absolute Maximum setting = $13 \times \text{FLA}$
 - 4. Determine maximum allowable instantaneous trip setting for a motor feeder circuit supplying multiple motors
 - a. Normal (standard) maximum setting
 - b. Absolute maximum setting
 - 5. Determine motor overload protection setting
 - a. Normal (standard) maximum setting
 - b. Absolute maximum setting
 - 6. Disconnect switches
 - a. Minimum rating allowed
 - b. Located in sight from and within 50 feet of the motor
 - 7. Motor controller
 - a. Minimum rating allowed
 - b. Capable of interrupting stalled rotor current
 - 8. NEC requirements concerning listed or labeled equipment
 - 9. Low-voltage circuit breakers protecting three-phase circuits supplying power to portable or mobile equipment are required to be tested and examined by a qualified person at least once each month
 - 10. Hazardous area classification criteria
 - a. Class I locations
 - b. Class II locations
 - c. Class III locations
 - 11. Fences enclosing transformer stations shall be isolated from transformer cases by a minimum of 3 feet
 - 12. Definitions
 - a. Ground fault
 - b. Short circuit
 - c. Overload
 - d. AWG
 - 13. The continuous load supplied by a branch circuit should not exceed 80% of its rated capacity
 - 14. Clearance requirements between energized lines and booms or masts of equipment (MSHA Part 77)

75.513 Ampacity of conductors The allowable ampacities of copper conductors are found in Tables 310-12, and 310-13 and the cable insulations are outlined in Table 310-2(a) of the National Electric Code 1968.

Conductor Sizes

The full-load current of the 25-horsepower motor is 34 amperes (Table 430-150). A full-load current of 34 amperes $\times 1.25 = 42.5$ amperes (Section 430-22) requires a No. 8 conductor with 75° C. insulation (Table 310-12). The full load current of the 30 –horsepower motor is 40 amperes $\times 1.25 = 50$ amperes (Section 430-22) requires a No. 6 conductor with 75° C. insulation (Table 310-12). The feeder conductor capacity will be 125 percent of 40, plus 40, plus 34, or 124 amperes (Section 430-24). In accordance with (Table 130-12), this would require a No. 1, 75° C., feeder conductor.

Conductors supplying two or more motors shall have an ampacity equal to the sum of the full-load current rating of all the motors plus 25 percent of the highest-rated motor in the group.

Insulators shall have adequate dielectric rating and mechanical rating to provide sufficient support for the power wires or cables installed on them. Manufacturers' specifications regarding intended use shall be used as a guide in determining adequate mechanical strength of an insulator.

Power wires and cables shall be installed under well-supported roof and far enough away from moving equipment to prevent damage; however, in many locations, metal or nonmetallic conduit

may be necessary for additional protection against damage. Some examples of these locations are: Where cables, other than trolley feeder, cross trolley wire or are installed within 12 inches of trolley wire; where cables pass through doors or stoppings; where cables are installed on tight corners with insufficient clearance; or other areas where the wires or cables cannot be isolated sufficiently to afford protection.

Electric equipment and circuits; Overload and short circuit protection.

Both short-circuit and overload protection shall be provided at the beginning of each branch line unless an interrupting device located in the same circuit outby the beginning of the branch line will open the circuit when the branch line becomes overloaded or short-circuited.

The proper values of overcurrent and short-circuit protection shall conform to the appropriate tables of the 1968 National Electric Code. The protective devices can be either automatic circuit-breaking devices or fuses. The proper trip setting or fuse rating to protect electric circuits is based on wire size, type of conductor insulation, and the number of conductors assembled together (in a cable or in a conduit). Protection for electric equipment is based on full load current ratings, circuit voltage, and consideration of inrush or energizing currents.

The instantaneous trip setting of a circuit breaker shall not be confused with the rating of a circuit breaker. A 100-ampere circuit breaker is designed to carry 100 amperes continuously, but the instantaneous trip setting of the common type Westinghouse KA 100-ampere circuit breaker ranges between 500 and 1,000 amperes. The 225-ampere KA circuit breaker is adjustable between 350 and 2,250 amperes and such adjustments are usually made by changing the magnetic trip settings on the front of the circuit breaker.

Three-phase motors require protection against the harmful effects of excessive heating caused by overloading and single-phase operation. Usually this is obtained by thermal overload devices in circuit breakers and line starters (three-pole contactors) controlling such motors.

Thermal devices in line starters and circuit breakers protecting three-phase motors, contain heater strips that are activated by heat generated by the flow of current and shall be rated at values not in excess of those specified in the 1968 National Electric Code and designed to cause all three phases to open when any phase is overloaded. Tables listing full-load current ratings for common-size or thermal trip setting for motor-running protection is determined by the 1968 national Electric Code and varies from 115 percent to 140 percent of the full-load current. Fuses of the correct type and capacity are acceptable as overload protection only for D.C. or single-phase A.C. circuits and motors. The proper selection is based on wire size, motor design, horsepower, and the method of

starting. If the computed value is other than a common size, the next higher common fuse size or thermal element is acceptable.

The following charts show the minimum wire size, overload (running) protection for motors, etc., for the more common motor sizes encountered in coal mining installations. It should be remembered that the wire size is based on 75-degree Centigrade insulation and if higher temperature insulation is used, higher ampacity must be allowed as shown in the accompanying ampacity chart, Table 310-12.

Installations where the thermal relays in line starters are accepted as providing overload protection for the motor branch circuit power conductors, an adjustable instantaneous trip circuit breaker may be installed at the beginning of such branch circuit to provide short circuit and ground fault protection. Such circuit breakers should be set just above the starting current of the motor and never more than 1300 percent of the motor running current.

THE 1968 NATIONAL ELECTRICAL CODE AS APPLICABLE TO UNDERGROUND COAL MINES

I. Electric Conductor Size and Protection for Power Cables

- A. When the load served by circuit conductors contains no electric motors the ampacity shall not be less than the rating of the branch circuit and not less than the maximum load to be served.
 - 1. These conductors shall be provided with overcurrent protection in accordance with their ampacities as given in Tables 310-12 through 310-15 of the National Electrical Code.
 - 2. The ampacities of all types of copper power conductors, except mining-type cables, should be determined from Table 310-12 of the 1968 National Electrical Code, which has been reprinted as Table 2 in the attached sheets.
 - 3. The ampacities of mining-type cables should be determined from the appropriate ICEA ampacity table. The attached Table 3 lists ampacities in accordance with ICEA standards for copper mining cables with a 90° C. insulation rating.
- B. When the load served by the circuit conductors contains only electric motors, the conductor ampacity is determined as indicated below in accordance with the 1968 National Electrical Code.
 - 1. Branch circuit conductors supplying a single motor shall have an ampacity not less than 125 percent of the motor full-load current rating as listed in Table 430-150 of the 1968 National Electrical Code, which has been reprinted as Table 5 in the attached sheets.
 - 2. Conductors supplying two or more motors shall have an ampacity equal to the sum of the full-load current rating of all the motors plus 25 percent of the highest rated motor in the group. The motor full-load current ratings shall be determined from Table 430-150 of the 1968 National Electrical Code, which has been reprinted as Table 5 in the attached sheets.
 - 3. The ampacities of all types of copper power conductors, except mining-type cables, should be determined from Table 310-12 of the 1968 National Electrical Code, which has been reprinted as Table 2 in the attached sheets.
 - 4. The ampacities of mining-type cables should be determined from the appropriate ICEA ampacity table. The attached Table 3 lists ampacities in accordance with ICEA standards for copper mining cables with a 90° C. insulation rating.

II. Electric Conductor Sizes and Protection for Trailing Cables

A. The trailing cable size is specified by the manufacturer and approved in conjunction with the machine on permissible mobile equipment. This cable size must be adhered to. A change of cable size requires a field change approval. The overcurrent protection (instantaneous trip circuit breaker) for trailing cables is specified by the Code of Federal Regulations. The attached Table 3 specifies the maximum allowable instantaneous trip setting for various trailing cable sizes in accordance with CFR.

