RADIO COMMUNICATIONS

An Amateur Radio Technician and General Class License Study Guide

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Based on the
Element 2 Technician Exam Question Pool Valid from 7/1/06 until 7/1/2010
and the
Element 3 General Exam Question Pool Valid 7/1/2007 until 7/1/2011

Acknowledgment:

My greatest thanks to Lynette – KD5QMD,
for her understanding and assistance, without which this book
would be filled with countless typographical and grammatical errors and
an overload of confusing jargon and
bewildering techno-babble.

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However,
Share the Fun.

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If you love the hobby you have a duty of honor
to pass it along to the next generation.

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How to use this study guide.

Contained within the next 73 pages is a text derived from the official exam question pools for Element 2 Technician and Element 3 General class exams.

It is the expressed opinion of the author and editor of this study guide that studying the full question pool text is counterproductive in attempting to obtain your Amateur Radio License.

We therefore do not recommend downloading the actual exam question pool texts.

This study guide is divided into sections of related information. Each section deals with a set of facts representing a block of the exam pool questions. The explanatory text is based on answering questions about the subjects contained in each block that have commonly been asked in classes over the years.

At the end of each section, the actual exam question text is displayed so that you may become familiar with the questions you will see on the exams.

Questions for the Element 2 exam are identified with question numbers starting with a T
Questions for the Element 3 are identified with questions numbers starting with a G.
Examples are shown below.

> T2A03 [97.113(a)(4), 97.211(b), 97.217] When is the transmission of codes or ciphers allowed to hide the meaning of a message transmitted by an amateur station?
> Only when transmitting control commands to space stations or radio control craft.
>
> G1B06 [97.113(a)(4) and 97.207(f)] When is an amateur station permitted to transmit secret codes?
> To control a space station.

In some there is a reference in [square brackets] that is a citation of the relevant info in Part 97 of the FCC rules and Regulations.

All the distractor answers have been removed to avoid placing the incorrect information in your mind while studying.

During the exams you should generally go with the first impression you have about the correct answer as your selected answer.

This study guide does not represent the total of knowledge you should have as a radio operator, but only represents the beginning step required to pass the Technician class license exam and the General class license exam. Since amateur radio is an on the job training program, you can continue to develop skills and knowledge about radio communications. When you have developed your skills and knowledge a bit, you can share it by teaching others about amateur radio.

If you have questions and need an answer, I will reply to email at:

jnordlund@earthlink.net

Be sure to put “Ham Radio Class Question” in the subject line.

We hope your study experience is a pleasant and successful one.

73 and good luck - AD5FU, John and KD5QMD, Lynette.

Have fun!

Let's get started..

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What is Amateur Radio?

Basis and purpose of the Amateur Radio Service ...

One of the basic purposes of the Amateur Radio Service as defined in Part 97 is to provide a voluntary noncommercial communications service to the public, particularly in times of emergency. Second is the continuation and extension of the amateur's proven ability to contribute to the advancement of the radio art. Third is the encouragement and improvement of the amateur service through rules which provide for advancing skills in both the communication and technical phases of the art. The last two of the five fundamental purposes for the Amateur Radio Service are to increase the number of trained radio operators and electronics experts, and to improve international goodwill.

Amateur radio has an established track record of providing communications in disasters when all other methods of communication have failed. Emergency agencies depend on us for that vital service because they know what we can do for them. We get out and explore what we can do with our equipment for the sake of the exploration. Along the way we acquire skills and experience that can not be obtained in any other way in the field of how to get the message 'from here to there' and back again. We make friends in distant places, some of whom we will never meet in person. We recognize them by voice and name. We are aware of the trials and triumphs in their lives just as if they lived across the street from us.

T1A02 [97.1] What is one of the basic purposes of the Amateur Radio Service as defined in Part 97?
To provide a voluntary noncommercial communications service to the public, particularly in times of emergency.

T1A08 [97.1] What are two of the five fundamental purposes for the Amateur Radio Service?
To increase the number of trained radio operators and electronics experts, and improve international goodwill.

Station Operations.

Rules and Regulations - Authority

The ITU (International Telecommunication Union) is the United Nations Agency that is responsible for the administration of international treaties and regulations of radio services world wide. The ITU divides the world into Regions that are used to assist in the management of frequency allocations. The Continental United States is in ITU Region 2.

Under authority given by the Communications Act of 1931, the Federal Communications Commission (FCC) makes and enforces the rules for the Amateur Radio Service in the United States. Those rules are known officially as the Code of Federal Regulations 47 part 97. We refer to this set of rules for the Amateur Radio Service as Part 97. The Federal Communications Commission is the government agency that grants your amateur radio license.

At any time the FCC may inspect your station equipment and records. Unless you have been very naughty, they will contact you to make an appointment for that inspection. The legal authority to conduct those inspections is granted in the law and regulations cited above.

A US amateur operator may communicate with an amateur in a foreign country at any time unless prohibited by either government. Most countries that allow their citizens to have amateur radio licenses have no objections to those licensees contacting US operators, but you do need to take note that if the other government objects to the contact, your government forbids contacting them via ham radio.

T1B01 [97.3(a)(28)] What is the ITU?
The International Telecommunication Union.

T1B02 [97.301] What is the purpose of ITU Regions?
They are used to assist in the management of frequency allocations.

T1A07 [97.5] Who makes and enforces the rules for the Amateur Radio Service in the United States?
The Federal Communications Commission.

T1D04 [97.5(a)] What government agency grants your amateur radio license?
The Federal Communications Commission.

T2D08 [97.103(c)] When is the FCC allowed to inspect your station equipment and station records?
At any time upon request.

T1C10 [97.111] When may a US amateur operator communicate with an amateur in a foreign country?
At any time unless prohibited by either government.

The License.

An amateur operator as defined in Part 97 is a person named in an amateur operator/primary license grant in the FCC ULS (Uniform Licensing System) database. The definition of an amateur radio station is a station in the Amateur Radio Service consisting of the apparatus necessary for carrying on radio communications. The license and callsign assigned to you in the amateur radio service is for both you as an operator and your station and its equipment. Only in the Amateur Radio Service is an operator/station license issued by the FCC. In all other radio services the station license has the callsign associated with it. The operator license when required has no callsign, but serves only as certification of a person being qualified to operate a station in their respective service. A person may hold only one amateur operator/primary station license.

The classes of US amateur radio licenses that may currently be earned by examination are Technician, General, and Extra. There are two other classes of license in the amateur radio service, the Novice and the Advanced class but there is no testing for those licenses in the current system. Novice and Advanced licenses are still renewable.

You may transmit after passing the required examination elements for your first amateur radio license and as soon as your license grant appears in the FCC ULS database.

An amateur radio license is usually granted for a period of 10 years and can be renewed at any time within 90 days of it's expiration date and for as long as 2 years after expiring without taking a new examination. You are not allowed to transmit during the 2 year “grace” period. You are allowed to transmit only when your name and callsign are listed as valid in the FCC ULS database.

T1A01 [97.3(a)(1)] Who is an amateur operator as defined in Part 97?
A person named in an amateur operator/primary license grant in the FCC ULS database.

T2C02 [97.5(b)(1)] How many amateur operator / primary station licenses may be held by one person?
Only one.

T1A09 [97.3(a)(5)] What is the definition of an amateur radio station?
A station in an Amateur Radio Service consisting of the apparatus necessary for carrying on radio communications.

T1D01 [97.17(a)] Which of the following services are issued an operator station license by the FCC?
Amateur Radio Service.

T1A03 [97.501] What classes of US amateur radio licenses may currently be earned by examination?
Technician, General, Extra.

T1D05 [97.5(a)] How soon may you transmit after passing the required examination elements for your first amateur radio license?
As soon as your license grant appears in the FCC's ULS database.

T1D06 [97.25(a)] What is the normal term for an amateur station license grant?
10 years.

T1D07 [97.21(b)] What is the grace period during which the FCC will renew an expired 10-year license without re-examination?
2 years.

Who can get it?

Anyone can become an amateur licensee in the US except a representative of a foreign government. If you are a spy, put down the book and back away.. There is no minimum age requirement to hold an amateur license. Children as young as 7 years have obtained licenses all the way to Extra class. There is no requirement to be a US citizen. If you can pass the exam elements required you will receive a license to operate.

T1D02 [97.5(b)(1)] Who can become an amateur licensee in the US?
Anyone except a representative of a foreign government.

T1D03 [97.5(b)(1)] What is the minimum age required to hold an amateur license?
There is no minimum age requirement.

Where can you use it?

A US amateur license allows you to transmit on amateur radio frequencies from wherever the Amateur Radio Service is regulated by the FCC and where reciprocal agreements are in place. A “reciprocal operating agreement” means that the officials of the other nation recognize your license as valid inside the territory of the other nation. You are allowed to operate your amateur station in a foreign country when there is a reciprocal operating agreement between the countries. A good example would be operating while visiting Canada. Canada recognizes US licenses and the US recognizes Canadian licenses as authority to operate. Where there is no reciprocal agreement between the US and another country you may be able to obtain a license issued by the other nation for use during your visit. You need to remember that while in a foreign nation you must follow the rules and regulations of that nation regarding radio operations even if your US license is recognized by that nation as operating authority.

T1B07 [97.107] When are you allowed to operate your amateur station in a foreign country?
When there is a reciprocal operating agreement between the countries.

Other requirements.

An Amateur radio operator must have a correct name and mailing address on file with the FCC to receive mail delivery from the FCC by the United States Postal Service. If mail is returned to the FCC as undeliverable the FCC may revoke or suspend a license because the mailing address of the holder is not current with the FCC. The address the FCC requires to be kept up to date on the Universal Licensing System database is the station licensee's mailing address. If you have issues with having your address published in an open database, you can use a Post Office Box number as your mailing address. You must keep the address listed in the ULS current when you move.

Your responsibility as a station licensee is to insure that your station operates in accordance with the FCC rules at all times.

T1D08 [97.103(a)] What is your responsibility as a station licensee?
Your station must be operated in accordance with the FCC rules.

T1D09 [97.23] When may the FCC revoke or suspend a license if the mailing address of the holder is not current with the FCC?
If mail is returned to the FCC as undeliverable.

T1D10 [97.23] The FCC requires which address to be kept up to date on the Universal Licensing System database?
The station licensee mailing address.

T1D11 [97.21(b)] When are you permitted to continue to transmit if you forget to renew your amateur license and it expires?
Transmitting is not allowed until the license is renewed and appears on the FCC ULS database.

T1C01 [97.5(a)] What is required before you can control an amateur station in the US?
You must be named in the FCC amateur license database, or be an alien with reciprocal operating authorization.

T1C02 [97.5(a)] Where does a US amateur license allow you to transmit?
From wherever the Amateur Radio Service is regulated by the FCC and where reciprocal agreements are in place.

T1C03 [97.111] Under what conditions are amateur stations allowed to communicate with stations operating in other radio services?
When authorized by the FCC.

T1D12 [97.23] Why must an Amateur radio operator have a correct name and mailing address on file with the FCC?
To receive mail delivery from the FCC by the United States Postal Service.

Callsigns.

In most cases the system the FCC uses to select new amateur radio callsigns is based on the callsigns being assigned in sequential order.
By international agreement the letters that must be used for the first letter in US amateur callsigns are A, K, N and W, and the number used in US amateur callsigns is a **single** digit, 0 through 9. The number usually refers to a region of the country where the callsign was issued. The letters after the number are used sequentially just like on automobile license plates. Examples would look like 'AD5FU' 'KD5QMD' 'W5RXU' 'N5WVI' 'W7OHM' 'KK7C' 'W1AW'

KB3TMJ is an example of a valid US amateur callsign. On the exam they might offer callsigns like UZ4FWD, KBL7766, or VE3TWJ. While KBL7766 does start with a K and would be a US callsign, the callsign does not follow the format rules for Amateur Radio callsigns.

The FCC callsign program you might use to obtain a callsign containing your initials is the vanity callsign program. With a vanity callsign you are not restricted to the district number where you live, but you can apply for any callsign that is not currently in use or has been expired for less than 2 years. The previous licensee can renew the license associated with a callsign for up to two years after it expires. There is a charge for vanity callsigns that must be paid at the time you apply for one and whenever it is renewed.

Any FCC-licensed amateur is eligible to apply for temporary use of a 1-by-1 format Special Event callsign. An example of a 1x1 callsign would be 'W3X' A special event station is a station set up to commemorate some event of significance. Usually the operators that set up a special event station also provide some type of certificate for contacts to that station event. Special event callsigns expire after a 30 day period and the callsign is returned to the pool for later use. Some amateurs make collecting special event certificates a central part of their involvement in the radio hobby.

T1B03 [97.17(d)] What system does the FCC use to select new amateur radio callsigns?
callsigns are assigned in sequential order.

T1B04 [97.19(d)] What FCC callsign program might you use to obtain a callsign containing your initials?
The vanity callsign program.

T1B05 [97.17(b)(2)] How might an amateur radio club obtain a club station callsign?
By applying through a Club Station callsign Administrator.

T7A10 What is a special event station?
A temporary station that operates in conjunction with an activity of special significance.

T1B06 Who is eligible to apply for temporary use of a 1-by-1 format Special Event callsign?
Any FCC-licensed amateur.

T1B08 Which of the following callsigns is a valid US amateur call?
A. UZ4FWD
B. KBL7766
C. KB3TMJ
D. VE3TWJ

T1B09 What letters must be used for the first letter in US amateur callsigns?
A, K, N and W.

T1B10 What numbers are used in US amateur callsigns?
A single digit, 0 through 9.

The Control Operator.

The definition of a control operator of an amateur station is an operator designated by the licensee to be responsible for the station's transmissions to assure compliance with FCC rules. Before you can control an amateur station in the US or it's territories, you must be named in the FCC amateur license database, or be an alien with reciprocal operating authorization.

An amateur station must have a control operator whenever the station is transmitting. You may share the radio experience with friends or family by letting them operate while you are present to supervise their actions on the air. Remember the control operator is responsible for the transmissions from an amateur station.

Unlicensed persons in your family are not allowed to transmit on your amateur station if you are not there because they must be licensed before they are allowed to be control operators. You might best keep unauthorized persons from using your amateur station by disconnecting the power and microphone cables when not using your equipment.

The minimum class of amateur license must you hold to be a control operator of a repeater station is a Technician license.

T2C01 [97.7] What must every amateur station have when transmitting?
A control operator.

T2C05 [97.7] When must an amateur station have a control operator?
Whenever the station is transmitting.

T2C04 [97.3(a)(1)(2)] Who is responsible for the transmissions from an amateur station?
The control operator.

T2D09 How might you best keep unauthorized persons from using your amateur station?
Disconnect the power and microphone cables when not using your equipment.

T2D10 [97.109(b)] Why are unlicensed persons in your family not allowed to transmit on your amateur station if you are not there?
They must be licensed before they are allowed to be control operators.

T2C03 [97.205(a)] What minimum class of amateur license must you hold to be a control operator of a repeater station?
Technician.

Club stations.

An amateur radio club might obtain a club station callsign by applying through a Club Station callsign Administrator. The trustee of a club station is the person responsible for maintaining station records and responding to official mail from the FCC. At least 4 persons are required to be members of a club for a club station license to be issued by the FCC.

T2D06 [97.5(b)(2)] How many persons are required to be members of a club for a club station license to be issued by the FCC?
At least 4.

Sharing your station with another ham.

The operating privileges allowed when another amateur holding a higher class license is controlling your station are all privileges allowed by the higher class license. When you are the control operator at the station of another amateur who has a higher class license than yours, only the privileges allowed by your license may be used. In either situation, both of you are responsible for proper operation of the station.

T2D01 [97.103(a)] Who is responsible for proper operation if you transmit from another amateur's station?
Both of you.

T2D02 [97.105(b)] What operating privileges are allowed when another amateur holding a higher class license is controlling your station?
All privileges allowed by the higher class license.

