

- 1) The minimum body-surface-contact 60 hz current that will induce ventricular fibrillation is about
 - a. 10 microamps
 - b. 100 microamps
 - c. 1 milliamp
 - d. 10 milliamps
 - e. 100 milliamps

Electrical current can cause many hazards. The least hazardous reaction would be a startle reaction as a person experiences an unexpected electrical shock. Higher current levels can cause much more serious problems, ranging from an inability to release an electrical wire, up to respiratory paralysis, ventricular fibrillation, sustained contraction of the heart, and burns.

It is important to realize that reactions to current have been found to vary widely between individuals, and between the sexes. Thus, any guidelines presented are approximations, and should be treated as such.

The table below gives approximate current levels at the body surface found to cause the types of reactions listed.

Current Level	Reaction
1 mA	Threshold of perception
5 mA	Maximum harmless current
10 - 20 mA	"Can't let go" reaction
50 mA	Pain, exhaustion, fainting
100 - 300 mA	Ventricular fibrillation
6 A	Sustained myocardial contraction, burns

Reference: Carr, Joseph J., and Brown, John M., Introduction to Biomedical Equipment Technology, second edition, Prentice Hall Career and Technology, 1993, page 416

- 2) The recommended enclosure risk current limit portable equipment that is “likely to contact patient” under normal conditions as specified by ANSI/AAMI Safe Current Limits of Electromedical Apparatus standard (ANSI/AAMI ES1) is
 - a. 10 microamps
 - b. 50 microamps
 - c. 100 microamps
 - d. 500 microamps
 - e. 5 milliamps

The ANSI/AAMI Safe Current Limits for Electromedical Apparatus standard provides recommended leakage currents for equipment used in a patient-care environment under a variety of conditions. In part of this standard, a table is shown with the following information:

Category	Enclosure risk current Cord-connected/ battery-powered
Isolated - Normal condition	100 microamps
Isolated - Single fault condition	300 microamps
Non-isolated - Normal condition	100 microamps
Non-isolated - Single fault	300 microamps
Likely to contact patient - Normal condition	100 microamps
Likely to contact patient - Single fault condition	300 microamps
No patient contact - Normal condition	100 microamps
No patient contact - Single fault condition	500 microamps

Reference: Association for the Advancement of Medical Instrumentation, Safe Current Limits for Electromedical Apparatus, ANSI/AAMI ES1-1993, Association for the Advancement of Medical Instrumentation, 1993, section 4.3.2, table 1

- 3) NFPA 99, standard for Health Care Facilities requires the impedance to Ground for either conductor of an isolated power system in an anesthetizing location to exceed
 - a. 200,000 ohms
 - b. 12,000 ohms
 - c. 100 ohms
 - d. 0.5 ohms

NFPA 99 is the National Fire Protection Association's Standard for Health Care Facilities. It contains standards related to a wide variety of health care issues, including electrical systems, medical gas and vacuum systems, electrical equipment, laboratories, and non-hospital health care facilities. This standard is an American National Standard.

This standard states, in part:

"The impedance (capacitive and resistive) to ground of either conductor of an isolated system shall exceed 200,000 ohms when installed."

Reference: National Fire Protection Association, NFPA 99 - Standard for Health Care Facilities

- 4) The human body's "cannot let go" reaction to 60 Hz current begins at about
 - a. 1.0 milliamperes
 - b. 5.0 milliamperes
 - c. 10 milliamperes
 - d. 100 milliamperes

Electrical current can cause many hazards. The least hazardous reaction would be a startle reaction as a person experiences an unexpected electrical shock. Higher current levels can cause much more serious problems, ranging from an inability to release an electrical wire, up to respiratory paralysis, ventricular fibrillation, sustained contraction of the heart, and burns.

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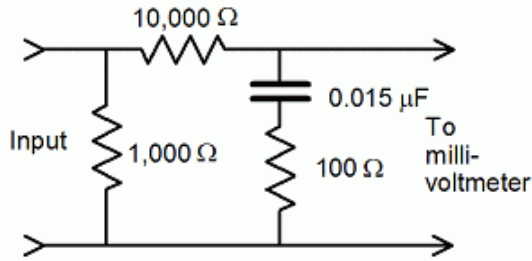
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Reference: Carr, Joseph J., and Brown, John M., Introduction to Biomedical Equipment Technology, second edition, Prentice Hall Career and Technology, 1993, page 416

- 5) According to the ANSI/AAMI Safe Current Limits for Electromedical Apparatus standard (ANSI/AAMI ES1), a leakage meter should have
 - a. an input impedance of approximately between DC and 1 Kilohertz
 - b. the ability to respond accurately to both AC and DC currents
 - c. a response to frequencies between 1 Kilohertz that is inversely proportional to the frequency in kilohertz
 - d. all of the above

The ANSI/AAMI Safe Current Limits for Electromedical Apparatus standard provides recommended leakage currents for a variety of conditions, for equipment used in a patient-care environment. This standard provides a schematic for the AAMI standard test load, which is reproduced below:



The 1,000 ohm resistor across the input leads provides an input impedance of about 1,000 ohms at low frequencies (below 1 kilohertz).

The network is designed to automatically provide a roll-off at higher frequencies (through the 0.015 microfarad capacitor providing a shunt for the millivoltmeter). This allows the network to compensate for the higher allowable risk current limits at higher frequencies. The millivoltmeter must be a true RMS voltmeter, with a bandwidth from DC up to at least 1 megahertz.

Thus, the circuit must be able to respond accurately to both AC and DC currents.

Reference: Association for the Advancement of Medical Instrumentation, Safe Current Limits for Electromedical Apparatus, ANSI/AAMI ES1-1993, Association for the Advancement of Medical Instrumentation, 1993, sections 4.3.1, 4.7, 5.2.1.1

- 6) When working with elemental mercury, it is very important to
 - e. avoid prolonged exposure of mercury to the air
 - f. maintain adequate ventilation, vented to the building exterior
 - g. work over a smooth surfaced pan to catch and contain any mercury spills
 - h. all of the above

The major problem associated with mercury is the evaporation of mercury, and the potential exposure to the mercury vapor. Breathing this vapor can cause mercury levels in the body to rise to levels which represent a significant health hazard.