B. Portable electrical equipment that is moved with production sections is also interpreted by MSHA to be supplied by trailing cables. In this case, the cable size should be in accordance with the manufacturer's specifications if available. If not available the cable should be sized in accordance with the instructions given previously to comply with the ampacity requirements of the 1968 National Electrical Code. Again, the maximum allowable instantaneous trip settings for trailing cables in this category are specified for various sizes of trailing cables in the attached Table 3 in accordance with CFR.

IV. Motor Circuit Overcurrent Protection Requirements

A. Motor and Branch-Circuit Running Overcurrent (Overload) Protection

1. Each continuous duty motor rated more than one horsepower shall be protected against running overcurrent by a separate overcurrent device which is responsive to motor current. This device shall be rated or selected to trip at no more than the following percent of the motor full-load current rating as determined from the motor nameplate.
 - a. Motors with a marked service factor 125% not less than 1.15
 - b. Motors with a marked service factor 125% rise not over 40° C.
 - c. Sealed (hermetic-type) motor compressors
 - overload relays 140%
 - other devices 125%
 - d. All other motors 115%

B. Motor Branch Circuit Short-Circuit Protection

1. The motor branch circuit overcurrent device shall be capable of carrying the starting current of the motor. Short circuit overcurrent protection shall be provided in accordance with Tables 430-152 of the 1968 National Electrical Code. In our case, adjustable instantaneous trip (magnetic trip) circuit breakers are used to provide the required short-circuit protection, and should be set as indicated below.
 - a. The motor branch circuit, short-circuit overcurrent device (instantaneous trip circuit breaker) for all ac motors shall be set to trip at no more than 700% of the motor full-load current rating as determined from the full-load current rating listed in Table 430-150 of the 1968 National Electrical Code, which has been reprinted as Table 5 in the attached sheets. The attached Table 4 lists the maximum short-circuit trip settings for our standard motor ratings.
 - b. Where the overcurrent protection specified above is not sufficient for the starting current of the motor, the setting of an instantaneous trip circuit breaker may be increased over 700 percent but shall in no case exceed 1300 percent of the motor full-load current rating listed in Table 430-150 of the 1968 National Electrical Code, which has been reprinted as Table 5 in the attached sheets, Table 4 lists the maximum short-circuit trip settings for our standard motor ratings.
 - c. A feeder which supplies a specific fixed motor load and consists of conductor sized in accordance with the previous instructions regarding motor circuit ampacities shall be provided with overcurrent protection which shall not be greater than the largest rating or setting for any motor of the group (based on Table 430-152 and 430-153 of the 1968 National Electrical Code), plus the sum of the full-load currents of the other motors of the group.
 - i. The standard maximum instantaneous circuit breaker trip setting for a feeder supplying more than one motor is calculated by adding 700 percent of the full-load current rating of the largest motor of the group to the sum of the full-load current ratings of the additional motors supplied. The motor full-load current ratings are determined from Table 430-150 of the 1968 National Electrical Code, reprinted as Table 5 in the attached sheets.

- ii. If the overcurrent protection specified in (i) is not sufficient for starting the motors in the group, the setting of the instantaneous trip circuit breaker may be increased but shall in no case exceed the sum of 1300 percent of the full-load current of the largest motor of the group plus the full-load current ratings of the additional motors supplied. The motor full-load current ratings are determined from Table 430-150 of the 1968 National Electrical Code, which has been reprinted in the attached Table 5.

Table 2: Copper Power Conductor Ampacities

**Ampacities of insulated copper conductors, not more
Than three conductors in raceway or cable or direct burial (based on
ambient temperature of 30° C.)**

Temperature Rating of Conductor							
Size							
AWG	60° C	75° C	85° C	90° C	110° C	125° C	200° C
MCM	(140° F)	(167° F)	(185° F)	(194° F)	(230° F)	(257° F)	(392° F)
	TYPES RUW (14-2), T TW	TYPES RH RHW RUH (14-2), THW THWN XHHW THW- MI TW	TYPES V MI	TYPES TA TBS, SA AVB, SIS FEP FEPB, RHH THHN	TYPES AVA AVL	TYPES AI (14-8) ALA	TYPES A (14-8), AA FEP FEPB
14	15	15	25	25	30	30	30
12	20	20	30	30	35	40	40
10	30	30	40	40	45	50	55
8	40	45	50	50	60	65	70
6	55	65	70	70	80	85	95
4	70	85	90	90	105	115	120
3	90	100	105	105	120	130	145
2	95	115	120	120	135	145	165
1	110	130	140	140	160	170	190
0	125	150	155	155	190	200	225
00	145	175	185	185	215	230	250
000	165	200	210	210	245	265	285
0000	195	230	235	235	275	310	340
250	215	255	270	270	315	335	***
300	240	285	300	300	345	380	***
350	360	310	325	325	390	420	***
400	380	335	360	360	420	450	***
500	520	360	405	405	470	500	***
600	355	420	455	455	525	545	***
700	385	460	490	490	560	600	***
750	400	475	500	500	580	620	***
800	410	490	515	515	600	640	***
900	435	520	555	555	***	***	***
1000	455	545	585	585	680	730	***
1250	495	590	645	645	***	***	***
1500	520	625	700	700	785	***	***
1750	545	650	735	735	***	***	***
2000	560	665	775	775	840	***	***

SOURCE: NATIONAL ELECTRICAL CODE, 1968 EDITION,
(NFPPA NO. 70-1968; USAS C - 1 1968),
NATIONAL FIRE PROTECTION ASSOCIATION

TABLE 3: COPPER MINING CABLE AMPACITY**CABLE DATA FOR 0-2000 VOLT, 3 CONDUCTOR CABLES**

<u>SIZE AWG/MCM</u>	<u>AMPACITY</u>	<u>TRAILING CABLES</u>	
	<u>90° C UNSHIELDED 20° C AMBIENT</u>	<u>MAXIMUM INSTANTANEOUS</u>	<u>MAXIMUM LENGTH</u>
14	17	50	500
12	22	75	500
10	28	150	500
8	70	200	500
6	93	300	550
4	123	500	600
3	142	600	650
2	163	800	700
1	190	1000	750
1/0	219	1250	800
2/0	254	1500	850
3/0	294	2000	900
4/0	329	2500	1000
250	378	2500	1000
300	421	2500	1000
350	465	2500	1000
400	507	2500	1000
500	575	2500	1000

TABLE 4: MOTOR OVERCURRENT SETTING AND CABLE SIZES**WESTINGHOUSE CIRCUIT BREAKERS MAGNETIC TRIP SETTINGS**

Bkr Size	Low	1	2	3	4	5	6	7	8	8	10	11	12	High
30	50	56	65	72	80	90	95	105	110	120	125	135	140	150
50	66	75	80	85	90	100	110	120	160	140	150	165	175	190
100	150	170	190	205	225	250	285	320	350	380	405	430	455	480
225	300	350	400	450	500	550	600	650	----	----	----	----	----	700
225	500	565	625	690	750	815	875	940	----	----	----	----	----	1000
400	800	900	1000	1100	1200	1300	1400	1500	----	----	----	----	----	1600
600	1500	1685	1875	2060	2250	2435	2625	2810	----	----	----	----	----	3000
800	2000	2250	2500	2750	3000	3250	3500	3750	----	----	----	----	----	4000
1200	2500	2815	3125	3440	3750	4065	4375	4690	----	----	----	----	----	5000

Type of Equipment	Cable Size	Maximum Cable Length	Instantaneous Standard	Maximum
5 HP PUMP	10/5	2000	50	100
5 HP PUMP	6/5	4400	50	100
5 HP PUMP	2/3	1000	50	100
13 HP PUMP	10/5	900	110	210
13 HP PUMP	6/5	2000	110	210
13 HP PUMP	2/3	4500	110	210
18 HP PUMP	6/5	1500	155	285
18 HP PUMP	4/3	2100	155	285
18 HP PUMP	2/3	3400	155	285
100 HP BELT	2/0	--	870	1610
150 HP BELT	2/0	--	1260	2340
200 HP BELT	4/0	--	1680	3120
2-150 HP BELT	350	--	1440	2520
2-200 HP BELT	500	--	1920	3360

