
Lesson 5: Electrical Safety

Preparation for
Amateur Radio
Technician Class
Exam

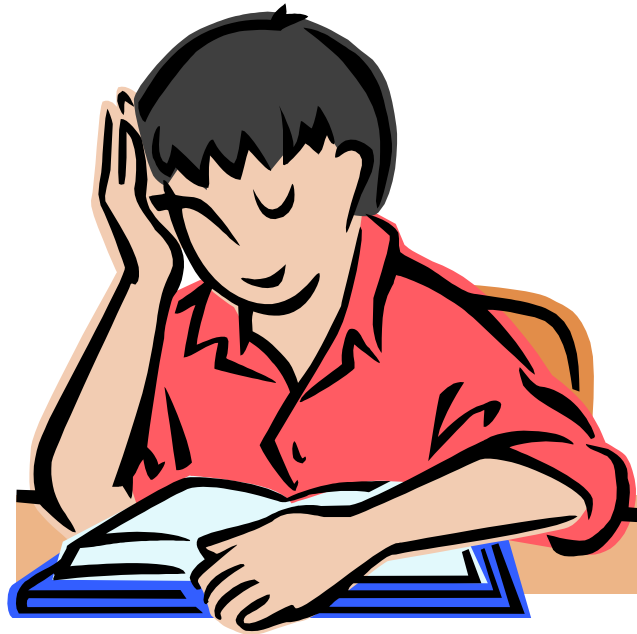
Topics

- Review
- Electrical Safety
- Open, Closed, and Short Circuits
- Ground
- RF Safety Practices
- Limiting RF Exposure
- FCC MPE Limits
- Exam Questions for this section

Reading

➤ Chapter 10 – 10.1-10.15

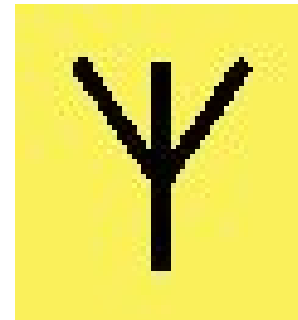
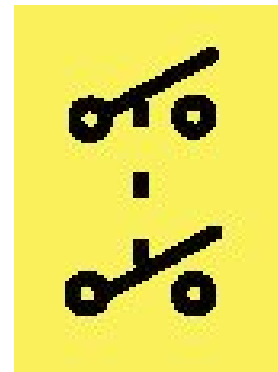
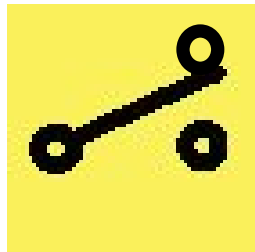
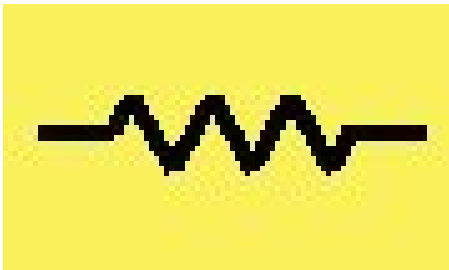
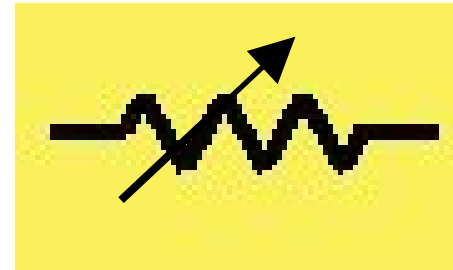
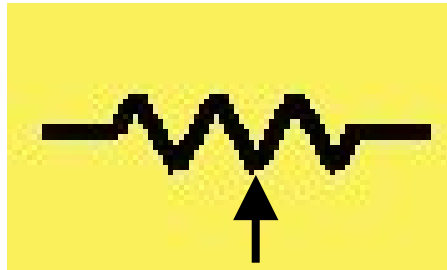
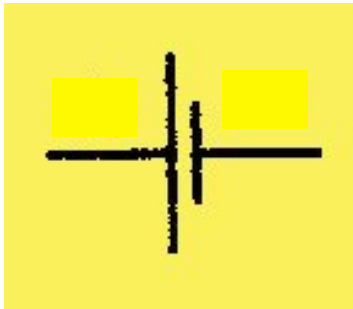
A Quick Review!