T2D03 [97.105(b)] What operating privileges are allowed when you are the control operator at the station of another amateur who has a higher class license than yours?
Only the privileges allowed by your license

In the air or on the Sea.

You may operate your amateur station aboard an aircraft only with the approval of the pilot in command and not using the aircraft's radio equipment. The same rules apply when operating on a ship at sea. The ultimate authority to operate subject to the terms of your license, is granted by the pilot or captain of the vessel and must be done with other equipment than the aircraft or ship communication equipment. Some cruise lines have amateur radio equipment available for guests with licenses to use. When operating in a plane or on a ship, remember that your license does not grant you the authority to operate in the territorial airspace or waters of another nation unless you have a permit, license, or reciprocal authorization from that nation.

T2D07 [97.11(a)] When may you operate your amateur station aboard an aircraft?
Only with the approval of the pilot in command and not using the aircraft's radio equipment.

The Control Point.

The control point of an amateur station is the location at which the control operator function is performed. This location is usually the same as the transmitter location, but not always. An example of this would be where the radio equipment is located on the upper floors of a building and the operating location is at ground level. Some form of wiring or radio link is required to connect the operating position and the equipment. A similar example would be a remote base. In this case the radio equipment is located on a mountain and the operating location is somewhere more convenient for use, like a home. Both of these examples are cases of “remote control” in action. Remote control is when the control operator is not at the physical transmitter location but can still make changes to and supervise the operation of the transmitter.

The three types of station control permitted and recognized by FCC rule are local, remote, and automatic control.

The type of control being used on a repeater when the control operator is not present is automatic control. All the control functions are performed by computer-based devices that control the operating conditions of the repeater system. The control operator does not have to be at the control point. Persons using the repeater are held responsible for their own actions when using the system. The control operator is responsible for making sure that the transmitting equipment does not malfunction, and that known offenders are not allowed to use the system.

The type of control being used when transmitting using a handheld or mobile radio is local control. You are at the same physical location as the transmitting equipment. This is the most common type of station control in use.

T2C06 [97.3] What is the control point of an amateur station?
The location at which the control operator function is performed.

T2C07 [97.109(d)] What type of amateur station does not require a control operator to be at the control point?
An automatically controlled station.

T2C08 [97.3(a)] What are the three types of station control permitted and recognized by FCC rule?
Local, remote and automatic control.

T2C09 [97.3(a)] What type of control is being used on a repeater when the control operator is not present?
Automatic control.

T2C10 [97.109(a)] What type of control is being used when transmitting using a handheld radio?
Local control.

T2C11 [97.3] What type of control is used when the control operator is not at the station location but can still make changes to a transmitter?
Remote control.

T2C12 [97.3(a)(13)] What is the definition of a control operator of an amateur station?
An operator designated by the licensee to be responsible for the station's transmissions to assure compliance with FCC rules.

Station Identification Rules.

A transmission that does not contain a station identification is called unidentified communications or signals. Whenever your station transmits you are required to identify it. The longest period of time an amateur station can operate without transmitting its callsign is 10 minutes. When two amateur stations end communications, identification is required and each station must transmit its own callsign.

There are only a couple of exceptions to this rule. An amateur station may transmit unidentified communications when sent from a space station such as an amateur satellite, the Shuttle, or the International Space Station. If you are using your amateur radio to control a model craft you are not required to transmit an identification if the transmitter power does not exceed 1 watt and you have attached a label with your name and callsign to the transmitter.

An illegal unidentified transmission describes a brief test transmission that does not include any station identification. When making a transmission to test equipment or antennas an amateur must properly identify the station at least every ten minutes and at the end of every transmission.

T2B01 [97.119(a)] What must you transmit to identify your amateur station?
Your callsign.

T2B02 [97.119(a)] What is a transmission called that does not contain a station identification?
Unidentified communications or signals.

T2B03 [97.119(a)] How often must an amateur station transmit the assigned callsign?
Every 10 minutes during communications and at the end of each communication.

T2A05 [97.119(b)] When may an amateur station transmit unidentified communications?
Only when sent from a space station or to control a model craft.

T3A05 [97.119(a)] What term describes a brief test transmission that does not include any station identification?
An illegal unidentified transmission.

T3A06 What must an amateur do when making a transmission to test equipment or antennas?
Properly identify the station.

T3A07 Which of the following is true when making a test transmission?
Station identification is required at least every ten minutes and at the end of every transmission.

T2B05 [97.119(a)] What identification is required when two amateur stations end communications?
Each station must transmit its own callsign.

T2B06 [97.119(a)] What is the longest period of time an amateur station can operate without transmitting its callsign?
10 minutes.

Special Identification Rules.

When you are speaking to another amateur operator using a language other than English you must identify using the English language. All the same rules about 10 minute intervals and end of communications still apply.

While operating using a special event callsign you must identify using your own assigned callsign once per hour. Typically this is done by giving the event callsign followed by " (your call) at the mike." or language to that effect. It is good practice to also do this when changing control operators as this is really the same as ending communications.

If you are using one or more self-assigned indicators with your assigned callsign, the indicator must not conflict with an indicator specified by FCC rules or with a prefix assigned to another country. This rule is addressed primarily at digital operations where you may have several relay stations located in different places all using your call and on the same frequency. For the traffic routing protocols to work, a hyphen followed by a number is appended to the callsign so that other stations can uniquely identify each relay point.

The correct way to identify when visiting a station if you hold a higher class license than that of the station licensee and you are using a frequency not authorized to his class of license is to send his callsign first, followed by your callsign. This is a much mis-understood regulation. If a General class operator is visiting your station and you are a Technician class operator, the visitor, when operating outside of your license authority, is still using your station equipment to transmit. The callsign that should be sent first is your callsign, followed by the visiting callsign to allow using privileges greater than your own.

When exercising the operating privileges earned by examination upgrade of a license you would append "/AG" to your callsign, meaning “authorized General.”

T2B07 [97.119(b)(2)] What is a permissible way to identify your station when you are speaking to another amateur operator using a language other than English?
You must identify using the English language.

T2B08 [97.119(d)] How often must you identify using your assigned callsign when operating while using a special event callsign?
Once per hour.

T2B09 [97.119(4)(c)] What is required when using one or more self-assigned indicators with your assigned callsign?
The indicator must not conflict with an indicator specified by FCC rules or with a prefix assigned to another country.

T2B10 [97.119(e)] What is the correct way to identify when visiting a station if you hold a higher class license than that of the station licensee and you are using a frequency not authorized to his class of license?
Send his callsign first, followed by your callsign.

T2B11 [97.119(f)(2)] When exercising the operating privileges earned by examination upgrade of a license what is meant by use of the indicator "/AG"?

Authorized General.

G1E09 [97.119(b)(2)] What language must you use when identifying your station if you are using a language other than English in making a contact?
English.

G1D01 [97.119(f)(2)] What is the proper way to identify when transmitting on General class frequencies if you have a CSCE for the required elements but your upgrade from Technician has not appeared in the ULS database?
Give your callsign followed by the words "temporary AG".

G1D06 [97.119(f)(2)] When must you add the special identifier "AG" after your callsign if you are a Technician Class licensee and have a CSCE for General Class operator privileges?
Whenever you operate using General class frequency privileges.

Wavelength and Frequency.

Radio waves travel through space at the speed of light, or about 300,000,000 meters per second. As the electromagnetic wave moves away from it's source, like the ripples in a pond, the points in space with the same value as the previous or the next wave will be physically separated by a distance known as the wavelength. You will often see the the Greek letter lambda (λ) used to identify the wavelength in formulas. We often identify groups of frequencies by their wavelength.

$$\lambda = \frac{c}{F} \quad \text{or} \quad \lambda_{meters} = \frac{300{,}000{,}000}{Frequency_{Hertz}} \quad \text{or a little easier to use} \quad \lambda_{meters} = \frac{300}{F_{MHz}}$$

There are several questions in the exam pools that will ask for the dimensions of antennas for a certain frequency. If you can remember this formula, you will have no trouble calculating the dimensions for any of those questions.
The basic unit of frequency is the Hertz. If we say that the frequency of a signal is 60 Hertz (Hz) we are saying that the signal waveform repeats 60 times each second.

Generally frequencies greater than 20,000 Hz are considered to be radio frequencies. Acoustic waves with higher frequencies do exist, but are not considered for the purposes of the exams. All of the essential information for recognizable speech is found between 300 and 3000 Hz.

T4B01 What is the name for the distance a radio wave travels during one complete cycle?
Wavelength.

T4B02 What term describes the number of times that an alternating current flows back and forth per second?
Frequency.

T4B03 What does 60 hertz (Hz) mean?
60 cycles per second.

T4B04 Electromagnetic waves that oscillate more than 20,000 times per second as they travel through space are generally referred to as what?
Radio waves.

T4B05 How fast does a radio wave travel through space?
At the speed of light.

T4B06 How does the wavelength of a radio wave relate to its frequency?
The wavelength gets shorter as the frequency increases.

T4B07 What is the formula for converting frequency to wavelength in meters?
Wavelength in meters equals 300 divided by frequency in megahertz.

T4B08 What are sound waves in the range between 300 and 3000 Hertz called?
Voice frequencies.

T4B09 What property of a radio wave is often used to identify the different bands amateur radio operators use?
The physical length of the wave.

Bands and Frequencies - Technician

This is one of the hardest parts of studying for your license to get your head around. There are many questions in both pools about frequency allocations on various bands. The only way to get these down is to memorize the band charts for all the bands referenced here. Don't panic! The good part is that the number of questions about specific frequencies on each exam element is very small.

The basic information for the tests is as follows..

For Technician operators:	Frequency	Band	Mode	Restrictions
	50 – 54 MHz	6 meter	Any	50.0-50.1 – CW only
	144 -- 148 MHz	2 meter	Any	144.0 -144.1 – CW only
CW Data only 219 - 220 MHz	222 – 225 MHz	1.25 meter	Any	Restricted portion is CW and Data only
	420 – 450 MHz	70 centimeter	Any	
	1240 – 1300 MHz	23 centimeter	Any	

This listing does not represent all the allocations for Technician licensees, but just those referenced in Element 2 pool questions.

There are some frequencies you need to recognize as a Technician class radio operator. For example 52.525 MHz is a frequency within the 6-meter band. You are using the 2 meter band when transmitting on 146.52 MHz. 443.350 MHz is a 70-centimeter frequency that is authorized to a Technician class license holder operating in ITU Region 2. 1296 MHz is a 23 centimeter frequency that is authorized to a Technician class license holder operating in ITU Region 2. If you are operating on 223.50 MHz, you are using the 1.25 meter band. The point-to-point digital message forwarding emission mode may be used by a Technician class operator in the 219 - 220 MHz frequency range.

While having a note card with the frequencies of band edges and sub-bands around as an operating aid is a good idea, these specific frequencies may be referenced in the questions you will see on your exam. Unfortunately you are not allowed to use such a reference aid when taking the exam.

When the FCC rules state that an amateur frequency band is said to be available on a secondary basis, amateurs may not cause harmful interference to primary users. We are operating essentially as guests in their band. If we cause interference to the other service we could lose access to those frequencies. An example of amateur radio as a secondary allocation is the 70 cm band where the primary service is military early warning radar. I think we can all agree that detecting incoming missiles is a bit more important than a conversation on the local 70 cm repeater.

On the 70 cm band and above, amateurs may transmit in standard NTSC video, just like broadcast TV. There are repeaters in some communities designed expressly for ATV or amateur television operation.

T1C04 [97.301(a)] Which frequency is within the 6-meter band?
52.525 MHz.

T1C05 [97.301(a)] Which amateur band are you using when transmitting on 146.52 MHz?
2 meter band.

T1C06 [97.301(a)] Which 70-centimeter frequency is authorized to a Technician class license holder operating in ITU Region 2?
443.350 MHz.

T1C07 [97.301(a)] Which 23 centimeter frequency is authorized to a Technician class license holder operating in ITU Region 2?
1296 MHz.

T1C08 [97.301(a)] What amateur band are you using if you are operating on 223.50 MHz?
1.25 meter band.

T1C09 [97.303] What do the FCC rules mean when an amateur frequency band is said to be available on a secondary basis?
Amateurs may not cause harmful interference to primary users.

T4B10 What is the frequency range of the 2 meter band in the United States?
144 to 148 MHz.

T4B11 What is the frequency range of the 6 meter band in the United States?
50 to 54 MHz.

T4B12 What is the frequency range of the 70 centimeter band in the United States?
420 to 450 MHz.

T3B08 [97.305(c)] Which of the bands available to Technician class licensees have mode restricted sub-bands?
The 6-meter, 2-meter, and 1 1/4-meter bands.

T3B09 [97.305 (a)(c)] What emission modes are permitted in the restricted sub-band at 50.0-50.1 MHz?
CW only.

T3B10 [97.305 (a)(c)] What emission modes are permitted in the restricted sub-band at 144.0-144.1 MHz?
CW only.

T3B11 [97.305 (a)(c)] What emission modes are permitted in the restricted portion of the 1 1/4-meter band?
CW and Data.

T6C04 What type of transmission is indicated by the term NTSC?
A standard fast scan color television signal.

T6C05 What emission mode may be used by a Technician class operator in the 219 - 220 MHz frequency range?
Point-to-point digital message forwarding.

Bands and Frequencies - General

There are secondary allocations that apply to the General class operator as well. When we are designated as secondary we must not cause interference to stations in the primary service. We must surrender the frequency when requested to do so, or when we encounter users from the primary services.

The General class license includes all the allocations of the Technician as well as the following HF bands..

CW and Data	Voice and Image	Band	Restrictions or notes
28.0 – 28.3 MHz	28.3 – 29.7 MHz	10 meters	
24.89 – 24.93MHz	24.93 – 24.99 MHz	12 meters	
21.0 – 21.2 MHz	21.3 – 21.45 MHz	15 meters	
18.068 – 18.11 MHz	18.11 – 18.168 MHz	17 meters	
14.025 – 14.15 MHz	14.225 – 14.35 MHz	20 meters	
10.1– 10.15 MHz	~~~~~~~~~~~	30 meters	**CW and Data only**, 200 watts PEP or less Secondary allocation worldwide.
7.025 – 7.125 MHz	7.175 – 7.3 MHz	40 meters	
~~	5 channels only	60 meters	**USB <u>voice only</u>,** 50 watts ERP, 2..8 kHz bandwidth Secondary allocation to US Govt agencies.
3.525 – 3.6 MHz	3.8 – 4.0 MHz	80/75meters	
1.8 – 2.0 MHz	1.8 – 2.0 MHz	160 meters	All modes across the whole band on 160

This is also not a complete listing of General class allocations, but only those referenced by Element 3 pool questions. Where there are gaps between the cw/data segment of the band and the voice segment, those frequencies are assigned to Advanced and Extra class operators.

G1A14 [97.303] Which of the following applies when the FCC rules designate the amateur service as a secondary user and another service as a primary user on a band?
Amateur stations are allowed to use the frequency band only if they do not cause harmful interference to primary users.

G1A15 [97.303] What must you do if, when operating on either the 30 or 60 meter bands, a station in the primary service interferes with your contact?
Stop transmitting at once and/or move to a clear frequency.

G1A16 [97.303(s)] Which of the following operating restrictions applies to amateur radio stations as a secondary service in the 60 meter band?
They must not cause harmful interference to stations operating in other radio services.

G1A01 [97.301(d)] On which of the following bands is a General Class license holder granted all amateur frequency privileges?
160, 30, 17, 12, and 10 meters.

G1A02 [97.305] On which of the following bands is phone operation prohibited?
30 meters.

G1A03 [97.305] On which of the following bands is image transmission prohibited?
30 meters.

G1A04 [97.303(s)] Which amateur band restricts communication to specific channels, using only USB voice, and prohibits all other modes, including CW and data?
60 meters.

G1C13 [97.303s] What is the maximum bandwidth permitted by FCC rules for amateur radio stations when operating on USB frequencies in the 60-meter band?
2.8 kHz.