EQUIPMENT TYPE	STANDARD G.E.	O.L. WEST	HEATERS SYLV
5 HP PUMP	C8.67A	FH37	2439
13 HP PUMP	C18.0B	FH45	2447
18 HP PUMP	C21.0B	FH48	2451
100 HP (400/5 CT)	C1.96A	FH20	2422
100 HP (300/5 CT)	C2.68A	FH23	2425
150 HP (400/5 CT)	C3.01A	FH24	2426
150 HP (300/5 CT)	C3.56A	FH27	2430
200 HP (400/5 CT)	C3.56A	FH27	2429
200 HP (300/5 CT)	C4.19A	FH30	2432

TABLE 5: 1968 NATIONAL ELECTRICAL CODE CHART ON THREE-PHASE A.C. MOTOR FULL-LOAD CURRENT RATINGS

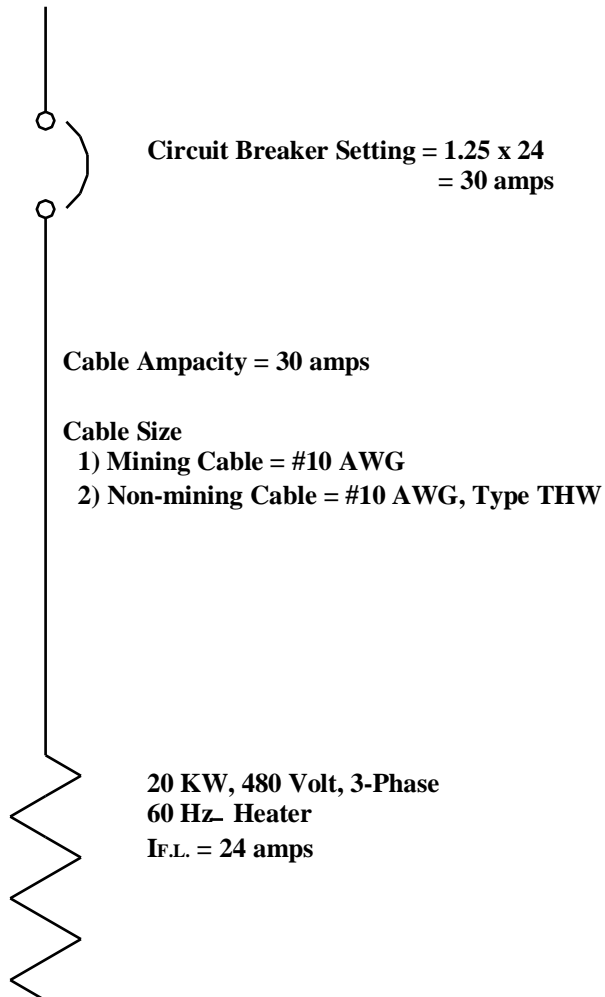
FULL-LOAD CURRENT*									
THREE-PHASE AC MOTORS									
INDUCTION SQUIRREL-CAGE & WOUND ROTOR AMPERES					SYNCHRONOUS TYPE + UNITY POWER FACTOR AMPERES				
HP	115 V	230 V	460 V	575 V	2300 V	220 V	440 V	550 V	2300 V
½	4	2	1	.8					
¼	5.6	2.8	1.4	1.1					
1	7.2	3.6	1.8	1.4					
1½	10.4	5.2	2.6	2.1					
2	13.6	6.8	3.4	2.7					
3		9.6	4.8	3.9					
5		15.2	7.6	6.1					
7½		22	11	9					
10		28	14	11					
15		42	21	17					
20		54	27	22					
25		68	34	27		54	27	22	
30		80	40	32		65	33	26	
40		104	52	41		86	43	35	
50		130	65	52		108	54	44	
60		154	77	62	16	128	64	51	12
75		192	96	77	20	161	81	65	15
100		248	124	99	26	211	106	85	20
125		312	156	125	31	264	132	106	25
150		360	180	144	37		158	127	30
200		480	240	192	49		210	168	40

For full-load currents of 208-200-volt motors, increase the corresponding 230 volt motor full-load current by 10 and 15 percent, respectively.

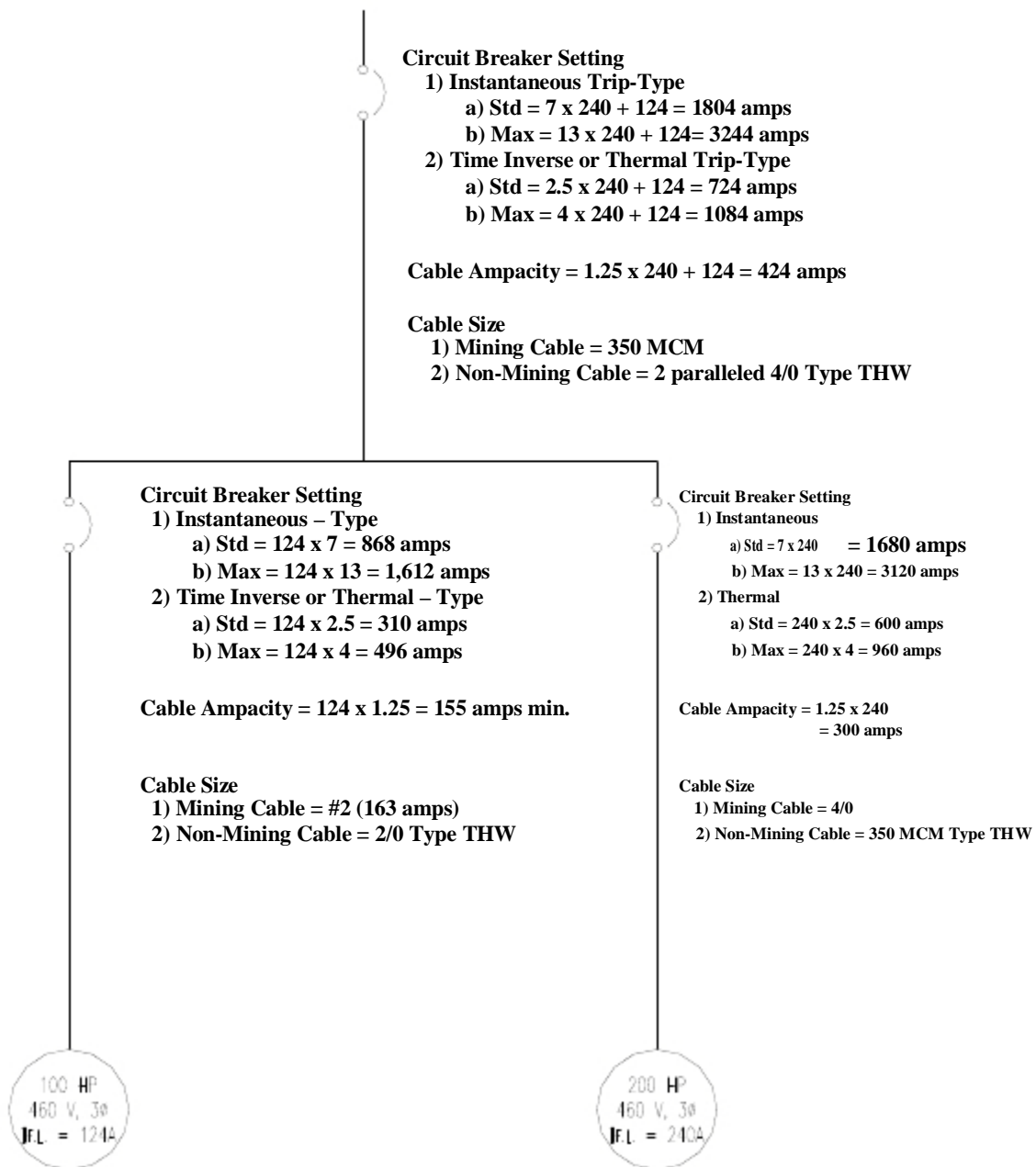
* These values of full-load current are for motors running at speeds usual for belted motors and motors with normal torque characteristics. Motors built for especially low speeds or high torques may require more running current, and multi-speed motors will have full load current varying with speed, in which case the nameplate current rating shall be used.