When mercury is exposed to air, some of it evaporates. The longer it is exposed to air, the more evaporation will take place.

A worker using mercury needs to assure that adequate ventilation is in place so that the possibility of exposure to the mercury vapor is minimized.

When mercury spills, it has a tendency to break into very small pieces. The more numerous the pieces, the larger the total surface area of the mercury, and the more will evaporate. By working over a smooth surfaced pan, any spills can be contained, and the entire quantity of mercury can be captured for safe and appropriate disposal.

Reference: None

- 7) The pressure in a full oxygen cylinder (sizes B, D, E or M) at room temperature is about
 - i. 30 psig
 - j. 100 psig
 - k. 900 psig
 - l. 2000 psig
 - m. 5000 psig

The pressure of a full oxygen cylinder varies by the size of the cylinder.

The table below shows the nominal pressures and capacities of full oxygen cylinders.

Cylinder size	Capacity (liquid) liters	Capacity (gas) liters	Pressure psig
B	1.43	200	1900
D	2.88	400	1900
E	4.80	660	1900
M	21.90	3450	2200
G	38.8	N/A	N/A

H or K	43.6	6900	2200
H or K	43.6	7800	2490 *

* H or K cylinders filled to this level are available upon special request.

Reference: National Fire Protection Association, NFPA 99 - Standard for Health Care Facilities

- 8) Electrical safety in the medical environment refers to
- n. limitation of electrical shocks
 - o. limitation of hazardous conditions
 - p. limitations of macroshocks
 - q. limitation of microshocks

The hazard presented by electricity comes from shocks.

A microshock applied directly to the heart can lead to fibrillation and death.

A macroshock, applied to the outside of the body, can cause death if the current involved is high enough. Even a lower magnitude shock can cause a startle reaction, which could cause a problem under the wrong conditions. For example, if a medication were dropped, or if the shock occurred while getting ready to draw blood.

Electrical safety is traditionally concerned with electric shocks from unintended grounding paths, such as chassis leakage current, which represents electrical current flowing outside its intended path to ground via a chassis connection.

Electrical safety must take into account all potential causes of shock, and seek to eliminate them.

Reference: None

- 9) A microshock is defined as
- r. a low value current passing directly through the heart
 - s. a shock due to leakage current
 - t. a and b
 - u. a shock due to static electricity

A microshock is a very low level current applied directly to the heart. This can lead to inadvertent fibrillation and death. Microshocks are usually a very low magnitude current, on the order of tens of microamperes.

One possible mechanism for microshocks is through chassis leakage currents, if these are sufficiently high, and if an appropriate path to ground exists through a patient's heart. However, leakage currents can also be a cause of macroshock, a much higher magnitude shock applied to the external body.

Reference: Carr, Joseph J., and Brown, John M., Introduction to Biomedical Equipment Technology, second edition, Prentice Hall Career and Technology, 1993, page 409

- 10) The hazard presented by an electrical shock is measured as a function of
- v. current intensity at specific frequencies
 - w. current intensity with no frequencies
 - x. a and b
 - y. none of the above

Studies indicate that electrical current at low frequencies is more likely to cause ventricular fibrillation than current at high frequencies. For this reason, the measurement of leakage current is performed using a meter which has a lower sensitivity to higher frequencies than lower frequencies.

The test loads specified by both the AAMI and the NFPA standards on leakage current provide a flat frequency response from DC to 1,000 hertz. From 1,000 hertz to 100 kilohertz, the test load has a roll-off characteristic of 20 decibels per decade. The frequency response is flat from 100 kilohertz on up.

Reference: Association for the Advancement of Medical Instrumentation, Safe Current Limits for Electromedical Apparatus, ANSI/AAMI ES1-1993, Association for the Advancement of Medical Instrumentation, 1993, section 4.7

- 11) Leakage current is defined as
- z. current flowing in a chassis
 - aa. current flowing in a resistor
 - bb. current flowing in a patient
 - cc. current flowing in a cable

Leakage current is a low level electrical current that flows out of its intended path (or circuit) into an unintended portion of the equipment. The unintended portion is the metal chassis of the equipment, where, this current represents a potential hazard because an equipment user or patient could touch the chassis, and receive a shock.

Leakage current may be flowing in a resistor (such as the standard test load used with a leakage current meter), or it may flow through a patient (in the event that a patient is completing an electrical circuit between the equipment chassis and ground), and it may flow through a cable (such as an ECG cable). However, leakage current, by definition, is **the current flowing in the chassis**, where it has the opportunity to cause a shock.

Reference: Carr, Joseph J., and Brown, John M., Introduction to Biomedical Equipment Technology, second edition, Prentice Hall Career and Technology, 1993, page 417

13) The set of wires in compliance with the National Electric Code (ANSI/NFPA 70) standard color code for electrical power wiring distribution is:

- a. black (hot), white (neutral) green (ground)
- b. black (hot), green (neutral) blue (ground)
- c. red (hot), green (neutral) green (ground)
- d. green (hot), white (neutral) red (ground)

For a branch circuit, three wires are used. The hot wire is the one carrying the high voltage (for example, nominally 120 volts AC for a common circuit). The neutral wire, or grounded conductor, is the wire which is connected to the ground in the circuit breaker or fuse panel box. The grounding (ground) conductor is the third wire in the system, and it is used to provide a safety connection to ground for the chassis of equipment.

(The difference between the grounded conductor and the grounding conductor is that the grounded conductor is intended to carry current during the normal operation of equipment, while the grounding conductor is a safety device, and is intended to carry current only under fault conditions.)

The National Electric Code requires that the grounded **(neutral) conductor be white or natural gray** in color, while the **grounding (ground) conductor be green**, green with one or more yellow stripes, or bare. The hot wire may be any color, as long as it is easily distinguished from both the neutral and ground wires.