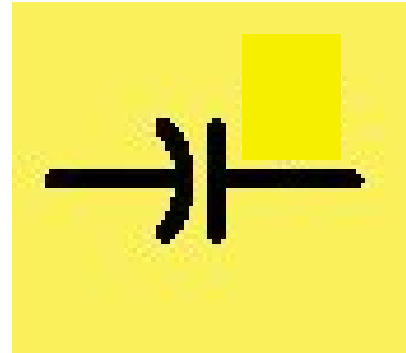
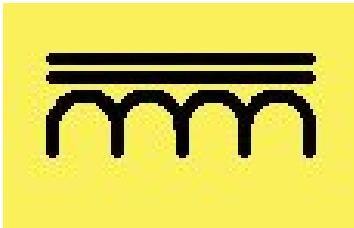
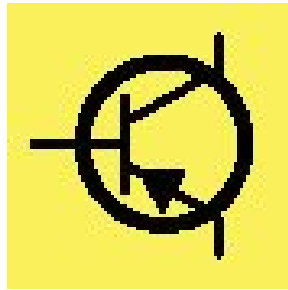
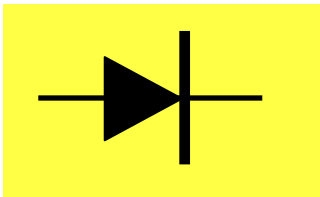
Electricity

➤ Too much current in a circuit becomes ???

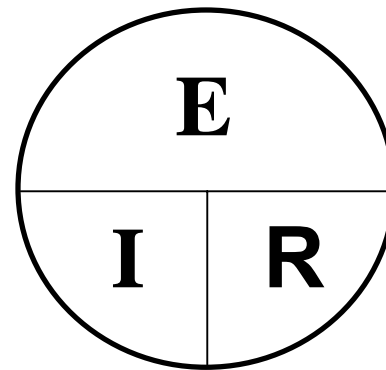
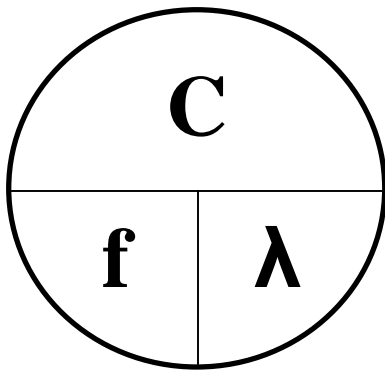
Circuit Review



Circuit Review



Formula Review



Electrical Safety

- Treat electricity with respect – it can be dangerous!
 - As little as 100 milliamps or 1/10 amp can be fatal!
 - At this level, heart rhythm can be disrupted
- The minimum voltage considered dangerous to humans is 30 volts

It's volts that jolts, but mills that kills!

Electrical Safety

- Be sure all household members know the location of the main switch for your gear
 - This should be easy to reach for all household members
 - They should also know where the main breaker is for the house

Electrical Safety

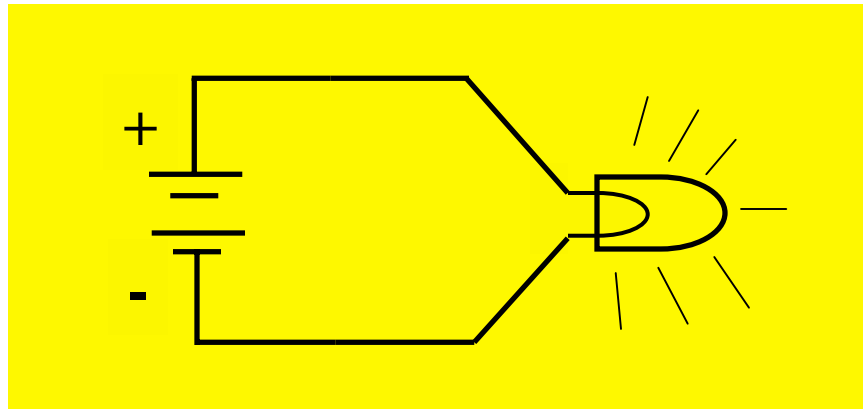
- All of your equipment must be shielded
 - Commercial equipment is built this way
- It is good to have a safety interlock switch connected to the equipment cabinet and the power supply circuit
 - If you remove the cabinet, the switch is automatically opened so you don't have power in the circuit
- Remember that capacitors have a residual charge even when the power is off
 - To prevent electric shock, don't touch the capacitors!