+ For 90 and 80 percent P.F. the above figures shall be multiplied by 1.1 and 1.25 percent respectively. The voltages listed are rated motor voltages. Corresponding nominal system voltages are 110 to 120, 220 to 240, 440 to 480 and 550 to 600 volts.

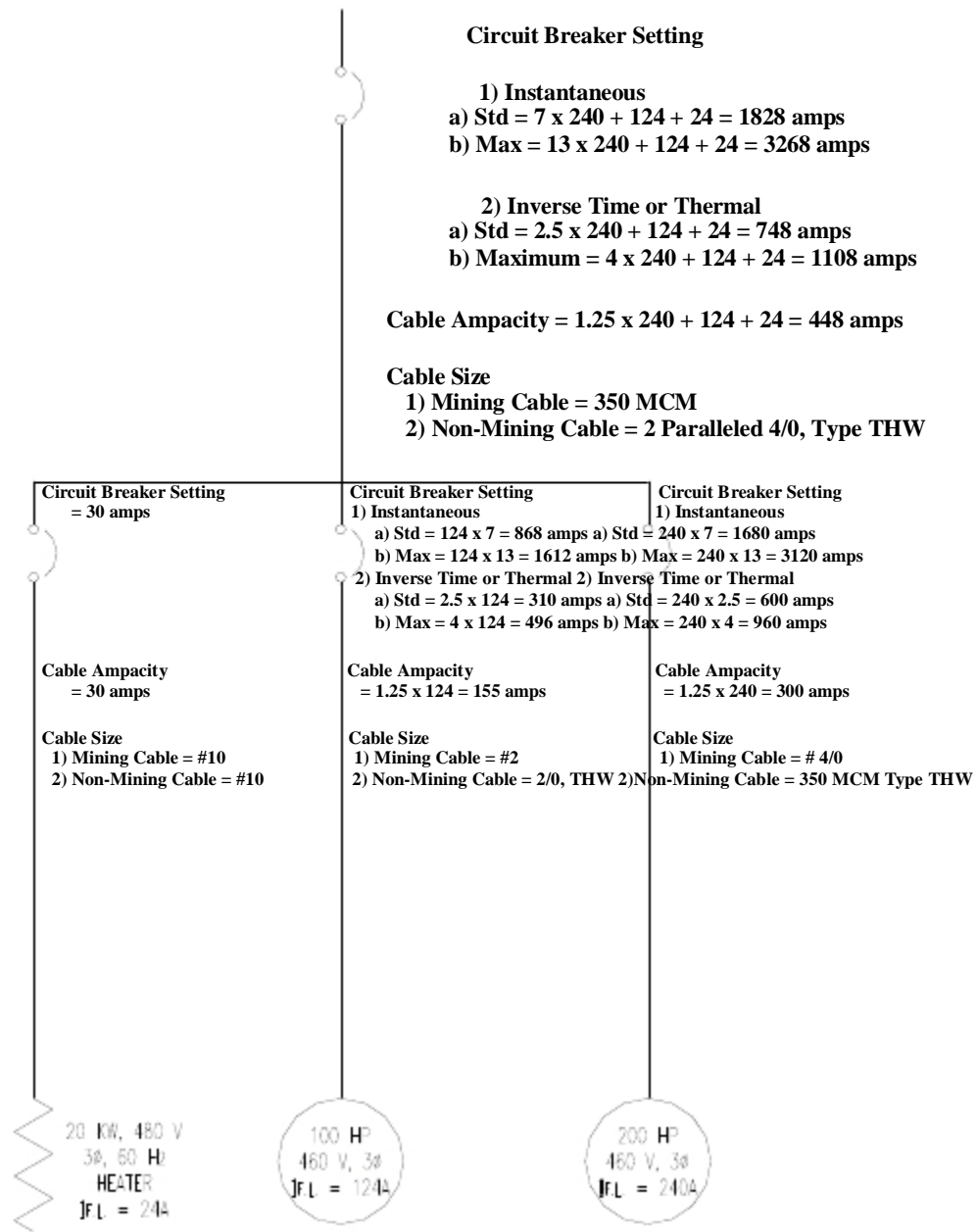
**NATIONAL ELECTRICAL CODE COMPLIANCE
EXAMPLE NO. 1
POWER CABLE AMPACITY, SIZE, AND PROTECTION WHEN NO
ELECTRIC MOTORS ARE SERVED.**



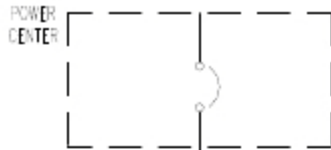
**NATIONAL ELECTRICAL CODE COMPLIANCE
EXAMPLE NO. 2
POWER CABLE AMPACITY, SIZE, AND PROTECTION WHEN ONLY
ELECTRIC MOTOR LOADS ARE SERVED**



**NATIONAL ELECTRICAL CODE COMPLIANCE
EXAMPLE NO. 3
POWER CABLE AMPACITY, SIZE AND PROTECTION WHEN A
COMBINATION OF ELECTRIC MOTOR LOADS AND NON-ELECTRIC
MOTOR LOADS ARE BEING SERVED**



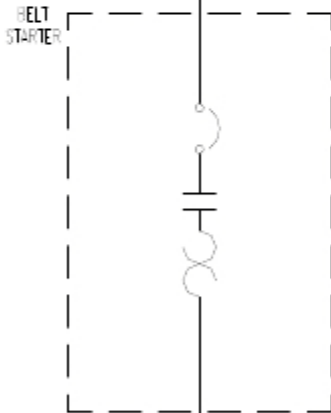
NATIONAL ELECTRICAL CODE COMPLIANCE EXAMPLE NO. 4



- Circuit Breaker Setting**
- 1) Instantaneous Trip-Type
 - a) Standard = $7 \times 83 = 581$ amps
 - b) Maximum = $13 \times 83 = 1079$ amps
 - 2) Inverse Time or Thermal Trip-Type
 - a) Standard = $2.5 \times 83 = 208$ amps
 - b) Maximum = $4 \times 83 = 332$ amps

Cable Ampacity = $1.25 \times 83 = 104$ amps
Cable Size and Rating (Mining Cables)

- 1) Unshielded = #4, 2 KV
- 2) Shielded = #6, 2 KV



- Circuit Breaker Setting**
- 1) Instantaneous Trip-Type
 - a) Standard = $7 \times 83 = 581$ amps
 - b) Maximum = $13 \times 83 = 1079$ amps
 - 2) Inverse Time or Thermal Trip-Type
 - a) Standard = $2.5 \times 83 = 208$ amps
 - b) Maximum = $4 \times 83 = 332$ amps