It is most common to make the hot wire black, with red used as an alternative in cases where an additional hot conductor is needed.

Reference: National Fire Protection Association, National Electrical Code, ANSI/NFPA 70, An American National Standard, National Fire Protection Association

13) If the ground wire in a power cord were to break the possibility of shock or electrocution could be reduced by

- a. Reducing equipment leakage current
- b. Adding an additional ground wire in parallel with the power cord safety ground
- c. Using an isolated power system
- d. All of the above

A ground wire is designed to provide a safe path to ground for leakage currents which could cause a shock or electrocution if they were to flow through a patient or an equipment user.

Power cords are subject to stress, and sometimes the ground wire in a power cord can break, or the ground pin of an electrical plug can be broken. The shock hazard that this presents can be reduced by taking one or more of the following measures.

- * **reducing internal equipment leakage current**
- * continuously monitoring the continuity of the ground wire, so that corrective action can be taken in the event of a fault
- * **adding an additional ground wire** (a redundant ground) in parallel with the power cord safety ground
- * periodically inspecting the ground-connection integrity of equipment
- * **using an isolated power system** that isolates the current-carrying wires in the equipment from the power system ground

Reference: Carr, Joseph J., and Brown, John M., Introduction to Biomedical Equipment Technology, second edition, Prentice Hall Career and Technology, 1993, page 419

14) A system used in the past to reduce or eliminate leakage current hazards in hospitals is a(n)

- a. equipotential grounding system
- b. ground fault circuit interrupter
- c. line isolation monitor
- d. a and b

An **equipotential grounding system** consists of a separate connection from each equipment chassis to a common ground terminal. By connecting all grounds together, the intention is to reduce the possibility of having a patient or staff member touch two grounding points which are at different electrical voltages, and so receive a shock. If a device has a large leakage current, along with a poor grounding connection, the voltage on the chassis could reach hazardous levels,

while another ground point within the patient environment was still at a low voltage, creating a potential for a shock.

The equipotential grounding system was a very common method of provide protection against electrical shocks in the 1970s and 1980s, particularly in operating rooms, intensive care units, and coronary care units. Many of these areas still have separate large green grounding connectors intended to be used to make these separate connections between equipment and the building ground.

However, equipotential grounding systems proved to be an ineffective way of dealing with this hazard because they actually served to increase the likelihood that a patient or equipment user would complete an undesirable path to ground for an electrical shock. Current ideas promote insulation over equipotential grounding as a more effective way to control leakage current hazards.

Ground fault interrupters will disconnect electrical power to a device which has a very high level (several milliamperes) of leakage current. They do not provide useful protection against the lower level leakage current hazards (on the order of hundreds of microamperes) that electrical safety programs try to control in a patient-care environment.

A line isolation monitor is part of an **isolated power system**. An isolated power system can provide some protection against macroshock. However, isolated power systems **offer virtually no protection** against the smaller shocks which can be caused by typical leakage currents.

References: Carr, Joseph J., and Brown, John M., Introduction to Biomedical Equipment Technology, John Wiley and Sons, 1981, pages 332 - 333 and National Fire Protection Association, NFPA 99 - Standard for Health Care Facilities

(Note: the first reference provides information on the theory of the equipotential grounding system at a time when it was still widely used, the second reference provides current information.)

15) An ethylene oxide sterilizer

- a. Should be operated by trained personnel
- b. Requires that sterilized material be aerated
- c. Uses ethylene oxide, which is toxic
- d. All of the above

Ethylene oxide is a gas which is used to sterilize a wide variety of medical products. It offers the advantage of being able to sterilize devices at far lower temperatures than steam sterilization requires. Compared to sterilization by radiation, the capital equipment and controls required are far less costly for gas sterilization. (Manufacturers processing very large volumes of devices to be sterilized typical use radioactive sterilization.)

Gas sterilization is often used to sterilize plastics which cannot take the high heat of steam sterilization.

However, **ethylene oxide is highly toxic**, and has been linked to irritation of the eyes and respiratory tract, as well as reproductive hazards, so it does represent a potential danger to improperly trained operators. In addition, the ethylene oxide is absorbed by many materials, such as plastics. Before use, the **gas must be purged from the material, either by using an aeration cabinet**, or a quarantine period when the sterilized object is left on a shelf exposed to room air for a substantial time period.

Reference: Stoner, David L., Smathers, James B., Hyamn, William A., Clapp, David E., Duncan, Dean D., Engineering a Safe Hospital Environment, John Wiley and Sons, 1982, page 56

16) Individual radiation exposure is monitored by a

- a. dosimetry system
- b. densitometry system
- c. decibel system
- d. metric system

Individual radiation exposure is measured using a **dosimetry system**.

Two types of dosimeters that are frequently used are film badges and thermoluminescent dosimeters (TLD). Both of these are designed to record total radiation exposure over an extended period of time (two weeks up to several months, depending upon the total dose expected).

A densitometer is used to measure the optical density of an object or fluid.

A decibel is a measure of relative noise levels or power levels.

The metric system is a general system of weights and measures based upon the decimal system.

Reference: Stoner, David L., Smathers, James B., Hyamn, William A., Clapp, David E., Duncan, Dean D., Engineering a Safe Hospital Environment, John Wiley and Sons, 1982, page 117

17) A document containing standards for health care facilities is

- a. NFPA 99
- b. NFPA 88
- c. NFPA 99
- d. NFPA 67

BMET Certification Review Class – Safety in Health Care Facilities

The National Fire Protection Association publishes NFPA 99, which is a compilation of most of the major NFPA standards that affect health care facilities.

Other NFPA standards also provide useful information health care organizations, such as NFPA 101, the Life Safety Code, which primarily addresses fire safety, and NFPA 70, the National Electric Code, which contains standards for electrical wiring.