G1A05 [97.301(d)] Which of the following frequencies is in the General Class portion of the 40 meter band?
7.250 MHz.

G1A06 [97.301(d)] Which of the following frequencies is in the 12 meter band?
24.940 MHz.

G1A07 [97.301(d)] Which of the following frequencies is within the General class portion of the 75 meter phone band?
3900 kHz.

G1A08 [97.301(d)] Which of the following frequencies is within the General Class portion of the 20 meter phone band?
14305 kHz.

G1A09 [97.301(d)] Which of the following frequencies is within the General Class portion of the 80 meter band?
3560 kHz.

G1A10 [97.301(d)] Which of the following frequencies is within the General Class portion of the 15 meter band?
21300 kHz.

G1A11 [97.301(d)] Which of the following frequencies is available to a control operator holding a General Class license?
A. 28.020 MHz
B. 28.350 MHz
C. 28.550 MHz
D. **All of these answers are correct.**

G1A12 [97.301] When a General Class licensee is not permitted to use the entire voice portion of a particular band, which portion of the voice segment is generally available to them?
The upper end.

G1A13 [97.303] Which amateur band is shared with the Citizens Radio Service?
None.

Third Party Traffic.

The definition of third-party communications is a message sent between two amateur stations for someone else. Another type of third party traffic is when we share our radio with an unlicensed person. The unlicensed person is the third party. You should not knowingly allow anyone that has had their license revoked to operate your station, even if you are present.

When handling third party messages into other countries we need to keep the content limited to radio related discussion or remarks of a personal character, or messages relating to emergencies or disaster relief. Discussions about their government or similar subjects might get the foreign amateur into trouble with authorities in his country.

We need to be aware of the rules for third party traffic when handling messages to persons in other countries. We are only allowed to pass messages to another country if there is a 'third party agreement' in place. This is to prevent the amateur radio service from competing with the message handling system in that country where there is no agreement in place. Usually the message services in question are owned and operated by that government, and there are fees/taxes to pay for getting the message delivered. The list of nations where we can handle third party traffic is available on the Internet at sites like WWW.ARRL.ORG. Remember, in countries where third party traffic is not allowed, we can not allow an unlicensed person to work the microphone, as this would be considered third party traffic also.

T2D05 (A) [97.3(a)46] What is the definition of third-party communications?
A message sent between two amateur stations for someone else.

G1E01 [97.115(b)(2)] Which of the following would disqualify a third party from participating in stating a message over an amateur station?
The third party is a person previously licensed in the amateur service whose license had been revoked.

G1E05 [97.115(a)(2), 97.117] What types of messages for a third party in another country may be transmitted by an amateur station?
Only messages relating to amateur radio or remarks of a personal character, or messages relating to emergencies or disaster relief.

G1E08 [97.115(a)(b)] Which of the following is a requirement for a non-licensed person to communicate with a foreign amateur radio station from a US amateur station at which a licensed control operator is present?
The foreign amateur station must be in a country with which the United States has a third party agreement.

G1E10 [97.115(a)(2)] Which of the following is a permissible third party communication during routine amateur radio operations?
Sending a message to a third party through a foreign station, as long as that person is a licensed amateur radio operator.

G1E07 [97.115(a)(2)] With which of the following is third-party traffic prohibited, except for messages directly involving emergencies or disaster relief communications?
Any country other than the United States, unless there is a third-party agreement in effect with that country.

Permitted activities.

Types of communications that are permitted would include brief transmissions to make adjustments to the station, brief transmissions to establish two-way communications with other stations, and transmissions to assist persons learning or improving proficiency in CW. Communications on a regular basis that could reasonably be furnished alternatively through other radio services are not permitted in the Amateur Radio Service.

Normally amateur stations may only communicate with other amateur stations. Occasionally, when authorized by the FCC, amateur stations are allowed to communicate with stations operating in other radio services. This would be for emergencies or events like Armed Forces Day.

T8A02 [97.113(a)(3)] Under what conditions are amateur stations allowed to communicate with stations operating in other radio services?
When specially authorized by the FCC, or in an actual emergency.

Radio control.

Amateur radio may also be used to control model craft. Many hams find the availability of amateur exclusive frequencies to be a great benefit in the radio control hobby. The maximum power allowed when transmitting telecommand signals to radio controlled models is 1 watt. Because the 'off the shelf' radio control transmitters that can be purchased and set up for amateur frequencies do not have an input for a microphone or other way to identify, the station identification requirement can be satisfied by attaching a label indicating the licensee's callsign and address to the transmitter.

T7A11 [97.215(c)] What is the maximum power allowed when transmitting telecommand signals to radio controlled models?
1 watt.

T7A12 [97.215(a)] What is the station identification requirement when sending commands to a radio control model using amateur frequencies?
A label indicating the licensee's callsign and address must be affixed to the transmitter

Bad language.

Indecent and obscene language are specifically prohibited in the Amateur Radio Service. If you wouldn't say it in church, don't say it on the radio. There is no list of prohibited words, but the rule stated above is the central point to remember. There may be children listening. There may be nice elderly Sunday school teachers listening. Most importantly, indecent language is prohibited by FCC rules, and violations will earn a fine or worse. Before anyone tries to claim this is a "freedom of speech" issue, remember, when you signed the license application you agreed to abide by the rules.

T2A07 [97.113(a)(4)] Which of the following are specifically prohibited in the Amateur Radio Service?
Indecent and obscene language.

False or deceptive signals.

Using a callsign that is not yours or transmitting a distress call when there is no emergency is defined as false or deceptive signals. An amateur station may never transmit false or deceptive signals.

T2A04 [97.113(a)(4)] When may an amateur station transmit false or deceptive signals?
Never.

Broadcasting.

The term broadcasting means transmissions intended for reception by the general public, either direct or relayed. Broadcasts are one-way communications intended for reception by the general public and may not be transmitted in the Amateur Radio Service. An amateur station is never authorized to transmit information to the general public.

An amateur station is not authorized to transmit music, except as incidental to an authorized rebroadcast of space shuttle communications. If you are driving in your car and the radio or CD is playing, you should turn the music down before transmitting to prevent it from being sent out over the air. When doing event communications for an event involving public music performance it may not be possible to turn down the volume, but we should never deliberately allow music to be sent on the amateur frequencies.

T2A01 [97.113(b)] When is an amateur station authorized to transmit information to the general public?
Never.

T2A02 [97.113(a)(4), 97.113(e)] When is an amateur station authorized to transmit music?
Amateurs may not transmit music, except as incidental to an authorized rebroadcast of space craft communications.

T2A06 [97.3(a)(10)] What does the term broadcasting mean?
Transmissions intended for reception by the general public, either direct or relayed.

T2A08 [97.3(a)(10), 97.113(b)] Which of the following one-way communications may not be transmitted in the Amateur Radio Service?
Broadcasts intended for reception by the general public.

G1B08 [97.113(a)(4), 97.113(e)] Which of the following is prohibited by the FCC Rules for amateur radio stations?
A. Transmission of music as the primary program material during a contact
B. The use of obscene or indecent words
C. Transmission of false or deceptive messages or signals
D. **All of these answers are correct.**

G1B05 [97.113(a)(4),(e)] When may music be transmitted by an amateur station?
When it is an incidental part of a space shuttle or ISS retransmission.

Secret messages.

Amateur radio operators are not allowed to use scrambling or codes to hide the meaning of a message. All of our transmissions are required to be easily understood or decoded by anyone that might choose to do so. There are only two exceptions to this rule. The transmission of codes or ciphers is allowed to hide the meaning of a message transmitted by an amateur station only when transmitting control commands to space stations (satellites) or radio control craft.

T2A03 [97.113(a)(4), 97.211(b), 97.217] When is the transmission of codes or ciphers allowed to hide the meaning of a message transmitted by an amateur station?
Only when transmitting control commands to space stations or radio control craft.

G1B06 [97.113(a)(4) and 97.207(f)] When is an amateur station permitted to transmit secret codes?
To control a space station.

G1B07 [97.113(a)(4)] What are the restrictions on the use of abbreviations or procedural signals in the amateur service?
They may be used if they do not obscure the meaning of a message.

Pay to play?

Amateur radio is a **non-commercial** service. We don't get paid for operating except in certain very strict circumstances. If someone offers to give you money or anything of value for using your amateur station to send a message, you are not allowed to accept.

The FCC allows an amateur radio station to be used as a method of communication for hire or material compensation only when in accordance with part 97 rules. It is permissible for the control operator of a club station to accept compensation for sending information bulletins or Morse code practice when the station makes those transmissions for at least 40 hours per week. A good example of this would be the operators of station W1AW, the ARRL club station, that sends code practice and information bulletins on a published schedule daily.

T2A09 [97.113(2)] When does the FCC allow an amateur radio station to be used as a method of communication for hire or material compensation?
Only when in accordance with part 97 rules.

T2D11 [97.113(d)] When is it permissible for the control operator of a club station to accept compensation for sending information bulletins or Morse code practice?
When the station makes those transmissions for at least 40 hours per week.

Business activity.

You may use your station to tell people about equipment you have for sale when you are offering amateur radio equipment for sale or trade on an occasional basis. The key word here is 'occasional' basis. If you are in the business of selling radio equipment, listing it on the weekly swap net would be a mis-use of your license and could subject you to a fine or loss of license.

Using amateur radio for conducting business is a prohibited amateur radio transmission. Examples of this would be calls to your employer requesting directions to a customer's office using a repeater autopatch, or ordering supplies to be delivered to a construction site.

News gathering is a business activity of the network or station doing the gathering. If a reporter asks to use your amateur radio transceiver to make a news report you should advise them that the FCC prohibits such use. Amateur radio can not be used for “live news reports” unless the information relates to the immediate safety of life or property. News organizations are permitted to monitor and use information from amateur radio communications. They can in fact retransmit received signals in real time. Most stations will not do so since they have no control over what may be said from moment to moment. The rule at the heart of all of this is that amateur radio can not be used for communications on a regular basis that can reasonably be handled by other methods.

Calls to a recorded weather report, to the police reporting a traffic accident, or to a public utility reporting an outage of your telephone would be permitted uses of an autopatch system. Other permitted uses would be to call a towing service for a stranded motorist. If you think about that situation, it rises to the immediate safety of life and property test for emergency communications. While it might not be necessary to “declare an emergency” on the channel, we should not hesitate to make the call to help insure someone's safety for fear of violating the prohibition on “business” communications.

T2D04 [97.113(a)(3)] Which of the following is a prohibited amateur radio transmission?
Using amateur radio for conducting business.

T1C11 [97.113(a)(5)] Which of the following types of communications are not permitted in the Amateur Radio Service?
Communications on a regular basis that could reasonably be furnished alternatively through other radio services.

T2A11 [97.113(a)3] When may you use your station to tell people about equipment you have for sale?
When you are offering amateur radio equipment for sale or trade on an occasional basis.

T8B10 What should you do if a reporter asks to use your amateur radio transceiver to make a news report?
Advise them that the FCC prohibits such use.

T8B11 When can you use a modified amateur radio transceiver to transmit on the local fire department frequency?
At no time.

G1B09 [97.113(a)(3)] When may an amateur station transmit communications in which the licensee or control operator has a pecuniary (monetary) interest?
Only when other amateurs are being notified of the sale of apparatus normally used in an amateur station and such activity is not done on a regular basis.

G1B04 [97.113(b)] Which of the following must be true before an amateur station may provide news information to the media during a disaster?
The information must directly relate to the immediate safety of human life or protection of property and there is no other means of communication available.

Repeater Stations.

A repeater is a special type of radio station that is designed to retransmit radio signals to extend the working range of low powered mobile or handheld radios. To accomplish this purpose, the repeater receives signals on one frequency and retransmits them on another. The difference between these input and output frequencies is referred to as the 'offset' or 'shift' of the repeater. This offset is required to keep the receiver of the repeater from 'hearing' it's own transmitter. In the 2 meter band, this offset is usually plus or minus 0.6 MHz or 600 kHz. On the 70 centimeter band the offset is usually plus or minus 5 MHz. To use the repeater our transmitter uses a frequency that is higher or lower than the frequency we listen to by the amount of the offset.

Like any other amateur radio station, a repeater must operate with a license. The control operator (or trustee in the case of club repeaters) of the repeater is the licensee that is responsible for technical compliance with the rules and regulations regarding the transmissions of the repeater, but individual users are held accountable for their own actions when using the repeater. The control operator of a repeater must have operating privileges on the frequency the repeater transmits on. If a Technician operator is using a repeater linked to an output on the 10 meter band for example, where the Technician does not have authority to transmit, the control operator must be a General class operator or higher.

T5C01 What is one purpose of a repeater?
To extend the usable range of mobile and low-power stations.

T5C03 Which of the following is the most important information to know before using a repeater?
The repeater input and output frequencies.

T5C05 What is the most common input/output frequency offset for repeaters in the 2-meter band?
0.6 MHz.

T5C06 What is the most common input/output frequency offset for repeaters in the 70-centimeter band?
5.0 MHz.

T5C07 What is meant by the terms input and output frequency when referring to repeater operations?
The repeater receives on one frequency and transmits on another.

T3B06 [97.205(g)] Who is accountable if a repeater station inadvertently retransmits communications that violate FCC rules?
The transmitting station.

G1E03 [97.3(a)(39)] What kind of amateur station simultaneously retransmits the signals of other stations on another channel?
Repeater Station.

G1E02 [97.205(a)] When may a 10 meter repeater retransmit the 2 meter signal from a station having a Technician Class control operator?
Only if the 10 meter control operator holds at least a General class license.

Coordinating Repeater Stations.

Because they are often located on high mountains, tall buildings, or towers, the service area of a repeater can be quite large. In the western states with their high mountains, it is not uncommon for a repeater to cover parts of several states. Because of this range and the limited number of frequencies available for repeater use in each band, some form of coordination is required to prevent repeater systems and their users from causing interference to adjacent repeater systems. The Repeater Coordinator is a recognized group that decides what frequency and power level a repeater may use to avoid interference to other systems. They may also assign control requirements where system coverage will overlap and simultaneous operation of the systems would not be desirable.

T3B05 What is the main purpose of repeater coordination?
To reduce interference and promote proper use of spectrum.

T3B04 Who is in charge of the repeater frequency band plan in your local area?
The recognized frequency coordination body.

T5C12 What is the main reason repeaters should be approved by the local frequency coordinator before being installed?
Coordination minimizes interference between repeaters and makes the most efficient use of available frequencies.

Repeater Interference Issues.

While it is not required that your repeater be coordinated, there are some things to consider. If your uncoordinated repeater causes interference to a coordinated system, you are required by Part 97 to take whatever measures might be needed to correct the situation, including taking your repeater off the air. You may also apply some form of access control to keep your system from operating when it might be a problem to other users of the band.

G1E06 [97.205(c)] Which of the following applies in the event of interference between a coordinated repeater and an uncoordinated repeater?
The licensee of the non-coordinated repeater has primary responsibility to resolve the interference.

Controlling Access to Repeater Stations.

You may want or need to control access to a repeater, either to prevent interference or to restrict access to a select group of users. The most commonly used control method is a low level audio tone transmitted in the background. This sub-audible tone is detected by devices in the repeater and allows the repeater transmitter to function. Another name for this system is Continuous Tone Controlled Squelch System or CTCSS.

T5C14 What term is used to describe a repeater when use is restricted to the members of a club or group?
A closed repeater.

T5C13 Which of the following statements regarding use of repeaters is true?
Access to any repeater may be limited by the repeater owner.

Beeps, Boops, Chirps, and Other Strange Sounds.

Just like any other amateur station, the repeater is required to identify itself every 10 minutes. Acceptable methods of transmitting a repeater station identification would include by phone using the English language, by video image conforming to applicable standards for a video repeater, or by Morse code at a speed not to exceed 20 words per minute. One good reason to be able to copy Morse code would be to identify the callsign of the repeater you are using.