Overload Setting

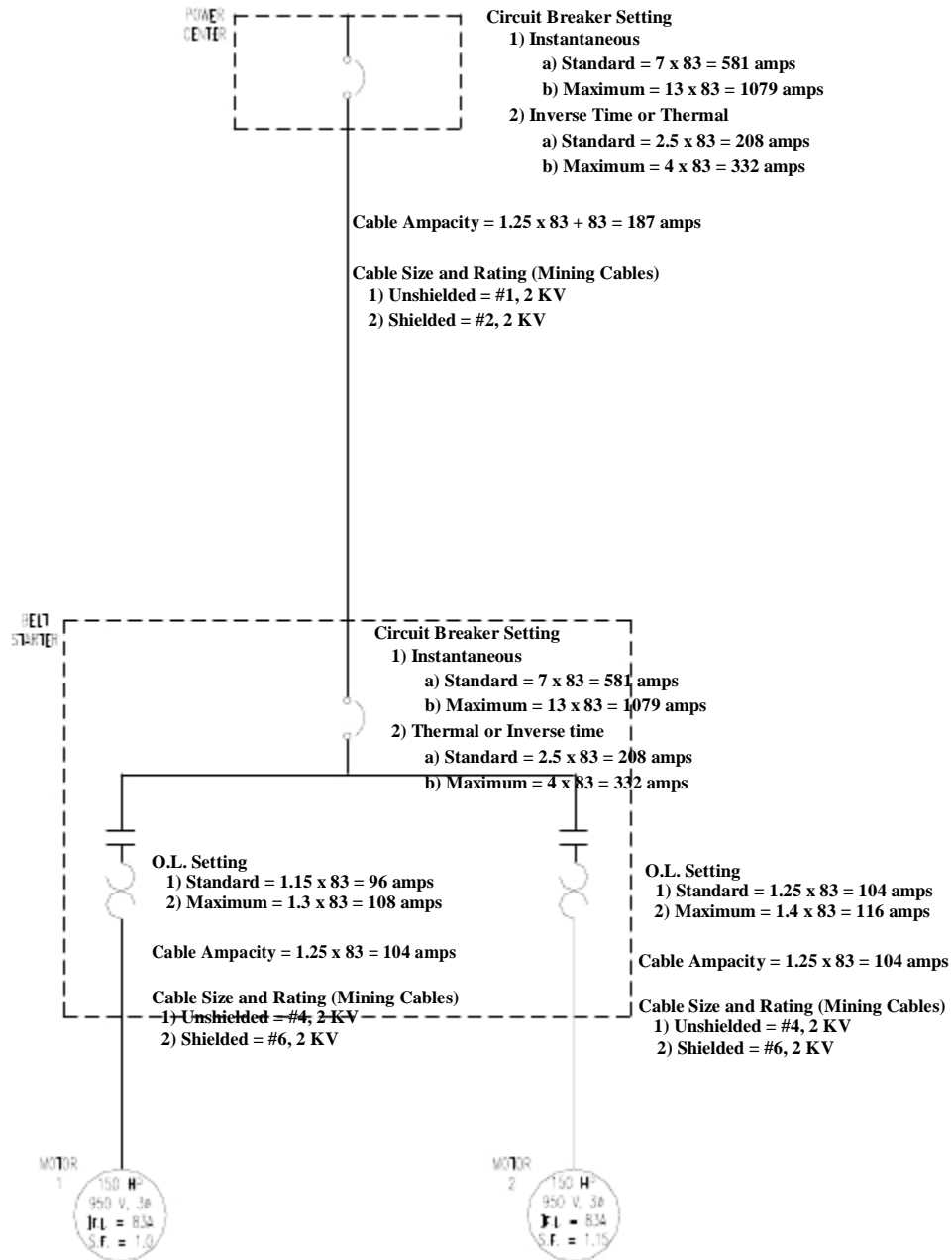
- 1) Standard = $1.15 \times 83 = 96$ amps
- 2) Maximum = $1.3 \times 83 = 108$ amps

Cable Ampacity = $1.25 \times 83 = 104$ amps
Cable Size And Rating (Mining Cables)

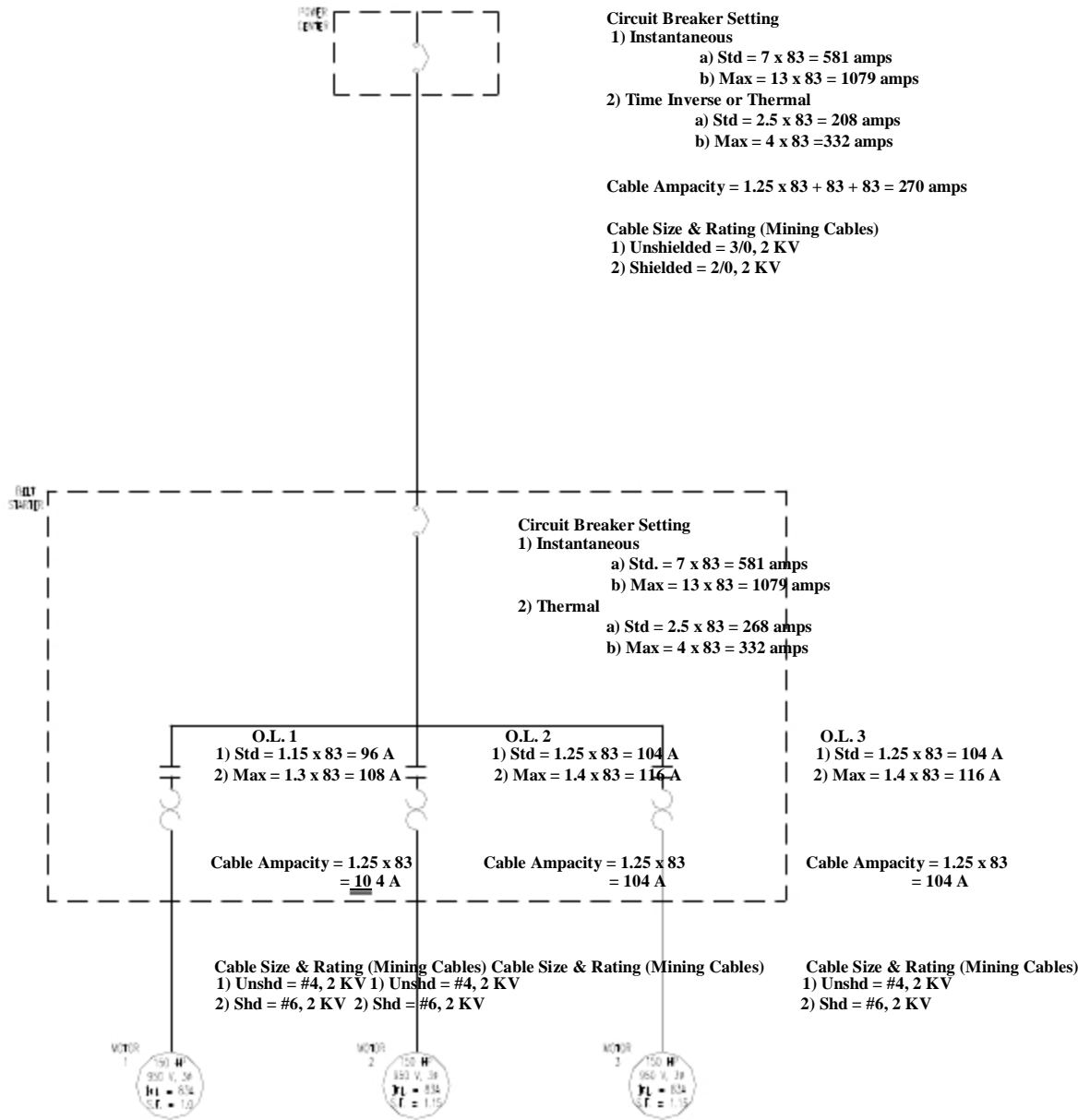
- 1) Unshielded = #4, 2 KV
- 2) Shielded = #6, 2 KV