Reference: National Fire Protection Association, NFPA 99 - Standard for Health Care Facilities

- 18) According to the ANSI/AAMI Standard for Electrosurgical Devices, (ANSI/AAMI HF18) an electrosurgical unit with a dispersive electrode cable continuity monitor should activate when the resistance in the conductor becomes
- greater than 50 ohms
 - greater than 100 ohms
 - greater than 300 ohms
 - greater than 1000 ohms

The ANSI/AAMI Standard for Electrosurgical Devices provides information on the performance, safety requirements, and labeling requirements of electrosurgical devices.

This standard states, in part:

"In an electrosurgical generator equipped with a dispersive electrode cable continuity monitor, the patient circuit safety monitor shall be activated when any individual conductor in the dispersive cable is open-circuited, or if resistances in that conductor are **greater than 1,000 ohms**."

Reference: Association for the Advancement of Medical Instrumentation, American National Standard for Electrosurgical Devices, ANSI/AAMI HF18-1994, Association for the Advancement of Medical Instrumentation, 1994, section 4.2.8.1.3

- 19) The most effective method of controlling nosocomial infection is
- handwashing
 - ethylene sterilization
 - ultraviolet light screening
 - enteric precautions

Nosocomial infections are infections acquired in the hospital. While there are many ways in which the possibility of the spread of infection can be minimized, the most effective is also the simplest, that is **handwashing**. Employees should always wash their hands after contact with an infected person, before meals, after using the restroom, after removing gloves, and after handling chemicals.

Reference: Chaff, Linda F., Safety Guide for Health Care Institutions, fourth edition, American Hospital Publishing, 1989, page 48

- 20) A medical oxygen gas cylinder is color coder
- red
 - silver with a blue bottom
 - yellow top with silver bottom
 - green with silver rim

The Compressed Gas Association writes standards for the use of compressed gas cylinders. The color code for compressed gas cylinders is:

Oxygen Green
Medical Oxygen Green with silver rim

Reference: Stoner, David L., Smathers, James B., Hyamn, William A., Clapp, David E., Duncan, Dean D., Engineering a Safe Hospital Environment, John Wiley and Sons, 1982, page 59

- 21) In NFPA 99, Standard for Health Care Facilities, the maximum acceptable testing interval for testing receptacles in critical care areas is
- 12 months
 - 6 months
 - 3 months
 - Monthly

NFPA 99 is the National Fire Protection Association's Standard for Health Care Facilities. It contains standards related to a wide variety of health care issues, including electrical systems, medical gas and vacuum systems, electrical equipment, laboratories, and non-hospital health care facilities. This standard is an American National Standard.

When discussing the testing of receptacles, this standard states, in part:

"Testing shall be performed no less frequently than as listed below.
General care areas: 12 months
Critical care areas: 6 months
Wet locations: 12 months"

Reference: National Fire Protection Association, NFPA 99 - Standard for Health Care Facilities

- 22) Standards to reduce the risk of microshock are designed to prevent
- a. currents greater than 10 microamps from passing through the heart
 - b. the patient from feeling a tingling sensation
 - c. damage to hospital equipment
 - d. injury to care providers

A microshock is a very low-level current applied directly to the heart. This can lead to inadvertent fibrillation and death. Microshocks are usually very low current value, on the order of tens of microamperes.

Studies done on dogs in the 1960s showed that ventricular fibrillation could be caused by a current as low as 20 microamperes applied directly to the heart. Through extrapolation of this data to humans, a level of 10 microamperes was thought to be a safe current level for the human heart, and so leakage current standards were written to prevent currents higher than this from entering the heart.

Reference: Carr, Joseph J., and Brown, John M., Introduction to Biomedical Equipment Technology, second edition, Prentice Hall Career and Technology, 1993, page 417

- 23) Incorrect connection of medical gas cylinders to medical equipment is prevented by all of the following except
- a. gas pressure regulators
 - b. pin-index safety system
 - c. diameter index safety system
 - d. medical gas cylinder color coding

Misconnection of gases can represent an extremely dangerous hazard. For example, if nitrous oxide were to be connected into an oxygen line, a patient death could result.

To prevent this, many standards have been established by the Compressed Gas Association.

The pin-index safety system relies on a unique configuration of pins and holes on compressed gas cylinder yokes and the cylinder outlet valves. Each type of gas has its own configuration of these pins, so that an inadvertent attempt to connect a gas cylinder to an incorrect yoke will be unsuccessful.

The diameter-index safety system specifies that cylinder yoke inserts and quick and threaded couplers must have a noninterchangeable diameter, so that inadvertent connections can be prevented.

Color coding of cylinders is also important, helping equipment operators quickly identify the type of gas in a cylinder by the color of the cylinder.

Gas pressure regulators are a safety feature used to lower the pressure inside a compressed gas cylinder from a very high level to a lower level that is safe for use in the application being supplied by the gas. While the regulators are a very important safety feature, they are not designed to prevent incorrect connections.

References: National Fire Protection Association, NFPA 99 - Standard for Health Care Facilities

and

Stoner, David L., Smathers, James B., Hyamn, William A., Clapp, David E., Duncan, Dean D., Engineering a Safe Hospital Environment, John Wiley and Sons, 1982, page 59

- 24) According to NFPA 99, the limit for chassis leakage current for cord-connected medical equipment intended for use in the patient care vicinity is
- a. 100 microamps
 - b. 300 microamps
 - c. 500 microamps
 - d. 5 milliamps

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This standard states, in part:

"The leakage current for cord-connected appliances shall be measured. The limit shall be 300 microamperes."

Reference: National Fire Protection Association, NFPA 99 - Standard for Health Care Facilities

- 25) NFPA 99 requires testing of equipment before being put into service, after repair or modification and at intervals determined by the equipment's location. Unless documentation justifies otherwise, intervals should not exceed

- a. general care areas – 6 months, critical care areas – 6 months, wet locations – 6 months
- b. general care areas – 12 months, critical care areas – 6 months, wet locations – 6 months
- c. general care areas – 12 months, critical care areas – 6 months, wet locations – 3 months
- d. general care areas – 12 months, critical care areas – 6 months, wet locations – 12 months

NFPA 99 is the National Fire Protection Association's Standard for Health Care Facilities. It contains standards related to a wide variety of health care issues, including electrical systems, medical gas and vacuum systems, electrical equipment, laboratories, and non-hospital health care facilities. This standard is an American National Standard.