Electrical Safety

- When working with 120V three wire power cords the three wires have different roles:
 - Black or red is the “hot” wire
 - White is the “neutral” wire
 - Green is the “ground” wire
- This color scheme is typical, but you can't depend on it

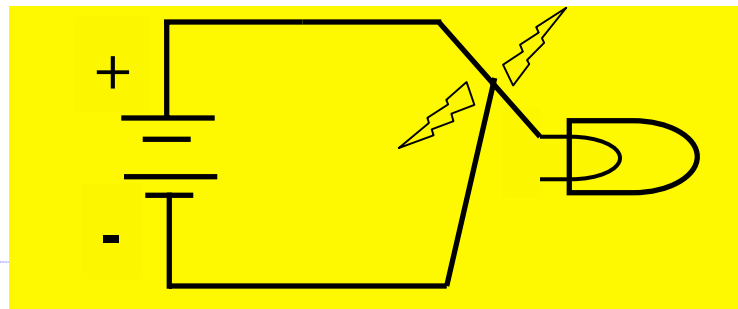
Closed Circuits

- Closed circuits are those we have been looking at
 - They have an uninterrupted path for the current to follow



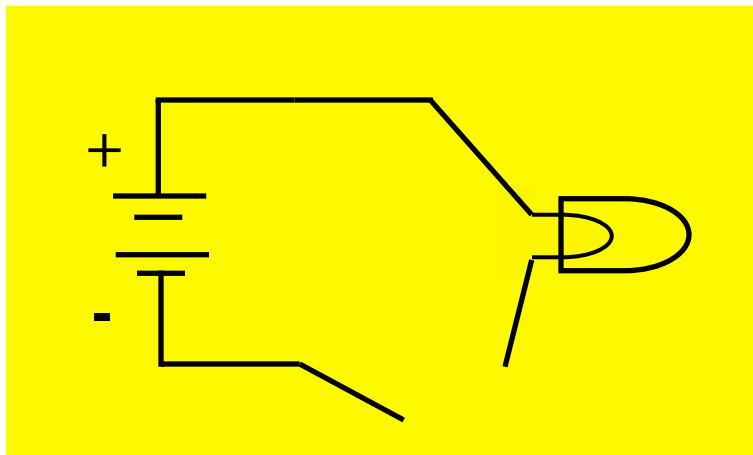
Short Circuits

- Short circuits occur when the current finds a shorter path between the terminals of the power source
 - Such as uninsulated wires touching
- The main problem with short circuits is they may draw more current through the circuit than it was designed to handle
 - This can cause the wires to overheat and start a fire



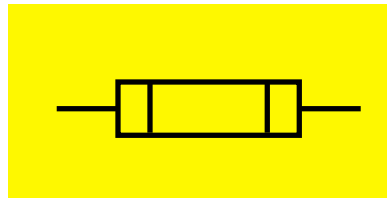
Open Circuits

- Open circuits are those that have a place where the current is interrupted
 - This could be due to a break in a wire, or due to a light switch being turned off