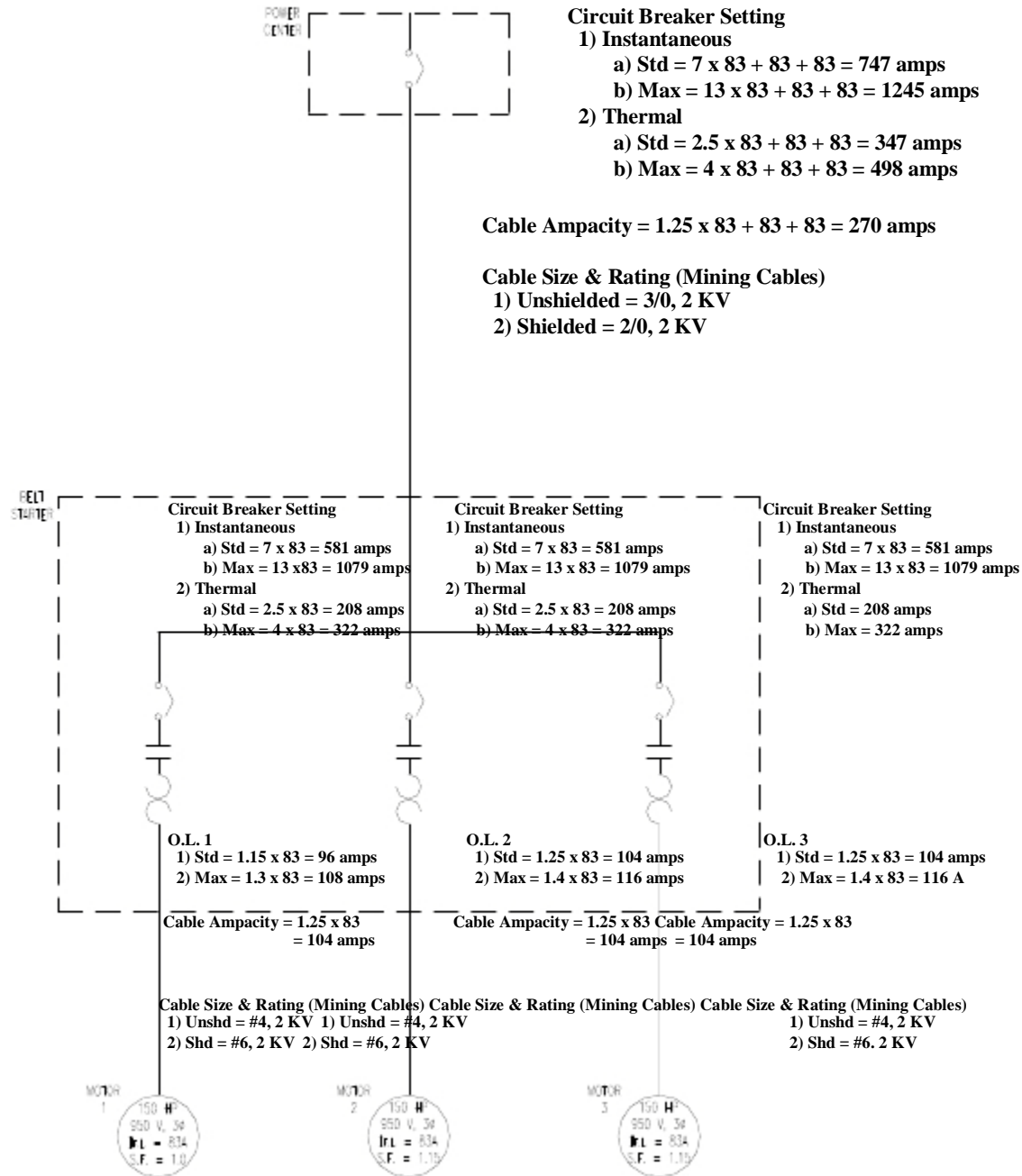
NATIONAL ELECTRICAL CODE COMPLIANCE EXAMPLE NO. 5



NATIONAL ELECTRICAL CODE COMPLIANCE EXAMPLE NO. 6



NATIONAL ELECTRIC CODE COMPLIANCE EXAMPLE NO. 7



NATIONAL ELECTRICAL CODE

1. A location in which hazardous concentrations of flammable gases or vapors exist continuously, intermittently, or periodically under normal operating conditions is classified as:
 - a. Class I, Division 1
 - b. Class I, Division 2
 - c. Class II, Division 1
 - d. Class II, Division 2
2. A location in which combustible dust is or may be in suspension in the air continuously, intermittently, or periodically under normal operating conditions in quantities sufficient to produce explosive or ignitable mixtures is classified as:
 - a. Class I, Division 1
 - b. Class I, Division 2
 - c. Class II, Division 1
 - d. Class II, Division 2
3. A location in which volatile liquids or flammable gases are handled in which hazardous concentrations of gases or vapors are normally prevented by positive mechanical ventilation, but which might become hazardous through failure or abnormal operation of the ventilation equipment is classified as:
 - a. Class I, Division 1
 - b. Class I, Division 2
 - c. Class II, Division 1
 - d. Class II, Division 2
4. A location in which combustible dust will not normally be in suspension in air or will not be likely to be thrown into suspension by the normal operation of equipment or apparatus in quantities sufficient to produce explosive or ignitable mixtures, but where deposits or accumulations of such combustible dust may be sufficient to interfere with the safe dissipation of heat from electric equipment or apparatus; or where such deposits or accumulations of electric equipment or apparatus; or where such deposits or accumulations of combustible dust on, in, or in the vicinity of electric equipment might be ignited by arcs, sparks, or burning material from such equipment is classified as:
 - a. Class I, Division 1
 - b. Class I, Division 2
 - c. Class II, Division 1
 - d. Class II, Division 2
5. Which of the following wiring methods is NOT approved for use in Class I, Division 1 locations?
 - a. Threaded rigid conduit
 - b. Threaded steel intermediate metal conduit
 - c. Electrical metallic tubing
 - d. Type MI cable with proper termination fittings

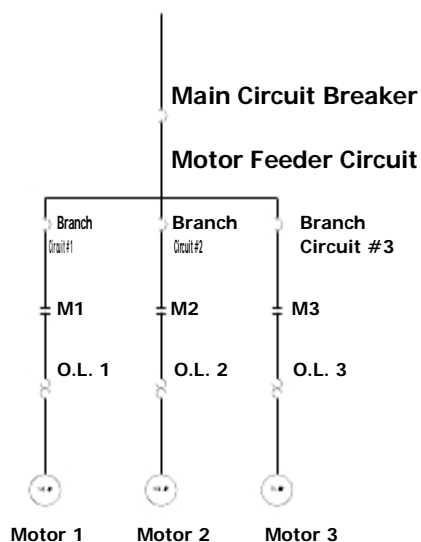
6. Which of the following wiring methods is **NOT** approved for use in Class I, Division 2 locations?
- Enclosed gasketed busways
 - Type PLTC cable
 - Rigid metal conduit
 - Electrical metallic tubing
7. All boxes, fittings, and joints used in Class I, Division 1 locations shall be:
- Threaded and explosion proof
 - Approved under Schedule 2 G
 - In compliance with AIEE standards
 - Waterproof
8. The term that best describes the type of wiring method and equipment used in Class I locations is:
- Explosion proof
 - Dust-ignition-proof
 - Watertight
 - Oiltight
9. The term that best describes the type of wiring methods and equipment used in Class II locations is:
- Explosion proof
 - Dust-ignition-proof
 - Watertight
 - Oiltight
10. The scope of the National Electrical Code does **NOT** include coverage for:
- Electric conductors and equipment installed within or on public buildings
 - Conductors that connect the installation to a supply of electricity
 - Installations underground in mines
 - Outside conductors on mine property
11. What is the minimum size of power conductor comprising each phase or neutral that shall be permitted to be connected in parallel?
- 2 AWG
 - 1/0 AWG
 - 2/0 AWG
 - 4/0 AWG
12. Which of the following is the approved equipment grounding conductor color code?
- White
 - Natural Gray
 - Black
 - Green or green with one or more yellow stripes