This standard states, in part:

"All appliances used in patient care areas shall be tested in accordance with 7-5.1.3 or 7-5.2.2.1 before being put into service for the first time and after repair or modification. Patient-care-related electrical appliances shall be retested at intervals determined by their normal location or area of normal use, but not exceeding the intervals listed below.

General Care Areas: 12 months

Critical Care Areas: 6 months

Wet Locations: 6 months"

Reference: National Fire Protection Association, NFPA 99 - Standard for Health Care Facilities

- 26) Class A ground fault circuit interrupters are required to trip when the fault current to ground is greater than
- a. 100 microamps
 - b. 500 microamperes
 - c. 1 milliamperes
 - d. 6 milliamperes
 - e. 20 milliamperes

Class A ground fault circuit interrupters (GFCI or GFI) must trip when a fault current to ground is 6 milliamperes or more.

Reference: National Fire Protection Association, NFPA 99 - Standard for Health Care Facilities

- 27) NFPA 99, Standard for Health Care Facilities, requires the impedance to ground for either conductor of an isolated power system in an anesthetizing location to exceed
- a. 200,000 ohms
 - b. 12,000 ohms
 - c. 100 ohms
 - d. 0.5 ohms

NFPA 99 is the National Fire Protection Association's Standard for Health Care Facilities. It contains standards related to a wide variety of health care issues, including electrical systems, medical gas and vacuum systems, electrical equipment, laboratories, and non-hospital health care facilities. This standard is an American National Standard.

This standard states, in part:

"The impedance (capacitive and resistive) to ground of either conductor of an isolated system shall exceed 200,000 ohms when installed."

Reference: National Fire Protection Association, NFPA 99 - Standard for Health Care Facilities

- 28) NFPA 99, Standard for Health Care Facilities, requires that a LIM alarm trip when the total hazard current from either isolated conductor to ground reaches a threshold value of
- a. 0.1 milliamperes
 - b. 0.5 milliamperes
 - c. 2.0 milliamperes
 - d. 5.0 milliamperes
 - e. 20 milliamperes

NFPA 99 is the National Fire Protection Association's Standard for Health Care Facilities. It contains standards related to a wide variety of health care issues, including electrical systems, medical gas and vacuum systems, electrical equipment, laboratories, and non-hospital health care facilities. This standard is an American National Standard.

This standard states, in part:

"The [line isolation] monitor shall be designed such that a green signal lamp, conspicuously visible to persons in the anesthetizing location, remains lighted when the system is adequately isolated from ground; and an adjacent red signal lamp and an audible warning signal (remote if desired) shall be energized when the total hazard current (consisting of possible resistive and capacitive leakage currents) from either isolated conductor to ground reaches a threshold value

of 5.0 mA under normal line voltage conditions. The line isolation monitor shall not alarm for a fault hazard current of less than 3.7 mA."

Reference: National Fire Protection Association, NFPA 99 - Standard for Health Care Facilities

- 29) According to NFPA 99, Standard for Health Care Facilities, the minimum required retention force for the grounding contact of power receptacles in patient-care areas is
- 4 ounces
 - 8 ounces
 - 1 pound
 - 3 pounds

NFPA 99 is the National Fire Protection Association's Standard for Health Care Facilities. It contains standards related to a wide variety of health care issues, including electrical systems, medical gas and vacuum systems, electrical equipment, laboratories, and non-hospital health care facilities. This standard is an American National Standard.

This standard states, in part:

"The retention force of the grounding blade of each electrical receptacle (except locking-type receptacles) shall be not less than 115 g (4 oz)."

Reference: National Fire Protection Association, NFPA 99 - Standard for Health Care Facilities

- 30) The present NIOSH recommended TWA exposure limit for nitrous oxide in hospital operating rooms is
- 1 part per million
 - 5 part per million
 - 25 part per million
 - 100 part per million

In 1977, NIOSH (the National Institute for Occupational Safety and Health) published its Criteria for a Recommended Standard ... Occupational Exposure to Waste Anesthetic Gases and Vapors, (Publication 77-140). This document recommended a TWA (time weighted average) exposure to nitrous oxide of no more than 25 parts per million (ppm). As of 1994, this recommendation remains a recommendation, and has never been incorporated into a standard.

Reference: National Institute for Occupational Safety and Health, U.S. Department of Health, Education and Welfare, Health and Safety Guide for Hospitals, DHEW (NIOSH) Publication 78-150, 1978, page 36

- 31) The basic advantage of four-wire resistance measurements is
- the measured resistance is independent of the test-lead and contact-point resistances
 - four-wire resistance meters are less expensive
 - four-wire resistance meters have digital displays
 - all of the above

Four-wire resistance measurements place a known current through a resistance, and measure the voltage across the load resistance using an independent set of leads. By measuring in this way, the load resistance can be measured independent of the contact-point resistance and the test lead resistance.

In a more traditional two-wire resistance measurement, contact resistance and lead resistance can alter the measurements. At high resistances, this error is not significant. However, when measuring grounding resistances, which are usually half an ohm or less, even a small contact or lead resistance can represent a very significant error.

Four-wire resistance measurement instruments are generally more expensive than a comparable two-wire ohmmeter. Four-wire ohmmeters are usually digital meters; however, this is not required. Most two-wire ohmmeters are also digital these days.

Reference: National Fire Protection Association, NFPA 99 - Standard for Health Care Facilities

- 32) The hazards associated with the clinical laboratory are
- chemicals
 - gases
 - broken equipment
 - all of the above

The clinical laboratory is probably one of the most hazardous places in the hospital. One of the most common hazards found in the laboratory are chemicals.