You might also hear other tones, sounds or odd things when listening to a repeater. Most repeaters have a courtesy tone that will sound a second or two after the incoming transmission stops. This tone is to let other users know that it is OK to transmit now. The short delay also allows other users who may need to use the repeater to break in, such as for an emergency call. If the repeater has no courtesy tone, you should pause for a second or two before transmitting to allow others to break in.

The tones may also indicate other conditions of the system, such as the presence of links to other repeaters or the Internet that are active. These linked repeater systems would be used to extend the range of communications over a much larger area. There are no rules that specify what, if any, courtesy tones are used on repeaters. Therefore you will need to contact the owner of the system to learn the meaning of these signals.

Another sound you might hear would be the tones used by the telephone system. Some repeaters have a device called an autopatch that allow users to connect to the telephone network and make phone calls. These systems are usually restricted to the local calling area only and generally should not be used routinely without paying club dues or user fees. Autopatch systems are usually open to anyone in emergencies.

T2B04 What is an acceptable method of transmitting a repeater station identification?
A. By phone using the English language
B. By video image conforming to applicable standards
C. By Morse code at a speed not to exceed 20 words per minute
D. All of these answers are correct.

T6C09 What is a practical reason for being able to copy CW when using repeaters?
To recognize a repeater ID sent in Morse code.

T6A03 What name is given to an amateur radio station that is used to connect other amateur stations to the Internet?
A gateway.

T2A10 What type of communications are prohibited when using a repeater autopatch?
A. Calls to a recorded weather report
B. Calls to your employer requesting directions to a customer's office.
C. Calls to the police reporting a traffic accident
D. Calls to a public utility reporting an outage of your telephone

T5C02 What is a courtesy tone?
A tone used to indicate when a transmission is complete.

T5C04 Why should you pause briefly between transmissions when using a repeater?
To listen for anyone wanting to break in.

T5C11 What is the term for a series of repeaters that can be connected to one another to provide users with a wider coverage?
Linked repeater system.

Echolink and IRLP.

A gateway is the name given to an amateur radio station that is used to connect other amateur stations to the Internet. Gateway stations are used in both Echolink and IRLP. The technology used by Echolink and IRLP is Voice over Internet protocol.

Stations using Echolink transmit information between them by using the Internet. Echolink allows computer-to-radio linking for voice transmission. Any licensed amateur radio operator may operate on the Echolink system.

The abbreviation IRLP means Internet Radio Linking Project. The term IRLP describes a method of linking between two or more amateur stations using the Internet.

You are listening to an Internet linked DX station if you hear a brief tone and then a station from Russia calling CQ on a 2-meter repeater.

You can find a list of active nodes using VoIP in a repeater directory or on the Internet. When using a portable transceiver you select a specific IRLP node by using the keypad to transmit the IRLP node numbers.

T6B01 How is information transmitted between stations using Echolink?
Internet.

T6B02 What does the abbreviation IRLP mean?
Internet Radio Linking Project.

T6B03 Who may operate on the Echolink system?
Any licensed amateur radio operator.

T6B04 What technology do Echolink and IRLP have in common?
Voice over Internet protocol.

T6B05 What method is used to transfer data by IRLP?
Voice over Internet protocol.

T6B06 What does the term IRLP describe?
A method of linking between two or more amateur stations using the Internet.

T6B07 Which one of the following allows computer-to-radio linking for voice transmission?
Echolink.

T6B08 What are you listening to if you hear a brief tone and then a station from Russia calling CQ on a 2-meter repeater?
An Internet linked DX station.

T6B09 How do the Echolink administrators confirm your right to use the system?
You must send a copy of your FCC license to Echolink for review.

T6B10 Where might you find a list of active nodes using VoIP?
A repeater directory or the Internet.

T6B11 When using a portable transceiver how do you select a specific IRLP node?
Use the keypad to transmit the IRLP node numbers.

What is 'Simplex'?

When it is possible to communicate without tying up a repeater, such as for short distance contacts, it is best to move to a frequency where there is no repeater. In this case you will transmit and receive on the same frequency, each station taking it's turn. To check if it is possible to move a conversation off the repeater, you would tune to the input frequency of the repeater to see if you can receive the other station's signal directly. If you can, then it would be polite to clear the repeater and continue your conversation on a simplex frequency.

T5C08 What is the meaning of the term simplex operation?
Transmitting and receiving on the same frequency.

T5C09 What is a reason to use simplex instead of a repeater?
To avoid tying up the repeater when direct contact is possible.

T5C10 How might you find out if you could communicate with a station using simplex instead of a repeater?
Check the repeater input frequency to see if you can hear the other station.

VE Testing.

License examinations are administered by Volunteer Examiners. A Volunteer Examiner is an amateur accredited by one or more VECs (Volunteer Examination Coordinators) who volunteers to administer amateur license exams. Qualifications to become a VE are that you must have a valid US General class or higher license and be 18 years of age. There is usually some form of testing to demonstrate that you have knowledge of how the exams are given and the rules and regulations that apply to the examination process. Once you have satisfied those requirements you will receive a VE credential.

In an exam session, the administering VE is the final authority regarding the correctness of answers given for exam questions. The exam is constructed from the published exam question pools using FCC guidelines for the number of questions selected from each Element sub-section. There are no surprise questions on an exam. Three Examiners holding a General Class license or higher and valid VE credentials are required to administer any license exam.

When you pass an examination element you will receive a Certificate of Successful Completion of Examination or CSCE. A CSCE is valid for license upgrade purposes for 365 days. Under the new rules, there will not be many situations where you would have a CSCE and not receive a license or upgrade. The CSCE document was used to show proof of passing the written exam elements when returning to take the Element 1 Morse code exams. The main purpose the CSCE serves now is to show proof of passing an exam if the exam session package should be lost in transit and as an operating authority when waiting for the result of an upgrade exam to be posted in the FCC ULS database.

T1A04 [97.509(b)] Who is a Volunteer Examiner?
An amateur accredited by one or more VECs who volunteers to administer amateur license exams.

T1A05 [97.505(a)(6)] How long is a CSCE valid for license upgrade purposes?
365 days.

T1A06 [97.509(a)(b)(3)(i)] How many and what class of Volunteer Examiners are required to administer an Element 2 Technician written exam?
Three Examiners holding a General Class license or higher.

G1D12 [97.509(b)(1)] Volunteer Examiners are accredited by what organization?
A Volunteer Examiner Coordinator.

G1D10 [97.509(b)(2)] What is the minimum age that one must be to qualify as an accredited Volunteer Examiner?
18 years

G1D13 [97.509] When may you participate as a VE in administering an amateur radio license examination?
Once you have been granted your General class license and received your VEC accreditation.

G1D11 [97.509 (b)(3)] What criteria must be met for a non U.S. citizen to be an accredited Volunteer Examiner?
The person must hold a U.S. amateur radio license of General class or above.

G1D04 [97.509(a)(b)] Which of the following are requirements for administering a Technician Class operator examination?
At Least three VEC-accredited General Class or higher VEs must be present.

G1D02 [97.509(b)(3)(i)] What license examinations may you administer when you are an accredited VE holding a General Class operator license?
Technician.

G1D05 [97.509(b)(3)(i)] Which of the following is sufficient for you to be an administering VE for a Technician Class operator license examination?
A FCC General class or higher license and VEC accreditation.

G1D03 [97.9(b)] Which of the following band segments may you operate on if you are a Technician Class operator and have a CSCE for General Class privileges?
On any General Class band segment.

G1D07 [97.509(h)] Who is responsible at a Volunteer Exam Session for determining the correctness of the answers on the exam?
The administering VEs.

G1D08 [97.509(i)] What document must be issued to a person that passes an exam element?
CSCE.

G1D09 [97.3(a)(15)] How long is a Certificate of Successful Completion of Examination (CSCE) valid for exam element credit?
365 days.

Interference Issues.

A transmission that disturbs other communications is called harmful interference. Harmful interference may or may not be intentional (malicious) interference. We live in a world of increasing electronic complexity. As new devices are introduced to the marketplace there will come a time when you are faced with an interference problem, either your equipment causing problems with someone else's or their's interfering with yours. Knowing how to identify the source of a problem is a vital part of correcting the problem.

The increasing use of digital signals instead of analog signals to communicate with another station is helping to solve many interference issues because many digital systems can automatically correct errors caused by noise and interference.

T1A10 [97.3(A)(23)] What is a transmission called that disturbs other communications?
Harmful interference.

T5D13 What is one of the reasons to use digital signals instead of analog signals to communicate with another station?
Many digital systems can automatically correct errors caused by noise and interference.

Cable Television.

Cable television systems are a common source of interfering signals. A break in the cable shielding may let TV signals on amateur frequencies escape. This would be indicated by the presence of TV audio being heard on the amateur receiver. In some cases your signal will disrupt the cable system when you transmit. Most cable companies are cooperative about fixing these faults as they are violations of FCC rules that apply to the cable company and it's system. Remember that it is the cable company that must make the correction in this type of case. The responsibility to maintain their system with no cable signal leaks is their's.

T3D07 What effect might a break in a cable television transmission line have on amateur communications?
TV interference may result when the amateur station is transmitting, or interference may occur to the amateur receiver.

Interference with consumer electronics and Grounding.

Your neighbors may complain about your transmitter disturbing their television or radio reception. Usually in this case the problem is caused by a front end overload of the television or radio receiver. Receiver front-end overload or fundamental overload is interference caused by strong signals from a nearby source.

This is due to poor design in the consumer electronic device. If the first stages of the receiver are poorly designed they may respond to strong signals on a close frequency other than the desired program. Legally, the owner of the equipment is responsible for correcting the problem provided that your station is operating within technical specification requirements of Part 97. Try to tell them this when your conversation is interrupting the broadcast of the Super Bowl. On a practical note, it is good for neighbor relations to be willing to help remove the problem, or at least avoid operating when the neighbors favorite program is on.

A notch filter should be connected to a TV receiver as the first step in trying to prevent RF overload from a nearby 2-meter transmitter. Snap-on ferrite beads which act like inductor chokes, low-pass and high-pass filters, and notch and band-pass filters all may be useful in correcting a radio frequency interference problem. remember that the filter circuits used should correctly match the impedance of the feedline they are used with for correct operation. Using a mis-matched filter may cause additional problems rather than correcting problems. The proper course of action to take when a neighbor reports that your radio signals are interfering with something in his home is to check your station and make sure it meets the standards of good amateur practice.

You would install bypass capacitors in home-entertainment systems to reduce or eliminate audio-frequency interference, by creating a relatively low impedance path to ground for the RF energy. The sound that is heard from a public-address or home stereo system if audio rectification of a nearby single-sideband phone transmission occurs is distorted speech from the transmitter's signals. A CW signal would sound like on-and-off humming or clicking. Unintended rectification of an RF signal is usually caused by induced currents in conductors that are in poor electrical contact. That poor contact rectifies the RF and generates mixing products with other frequencies in the area. The resulting mish-mash of RF noise can be a real problem.

The most likely cause of telephone interference from a nearby transmitter is the transmitter's signals are causing the telephone to act like a radio receiver. The logical first step when attempting to cure a radio frequency interference problem in a nearby telephone is to install an RF filter at the telephone. This filter device which costs only a few dollars blocks the RF energy from entering the telephone device.

The new electronic phones are also likely to be disturbed by amateur radio transmissions. This was a very big problem when the cordless phone first hit the market. The newer cordless phones are not as susceptible to interference. The base to handset frequencies of the older phones was right next to the 160 meter band. A moderately strong signal would wipe out the phone signal in the handset replacing it with muffled voice-like sounds that your neighbor would usually recognize as being you. Once again the problem was in educating the neighbor to the fact that their new cordless phone was not as good as they thought it was and that the problem was theirs to deal with. In any case like this it is best to try to be a good neighbor and help correct the problem.

If a "Part 15" device in your neighbor's home is causing harmful interference to your amateur station, you should work with your neighbor to identify the offending device, politely inform your neighbor about the rules that require him to stop using the device if it causes interference, and check your station and make sure it meets the standards of good amateur practice.

In some cases the problem can not be solved. The effected receiver is of good engineering design and the amateur station is fully compliant with all rules and regulations. In such a case the FCC can require quiet hours for the amateur station. This would restrict the amateur station operation to times other than 8 pm to 10:30 pm local time every day, as well as on Sundays from 10:30 am to 1 pm local time.

T3D11 What is meant by receiver front-end overload?
Interference caused by strong signals from a nearby source.

T9B03 What is the most likely cause of sudden bursts of tones or fragments of different conversations that interfere with VHF or UHF signals?
Strong signals are overloading the receiver and causing undesired signals to be heard.

T5D01 What is meant by fundamental overload in reference to a receiver?
Interference caused by very strong signals from a nearby source.

T3D02 Who is responsible for taking care of the interference if signals from your transmitter are causing front end overload in your neighbor's television receiver?
The owner of the television receiver is responsible.

T3D03 What is the major cause of telephone interference?
The telephone was not equipped with adequate interference protection when manufactured.

T5D03 What is the most likely cause of telephone interference from a nearby transmitter?
The transmitter's signals are causing the telephone to act like a radio receiver.

T5D04 What is a logical first step when attempting to cure a radio frequency interference problem in a nearby telephone?
Install an RF filter at the telephone.

T5D05 What should you do first if someone tells you that your transmissions are interfering with their TV reception?
Make sure that your station is operating properly and that it does not cause interference to your own television.

T5D06 Who is responsible for correcting the problem if your signals are causing front-end overload interference to your neighbor's TV set and your station meets good amateur practices?
The owner of the television receiver is responsible.

T5D07 Which of the following may be useful in correcting a radio frequency interference problem?
A. Snap-on ferrite chokes
B. Low-pass and high-pass filters
C. Notch and band-pass filters
D. All of these answers are correct.

T5D08 What is the proper course of action to take when a neighbor reports that your radio signals are interfering with something in his home?
Check your station and make sure it meets the standards of good amateur practice.

T5D09 What should you do if a "Part 15" device in your neighbor's home is causing harmful interference to your amateur station?
A. Work with your neighbor to identify the offending device
B. Politely inform your neighbor about the rules that require him to stop using the device if it causes interference
C. Check your station and make sure it meets the standards of good amateur practice
D. All of these answers are correct.

G7A05 What should be the impedance of a low-pass filter as compared to the impedance of the transmission line into which it is inserted?
About the same.

G4C01 Which of the following might be useful in reducing RF interference to audio-frequency devices?
Bypass capacitor.

G4C02 Which of the following should be installed if a properly operating amateur station is interfering with a nearby telephone?
An RFI filter at the affected telephone.

G4C03 What sound is heard from a public-address system if there is interference from a nearby single-sideband phone transmitter?
Distorted speech.

G4C04 What is the effect on a public-address system if there is interference from nearby CW transmitter?
On-and-off humming or clicking.

G4C08 Which of the following is a reason to place ferrite beads around audio cables to reduce common mode RF interference?
They act as a series inductor.

G4C11 Which of the following can cause unintended rectification of RF signal energy and can result in interference to your station as well as nearby radio and TV receivers?
Induced currents in conductors that are in poor electrical contact.

G1B13 [97.121(a)] What restrictions may the FCC place on an amateur station that is causing interference to a broadcast receiver of good engineering design?
Restrict the amateur station operation to times other than 8 pm to 10:30 pm local time every day, as well as on Sundays from 10:30 am to 1 pm local time.

Interference with Other Hams.

Sometimes despite our best efforts, we will bump into another ham when operating our radio. Usually this is a chance to make a new friend and score one more contact, but sometimes it is a problem. If you are operating and are told that you are interfering with a Net that you couldn't hear, just be polite, identify your station, and move to another frequency. No harm, no foul. The radio path is not always bi-directional. This means that sometimes you will be heard by stations that you can't hear or you will hear stations that can't hear you. This is part of the sport of radio.