Fuses

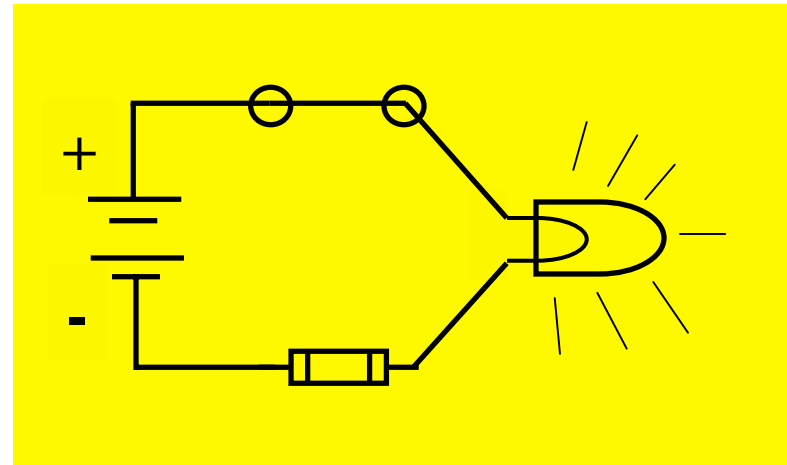
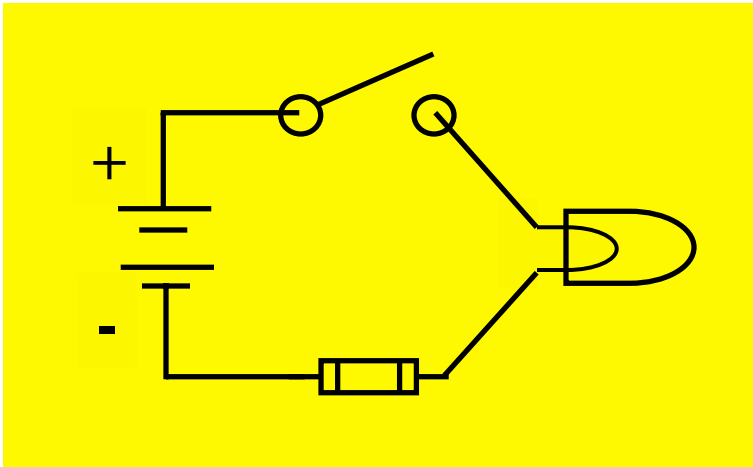
- Fuses are added to circuits to prevent problems due to short circuits and other issues
 - A fuse is a device that heats up and melts at a certain current level, thus causing an open circuit



Fuses

- If the fuse is too big, it won't melt in time, and you can have damage to your equipment
 - For example, in your transceiver, if you replace a 5 amp fuse with a 30 amp fuse the unit may draw too much power and burn out the transceiver
 - Fuses are pretty cheap – it's better to melt a fuse than your radio!
 - If you build your own rig running off household 110 AC, be sure to include a fuse (or circuit breaker) in series in the circuit where the power line enters the equipment
 - If running the equipment off a 12V DC power source (battery), the fuse goes next to the power source

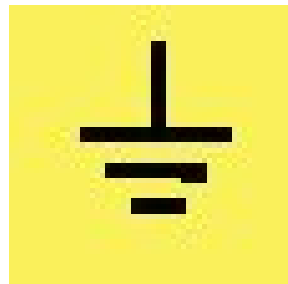
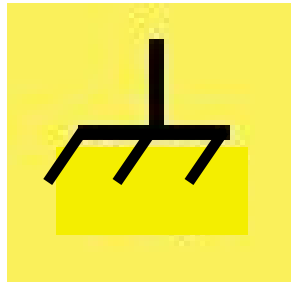
A safe circuit!



Ground

➤ There are two kinds of ground:

- Chassis
- Earth



- An earth ground literally means the earth
- We typically get this connection by driving an 8 foot long copper rod into the earth and attaching our radio ground wire to it
- An earth ground of your gear helps protect you from electric shock in case of damage to your gear

Ground

- For lightning protection, also ground your antenna when it is not in use
 - Antennas can pick up large electrical charges from storms, even if not directly hit by lightning
 - You don't want that electricity to come back to your rig!
 - It is best to disconnect your gear from power and the antenna during an electrical storm
 - Many commercial antennas are protected by lightning arrestors

RF Energy

- Electromagnetic Radiation (EMR)
 - RF energy
 - Power-frequency electromagnetic fields (50-60 Hz)
- FCC has set Maximum Permissible Exposure (MPE) limits

RF Energy

- RF and 60 Hz fields are called non-ionizing radiation
 - The frequency is too low to ionize atoms
- X-rays, gamma rays, and some UV are ionizing radiation
- RF energy causes heating of body tissues
 - You can get a nasty burn from an improperly grounded radio chassis or energized antenna
 - In extreme cases, RF heating of the eyes can cause cataracts and blindness