Chemicals can cause many problems, including poisoning, injury to skin or eyes, and damage to clothing.

Many chemicals emit hazardous vapors, which, when inhaled, can cause irritation or damage to the respiratory tract. Fume hoods in laboratories are designed to contain, and safely exhaust, hazardous gases from the laboratory environment.

Equipment can represent a significant hazard, both to equipment operators and patients. The equipment in a laboratory

is in an area where spills are not uncommon. These spills can harm the equipment. In addition, if the grounding system of electrical equipment is not intact, these spills can result in a significant shock hazard to the operator. Finally, broken or out of calibration equipment can give erroneous results, and might result in the misdiagnosis or mistreatment of a patient's illness.

Reference: Stoner, David L., Smathers, James B., Hyman, William A., Clapp, David E., Duncan, Dean D., Engineering a Safe Hospital Environment, John Wiley and Sons, 1982, pages 56 - 57

- 33) Safety Concerns regarding diagnostic x-ray machines are
- proper shielding and filtering of the x-ray tube
 - preventing multiple exposures to low-level radiation
 - a and b
 - none of the above

Shielding of the x-ray tube helps assure that x-rays are restricted to only going where they are intended to go, and not in directions which might be hazardous to equipment operators, or might expose patients unnecessarily to radiation not used to expose an x-ray film.

Filtering of the x-ray beam eliminates low energy components of the x-ray beam. These low energy components are referred to as low quality because they do not have enough energy to penetrate a patient's body to expose x-ray film. Thus, they expose the patient to radiation without providing any benefit.

Appropriate use of lead shielding and lead glass windows allows an x-ray technician to observe the patient without **risking unnecessary exposure to low-level scattered radiation** produced whenever an x-ray beam is on. An x-ray technician will typically be involved in making many x-rays each day, and so could risk substantial exposure to radiation if proper shielding is not employed.

Controls for x-ray equipment should always be placed in an area that forces the operator to remain behind appropriate shielding during the operation of the x-ray beam.

Reference: Stoner, David L., Smathers, James B., Hyman, William A., Clapp, David E., Duncan, Dean D., Engineering a Safe Hospital Environment, John Wiley and Sons, 1982, pages 122 - 123

- 34) An electrical source of heat that has the potential for starting a fire is
- standard ohmic heating
 - undersized conductors
 - insulation breakdown
 - all of the above

Fire can result from excessive heat. Whenever electricity flows through a conductor, heat results. Since the power dissipated in a conductor is equal to the square of the current flowing through the current, times its resistance, the higher the resistance, the more power (heat) will be generated.

Ohmic heating, caused by the intentional generation of heat, for example, in a heating element, is a possible source of heat.

Undersized conductors in a wire can cause heating in a power cord, or in other wires carrying large currents. The smaller the diameter of the conductor, the greater its resistance, and thus, the greater heat is generated by its use.

The **breakdown of insulation** can cause resistive paths to exist where they are not intended to be. When this happens, heat can be produced unintentionally, and can be the source of a fire.

Reference: Carr, Joseph J., and Brown, John M., Introduction to Biomedical Equipment Technology, second edition, Prentice Hall Career and Technology, 1993, page 409

- 35) Surgical lasers can cause fires by igniting
- halothane anesthesia gases
 - surgical drapes
 - the patient's colonic gases
 - a, b and c
 - b and c only

Halothane is a non-flammable anesthetic gas.

Surgical drapes can be ignited by excessive heat, such as might be generated by improper use of a laser.

Colonic gases contain methane, which is flammable. Laser surgery which takes place in the presence of these gases can represent a fire hazard.

Reference: None

- 36) The key elements of cardiopulmonary resuscitation are
- airway, breathing and cardiac defibrillation

- b. anoxia, bicarbonate and cardioversion
- c. airway , breathing and circulation
- d. incubation, infusion and interdiction

Cardiopulmonary resuscitation is a first aid life-support technique used to maintain a patient's circulation and respiration until appropriate medical intervention is available.

The key steps in cardiopulmonary resuscitation are summarized as ABC. A stands for **airway**, and reminds the rescuer that air cannot enter the lungs unless the patient's airway is clear and open. B stands for **breathing**, reminding the rescuer to provide breathing assistance, usually through mouth-to-mouth resuscitation, to the patient. C stands for **circulation**. The circulation of blood is provided by simulating a heart beat through successive chest compressions performed about once per second.

Reference: None

- 37) According to NFPA 99, Standard for Healthcare Facilities, the minimum acceptable wire size for ground conductors in power cords for power cord lengths less than 15 feet in length is
- a. 14 AGW
 - b. 16 AGW
 - c. 18 AGW
 - d. 20 AGW

NFPA 99 is the National Fire Protection Association's Standard for Health Care Facilities. It contains standards related to a wide variety of health care issues, including electrical systems, medical gas and vacuum systems, electrical equipment, laboratories, and non-hospital health care facilities. This standard is an American National Standard.

This standard states, in part:

"Each electric appliance shall be provided with a grounding conductor in its power cord. The grounding conductor shall be no smaller than No. 18 AWG. The grounding conductor of cords longer than 15 ft (4.6 m) shall be **no smaller than No. 16 AWG.**"

Reference: National Fire Protection Association, NFPA 99 - Standard for Health Care Facilities

- 38) The Environment of Care standard is part of the
- a. National Electric Code
 - b. Joint Commission Accreditation Manual for Hospitals
 - c. mechanical engineering standards for hospital building construction
 - d. American Hospital Association guidelines

- 39) Proper use of protective garments such as gloves, gowns and masks, is a type of infection control known as
- a. barrier technique
 - b. filtration
 - c. isolation
 - d. arthropod vector

A basic method of protecting hospital personnel from the dangers of infection is the construction of barriers between the potential infectious agent, and the employee. Typical **barriers include gloves, gowns and masks.**

Filtration typically involves cleaning the air in a room with a high-efficiency particulate air filter (HEPA filter). This type of filter traps all but the very smallest particles, providing very effective cleaning of the air.