13. Ungrounded conductors shall be distinguished by colors other than:
- White, natural gray, or green
 - White only
 - Green only
 - Any color is acceptable
14. What is the ampacity of a #6 AWG, Type XHHW, copper conductor at an ambient temperature of 30°C and with three conductors in a rigid conduit?
- 55 amperes
 - 65 amperes
 - 70 amperes
 - 75 amperes
15. What is the ampacity of a #6 AWG, Type THW, copper conductor at an ambient temperature of 40°C and with six conductors in a rigid conduit?
- 42 amperes
 - 52 amperes
 - 53 amperes
 - 45 amperes
16. What is the minimum acceptable size of rigid conduit to enclose three #2 AWG, Type THWN, copper conductors?
- $\frac{3}{4}$ inch
 - 1 inch
 - 1 $\frac{1}{4}$ inch
 - 1 $\frac{1}{2}$ inch
17. What is the maximum number of 4/0 AWG, Type TW, copper conductors that may be enclosed by a 2 $\frac{1}{2}$ inch EMT?
- 3
 - 4
 - 5
 - 6

Questions 18 – 23 are regarding the electric motor specified below (motor nameplate data):
150 HP, Three Phase, 60 Hertz
444 T Frame, 1750 RPM, Code F
460 Volts, 180 Amperes F.L.
Continuous Duty, 40°C ambient

18. What is the required ampacity of the branch circuit conductors for this motor?
- 144 amperes
 - 180 amperes
 - 207 amperes
 - 225 amperes
19. What is the minimum size of branch circuit conductors and rigid conduit acceptable for this application? Assume three copper conductors with an insulation rating of 75° C enclosed in the rigid conduit.
- 3/0 AWG, 1 ½ inch
 - 4/0 AWG, 2 inch
 - 4/0 AWG, 2 1/2 inch
 - 250 MCM, 2 inch
20. What is the maximum allowable instantaneous-type circuit breaker trip setting to provide branch circuit overcurrent protection without using exceptions?
- 900 amperes
 - 1,260 amperes
 - 1,800 amperes
 - 2,340 amperes
21. What is the maximum allowable inverse-type circuit breaker trip setting to provide branch circuit overcurrent protection without using exceptions?
- 270 amperes
 - 360 amperes
 - 450 amperes
 - 540 amperes
22. What is the maximum allowable motor running overcurrent protection trip setting without using exceptions?
- 207 amperes
 - 189 amperes
 - 198 amperes
 - 225 amperes
23. Where the specified instantaneous-type circuit breaker trip setting for motor branch-circuit protection is not sufficient for the starting of the motor, the setting shall be permitted to be increased to maximum of:
- 900 amperes
 - 1,260 amperes
 - 1,800 amperes
 - 2,340 amperes

Questions 24 – 30 are regarding the multiple motor feeder circuit shown in Figure 1.
The nameplate data of each electric motor is given below.



Motor 1: 150 HP, Three Phase, 60 Hertz
444 T Frame, 1,750 RPM, Code F
460 Volts, 180 Amperes F.L.
Continuous Duty, 40° C Ambient

Motor 2: 100 HP, Three Phase, 60 Hertz
405 TS Frame, 1,740 RPM, Code G
460 Volts, 124 Amperes F.L.
Continuous Duty, 40° C Ambient

Motor 3: 75 HP, Three Phase, 60 Hertz
365 TS Frame, 1,740 RPM
460 Volts, 96 Amperes F.L.
Continuous Duty, 1.0 Service Factor

24. What is the minimum size of conductors and rigid conduit for motor branch circuit 2?
Assume three copper conductors with an insulation rating of 75° C enclosed in the rigid conduit?
- 2/0 AWG, 1 ½ inch
 - 2/0 AWG, 2 inch
 - 1/0 AWG, 1 ¼ inch
 - 3/0 AWG, 1 ½ inch

25. What is the maximum allowable instantaneous trip setting for branch circuit 2 overcurrent protection without exceptions?
- 310 amperes
 - 620 amperes
 - 868 amperes
 - 1,612 amperes
26. What is the maximum allowable trip setting for motor 2 running overcurrent overload protection without using exceptions?
- 124 amperes
 - 136 amperes
 - 143 amperes
 - 155 amperes
27. What is the minimum conductor size and rigid conduit size and maximum allowable instantaneous trip setting for branch circuit 3 overcurrent protection? Assume three copper conductors with an insulation rating of 90° C enclosed in the rigid conduit, and take no exception on overcurrent protection settings.
- #2 AWG, 1-inch, 240 amperes
 - #2 AWG, 1 1/4-inch, 672 amperes
 - 1/0 AWG, 1-inch, 672 amperes
 - #2 AWG, 1-inch, 1,248 amperes
28. What is the maximum allowable motor running overcurrent (overload) protection trip setting for motor 3?
- 96 amperes
 - 106 amperes
 - 110 amperes
 - 120 amperes
29. What is the required ampacity of the motor feeder conductors, and what is the minimum conductor size that will satisfy this requirement? Assume three copper conductors with an insulation rating of 90° C in a rigid conduit.
- 400 amperes, 500 MCM
 - 445 amperes, 600 MCM
 - 445 amperes, 700 MCM
 - 500 amperes, 700 MCM
30. What is the maximum allowable instantaneous trip setting for the motor feeder conductors without considering exceptions?
- 1,260 amperes
 - 1,480 amperes
 - 2,560 amperes
 - 2,800 amperes

ANSWER SHEET FOR NATIONAL ELECTRICAL CODE

- | | | | |
|-----|---|-----|---|
| 1. | a | 16. | c |
| 2. | c | 17. | a |
| 3. | b | 18. | d |
| 4. | d | 19. | c |
| 5. | c | 20. | b |
| 6. | d | 21. | c |
| 7. | a | 22. | a |
| 8. | a | 23. | d |
| 9. | b | 24. | b |
| 10. | c | 25. | c |
| 11. | b | 26. | c |
| 12. | d | 27. | b |
| 13. | a | 28. | c |
| 14. | b | 29. | b |
| 15. | d | 30. | b |

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NATIONAL ELECTRIC CODE

1. Q. The frame-grounding conductor in a DC trailing cable is usually colored:

A. Green.

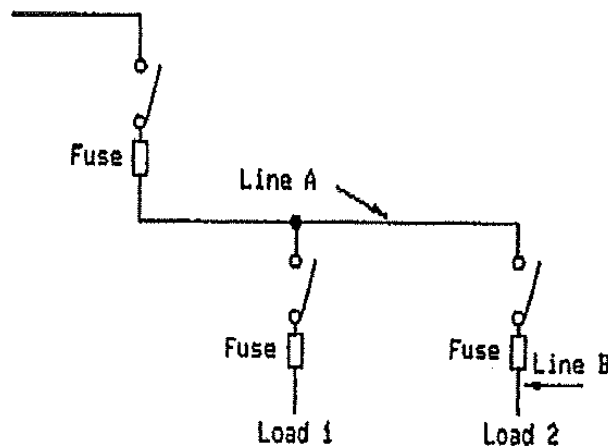
2. Q. What is the purpose of a thermal strip in an AC linestarter?

A. To provide overload protection.

3. Q. In most cases, the voltage to ground on branch circuits supplying lampholders, fixtures, or standard receptacles of 15 amps or less should not exceed:

A. 150 volts.

4. Q. According to the diagram below:



A. Line "A" is a feeder circuit and line "B" is a branch circuit.

5. Q. If a branch circuit were protected by a 20-amp fuse, what would be the allowable continuous load of the circuit?

A. 16 amps.

6. Q. The voltage drop to the most remote outlet of a branch circuit should not exceed what value for power, heating, lighting, or combinations thereof?

A. 3 percent.

7. Q. The part of the wiring system extending beyond the last overcurrent protective device is called the:

A. Branch circuit.

8. Q. A _____ is that part of the wiring system extending beyond the last overcurrent protective device.

A. Branch circuit.

9. Q. The minimum wire size of a 15-amp branch circuit is:

A. No.14 AWG.

10. Q. What is the minimum-sized grounding conductor that may be used in a DC system?

A. 8 AWG.

11. Q. Within one minute after a 550-volt capacitor is disconnected, its residual voltage must be reduced to:

A. 50 volts or less.

12. Q. A 500-volt capacitor is disconnected. Its residual voltage must be reduced to the permitted voltage or less within:

A. 1 minute.

13. Q. The circuit breaker setting is the value of the:

A. Current at which it is set to trip.

14. Q. What is the standard shipping length, including one coupling, of rigid conduit?

A. 10 feet.

15. Q. Which of the following is required when the conductor bushing at the entrance of _____ a cabinet, junction box, or pull box is made entirely of insulating materials?