RF Energy

- The effect of RF on your body depends on several things:
 - Frequency of the energy (some frequencies are more readily absorbed than others)
 - Power density of the RF field (measured in Milliwatts per square centimeter). This is not regulated by the FCC, only the total RF exposure.
 - Polarization of the wave
 - Body size (wavelengths that affect children are shorter than wavelengths that affect adults)

RF Energy

- At wavelengths near the body's natural resonant frequency, RF is more readily absorbed
- Specific Absorption Rate (SAR) describes the rate at which RF is absorbed by the human body
- This is used to help determine safe RF exposure levels

RF Energy

- While amateur wavelengths are in the right frequency range for human absorption, we don't generally use enough power to cause a problem

Limiting RF Exposure

- Stay below the Maximum Permissible Exposure (MPE)
 - Use minimum power
 - Use lower duty cycles
 - Reduce transmission time
 - Use a different frequency
 - Pick an antenna whose radiation pattern reduces exposure

Limiting RF Exposure: Use Minimum Power

- The less power you use to transmit, the less RF exposure
- RF electric field strength is measured in Volts per meter (V/m)

Limiting RF Exposure: Use Lower Duty Cycles

- A lower duty cycle produces less RF radiation exposure for the same PEP
 - Your antenna can be closer to people if you use a lower duty cycle; the FCC compliance distance is smaller
 - The compliance distance is the distance within which you must comply with FCC MPE regulations
- Single sideband has a one of the lowest duty cycles

Limiting RF Exposure: Reduce Transmission Time

- The amount of time you transmit within a measured period affects your RF exposure
 - Transmitting 6 minutes straight is very different from transmitting 6 minutes total over an hour period
- In a controlled RF environment, you measure the transmitting time within a 6 minute period
- In an uncontrolled RF environment, you measure the transmitting time within a 30 minute period

Limiting RF Exposure: Use a Different Frequency

- RF radiation is from 3 kHz to 300 GHz
 - All frequencies between 300 kHz and 100 GHz are controlled by MPE
 - FCC is most concerned with frequencies in the 30 MHz to 300 MHz range

Limiting RF Exposure: Antenna Selection

- Mount as far from accessible areas as possible
 - In general the higher the antenna the less the RF radiation exposure at ground level
- Alter antenna patterns
 - A 1/2 wave dipole antenna 5 meters above ground generally creates more RF exposure at ground level than other kinds of antennas

Exam Questions

- The following slides contain questions from the exam pool that are covered in this section of the notes

T0A01

- T0A01 What is the minimum voltage that is usually dangerous to humans?
- A. 30 volts
 - B. 100 volts
 - C. 1000 volts
 - D. 2000 volts

T0A02

- T0A02 Which electrical circuit draws high current?
- A. An open circuit
 - B. A dead circuit
 - C. A closed circuit
 - D. A short circuit

T0A03

- T0A03 What could happen to your transceiver if you replace its blown 5 amp AC line fuse with a 30 amp fuse?
- A. The 30-amp fuse would better protect your transceiver from using too much current
 - B. The transceiver would run cooler
 - C. The transceiver could use more current than 5 amps and a fire could occur
 - D. The transceiver would not be able to produce as much RF output

T0A04

- T0A04 How much electrical current flowing through the human body will probably be fatal?
- A. As little as 1/10 of an ampere
 - B. Approximately 10 amperes
 - C. More than 20 amperes
 - D. Current through the human body is never fatal

T0A05

- T0A05 Which body organ can be fatally affected by a very small amount of electrical current?
- A. The heart
 - B. The brain
 - C. The liver
 - D. The lungs

T0A07

- T0A07 Which potential does the green wire in a three-wire electrical plug represent?
- A. Neutral
 - B. Hot
 - C. Hot and neutral
 - D. Ground

T0A08

- T0A08 What is an important consideration for the location of the main power switch?
- A. It must always be near the operator
 - B. It must always be as far away from the operator as possible
 - C. Everyone should know where it is located in case of an emergency
 - D. It should be located in a locked metal box so no one can accidentally turn it off

T0A09

- T0A09 What circuit should be controlled by a safety interlock switch in an amateur transceiver or power amplifier?
- A. The power supply
 - B. The IF amplifier
 - C. The audio amplifier
 - D. The cathode bypass circuit