Isolation involves restricting access to a patient so that the patient's infection is less likely to spread, or to protect the patient against infections from other people. Isolation is frequently used in conjunction with barrier techniques to control the spread of infections.

Reference: None

- 40) Of the following, the device not primarily designed to prevent electric shock to hospital personnel or patients is (are)
- a. fuses in medical equipment
 - b. ground fault circuit interrupters
 - c. insulation
 - d. grounding wires in power distribution systems

Fuses in equipment are designed primarily to prevent a fire hazard associated with the heat that can be generated if an electrical short circuit develops inside a piece of equipment. Fuses are also used to prevent damage to components in equipment from the effects of excessive currents.

Ground fault interrupters are used in wet areas to prevent shocks to equipment operators or patients. They are often

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used in bathrooms, for example, to turn off power if an electrical device, such as a hair dryer, is dropped in a sink full of water.

Insulation is the primary method of protecting personnel and patients against shock. Insulation provides a very high-impedance path between current carrying portions of equipment and those who may have contact with the equipment.

Grounding wires are used to provide a low-impedance path to ground for chassis leakage currents. In this way, the voltage on case of the equipment will remain at a safe level, below the level where a person could experience a hazardous electric shock.

Reference: National Fire Protection Association, NFPA 99 - Standard for Health Care Facilities

- 41) According to NFPA 99, lead leakage testing for portable equipment is required
- a. for incoming inspections, following repairs and modifications and at least every 12 months
 - b. for incoming inspections and following repairs and modifications
 - c. for incoming inspections, following repairs and modifications and at least every 6 months
 - d. for incoming inspections, and at least every 6 months thereafter

NFPA 99 is the National Fire Protection Association's Standard for Health Care Facilities. It contains standards related to a wide variety of health care issues, including electrical systems, medical gas and vacuum systems, electrical equipment, laboratories, and non-hospital health care facilities. This standard is an American National Standard.

This standard states, in part:

"The tests specified in 7-5.1.3.6, 'Lead Leakage Current Tests and Limits, Portable Equipment,' shall be required **only for incoming inspections and following repairs and modifications** that may have compromised the patient lead leakage current."

Reference: National Fire Protection Association, NFPA 99 - Standard for Health Care Facilities

- 42) According to NFPA 99, when testing a portable electrical device used in the patient vicinity, the resistance between the appliance's cord connected chassis and the ground pin of the attached plug should not be more than
- a. 1.15 ohms
 - b. 0.50 ohms
 - c. 1.0 kilohms
 - d. 10 kilohms

Standard for Health Care Facilities. It contains standards related to a wide variety of health care issues, including electrical systems, medical gas and vacuum systems, electrical equipment, laboratories, and non-hospital health care facilities. This standard is an American National Standard.

This standard states, in part:

"The resistance between the appliance chassis, or any exposed conductive surface of the appliance, and the ground pin of the attachment plug shall be measured. The resistance shall be **less than 0.50 ohm**."

Reference: National Fire Protection Association, NFPA 99 - Standard for Health Care Facilities

- 43) According to NFPA 99, when multiple cord-connected devices are rack or cart mounted and powered by one power cord, chassis leakage current shall be measured by
- a. unplugging and testing each unit separately
 - b. testing the rack and cart assembly
 - c. testing only one device and multiply the chassis leakage current by the number of devices connected to the single power cord
 - d. either a or b

NFPA 99 is the National Fire Protection Association's Standard for Health Care Facilities. It contains standards related to a wide variety of health care issues, including electrical systems, medical gas and vacuum systems, electrical equipment, laboratories, and non-hospital health care facilities. This standard is an American National Standard.

This standard states, in part:

"When multiple devices are connected together and more than one power cord supplies power, the devices shall be separated into groups according to their power supply cord and the **leakage current shall be measured independently for each group as an assembly**."

Reference: National Fire Protection Association, NFPA 99 - Standard for Health Care Facilities

- 44) To comply with the FDA device tracking amendment that went into effect August 1993, once a patient receives a heart valve prosthesis, the hospital

- a. must assume responsibility as the “distributor” of the device.
- b. needs only note in the patient’s chart the name of the manufacturer, the model/serial number of the device and the date of surgery
- c. must report the name of the surgeon to the FDA, since that individual is now the “distributor” of the device
- d. has no responsibility for device tracking, since that is a function of the company that sold the device to the hospital, whether or not it is the same company that manufactured the device

The regulations promulgated by the Food and Drug Administration to enforce the Safe Medical Device Amendments require that certain devices, particularly implantable devices, be tracked from manufacture to implant. The intention of these regulations is to allow rapid notification of patients who may be affected by a device in which a defect has been found.

To facilitate tracking, the FDA requires distributors of tracked devices to keep records related to those devices and to report the disposition of those devices to the manufacturer. Under the regulations, **the hospital where an implant takes place is considered the distributor** of the device and must follow all the required regulations.

Reference: FDA Regulations

- 45) The major hazard to the body from scattered or reflected laser radiation is
- a. genetic mutations
 - b. skin damage
 - c. cataract formation
 - d. retinal damage

Lasers emit a very high energy beam of light. They have a wide variety of surgical uses, including gynecological, general, plastic, and eye surgeries.

The major problem associated with lasers is their potential for **eye damage, specifically, damage to the retina**, as this high intensity light source is concentrated on a very small spot on the retina. To prevent this damage, appropriate eye protection should be worn whenever a surgical laser is in use.

The radiation given off by lasers is non-ionizing radiation, so there is no danger of genetic mutations.

Another danger associated with lasers is the smoke produced by the burning that accompanies the use of lasers. This smoke problem can be alleviated by the use of a smoke evacuator.