To avoid causing interference to other hams when testing or adjusting your equipment, you should use a dummy load in place of your antenna. A dummy load, or load resistor, is a device designed to present the transmitter with the correct operating impedance to simulate an antenna. Instead of radiating your signal all over the universe, the dummy load converts it to heat, and allows little if any radio signal to escape.

There are several different types of interference signals we could cause. Knowing how to identify them, as always, is the first step in correcting the problem.

Splatter is the name for signals that are heard on frequencies near your transmitting frequency. It is usually caused by over-modulation, or by equipment that is operating off it's designed frequency.

Harmonics are identifiable by the fact that they occur on exact multiples of the transmitter frequency. Unfortunately the multiple of some of our operating frequencies will land you right in the middle of services like television broadcast. Your neighbors will notice this, and they WILL let you know about it.

The use of a low pass filter in the transmission line can reduce or eliminate harmonics before they get to the antenna, but will not correct splatter caused by over modulating the transmitter. Splatter problems will require a deeper technical solution than this book has room for except to say that usually turning the microphone gain down will correct the problem by eliminating over modulation of the signal.

If another operator reports that your SSB signal is very garbled and breaks up then RF energy may be getting into the microphone circuit and causing feedback.

If another operator tells you he is hearing a variable high-pitched whine on the signals from your mobile transmitter then the power wiring for your radio is picking up noise from the vehicle's electrical system.

If you receive a report that your signal through the repeater is distorted or weak, your transmitter may be slightly off frequency, your batteries may be running low, or you could be in a bad location. It might be any one or a combination of these causes.

Sometimes the problem is that you want to receive a station in one part of the world, and another station in a different location is on the same frequency. In this case a unidirectional antenna that is oriented to favor the desired signal or has an area of reduced gain to 'notch' out the unwanted signal is the answer.

Of course we can't anticipate all the situations that you might encounter. If you find yourself faced with an interference situation that you can not resolve yourself don't hesitate to ask other hams for help. The ARRL in cooperation with the local affiliate clubs maintain organized 'Interference Committees' the can bring years of education and field experience to bear in resolving your interference problems. In any situation not specifically covered by FCC rule, you should use good engineering and amateur practices. Remember you must never deliberately interfere with the signals of another station.

T3D08 What is the best way to reduce on the air interference when testing your transmitter?
Use a dummy load when testing.

T3C10 [97.101 (a)] When circumstances are not specifically covered by FCC rules what general operating standard must be applied to amateur station operation?
Good engineering and amateur practices.

T5D10 What could be happening if another operator tells you he is hearing a variable high-pitched whine on the signals from your mobile transmitter?
The power wiring for your radio is picking up noise from the vehicle's electrical system.

T5D02 Which of the following is NOT a cause of radio frequency interference?
A. Fundamental overload
B. Doppler shift.
C. Spurious emissions
D. Harmonics

T5D11 What may be the problem if another operator reports that your SSB signal is very garbled and breaks up?
RF energy is getting into the microphone circuit and causing feedback.

T5D12 What might be the problem if you receive a report that your signal through the repeater is distorted or weak?
A. Your transmitter may be slightly off frequency
B. Your batteries may be running low
C. You could be in a bad location
D. All of these answers are correct

T3D01 What should you do if you receive a report that your transmissions are causing splatter or interference on nearby frequencies?
Check transmitter for off frequency operation or spurious emissions.

T3D04 What is the proper course of action if you unintentionally interfere with another station?
Properly identify your station and move to a different frequency.

T3D05 [97.101(d)] When may you deliberately interfere with another station's communications?
Never.

G1B11 [97.101(a)] How does the FCC require an amateur station to be operated in all respects not covered by the Part 97 rules?
In conformance with good engineering and good amateur practice.

G1B12 [97.101(a)] Who or what determines "good engineering and good amateur practice" that apply to operation of an amateur station in all respects not covered by the Part 97 rules?
The FCC.

G2D11 Which HF antenna would be the best to use for minimizing interference?
A unidirectional antenna.

Special locations and Situations.

In some special locations and situations you will need to make special efforts to avoid interfering with other spectrum users. Some examples would be: if you are located within 1 mile of an FCC monitoring station, are inside the quiet zone around the National Radio Telescope site, within radio range of certain military facilities, operating on any band where the amateur service is a secondary user, or any time you are transmitting in a spread spectrum mode. In all of these situations the possibility to cause interference to critical systems is enhanced either by your location or the experimental nature of the spread spectrum modulation you are using.

G1E04 [97.13(b),97.311(b), 97.303] Which of the following conditions require an amateur radio station to take specific steps to avoid harmful interference to other users or facilities?
A. When operating within one mile of an FCC Monitoring Station
B. When using a band where the amateur service is secondary
C. When a station is transmitting spread spectrum emissions
D. All of these answers are correct

Antenna structures.

If you are planning to erect a tall tower to support your antenna system you need to consider the height carefully. Antenna structures over 200 feet tall must be equipped with night lighting devices and be registered with the FAA so they can be noted as a hazard to navigation on aeronautical charts. In some locations near airports the height restrictions are much more severe. It would not be good to have a new antenna tower sprout up 100 feet in the approach path of the local airport. The resulting aircraft debris would make a mess of the flower beds in your back yard.

G1B01 [97.15(a)] What is the maximum height above ground to which an antenna structure may be erected without requiring notification to the FAA and registration with the FCC, provided it is not at or near a public-use airport?
200 feet.

Beacon stations.

Beacon stations are used to explore the current radio propagation conditions. The stations are located in various places around the world and operate automatically in sending a sequence of reduced power levels starting at 100 watts at a certain time in each three minute cycle of the beacon system. By tuning to the correct frequency and listening at the designated time slot you can tell if band conditions allow contact with that part of the world from your location. The lowest sequential power step that is heard identifies the quality of the radio propagation along that path. To make efficient use of spectrum, there are usually several beacons sharing each frequency.

G1B02 [97.203(b)] With which of the following conditions must beacon stations comply?
There must be no more than one beacon signal in the same band from a single location.

G1B03 [97.1(a)(9)] Which of the following is a purpose of a beacon station as identified in the FCC Rules?
Observation of propagation and reception, or other related activities.

G1B10 [97.203(c)] What is the power limit for beacon stations?
100 watts PEP output.

Transmitter power regulations.

The general rule for an amateur radio station regarding power output is that you are allowed to use only the amount of power required to maintain contact up to a maximum of 1500 watts Peak Envelope Power (PEP). This is a lot more than you need for most situations. There are some exceptions to the general rule however.

In some geographic areas, the 70 cm band is restricted to 50 watts or less.

On the 30 meter band, between 10.1 and 10.15 MHz, all stations are restricted to 200 watts PEP.

On the 60 meter band, in addition to being restricted to 5 specific voice channels, we are limited to 50 watts Effective Radiated Power (ERP) as referenced to a simple dipole antenna.

You need to know that it is also possible to conduct communications with extremely small amounts of output power. This is known as QRP operation, meaning low power operation. QRP operators typically use power levels below 5 watts. Some ham operators focus on this aspect of the hobby with tiny radios that will fit inside things like an Altoids tin. World wide contacts have been made with transmitter power in the milliwatt range. Yes that is thousandths of a watt! For comparison, your body is radiating about 900 watts of thermal energy right now. The average incandescent light bulb is 60 watts. The lamp in a flashlight is typically about 2 to 3 watts.

T3B07 Which of these statements is true about legal power levels on the amateur bands?
An amateur must use the minimum transmitter power necessary to carry out the desired communication.

G1C01 [97.313(c)(1)] What is the maximum transmitting power an amateur station may use on 10.140 MHz?
200 watts PEP output.

G1C02 [97.313(a),(b)] What is the maximum transmitting power an amateur station may use on the 12 meter band?
1500 watts PEP output.

G1C03 [97.313] What is the maximum transmitting power a General class licensee may use when operating between 7025 and 7125 kHz?
1500 watts PEP output.

G1C04 [97.313] What limitations, other than the 1500 watt PEP limit, are placed on transmitter power in the 14 MHz band?
Only the minimum power necessary to carry out the desired communications should be used.

G1C05 [97.313] What is the maximum transmitting power a station with a General Class control operator may use on the 28 MHz band?
1500 watts PEP output.

G1C06 [97.313(b)] What is the maximum transmitting power an amateur station may use on 1825 kHz?
1500 watts PEP output.

G1C07 [97.303(s)] Which of the following is a requirement when a station is transmitting on the 60 meter band?
Transmissions must not exceed an effective radiated power of 50 Watts PEP referred to a dipole antenna.

G2D10 What is QRP operation?
Low power transmit operation, typically about 5 watts.

HF data emission standards.

Data is the name of information being sent by computer or sometimes by mechanical device. Early data transmissions in amateur radio used the mechanical teleprinters of the same type used by companies like Western Union. The code used by these machines is a 5 bit system called Baudot Code. The typical machine speeds allowed contact at the blistering speed of 45 baud. We call this mode RTTY (**R**adio **t**ele**ty**pe) Compare this to today's dial-up modem running 53 Kilobaud.

The information is sent usually by shifting a radio carrier back and forth between two frequencies to represent the binary 1s and 0s of the code stream. 170 Hz is the most common frequency shift for RTTY emissions in the amateur HF bands. When tuning up and preparing to send a message using RTTY, a string of letters R and Y (sent as "RYRYRYRY...") are sent to allow the receiving stations time to 'tune in' the sending station prior to the actual message being sent. In the old mechanical teleprinters, this also exercised all of the 'bits' of the printing mechanism as the Baudot codes for R and Y contained opposite bit patterns. This practice has been carried over into other types of data transmissions to assist in tuning the signal.

As the data rate increases, the bandwidth or amount of spectrum occupied by the signal increases. Because the HF spectrum is a very limited resource, there are regulatory 'speed limits' placed on data transmissions. Below 28 MHz, the maximum character or symbol rate allowed is 300 per second, or 300 baud. As the frequency of the radio system increases, the allowable bandwidth for modulation increases too. On the 10 meter band (above 28 MHz) the symbol rate is allowed to be up to 1200 per second. On the 6 and 2 meter bands the symbol rate is allowed to be up to 19.6 kilobaud. When using 6 or 2 meters the total modulation bandwidth may not exceed 20 kHz for any digital modulation code.

G1C08 [97.305(c) and 97.307(f)(3)] What is the maximum symbol rate permitted for RTTY emissions transmitted on frequency bands below 28 MHz?
300 baud.

G1C09 [97.305(c) and 97.307(f)(5)] What is the maximum symbol rate permitted for packet emission transmissions on the 2 meter band?
19.6 kilobaud.

G1C10 [97.305(c) and 97.307(f)(4)] What is the maximum symbol rate permitted for RTTY or data emission transmissions on the 10 meter band?
1200 baud.

G1C11 [97.305(c) and 97.307(f)(5)] What is the maximum symbol rate permitted for RTTY or data emission transmissions on the 6 and 2 meter bands?
19.6 kilobaud.

G1C12 [97.305(c) and 97.307(f)(5)] What is the maximum authorized bandwidth for RTTY, data or multiplexed emissions using an unspecified digital code transmitted on the 6 and 2 meter bands?
20 kHz.

FCC Declarations of an Communications Emergency.

If a disaster disrupts normal communications in your area, the FCC may declare a temporary state of communication emergency. This declaration would include any special conditions and special rules to be observed by stations during the emergency. When the FCC declares a temporary state of communication emergency, you must abide by the limitations or conditions set forth in the FCC notice.

When the FCC has NOT declared a communication emergency no station has exclusive use of any frequency.

An FCC declaration of a communications emergency is legally required to restrict a frequency to emergency-only communication. The restrictions on amateur radio communications after the FCC has declared a communications emergency are that you must avoid those frequencies dedicated to supporting the emergency unless you are participating in the relief effort.

T8A01 [97.401(b)] What information is included in an FCC declaration of a temporary state of communication emergency?
Any special conditions and rules to be observed during the emergency.

T8A06 [97.401(b)] What is legally required to restrict a frequency to emergency-only communication?
An FCC declaration of a communications emergency.

T8A07 Who has the exclusive use of a frequency if the FCC has not declared a communication emergency?
No station has exclusive use in this circumstance.

T8A04 What are the restrictions on amateur radio communications after the FCC has declared a communications emergency?
You must avoid those frequencies dedicated to supporting the emergency unless you are participating in the relief effort.

T3D06 Who has exclusive use of a specific frequency when the FCC has not declared a communication emergency?
No station has exclusive use of any frequency.

Emergency traffic.

Emergency traffic is any message that concerns the **immediate safety of life and/or property.** If your message does not rise to that level, it probably isn't an emergency message, and should be handled at a lower priority level.

During a disaster when normal communication systems are overloaded, damaged, or disrupted, an amateur station can make transmissions necessary to meet essential communication needs and assist relief operations. These communications are usually not emergency messages, but we discuss them in the framework of emergency traffic because the distinction can be difficult to make in the rush of the moment, and because a 'routine' situation such as a bike race or marathon can become an 'emergency' in a single moment. Public and private response agencies depend on us for that communication support.

Because ham radio is not dependent on the public infrastructure, like cell phones and other methods of communication, hams are able to deploy into storm ravaged areas or earthquake zones and set up functional communication networks at any time.

We test our skills regularly in drills and exercises, or in public service events for marathons, parades, and similar events. We learn in these events the methods for keeping the net functional when unexpected situations arise that might make the primary frequency unusable. We learn about employing alternative power sources to keep equipment running, and how to construct field antennas from any available hunk of wire. We practice running the net with tactical callsigns to keep confusion to a minimum, and we learn the importance of network discipline, keeping non-essential chatter off the frequency to avoid the confusion that it may cause. And most importantly, we reinforce the knowledge of how the FCC rules govern how we are allowed to help these agencies when our service is needed. Only in ham radio do you get the opportunity to learn these kind of communication skills.

To be prepared for an emergency situation where your assistance might be needed you should check at least twice a year to make sure you have all of your emergency response equipment and know where it is, make sure you have a way to run your equipment if there is a power failure in your area, and participate in drills that test your ability to set up and operate in the field.

T3D09 [97.103(a)] What rules apply to your station when using amateur radio at the request of public service officials or at the scene of an emergency?
FCC.

T8B01 What can you do to be prepared for an emergency situation where your assistance might be needed?
A. Check at least twice a year to make sure you have all of your emergency response equipment and know where it is
B. Make sure you have a way to run your equipment if there is a power failure in your area
C. Participate in drills that test your ability to set up and operate in the field
D. All of these answers are correct

T8A05 What is one reason for using tactical callsigns such as "command post" or "weather center" during an emergency?
They are more efficient and help coordinate public-service communications.

T8B07 What could be used as an alternate source of power to operate radio equipment during emergencies?
A. The battery in a car or truck
B. A bicycle generator
C. A portable solar panel
D. All of these answers are correct

T8B09 Why should casual conversation between stations during a public service event be avoided?
Idle chatter may interfere with important traffic.

G2C09 [97.111(a)(2)] What type of transmissions may an amateur station make during a disaster?
Transmissions necessary to meet essential communications needs and to facilitate relief actions.

Wait! The Emergency is Mine! **HELP!**

An amateur station in distress may use any means of radio communication to attract attention, make known its condition and location, and obtain assistance. During an emergency, there are no power output limitations that must be observed by a station in distress. The station in distress may use any means required to summon assistance.

During a disaster or emergency in the US, **any** frequency or mode of emission may be used to obtain assistance. You would use the frequency that has the best chance of communicating the distress message. You may use your amateur station to transmit a "SOS" or "MAYDAY" signal when there is immediate threat to human life or property.

Anyone who sends a distress transmission should give to stations who answer, the location and nature of the distress. An appropriate way to initiate an emergency call on amateur radio is to say "Mayday, Mayday, Mayday" followed by "any station come in please" and identify your station. Always identify your station, even if you're not on an amateur frequency or outside your authorized sub-bands. An unidentified transmission is more likely to be assumed to be a false distress call.