T0A10

- T0A10 What type of electrical circuit is created when a fuse blows?
- A. A closed circuit
 - B. A bypass circuit
 - C. An open circuit
 - D. A short circuit

T0A11

- T0A11 Why would it be unwise to touch an ungrounded terminal of a high voltage capacitor even if it's not in an energized circuit?
- A. You could damage the capacitor's dielectric material
 - B. A residual charge on the capacitor could cause interference to others
 - C. You could damage the capacitor by causing an electrostatic discharge
 - D. You could receive a shock from a residual stored charge

T0A12

- T0A12 What safety equipment item should you always add to home built equipment that is powered from 110 volt AC lines?
- A. A fuse or circuit breaker in series with the equipment
 - B. A fuse or circuit breaker in parallel with the equipment
 - C. Install Zener diodes across AC inputs
 - D. House the equipment in a plastic or other non-conductive enclosure

T0A13

- T0A13 When fuses are installed in 12-volt DC wiring, where should they be placed?
- A. At the radio
 - B. Midway between voltage source and radio
 - C. Fuses aren't required for 12-volt DC equipment
 - D. At the voltage source

T0A06

- T0A06 For best protection from electrical shock, what should be grounded in an amateur station?
- A. The power supply primary
 - B. All station equipment connected to a common ground
 - C. The antenna feed line
 - D. The AC power mains

T0B01

- T0B01 How can an antenna system best be protected from lightning damage?
- A. Install a balun at the antenna feed point
 - B. Install an RF choke in the antenna feed line
 - C. Ground all antennas when they are not in use
 - D. Install a fuse in the antenna feed line

T0B02

- T0B02 How can amateur station equipment best be protected from lightning damage?
- A. Use heavy insulation on the wiring
 - B. Never turn off the equipment
 - C. Disconnect the ground system from all radios
 - D. Disconnect all equipment from the power lines and antenna cables

T0C10

- T0C10 Which of the following is considered to be non-Ionizing radiation?
- A. X-radiation
 - B. Gamma radiation
 - C. Ultra violet radiation
 - D. Radio frequency radiation

T0C17

- T0C17 Why is the concept of "specific absorption rate (SAR)" one factor used to determine safe RF radiation exposure levels?
- A. It takes into account the overall efficiency of the final amplifier
 - B. It takes into account the transmit/receive time ratio during normal amateur communication
 - C. It takes into account the rate at which the human body absorbs RF energy at a particular frequency
 - D. It takes into account the antenna feed line loss

T0C18

- T0C18 Why must the frequency of an RF source be considered when evaluating RF radiation exposure?
 - A. Lower-frequency RF fields have more energy than higher-frequency fields
 - B. Lower-frequency RF fields penetrate deeper into the body than higher- frequency fields
 - C. Higher-frequency RF fields are transient in nature, and do not affect the human body
 - D. The human body absorbs more RF energy at some frequencies than at others

T0D02

- T0D02 Why do exposure limits vary with frequency?
- A. Lower-frequency RF fields have more energy than higher-frequency fields
 - B. Lower-frequency RF fields penetrate deeper into the body than higher- frequency fields
 - C. The body's ability to absorb RF energy varies with frequency
 - D. It is impossible to measure specific absorption rates at some frequencies

T0E07

- T0E07 On what value are the maximum permissible exposure (MPE) limits based?
- A. The square of the mass of the exposed body
 - B. The square root of the mass of the exposed body
 - C. The whole-body specific gravity (WBSG)
 - D. The whole-body specific absorption rate (SAR)

T0E08

- T0E08 What is one biological effect to the eye that can result from RF exposure?
- A. The strong magnetic fields can cause blurred vision
 - B. The strong magnetic fields can cause polarization lens
 - C. It can cause heating, which can result in the formation of cataracts
 - D. It can cause heating, which can result in astigmatism

T0E09

- T0E09 Which of the following effects on the human body are a result of exposure to high levels of RF energy?
- A. Very rapid hair growth
 - B. Very rapid growth of fingernails and toenails
 - C. Possible heating of body tissue
 - D. High levels of RF energy have no known effect on the human body