Reference: Chaff, Linda F., *Safety Guide for Health Care Institutions*, fourth edition, American Hospital Publishing, 1989, page 41

- 46) The two basic electrical safety tests that should be performed on line-powered patient-care equipment are
- a. input isolation and defibrillation protection
 - b. ground wire integrity and ground wire leakage
 - c. exposed metal leakage and leakage current between leads
 - d. proper polarity and contact tension

A primary hazard of electricity is associated with the shocks that electricity can cause when it flows in unintended paths. Shock prevention relies on four factors: prevention by appropriate insulation and enclosure, prevention by grounding, prevention by device design, and prevention through user procedures.

Prevention by appropriate insulation and enclosure relies on the principle that non-insulated wires are protected by an appropriate enclosure (i.e., an insulated case, and physical space between the wires themselves, and the case.), and by insulation of the wires which are not in the case, such as the power cord.

Prevention by grounding relies upon a low-impedance grounding system that provides a safe path to ground for any leakage currents which might exist, along with adequate electrical receptacles for line-powered appliances.

Prevention by device design relies on the manufacturer to assure that equipment design seeks to minimize leakage currents, and to not intentionally provide a low-impedance path at 60 hertz from patient to ground.

Prevention through user procedures relies on appropriate training of equipment users so that they do not perform their job in a way that could create a hazard for themselves or their patients.

Of these aspects of electrical safety, only two can be tested for by direct equipment inspection: **the adequacy of the insulation and enclosure, and the adequacy of grounding**. (It is not reasonable to change equipment design after the device is already in use, and the testing of user procedures is a complicated task which cannot be considered a "basic" test.) The adequacy of the insulation and enclosure is determined by leakage current testing, and the adequacy of grounding is determined by testing the ground wire's integrity.

Reference: National Fire Protection Association, NFPA 99 - Standard for Health Care Facilities

- 47) An isolated power system does not
- a. provide protection against macroshock
 - b. protect against microshock

- c. provide a ground fault warning
- d. allow continued equipment operation after “first fault”

An isolated power system is constructed so that the two electrical power lines supplying voltage for equipment operation (such as 120 VAC) are not referenced back to ground.

In a normal power system, one line is deliberately connected to ground (the neutral wire), and so the other line (the hot wire) is referenced back to ground.

Isolated power systems were initially designed for use in operating rooms where an electrical spark might accidentally ignite a flammable anesthetic. In a normal power system, an inadvertent connection between the hot wire and ground could cause a spark (i.e., a macroshock). In an isolated power system, a connection between one of the power lines and ground (a first fault) will not have any effect on the operation of the equipment, and will not produce a spark.

Areas which are served by an isolated power system are required to have a Line Isolation Monitor. This monitor must incorporate an alarm which sounds if the isolation between the power system and ground deteriorates (a ground fault).

Isolated power systems **do not provide protection against microshock**, which are caused by electrical currents on the order of tens of microamperes. Isolated power systems are designed to protect against shocks of several milliamperes.

Reference: None

48) The classic remedy for excessive leakage current is to

- a. use a third or safety ground
- b. use a two wire system
- c. add a line isolation monitor
- d. call an electrician

Leakage current is a low level electrical current that flows out of its intended path (or circuit) into an unintended portion of the equipment. The unintended portion is the metal chassis of the equipment, where, this current represents a potential hazard because an equipment user or patient could touch the chassis, and receive a shock.

Assuming a leakage current exists, **the simplest solution is to add a third wire to the power cord**. This is the safety ground wire, which connects the equipment chassis to the power system ground, and provides a low-impedance return path for electrical leakage current.

A two-wire system does not provide leakage current protection, although a double-insulated appliance, because of its construction, uses only two wires, and is constructed so that an electrical connection between the external parts of the device and the energized parts of the device is very unlikely, so leakage current is not a problem.

A line isolation monitor does not provide protection against leakage current directly, although it is part of an isolated power system, and this can provide a degree of protection against some types of macroshock.

An electrician may be consulted in cases of excessive leakage current, but that would be after an excessive current was identified. The electrician might act to install a ground wire, or perform a repair on the equipment. Calling the electrician would not be a remedy, although the action taken by the electrician might be.

Most modern hospital equipment is designed with a three-wire power cord that offers a safety ground wire as part of the equipment's design.

Reference: Carr, Joseph J., and Brown, John M., Introduction to Biomedical Equipment Technology, second edition, Prentice Hall Career and Technology, 1993, page 417

49) An electrical instrument has a leakage current of 100 microamps flowing through a 1 ohm ground resistance. If a patient of 500 ohms resistance touches the instrument's case, the current flowing through the patient will be

- a. 0.2 microamperes
- b. 99.8 microamperes
- c. 2.0 microamperes
- d. 98.0 microamperes

This problem is solved using Ohm's law. In this case, we have two parallel resistors. First, the 1 ohm grounding resistance, and second, the 500 ohm patient resistance.

The 1 ohm ground resistance has a current of 100 microamperes flowing through it. The voltage across it will be:
 $V = I \times R$
 $V = 100 \text{ microA} \times 1 \text{ ohms}$
 $V = 100 \times 10^{-6} \times 1$
 $V = 1 \times 10^{-4}$

This same voltage will also be across the patient, so the current through the patient will be:
 $I = V / R$
 $I = (1 \times 10^{-4}) / 500$
 $I = 2 \times 10^{-7}$
 $I = \text{0.2 microamperes}$

Reference: Stoner, David L., Smathers, James B., Hyamn, William A., Clapp, David E., Duncan, Dean D., Engineering a Safe Hospital Environment, John Wiley and Sons, 1982, pages 7 - 8

- 50) A LIM is a device that continuously monitors the
- a. impedance of isolated power lines to ground
 - b. resistance of isolated power lines to chassis
 - c. conductance of isolated power lines
 - d. none of the above

NFPA 99, Standard for Health Care Facilities, states, in part:

"The [line isolation] monitor shall be designed such that a green signal lamp, conspicuously visible to persons in the anesthetizing location, remains lighted when the system is adequately isolated from ground ..."

Reference: National Fire Protection Association, NFPA 99 - Standard for Health Care Facilities