If you are communicating with another amateur station and hear a station in distress break in, the thing you should do is stop your contact immediately, acknowledge the station in distress and determine its location, and what assistance may be needed.

You must assume the distress call is real and act accordingly!

You are not ever prohibited from helping any station in distress, even if doing so would require you to operate outside of the authorization of your amateur license. Remember, someday the roles may be reversed, and you would want someone to answer your call for help. Also remember to take note about what you did and when, or to write out an account of the event as soon as you are able to do so. If you are operating outside of the authority of your license you may be called upon to explain why you chose to do what you did, and having notes written down while the event is fresh in your mind could be very helpful.

If you are in contact with another station and an emergency call is heard, take the emergency call. Again, someday the roles may be reversed, and you would want someone to answer your call for help.

Keep in mind that there are penalties for making a false emergency call. You could have your license revoked. You could be fined a large sum of money. You could be sent to prison. Any or all of these penalties may apply.

Emergency communications has priority at all times in the Amateur Radio Service. Priority must be given to stations providing emergency communications at all times and on all frequencies. It doesn't matter who started the call. The only reason you should transmit on a frequency that is in use for emergency contact is **if** you are in a position to render aid to that communication. In any case, you should take written notes of callsigns and locations of the emergency and any information about the nature of the emergency. The responding station may be having trouble hearing the station in distress, or the calling station may be forced to abandon the contact suddenly. Your notes could save lives. You may be the only person who actually got the vital information that responders need to effectively give aid to the calling station.

Can you use non-amateur frequencies or equipment to call for help in a situation involving immediate danger to life or property? Yes in a genuine emergency you may use **any** means at your disposal to call for help on **any** frequency. A modified amateur radio transceiver **may not** be used to transmit on the local fire department frequency however, except in a **genuine** emergency when you may use **any** means at your disposal to call for help on **any** frequency. Remember, you most likely will be required to explain your reasons for doing whatever you did to the appropriate authorities after the action is over. If we act in good faith, and follow the rules as closely as practical, we will have nothing to fear in the explanations after the event is over.

T8A03 What should you do if you are in contact with another station and an emergency call is heard?
Stop your contact immediately and take the emergency call.

T8A08 What should you do if you hear someone reporting an emergency?
Assume the emergency is real and act accordingly.

T8A09 What is an appropriate way to initiate an emergency call on amateur radio?
Say "Mayday, Mayday, Mayday" followed by "any station come in please" and identify your station.

T8A10 What are the penalties for making a false emergency call?
You could have your license revoked

*Editor's note for T8A10: In reality all the answer options on this question are correct, but the one listed here is the **official** answer for the purposes of the exam.*

T8B02 [97.403] When may you use your amateur station to transmit a "SOS" or "MAYDAY" signal?
When there is immediate threat to human life or property.

T8B08 When can you use non-amateur frequencies or equipment to call for help in a situation involving immediate danger to life or property?
In an genuine emergency you may use whatever is at hand to call for help on any frequency.

T8C03 What should you do to minimize disruptions to an emergency traffic net once you have checked in?
Do not transmit on the net frequency until asked to do so by the net control station.

G2C01 [97.403] When normal communications systems are not available, what means may an amateur station use to provide essential communications when there is an immediate threat to the safety of human life or the protection of property?
Any means of radio communication at its disposal.

G2C04 [97.405(b)] When is an amateur station prevented from using any means at its disposal to assist another station in distress?
Never.

G2C05 [97.403] What type of transmission would a control operator be making when transmitting out of the amateur band without station identification during a life threatening emergency?
An unidentified transmission.

G2C07 What is the first thing you should do if you are communicating with another amateur station and hear a station in distress break in?
Acknowledge the station in distress and determine what assistance may be needed.

G2C08 [97.405(b)] When are you prohibited from helping a station in distress?
You are never prohibited from helping any station in distress.

G2C10 Which emission mode must be used to obtain assistance during a disaster?
Any mode.

G2C11 What information should be given to a station answering a distress transmission?
The location and nature of the emergency.

G2C12 What frequency should be used to send a distress call?
Whatever frequency has the best chance of communicating the distress message.

Emergency Network Operations.

A strong and clear signal is of primary importance for a net control station. If a large scale emergency has just occurred and no net control station is available you should open the emergency net immediately and ask for check-ins. The designated net control station may have been rendered inoperable by the emergency. Someone needs to get started organizing the radio response. Be sure to write down the callsigns and location/condition of stations checking in. This information is essential to net operations. If the designated net control station comes on frequency later they will be happy to take over the net and relieve you of net control duties. You can give a short 'briefing' of what has been accomplished up to that time when turning over control of the net.

If all goes according to plan, the net will be activated by the designated net control station. Check in to the net if you are able to help in the communications effort that will follow. To minimize disruptions to an emergency traffic net once you have checked in do not transmit on the net frequency until asked to do so by the net control station. Net control is like a traffic cop, directing who talks to where and when, to best utilize the resources of the net that are available.

Emergency traffic always has the highest priority. If someone breaks in to the net with emergency traffic the net control station should stop all net activity until the emergency has been handled.

T8A11 [97.101(c)] What type of communications has priority at all times in the Amateur Radio Service?
Emergency communications.

T8A12 [97.101(c)] When must priority be given to stations providing emergency communications?
At all times and on all frequencies.

T8C01 Which type of traffic has the highest priority?
Emergency traffic.

T8C06 What is of primary importance for a net control station?
A strong and clear signal.

T8C07 What should the net control station do if someone breaks in with emergency traffic?
Stop all net activity until the emergency has been handled.

T8C08 What should you do if a large scale emergency has just occurred and no net control station is available?
Open the emergency net immediately and ask for check-ins.

Message handling.

Messages passed from station to station need to follow format guidelines to make sure the correct information arrives at the correct destination. The source and destination of the message are listed in the preamble of a message. This part of the message contains all the information needed to track the message as it passes through the amateur radio traffic handling system.

One item in the message preamble is the 'check' of the message. The term 'check' in reference to a message is a count of the number of words in the message. We use this to help insure that the message was copied correctly as sent by the originating station. To avoid errors in messages, 25 words is the recommended guideline for the maximum number of words to be included in the text of an emergency message.

One thing that must be included when passing emergency messages is the name of the person originating the message. If for example the message is a request for meals for 500 people, you need to have the name and title of the person sending the message. You don't want to be the one paying for those meals. The agency receiving the message needs to know that the request comes from someone with authority to make the request.

Messages of personal information concerning victims should not be transmitted over amateur radio frequencies during emergencies. Remember, their family may be listening to the net and this would be a poor way to hear about the fate of a family member. It is better if these kinds of messages are left to the proper authorities.

One way to reduce the chances of casual listeners overhearing sensitive emergency traffic is to pass messages using a non-voice mode such as packet radio or Morse code. Packet radio has the advantage of using an error correcting protocol that insures the sent message will be received correctly, and also because it uses computer equipment for transmission, there is a quick availability of printed output for delivery to the intended recipient of the message.

T8C02 What type of messages should not be transmitted over amateur radio frequencies during emergencies?
Personal information concerning victims.

T8C04 What is one thing that must be included when passing emergency messages?
The name of the person originating the message.

T8C05 What is one way to reduce the chances of casual listeners overhearing sensitive emergency traffic?
Pass messages using a non-voice mode such as packet radio or Morse code.

T8C09 What is the preamble of a message?
The information needed to track the message as it passes through the amateur radio traffic handling system.

T8C10 What is the meant by the term "check" in reference to a message?
The check is a count of the number of words in the message.

T8C11 What is the recommended guideline for the maximum number of words to be included in the text of an emergency message?
25 words.

RACES/ARES.

RACES and ARES are both organizations that provide communications during emergencies.

The primary function of RACES in relation to emergency activities is RACES organizations are restricted to serving local, state, and federal government emergency management agencies. You must register with the responsible civil defense organization before you can participate in RACES activities. RACES stations participate in training tests and drills to provide orderly and efficient operations for the government organization they serve in the event of an emergency. In times of National Emergency, when the President invokes the 'War Powers Act', amateur radio operators may be ordered off the air. During such a period, only RACES registered stations will be allowed to operate, and then only when in direct support of their sponsoring agency.

The primary function of ARES in relation to emergency activities is ARES supports agencies like the Red Cross, Salvation Army, and National Weather Service. ARES may also operate in support of government agencies. ARES groups provide communications support to events like marathons, parades, and other public events. ARES stations may also serve government entities. You must have an amateur radio license before you can join an ARES group. The main advantage of ARES operations is that there is no regulation preventing the ARES organization from deploying personnel or assets in anticipation of a communications need.

T3D10 What do RACES and ARES have in common?
Both organizations provide communications during emergencies.

T8B03 What is the primary function of RACES in relation to emergency activities?
RACES organizations are restricted to serving local, state, and federal government emergency management agencies.

T8B04 What is the primary function of ARES in relation to emergency activities?
ARES supports agencies like the Red Cross, Salvation Army, and National Weather Service.

T8B05 [97.407(a)] What organization must you register with before you can participate in RACES activities?
The responsible civil defense organization.

T8B06 What is necessary before you can join an ARES group?
You must have an amateur radio license.

G2C02 [97.407(a)] Who may be the control operator of an amateur station transmitting in RACES to assist relief operations during a disaster?
Only a person holding an FCC issued amateur operator license.

G2C03 [97.407(b)] When may the FCC restrict normal frequency operations of amateur stations participating in RACES?
When the President's War Emergency Powers have been invoked.

Traditions and Customs.

Up to this point, we have been looking mostly at the regulatory foundations of amateur radio. Many of the choices we make in operating our stations are determined by custom rather than regulation. Amateur radio is and always has been a self-policing service, meaning that we keep our fellow operators in compliance with the rules and they keep us in compliance. Part of that 'herd' behavior extends to include following traditions and customs when there is no explicit rule to direct us. An example of this would be the question of which sideband to use on each of our bands. At some time there may have been a reasonable explanation for the use of upper sideband on frequencies above the 40meter band, and lower sideband on and below 40 meters. There is no regulation specifying the sideband to use except for the requirement to use USB on the 60 meter band. Our equipment today can modulate either sideband just as well. If you want people to talk to you however, you will follow the 'herd' and use the traditional sideband for the band you wish to operate on.

USB/LSB Utilization Conventions.

Single sideband (SSB) is most commonly used on the High Frequency Amateur bands for voice or phone communications. Single sideband transmissions are used more frequently than Amplitude Modulation (AM) on the HF amateur bands because they use less spectrum space, are more power efficient, and no carrier is transmitted. LSB or lower sideband means that only the lower sideband is transmitted, and the upper sideband is suppressed while for USB or upper sideband transmission only the upper sideband is transmitted, and the lower sideband is suppressed. In both cases the carrier is also suppressed, and will be reconstructed by the receiving station to recover the transmitted audio signal. Both the upper and lower sidebands contain the same audio modulation signal. By tradition frequencies in the 160-, 75- and 40-meter bands use lower sideband (LSB) for phone operations. Frequencies above the 40 meter band use upper sideband (USB).

G2A01 Which sideband is most commonly used for phone communications on the bands above 20 meters?
Upper Sideband.

G2A02 Which sideband is commonly used on the 160, 75, and 40 meter bands?
Lower Sideband.

G2A03 Which sideband is commonly used in the VHF and UHF bands?
Upper Sideband.

G2A04 Which mode is most commonly used for voice communications on the 17 and 12 meter bands?
Upper Sideband.

G2A05 Which mode of voice communication is most commonly used on the High Frequency Amateur bands?
SSB.

Phonetic Alphabet.

You should avoid using cute phrases or word combinations to identify your station because they are not easily understood by some operators. Foreign stations especially may not understand your cute tag phrase for the letters in your callsign. You should use the International Telecommunication Union (ITU) phonetic alphabet when identifying your station because the words are internationally recognized substitutes for letters. In noisy conditions, these words are easier to understand correctly. The letter A, when spoken, sounds like K or J, and B, C, D, G, T, E and Z all sound alike. It doesn't take much noise in the received signal to confuse S with F, I with Y, or M with N. We have all heard these words used, but now you know why we use them.

Alpha - Bravo – Charlie – Delta – Echo – Foxtrot – Golf – Hotel – India – Juliet – Kilo – Lima – Mike – November – Oscar – Papa - Quebec – Romeo – Sierra – Tango – Uniform – Victor – Whiskey – X-ray – Yankee – Zulu

You don't have to know these to pass the exam, but it's good to become familiar with them before you get on the air.

T3A09 [97.119(b)(2)] Why should you avoid using cute phrases or word combinations to identify your station?
They are not easily understood by some operators.

T3A11 [97.119(b)(2)] Why should you use the International Telecommunication Union (ITU) phonetic alphabet when identifying your station?
The words are internationally recognized substitutes for letters

CW Operating.

Morse code or CW operations have a few special things you need to consider. When sending a call in Morse, you should not send faster than you can reliably receive. When the other station answers they will answer at the same speed as you are sending. It is the nature of Morse that you can in fact send much faster than you can receive the code.

When tuning in to a Morse code signal you want to match your frequency closely to the frequency of the sending station. We refer to this as 'zero beating' the signal. As two different signals approach the same frequency they cause an audible interference with each other. We hear this as an audio tone that descends in pitch as the two signals approach the same frequency. When the frequencies match up, that tone will become a rising and falling of the signal strength. Our ears can not discern frequencies below about 30 Hz. The rise and fall of the signal is the only clue we get that we are correctly tuned in.
Correct tuning of a CW signal would match the frequencies that closely because with the narrow filter bandwidths used for CW, the other station will not be able to hear us unless we match frequency very closely.

T6C08 What sending speed is recommended when using Morse code?
Any speed at which you can reliably receive.

G2F01 Which of the following describes full break-in telegraphy (QSK)?
Incoming signals are received between transmitted code character elements.

G2F05 What is the best speed to use answering a CQ in Morse Code?
The speed at which the CQ was sent.

G2F06 What does the term "zero beat" mean in CW operation?
Matching the frequency of the transmitting station.

CW Procedures and Procedural Signals.

The most often heard prosign is 'CQ' and means 'calling any station' for a contact. A station will typically call CQ three times followed by their callsign. When responding to a call of CQ you should transmit the other station's callsign followed by your callsign. In place of "CQ" to indicate that you are listening for calls on a repeater just say your callsign. A station looking to talk to stations in other countries would use "CQ DX" to indicate that preference. You might not want to reply to a "CQ DX" call when it is from a station located close to you.

The origins of most of our procedural signals or prosigns lay in the history of radio when all operations were via Morse code. To reduce the amount of characters transmitted ham operators began using shorthand codes that could be used either as a question or the answer to the question. To use the Q signal as a question in Morse code, the three letter Q signal was sent with a question mark. The answer was/is often simply to send the Q signal back. Some examples are shown below.

As a question		As an answer or statement	
QSK?	(Do you have full break in keying?)	QSK	(Yes I have full break in keying.)
QRM?	(Are you being interfered with?)	QRM	(I am experiencing interference. M - man made)
QRN?	(Are you experiencing noise?)	QRN	(Conditions are noisy. N - natural)
QSY?	(Can/Will you change frequency?)	QSY	(I am changing frequency.. optional info for what freq or up/dwn how much)
QSB?	(Is my frequency unstable?)	QSB	(Your signal is unstable.)
QRL?	(Is this frequency in use?)	QRL	(This frequency is in use.)
QSL?	(Do you acknowledge my last message)	QSL	(I acknowledge your last message.)
QRS	(Please send slower!)		(Send slower)
QRQ	(Please send faster)		(Send faster)

The full list of Q signals is too large for this book, but there are a few you need to know about for the exams. The use of some of these 'Q' signals have been carried over into voice operations as well. While there is no rule prohibiting this use, on voice modes it would be better to just ask the question or make the statement.