T0E11

- T0E11 What is one effect of RF non-ionizing radiation on the human body?
- A. Cooling of body tissues
 - B. Heating of body tissues
 - C. Rapid dehydration
 - D. Sudden hair loss

T0C01

- T0C01 What is radio frequency radiation?
- A. Waves of electric and magnetic energy between 3 kHz and 300 GHz
 - B. Ultra-violet rays emitted by the sun between 20 Hz and 300 GHz
 - C. Sound energy given off by a radio receiver
 - D. Beams of X-Rays and Gamma rays emitted by a radio transmitter

T0C03

- T0C03 Which of the following units of measurement are used to specify the power density of a radiated RF signal?
- A. Milliwatts per square centimeter
 - B. Volts per meter
 - C. Amperes per meter
 - D. All of these choices are correct

T0C04

- T0C04 Over what frequency range are the FCC Regulations most stringent for RF radiation exposure?
- A. Frequencies below 300 kHz
 - B. Frequencies between 300 kHz and 3 MHz
 - C. Frequencies between 3 MHz and 30 MHz
 - D. Frequencies between 30 MHz and 300 MHz

T0C06

- T0C06 From an RF safety standpoint, what impact does the duty cycle have on the minimum safe distance separating an antenna and people in the neighboring environment?
 - A. The lower the duty cycle, the shorter the compliance distance
 - B. The compliance distance is increased with an increase in the duty cycle
 - C. Lower duty cycles subject people in the environment to lower radio-frequency radiation
 - D. All of these answers are correct

T0C09

- T0C09 (B) What unit of measurement specifies RF electric field strength?
- A. Coulombs (C) at one wavelength from the antenna
 - B. Volts per meter (V/m)
 - C. Microfarads (uF) at the transmitter output
 - D. Microhenrys (uH) per square centimeter

T0C11

- T0C11 What do the FCC RF radiation exposure regulations establish?
- A. Maximum radiated field strength
 - B. Minimum permissible HF antenna height
 - C. Maximum permissible exposure limits
 - D. All of these choices are correct

T0C12

- T0C12 Which of the following steps would help you to comply with RF-radiation exposure guidelines for uncontrolled RF environments?
- A. Reduce transmitting times within a 6-minute period to reduce the station duty cycle
 - B. Operate only during periods of high solar absorption
 - C. Reduce transmitting times within a 30-minute period to reduce the station duty cycle
 - D. Operate only on high duty cycle modes

T0C13

- T0C13 Which of the following steps would help you to comply with RF-exposure guidelines for controlled RF environments?
- A. Reduce transmitting times within a 30-minute period to reduce the station duty cycle
 - B. Operate only during periods of high solar absorption
 - C. Reduce transmitting times within a 6-minute period to reduce the station duty cycle
 - D. Operate only on high duty cycle modes

T0C14

- T0C14 To avoid excessively high human exposure to RF fields, how should amateur antennas generally be mounted?
- A. With a high current point near ground
 - B. As far away from accessible areas as possible
 - C. On a nonmetallic mast
 - D. With the elements in a horizontal polarization

T0C15

- T0C15 What action can amateur operators take to prevent exposure to RF radiation in excess of the FCC-specified limits?
- A. Alter antenna patterns
 - B. Relocate antennas
 - C. Revise station technical parameters, such as frequency, power, or emission type
 - D. All of these choices are correct

T0C16

- T0C16 (C) Which of the following radio frequency emissions will result in the least RF radiation exposure if they all have the same peak envelope power (PEP)?
- A. Two-way exchanges of phase-modulated (PM) telephony
 - B. Two-way exchanges of frequency-modulated (FM) telephony
 - C. Two-way exchanges of single-sideband (SSB) telephony
 - D. Two-way exchanges of Morse code (CW) communication

T0C19

- T0C19 What is the maximum power density that may be emitted from an amateur station under the FCC RF radiation exposure limits?
- A. The FCC Rules specify a maximum emission of 1.0 milliwatt per square centimeter
 - B. The FCC Rules specify a maximum emission of 5.0 milliwatts per square centimeter
 - C. The FCC Rules specify exposure limits, not emission limits
 - D. The FCC Rules specify maximum emission limits that vary with frequency