A. A locknut must be installed on the conduit both inside and outside the enclosure to _____ which the conduit is attached.

16. Q. Conduit must be firmly fastened within how many feet of each outlet box, junction _____ box, cabinet, or fitting?

A. 3 feet.

17. Q. What is the maximum-sized electrical metallic tubing that may be used?

A. 4 inches.

18. Q. Which device protects the wire from abrasion where conduit enters a disconnect _____ switch box?

A. Bushings.

19. Q. What is the maximum distance allowed between supports for one-inch diameter _____ rigid metal conduits?

A. 12 feet.

20. Q. Conduit must be clearly and durably identified every:

A. 10 feet.

21. Q. What is the minimum-sized metallic tubing that may be used?

A. 1/2 inch.

22. Q. What is the minimum-sized diameter allowed for rigid metal conduit?

A. 1/2 inch.

23. Q. Rigid metal conduit up to 3/4-inch in size must be firmly fastened within 3 feet _____ of each outlet box or fitting and be supported at what minimum interval?

A. Every 10 feet.

24. Q. A run of conduit less than one inch in diameter must be supported at least every:

A. 10 feet.

25. Q. Rigid metal conduit 1/2-inch in diameter must be supported every:

A. 10 feet.

26. Q. What is the maximum number of bends allowed in one run of conduit, between outlet and outlet, fitting and fitting, or fitting and outlet?

A. 4 quarter bends (360 degrees).

27. Q. "Grounded conductors" (not the frame ground) will be identified by their color, which is:

A. White or natural gray.

28. Q. What minimum length of free conductor should be left at each outlet and switch point for making up joints, or connecting fixtures or devices?

A. 6 inches.

29. Q. Individually covered or insulated grounding conductors should have a continuous outer finish that is:

A. Either green or green with one or more yellow stripes.

30. Q. The secondary winding of a single-phase transformer has a full load current of 30 amperes. The power leads are single conductor, type TW rated at 60 centigrade. What would be the minimum size conductor used on the secondary?

A. No.10 AWG.

31. Q. In most cases, the minimum-sized (solid or stranded) conductor allowed when wiring a control panel is:

A. No. 14 wire.

32. Q. What color insulation is associated with the frame-grounding conductor?

A. Green.

33. Q. Conductors that supply one or more resistance welders must be protected by _____ an overcurrent device rated or set at not more than:

A. 300% of the conductor rating.

34. Q. What color insulation is associated with the grounded, current-carrying conductor?

A. White.

35. Q. When reference is made to conductors in the NEC, what type of material is assumed?

A. Copper.

36. Q. An electrician knowing a conductors "AWG" can determine the:

A. Allowable current-carrying capacity.

37. Q. "THW" marked on a conductor refers to that conductors:

A. Application and insulations.

38. Q. De-rating of conductors begins when the number of current-carrying conductors _____ pulled into a conduit exceeds:

A. Three.

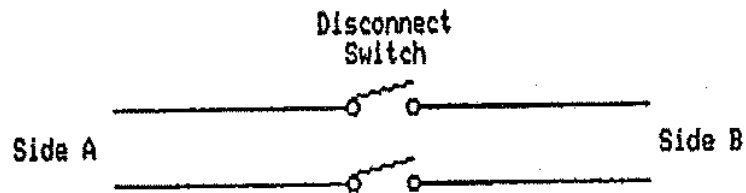
39. Q. Branch-circuit conductors supplying a single motor should have an ampacity of _____ not less than _____ of the motor full-load rating.

A. 125 percent.

40. Q. What is the maximum number of service disconnects allowed on a single service entrance?

A. Six.

41. Q. According to the diagram below, the disconnect switch must be connected:



A. So that side A is connected to the load.

42. Q. Single-throw knife switches are mounted hinge-end down so that:

A. Gravity will not tend to close them.

43. Q. Flexible metal conduit must be secured within _____ of each outlet box or fitting.

A. 12 inches.

44. Q. The continuous load supplied by a branch circuit should not exceed a rating of:

A. 80 percent.

45. Q. An enclosure constructed, protected, or treated so as to prevent rain from _____ interfering with successful operation of the apparatus is termed:

A. Rainproof.

46. Q. An electrical apparatus enclosed in a case that is capable of withstanding an _____ explosion from a specified gas or vapor is termed:

A. Explosion-proof.

47. Q. According to the National Electrical Code, “dustproof” means so constructed or protected that:

A. Dust will not interfere with successful operation.

48. Q. According to the National Electrical Code, “dust-tight” means:

A. Dust will not enter the enclosing case.

49. Q. Locations that are hazardous due to the presence of combustible dust are _____ classified by the NEC as:

A. Class II.

50. Q. A Class II location refers to:

A. Combustible dust locations.

51. Q. Electrical equipment used in atmospheres containing hazardous concentrations _____ of gases and vapors are classified as:

A. Class I.

52. Q. Thermal overload relays are designed to provide what type of protection?

A. Overload and single-phase.

53. Q. Plug fuses and fuseholders may not be used in circuits exceeding _____ between conductors.

A. 125 volts.

54. Q. Cartridge fuses are rated and marked for all of the following, EXCEPT:

A. The type of current (AC or DC).

55. Q. When fuses and thermal cutouts are both used in a motor circuit:

A. The fuses protect the motor and circuit against shorts.

56. Q. Except where rock bottom is encountered, grounding pipes or rods should be _____ driven to a depth of at least:

A. 8 feet.

57. Q. The resistance of a pipe electrode to ground (a made electrode) should not be:

A. Greater than 25 ohms.

58. Q. What is the minimum-sized diameter allowed for grounding electrodes made of _____ either steel or iron rods?

A. 5/8 inch.

59. Q. Which of the following is NOT an appropriate material for grounding electrode conductors?

A. Steel.

60. Q. When used as a ground, the resistance of made electrodes should be:

A. 25 ohms or less to ground.

61. Q. What is the minimum-sized diameter allowed for grounding electrodes made of galvanized iron, steel pipe, or rigid conduit?

A. 3/4 inch.

62. Q. Which of the following is NOT a good grounding electrode?

A. An 8-foot roof bolt driven into moist ground.

63. Q. According to the NEC, the resistance of a pipe electrode to ground (a made electrode) should be:

A. Not greater than 25 ohms.

64. Q. Which of the following is NOT a good electrode for obtaining a ground field?

A. Roof bolt electrode.

65. Q. Cable or wire insulation is NOT rated for:

A. Current.

66. Q. According to the National Electrical Code, “continuous load” is defined as a load where maximum current is expected to continue for”

A. 3 hours or more.

67. Q. All wiring and electrical equipment must meet the requirements of the:

A. National Electrical Code that is in effect at the time of installation.

68. Q. The National Electrical Code is:

A. A recognized guideline for electrical installations.

69. Q. The NEC generally applies to:

A. Fixed installations.

70. Q. The NEC does not apply to:

A. Pit distribution or electrical mobile equipment.

71. Q. Operation of equipment in excess of the normal, full-load rating or of a conductor in excess of rated ampacity which, when it persists for a sufficient length of time would cause damage or dangerous overheating, is termed:

A. An overload.

72. Q. Which one of the following methods of splicing is NOT allowed when the splicing conductors are made of the same material?

A. Twisting the conductors securely and taping.

73. Q. What is the approved method for splicing conductors made of the same material?

A. Brazing or welding with fusible metal or alloy.

74. Q. Overcurrent protection of single-phase transformers under 600 volts should not exceed what percentage of the full load secondary current?

A. 250%.