Most of the Q signals are intended for use as shortcuts when operating in Morse code (CW) because they replace much longer phrases and reduce transmission time. There are other prosigns that you should know about also. At the end of a message the sending station will add a K when sending in Morse code. This is the equivalent of the voice proword 'over' used to indicate the end of this transmission. If the sending station wishes only one station to reply, KN is added to the end of the transmission to only the receiving station is welcome to reply. The prosign AR is sent at the end of a formal message to indicate the end of the message. Another message may immediately follow. When a CW operator is going off the air he might send a CL at the end of his last transmission to indicate that he is closing his station, but more often you will here the Q signal QRT used for that purpose.

Using RTTY or other data modes, you insert the character sequence 'NNNN" to indicate the end of a formal message. The sending station may continue transmission of the next message without stopping. This would be a common practice during emergency traffic handling.

T3A04 What should you transmit when responding to a call of CQ?
The other station's callsign followed by your callsign.

T3A08 What is the meaning of the procedural signal "CQ"?
Calling any station.

T3A10 What brief statement is often used in place of "CQ" to indicate that you are listening for calls on a repeater?
Say your callsign.

T6C10 What is the "Q" signal used to indicate that you are receiving interference from other stations?
QRM.

T6C11 What is the "Q" signal used to indicate that you are changing frequency?
QSY.

G2A13 What does the expression "CQ DX" usually indicate?
The caller is looking for any station outside their own country.

G2F02 What should you do if a CW station sends "QRS" when using Morse code?
Send slower.

G2F03 What does it mean when a CW operator sends "KN" at the end of a transmission?
Listening only for a specific station or stations.

G2F04 What does it mean when a CW operator sends "CL" at the end of a transmission?
Closing station.

G2FO7 When sending CW, what does a "C" mean when added to the RST report?
Chirpy or unstable signal.

G2F08 What prosign is sent using CW to indicate the end of a formal message?
AR.

G2F09 What does the Q signal "QSL" mean when operating CW?
I acknowledge receipt.

G2F10 What does the Q signal "QRQ" mean when operating CW?
Send faster.

G2F11 What does the Q signal "QRV" mean when operating CW?
I am ready to receive messages.

Breaking into a QSO in progress.

The proper way to break into a conversation between two stations that are using the frequency is to say your callsign between their transmissions. Proper repeater operating practice involves three simple concepts: monitor before transmitting and keep transmissions short, identify legally, and use the minimum amount of transmitter power necessary. If you are listening on a frequency and hear a station calling, pause to be sure your license allows you to transmit on that frequency before responding. Remember to be polite in either situation. All licensed stations have equal right to use a frequency. Operators should share nicely, but if they don't want to, move to another frequency.

T3C01 What is the proper way to break into a conversation between two stations that are using the frequency?
Say your callsign between their transmissions.

T3C02 (D) What is considered to be proper repeater operating practice?
A. Monitor before transmitting and keep transmissions short
B. Identify legally
C. Use the minimum amount of transmitter power necessary
D. All of these answers are correct.

T3C03 What should you do before responding to another stations call?
Make sure you are operating on a permissible frequency for your license class.

T3C04 [97.101(b)] What rule applies if two amateur stations want to use the same frequency?
No frequency will be assigned for the exclusive use of any station and neither has priority.

G2A12 What is the recommended way to break into a conversation when using phone?
Say your callsign during a break between transmissions from the other stations.

VOX operation.

A VOX is a circuit that automatically switches your transmitter on when it detects audio on your microphone. This can be a very handy when you need both hands to work with other station controls, or to type your message text into a printed form. This can also be very embarrassing when you forget about the VOX and are involved in a conversation that was not intended for the radio. User caution is required. There are some VOX controls you need to know about. VOX sensitivity is the gain setting that determines how loudly you must talk to switch the transmitter on. VOX delay is the 'hang time' that the VOX will keep the transmitter on during silence. ANTI-VOX is a feedback system that samples the audio from your receiver to keep it from triggering the transmitter when it is detected by the microphone.

G2A10 Which of the following statements is true of VOX operation?
VOX allows "hands free" operation.

G2A11 Which of the following user adjustable controls are usually associated with VOX circuitry?
A. Anti-VOX
B. VOX Delay
C. VOX Sensitivity
D. **All of these choices are correct.**

Operating courtesy.

Amateur radio operators should avoid the use of racial or ethnic slurs when talking to other stations because it is offensive to some people and reflects a poor public image on all amateur radio operators. You never know who might be listening to your operations. Would you want them to hear you saying those kind of things? Amateurs should respect all people in their 'on the air' behavior. If in your private thoughts you do have those kind of opinions, keep them to yourself, as nobody else really wants to hear them.

Political discussions, jokes and stories, and religious preferences are not prohibited communications while using amateur radio. Keep in mind however that some of these topics may start a big argument. You can discuss about anything actually, except business, and indecent or obscene subjects. There is no list of prohibited words or phrases, but obscene or indecent language is specifically prohibited by FCC rules because some people find it offensive, and children may be listening. The easiest rule to stay out of trouble is to remember that if you wouldn't say it in a church, or to your mother, you shouldn't say it on the radio.

Remember that we were all new at some point, and always try to help the new operators while they are learning their way around a station. If you hear a newly licensed operator that is having trouble with their station you should contact them and offer to help with the problem. If you are offered assistance or instruction along the way, don't be offended. Amateur radio is a self-policing service, and that should always start with a friendly suggestion about how to do things better.

If a net is about to begin on a frequency which you and another station are using, you should, as a courtesy to the net, move to a different frequency. On the reverse, if you are the net control station of a daily HF net, and the frequency on which you normally meet is in use just before the net begins you should conduct the net on a clear frequency 3 to 5-kHz away from the regular net frequency. Even if the net has been using that frequency since Marconi was a boy, you and the net have no more 'right' to it than any other ham. There is no reservation of any frequency to any station's exclusive use except when the FCC declares a communication emergency.

If propagation changes during your contact and you notice increasing interference from other activity on the same frequency, you should move your contact to another frequency. You may be causing interference to other stations on the frequency. If we all share the 'sandbox' nicely, we all have more fun.

T3C05 [97.113(a)(4)] Why is indecent and obscene language prohibited in the Amateur Service?
A. Because it is offensive to some individuals
B. Because young children may intercept amateur communications with readily available receiving equipment
C. Because such language is specifically prohibited by FCC Rules
D. All of these choices are correct.

T3C06 Why should amateur radio operators avoid the use of racial or ethnic slurs when talking to other stations?
It is offensive to some people and reflects a poor public image on all amateur radio operators.

T3C07 What should you do if you hear a newly licensed operator that is having trouble with their station?
Contact them and offer to help with the problem.

T3C08 [97.113(a)(4)] Where can an official list be found of prohibited obscene and indecent words that should not be used in amateur radio?
There is no official list of prohibited obscene and indecent words.

T3C09 [97.113(a)(4)] What type of subjects are not prohibited communications while using amateur radio?
A. Political discussions
B. Jokes and stories.
C. Religious preferences
D. All of these answers are correct

G2B01 What action should be taken if the frequency on which a net normally meets is in use just before the net begins?
Ask the stations if the net may use the frequency, or move the net to a nearby clear frequency if necessary.

G2B02 What should be done if a net is about to begin on a frequency you and another station are using?
Move to a different frequency as a courtesy to the net.

G2B03 What should you do if you notice increasing interference from other activity on a frequency you are using?
Move your contact to another frequency.

Band plans.

A band plan is a voluntary guideline, beyond the divisions established by the FCC for using different operating modes within an amateur band. Band plans are voluntary guidelines for efficient use of the radio spectrum. The amateur community developed the band plans used by amateur radio operators. Some modes of operation are not compatible with each other, and it is helpful when operators avoid mixing signal types on the same frequencies. Some frequencies are reserved for operations seeking contact with foreign stations. If all operators follow the band plans when choosing frequencies and modes, all operators will have more success in communicating with other operators.

T3B01 What is a band plan?
A voluntary guideline, beyond the divisions established by the FCC for using different operating modes within an amateur band.

T3B02 Which of the following statements is true of band plans?
They are voluntary guidelines for efficient use of the radio spectrum.

T3B03 Who developed the band plans used by amateur radio operators?
The amateur community.

G2B07 What is a band plan?
A voluntary guideline for band use beyond the divisions established by the FCC.

G2B08 What is the "DX window" in a voluntary band plan?
A portion of the band that should not be used for contacts between stations within the 48 contiguous United States.

Choosing an Operating Frequency.

When you are about to transmit on a frequency, you should always check to see if the frequency is in use. You wouldn't (or at least shouldn't) pull out of your driveway without looking to see if the road is clear would you? When using phone (voice) a considerate way to avoid harmful interference is to ask if the frequency is in use, and say your callsign. If there is no answer, you may proceed to make your call. When using Morse Code, send "QRL? de" followed by your callsign and listen for a response.

It is best to use the frequencies designated in the band plan for the band on which you are operating. Think of this as keeping your slow moving bus to the right when on a multi-lane road so that faster traffic can pass in the left lanes. The FCC rules are very broad in their definitions of what type of signals can go where. Some signal types just don't work together though, and so the band plans are used to keep each of us in our proper lane.

It is also important to allow sufficient space between signals to avoid interference. This is a little like staying in your own lane when driving.

When selecting a CW transmitting frequency, you should try to allow 150 to 500 Hz separation from a contact in progress to minimize interference.

When selecting a single-sideband phone transmitting frequency, you should allow approximately 3 kHz separation (between suppressed carriers) from a contact in progress to minimize interference.

When selecting a RTTY transmitting frequency, you should allow 250 to 500 Hz (center to center) separation from a contact in progress to minimize interference.

In each of these statements the separation requirement is based on the bandwidth requirement of the modulated signal. Each operating mode has it's own bandwidth requirement, and operating too close to a contact in progress will only result in interference for both contacts.

The exam questions may ask you about selecting frequencies for Slow-Scan TV (SSTV) operation, radioteletype (RTTY) operation, or HF Packet operation. For any of those questions, remember, to comply with good amateur practice when choosing a frequency for any type of radio transmission, you should review FCC Part 97 Rules regarding permitted frequencies and emission types, follow the generally accepted gentleman's agreement band plans, and before transmitting be sure to listen to the frequency to be used to avoid interfering with an ongoing communication.

T3A01 Which of the following should you do when selecting a frequency on which to transmit?
Listen to determine if the frequency is busy.

T3A02 How do you call another station on a repeater if you know the station's callsign?
Say the station's callsign then identify your own station.

T3A03 How do you indicate you are looking for any station with which to make contact?
CQ followed by your callsign.

G2B04 What minimum frequency separation between CW signals should be allowed to minimize interference?
150 to 500 Hz.

G2B05 What minimum frequency separation between SSB signals should be allowed to minimize interference?
Approximately 3 kHz.

G2B06 What minimum frequency separation between 170 Hz shift RTTY signals should be allowed to minimize interference?
250 to 500 Hz.

G2B09 What should you do to comply with good amateur practice when choosing a frequency for Slow-Scan TV (SSTV) operation?
Follow generally accepted band plans for SSTV operation.

G2B10 What should you do to comply with good amateur practice when choosing a frequency for radio-teletype (RTTY) operation?
Follow generally accepted band plans for RTTY operation.

G2B11 What should you do to comply with good amateur practice when choosing a frequency for HF PSK operation?
Follow generally accepted band plans for PSK operation.

G2B12 What is a practical way to avoid harmful interference when selecting a frequency to call CQ using phone?
Ask if the frequency is in use, say your callsign, and listen for a response.

G2B13 What is a practical way to avoid harmful interference when calling CQ using Morse code or CW?
Send "QRL? de" followed by your callsign and listen for a response.

Amateur Auxiliary.

The Amateur Auxiliary to the FCC Compliance and Information Bureau are amateur volunteers who are formally enlisted to monitor the airwaves for rules violations. The objective of this group is to encourage amateur self-regulation and compliance with the rules. Getting a notice in the mail from from an Official Observer or OO station doesn't mean that you are in trouble. The first contact with these people is intended to be a friendly reminder of the rules and/or a helpful observation of things about your station operation that you might not be able to see for yourself. Direction-finding "Fox Hunts" are important to the Amateur Auxiliary, as they provide an opportunity to practice direction-finding skills.

G2D01 What is the Amateur Auxiliary to the FCC?
Amateur volunteers who are formally enlisted to monitor the airwaves for rules violations.

G2D02 What are the objectives of the Amateur Auxiliary?
To encourage amateur self-regulation and compliance with the rules.

G2D03 What skills learned during "Fox Hunts" are of help to the Amateur Auxiliary?
Direction-finding skills used to locate stations violating FCC Rules.

Direction Finding.

Sometimes people don't play nicely. Sometimes other systems may cause interference to a repeater that comes from a place located far from the repeater site. Sometimes people use electronic equipment that was not designed or approved for use in this country. When this happens, a method used to locate sources of noise interference or jamming is radio direction finding. Directional antennas are used to determine the direction of the signal from several locations and when those lines are being plotted on a map the location of the signal source is identified. Similar techniques are used close in to the source to pinpoint the location.

Direction finding concepts also come into play in HF radio. If you are using a directional HF antenna, it is helpful to know which direction to point it. An azimuthal projection map is a map projection centered on a particular location. It is used to determine the shortest path between points on the surface of the earth. It is also a useful type of map to use when orienting a directional HF antenna toward a distant station.

A directional antenna pointed in the long-path direction to another station is generally oriented 180 degrees from its short-path heading. A well-defined echo can be heard in a skywave signals sound if it arrives at your receiver by both short path and long path propagation, due to the different lengths of the respective paths.

T7A05 What is a method used to locate sources of noise interference or jamming?
Radio direction finding.

T7A06 Which of these items would be the most useful for a hidden transmitter hunt?
A directional antenna.

G2D04 What is an azimuthal projection map?
A world map projection centered on a particular location.

G2D05 What is the most useful type of map to use when orienting a directional HF antenna toward a distant station?
Azimuthal projection.

G2D06 How is a directional antenna pointed when making a "long-path" contact with another station?
180 degrees from its short-path heading.

Station Records.

There was a time when amateur stations were required to keep very detailed logs of all activity. Items recorded included time of transmissions, station contacted, and all other relevant information. Fortunately for us these requirements were removed several years ago. There are still advantages to keeping a detailed log book that make it worth the time. If the FCC asks you for information about the operation of your station, your log book would be a helpful source document to refer to when making your reply. Many of the award programs require submission of log records to verify contacts made. There are some situations where you are required to keep information in your station records. If you are using any antenna on the 60 meter band than a simple dipole you must keep information documenting your gain calculations, or a copy of the manufacturers data sheet for that antenna. You would want to include documentation of the RF hazard evaluation you performed for your station if the transmitter power level and frequency is within the FCC guidelines that require such an evaluation. It is a good idea also to keep any official correspondence with the FCC in a file with all other station records.

G2D07 [97.103b] Which of the following information must a licensee retain as part of their station records?
Antenna gain calculations or manufacturer's data for antennas used on 60 meters.

G2D08 Why do many amateurs keep a log even though the FCC doesn't require it?
To help with a reply if the FCC requests information on who was control operator of your station at a given date and time.

G2D09 What information is traditionally contained in a station log?
A. Date and time of contact
B. Band and/or frequency of the contact
C. callsign of station contacted and the signal report given
D. **All of these choices are correct.**

G2D12 [97.303s] Which of the following is required by the FCC rules when operating in the 60 meter band?
If you are using other than a dipole antenna, you must keep a record of the gain of your antenna.

Digital Operating Procedures.

Any time we connect a computer or similar equipment to our transmitter, we are dealing with what the FCC rules defines as Data. RTTY, Morse code, PSK31 and Packet radio are all digital communications. As in all other modes, different data modes have different bandwidth requirements and operating techniques. Understanding the structure of the digital code and the duty cycle requirements is essential to digital operations. Some digital modes are 100% transmission and the transmitter may not be designed to operate at full power 100% of the time.