T0D06

- T0D06 Why should you never look into the open end of a microwave feed horn antenna while the transmitter is operating?
- A. You may be exposing your eyes to more than the maximum permissible exposure of RF radiation
 - B. You may be exposing your eyes to more than the maximum permissible exposure level of infrared radiation
 - C. You may be exposing your eyes to more than the maximum permissible exposure level of ultraviolet radiation
 - D. All of these choices are correct

T0E03

- T0E03 To determine compliance with the maximum permitted exposure (MPE) levels, safe exposure levels for RF energy are averaged for an "uncontrolled" RF environment over what time period?
- A. 6 minutes
 - B. 10 minutes
 - C. 15 minutes
 - D. 30 minutes

T0E04

- T0E04 To determine compliance with the maximum permitted exposure (MPE) levels, safe exposure levels for RF energy are averaged for a "controlled" RF environment over what time period?
- A. 6 minutes
 - B. 10 minutes
 - C. 15 minutes
 - D. 30 minutes

T0E05

- T0E05 Why are Amateur Radio operators required to meet the FCC RF radiation exposure limits?
 - A. The standards are applied equally to all radio services
 - B. To ensure that RF radiation occurs only in a desired direction
 - C. Because amateur station operations are more easily adjusted than those of commercial radio services
 - D. To ensure a safe operating environment for amateurs, their families and neighbors

T0E06

- T0E06 At what frequencies do the FCC's RF radiation exposure guidelines incorporate limits for Maximum Permissible Exposure (MPE)?
- A. All frequencies below 30 MHz
 - B. All frequencies between 20,000 Hz and 10 MHz
 - C. All frequencies between 300 kHz and 100 GHz
 - D. All frequencies above 300 GHz

T0F05

- T0F05 Which of the following antennas would (generally) create a stronger RF field on the ground beneath the antenna?
- A. A horizontal loop at 30 meters above ground
 - B. A 3-element Yagi at 30 meters above ground
 - C. A 1/2 wave dipole antenna 5 meters above ground
 - D. A 3-element Quad at 30 meters above ground

T0F12

- T0F12 As a general rule, what effect does antenna height above ground have on the RF exposure environment?
 - A. Power density is not related to antenna height or distance from the RF exposure environment
 - B. Antennas that are farther above ground produce higher maximum permissible exposures (MPE)
 - C. The higher the antenna the less the RF radiation exposure at ground level
 - D. RF radiation exposure is increased when the antenna is higher above ground

T0C05

- T0C05 (B) Which of the following categories describes most common amateur use of a hand-held transceiver? A. Mobile devices B. Portable devices C. Fixed devices D. None of these choices is correct

T0D01

- T0D01 (A) What factors must you consider if your repeater station antenna will be located at a site that is occupied by antennas for transmitters in other services? A. Your radiated signal must be considered as part of the total RF radiation from the site when determining RF radiation exposure levels B. Each individual transmitting station at a multiple transmitter site must meet the RF radiation exposure levels C. Each station at a multiple-transmitter site may add no more than 1% of the maximum permissible exposure (MPE) for that site D. Amateur stations are categorically excluded from RF radiation exposure evaluation at multiple-transmitter sites

T0C02

- T0C02 (B) Why is it a good idea to adhere to the FCC's Rules for using the minimum power needed when you are transmitting with your hand-held radio? A. Large fines are always imposed on operators violating this rule B. To reduce the level of RF radiation exposure to the operator's head C. To reduce calcification of the NiCd battery pack D. To eliminate self-oscillation in the receiver RF amplifier

T0D03

- T0D03 (C) Why might mobile transceivers produce less RF radiation exposure than hand-held transceivers in mobile operations? A. They do not produce less exposure because they usually have higher power levels. B. They have a higher duty cycle C. When mounted on a metal vehicle roof, mobile antennas are generally well shielded from vehicle occupants D. Larger transmitters dissipate heat and energy more readily

T0F13

- T0F13 (C) Why does the FCC consider a hand-held transceiver to be a portable device when evaluating for RF radiation exposure? A. Because it is generally a low-power device B. Because it is designed to be carried close to your body C. Because it's transmitting antenna is generally within 20 centimeters of the human body D. All of these choices are correct