ASCII is a 7-bit code, with start, stop and parity bits. ASCII is the code set used in most computer equipment, and is the underlying code set for Packet and APRS communications. ASCII can be used in a burst mode like in Packet radio or in a continuous mode like RTTY.

Baudot is a 5-bit code, with additional start and stop bits. Baudot is the code used by the original RTTY teleprinters. The small number of bits per character limits the number of character codes that may be sent, so two of the codes are used to 'shift' into and out of numbers and punctuations from letters. There is no upper or lower case in RTTY, as there are only enough codes for 26 letters, the numbers and punctuations, and the two shift codes.

The number of bits in a PSK31 character is variable due to it being designed for very efficient use of spectrum bandwidth. PSK31 only occupies 31 Hz. of spectrum space to conduct a contact. This extremely efficient use of power allows very long distance contacts with transmitter power levels in the single digit watts range.

AMTOR (Amateur Teleprinting Over Radio) is a digital communications method used by radio amateurs, in which the frequency of errors is reduced by handshaking or character repetition. There are two modes in AMTOR, known as automatic repeat request (ARQ) or Mode A, and forward error correction (FEC) or Mode B.

APRS or Automatic Position Reporting System communication is an advanced message routing system for Packet radio. It uses position information from a Global Positioning Receiver to direct transmissions from the sending station to the receiving station. There may be many relay points between sending and receiving stations. The header part of a data packet contains the routing and handling information.

Most of the data modes on HF use either Frequency Shift Keying (FSK) or Phase Shift Keying (PSK) to modulate the transmitter signal. On the lower frequencies there are limits to the character speed allowed because greater keying speeds in an FSK or PSK signal require greater frequency shifts. In general, we are limited to data rates that will not require more bandwidth than a standard voice channel. Usually we feed an Audio Shift keyed signal into the microphone input of a SSB transmitter set to Lower sideband or LSB mode to send data on HF.

A relatively new mode in amateur data is MFSK16. MFSK uses relatively narrow tone spacings, so remarkable data rates are achieved for a given bandwidth - 64 bps in a signal bandwidth of 316 Hz is typical. An MFSK16 signal (16 carriers) with a spacing of 15.625 Hz and operating at 15.625 baud operates at 62.5 bps (raw data rate of about 80 words per minute!) and occupies about 316 Hz bandwidth. MFSK16 is always operated with FEC, so the text throughput is actually only about 42 WPM.

Knowing where to look for these data modes is helpful. Most PSK31 operations in the 20 meter band are found below the RTTY segment, near 14.070 MHz. In the 80-meter band, most data transmissions take place between 3580 – 3620-kHz. In the 20-meter band most RTTY transmissions take place between 14.070 - 14.100 MHz.

T6C01 Which of the following is an example of a digital communications method?
Packet radio.

T6C02 What does the term APRS mean?
Automatic Position Reporting System.

T6C03 What item is required along with your normal radio for sending automatic location reports?
A global positioning system receiver.

T6C06 What does the abbreviation PSK mean?
Phase Shift Keying.

T6C07 What is PSK31?
A low-rate data transmission mode that works well in noisy conditions.

G2E01 Which mode should be selected when using a SSB transmitter with an Audio Frequency Shift Keying (AFSK) RTTY signal?
LSB.

G2E02 How many data bits are sent in a single PSK31 character?
The number varies.

G2E03 What part of a data packet contains the routing and handling information?
Header.

G2E04 Which of the following 20 meter band segments is most often used for most data transmissions?
14.070 - 14.100 MHz.

G2E05 Which of the following describes Baudot RTTY?
5-bit code, with additional start and stop bits.

G2E06 What is the most common frequency shift for RTTY emissions in the amateur HF bands?
170 Hz.

G2E07 What does the abbreviation "RTTY" stand for?
Radio-Teletype.

G8B08 How is frequency shift related to keying speed in an FSK signal?
Greater keying speeds require greater frequency shifts.

G8B09 What do RTTY, Morse code, PSK31 and packet communications have in common?
They are digital modes.

G8B10 When transmitting a data mode signal, why is it important to know the duty cycle of the mode you are using?
To prevent damage to your transmitter's final output stage.

G8B11 What part of the 20 meter band is most commonly used for PSK31 operation?
Below the RTTY segment, near 14.070 MHz.

G2E08 What segment of the 80 meter band is most commonly used for data transmissions?
3570 - 3600 kHz.

G2E09 Where are PSK signals generally found on the 20 meter band?
Around 14.070 MHz.

G2E10 What is a major advantage of MFSK16 compared to other digital modes?
It offers good performance in weak signal environment without error correction.

G2E11 What does the abbreviation "MFSK" stand for?
Multi (or Multiple) Frequency Shift Keying.

Operating In the Field.

Field operations are essential to emergency response and recovery operations. Amateurs who wish to participate in emergency communications should have equipment and supplies sufficient to operate their equipment. The most common problem during emergency responses is that the power will be out. Equipment like powerful linear amplifiers that require AC power are not practical for emergency use. All of your equipment will likely be running on batteries for the duration of the event or until your batteries go dead. If your emergency kit includes a set of cables and clips to attach to the battery in an automobile, you may extend your operations for several days.

You would want to have extra batteries for your hand held radio, or an adapter that allows the use of disposable alkaline cells. An external antenna and connecting cable would a good addition as this will allow your radio to operate over greater distances. Remember, the power will likely be off and only a few repeater systems have backup power service.

If you will be operating in noisy environments like a crowded evacuation shelter it would be helpful to have headset with a microphone. This will allow you to hear the radio traffic without as much interference from background noise.

Another thing to be sure to have on hand is sufficient food and water for you to function. You won't be much help in the emergency event if you become part of the emergency yourself. Be sure to have a supply of any medications you might need as well. FEMA and many other organizations have information on the Internet about the concept of a 72 hour kit. It is good to plan to be completely self reliant, both for you and your equipment, for at least three days in the event of an area wide emergency.

T7A01 What is a good thing to have when operating a hand-held transceiver away from home?
One or more fully charged spare battery packs.

T7A02 Which of these items would probably not be very useful include in an emergency response kit?
A. An external antenna and several feet of connecting cable
B. A 1500 watt output linear amplifier.
C. A cable and clips for connecting your transceiver to an external battery
D. A listing of repeater frequencies and nets in your area

T7A03 How can you make the signal from a hand-held radio stronger when operating in the field?
Use an external antenna instead of the rubber-duck antenna.

T7A04 What would be a good thing to have when operating from a location that includes lots of crowd noise?
A combination headset and microphone.

Contests.

A popular operating activity that involves contacting as many stations as possible during a specified period of time is contesting. A good example of this is the annual Field Day event, where all participants are required to make as many contacts as possible during a 24 hour period while running the station on emergency power and usually from a temporary location like a park or campsite. There are no prizes for these contests, the only thing you win is bragging rights, but the purpose is to have fun and improve skills by participating.

There are certificates and contests for just about any kind of thing you might imagine: working contacts in all states, all counties, on VHF and UHF bands, or working the most grid squares during a certain time frame. A grid square locator is a letter-number designator assigned to a geographic area.

T7A07 What is a popular operating activity that involves contacting as many stations as possible during a specified period of time?
Contesting.

T7A08 What is the most important benefit of operating in amateur radio contests?
It improves skills that are important during emergency operations.

T7A09 What is a grid locator?
A letter-number designator assigned to a geographic location.

Satellite Operation.

One very exciting area of experimentation in amateur radio is with amateur radio satellites. Amateur operators fund through donations the construction, launch, and maintenance of orbiting satellites. There are currently 63 amateur radio satellites listed as being in orbit. Unfortunately not all of them are still functional at this time, but 28 are still listed as operational. There is also an amateur radio station aboard the International Space Station that is used by the astronauts stationed there. Most of the astronaut corps of nations using the ISS are hams.

Full information about what satellites are working and what mode is scheduled at what time can be obtained from the AMSAT web site. http://www.amsat.org AMSAT also has tracking software available for download that allows you to see where the satellites are and when they will be in range of your station. You should use a satellite tracking program to determine when you can access an amateur satellite. Some of these satellites are in low earth orbits (LEO) and will pass from horizon to horizon in just a few minutes, while others are in long elliptical orbits and appear to hang in a fixed part of the sky for hours at a time. Knowing where to point the antennas is very helpful in working with satellites.

Knowing what frequency to tune to is also important. Orbiting satellites are moving a very high speeds relative to your position, so you must compensate for Doppler shift. Doppler shift is a change in signal frequency caused by motion through space. Just like the change in pitch of a horn on a passing vehicle, the radio frequency of a moving transmitter will shift up or down according to the relative direction of motion. Continuous frequency adjustment is required during a satellite contact to adjust for this shift.

Any amateur operator who has transmit authority on the satellite uplink frequency may use the satellite. The same is true for talking to the astronauts on ISS. For example the satellite sub-band on 70 cm is 435 to 438 MHz. so a technician licensee is authorized to operate there. Satellites offer technician operators a good opportunity to contact stations in other countries.

The power you should use to transmit when using an amateur satellite is the minimum amount of power needed to complete the contact. Something you can do when using an amateur radio satellite is talk to amateur radio operators in other countries. A satellite beacon is a signal that contains information about a satellite.

T7B01 What class of license is required to use amateur satellites?
Any amateur whose license allows them to transmit on the satellite uplink frequency.

T7B02 How much power should you use to transmit when using an amateur satellite?
The minimum amount of power needed to complete the contact.

T7B03 What is something you can do when using an amateur radio satellite?
Talk to amateur radio operators in other countries.

T7B04 Who may make contact with an astronaut on the International Space Station using amateur radio frequencies?
Any amateur with a Technician or higher class license.

T7B05 What is a satellite beacon?
A signal that contains information about a satellite.

T7B06 What should you use to determine when you can access an amateur satellite?
A satellite tracking program.

T7B07 What is Doppler shift?
A change in signal frequency caused by motion through space.

T7B08 What is the name of the group that coordinates the building and/or launch of the largest number of amateur radio satellites?
AMSAT.

T7B09 What is a satellite sub-band?
A portion of a band where satellite operations are permitted.

T7B10 What is the satellite sub-band on 70-CM?
435 to 438 MHz.

T7B11 What do the initials LEO tell you about an amateur satellite?
The satellite is in a Low Earth Orbit.

Electronics.

Some of the people using this study guide will find this part to be the most challenging. It used to be possible to just memorize the answers to a handful of questions and the test was an easy pass. The new question pool for the General class license has brought back a need to know the formulas used to calculate the answer to the question. Fortunately there aren't too many formulas you need to know. You will find then all in the following sections.

Basic Math of Electronics.

Electronics is a metric science. The first thing we need to cover, for those who haven't become familiar with them is the metric prefixes we use in electronics. All of the basic units we refer to can be multiplied or divided to make larger or smaller measurements. Some of the basic units, while making perfect sense from a definition standpoint, are too large for actual real world use. The prefixes commonly used in radio are listed here.

Prefix		Exponent	Unit times	Example of use
giga-	(G-)	10^9	1 billion	gigahertz
mega-	(M-)	10^6	1 million	megahertz
kilo-	(k-)	10^3	1 thousand	kilohertz
hecto-	(h-)	10^2	1 hundred	not used in electronics
deka-	(da-)	10	ten	not used in electronics
Unit		1		any basic unit
deci-	(d-)	10^{-1}	1 tenth	decibel
centi-	(c-)	10^{-2}	1 hundredth	centimeter
milli-	(m-)	10^{-3}	1 thousandth	milliwatt
micro-	(µ-)	10^{-6}	1 millionth	microvolt
nano-	(n-)	10^{-9}	1 billionth	nanosecond
pico-	(p-)	10^{-12}	1 trillionth	picofarad

There are several questions in both pools that expect you to know some of these metric prefixes and their equivalents.

We have used many of these for years without thinking about it. A kilometer is 1000 meters. A millimeter is 1/1000th of a meter. A megahertz is 1000 kilohertz. A gigawatt is 1 billion watts.

All of these prefixes help to make very large and very small numbers easier to work with. In doing the math they effectively shift the decimal point to the left or right by the number of places shown in the exponent column of the list above.

T4E07 How many milliamperes is the same as how many 1.5 amperes?
1500 milliamperes.

T4E08 What is another way to specify the frequency of a radio signal that is oscillating at 1,500,000 Hertz?
1500 kHz.

T4E09 How many volts are equal to one kilovolt?
one thousand volts.

T4E10 How many volts are equal to one microvolt?
one one-millionth of a volt.

T4E11 How many watts does a hand-held transceiver put out if the output power is 500 milliwatts?
0.5 watts.

Names of Electrical Units.

The best approach to this is to start with a chart. These are some of the common units we will be discussing in following sections.

Unit	Measure of	Symbol used in electronics equations
Volt	Electromotive force	E
Ohm	Resistance to the flow of electrons	R
Ampere or Amp	Current or flow of electrons in a circuit	I
Watt	Power, or the actual work being done	P

We can measure these values with meters and use the information to learn what is happening inside a circuit. For example the current required for a circuit to operate as indicated by an ammeter may rise or fall sharply when the circuit is tuned correctly. Most circuits are designed to operate with a specific supply voltage which we could measure with a voltmeter. The battery in a car typically would deliver 12 volts, when measured from one terminal of the battery to the other with a voltmeter.

T4A01 Electrical current is measured in which of the following units?
Amperes.

T4A02 Electrical Power is measured in which of the following units?
Watts.

T4A03 What is the name for the flow of electrons in an electric circuit?
Current.

T4A06 How much voltage does an automobile battery usually supply?
About 12 volts.

T4A07 What is the basic unit of resistance?
The ohm.

T4A12 What instrument is used to measure the flow of current in an electrical circuit?
Ammeter.

T4A13 What instrument is used to measure Electromotive Force (EMF) between two points such as the poles of a battery?
Voltmeter.

DC and AC.

Electrical energy comes in two basic types. The power from a battery is referred to as direct current, or DC. The electrons are all going in the same direction around the circuit all the time. The other type of electrical energy is alternating current or AC. Here the electrons periodically reverse directions. This is the kind of electricity we get from a wall outlet. The rate of reversal is referred to as the frequency. The basic unit of frequency is the Hertz. If we say the wall voltage has a frequency of 60 Hertz, it means the flow of electrons flows first one way, then the other, and repeats this 60 times each second. Each repetition is called a cycle. It is important to know when doing calculations if you are using AC or DC, because with AC you must consider the effect of the frequency on the result. More about that later in the section about reactance.

T4A04 What is the name of a current that flows only in one direction?
A direct current.

T4A05 What is the standard unit of frequency?
The Hertz.

T4A08 What is the name of a current that reverses direction on a regular basis?
An alternating current.

Conductors and Insulators.

If we are dealing with voltage and current flow, we also need to understand how some things allow current flow and some things don't. Most metals conduct electricity. Materials like glass or ceramic usually do not.

T4A09 Which of the following is a good electrical conductor?
A. Glass
B. Wood
C. Copper.
D. Rubber

T4A10 Which of the following is a good electrical insulator?
A. Copper
B. Glass.
C. Aluminum
D. Mercury

Resistance.

Things get a little more interesting when you are looking at other materials, as they may conduct electricity, but do so poorly. Even metal wire has a small amount of resistance to the flow of electrons, and certain metals are used for high power resistors and for heating elements. We use the properties of such materials to control the flow of electricity in a circuit. Carbon has been used as the working element of resistors since the beginnings of experimentation with electricity. When you take powdered carbon and blend it with certain binding materials, the resulting stuff will have very predictable amounts of resistance in a given cross section and length. We can take this blended stuff and package it in a capsule with wire leads and use it to control the flow of electricity in our circuits in a predictable way. It is important to know a little more about this resistor you are using. As the temperature of the resistor is increased, the resistance will change depending on the resistor's temperature coefficient rating. This can lead to unpredictable events in your circuits. We can and do take advantage of this property in a device called a thermistor, where there is a known change in resistance for each degree of temperature change. We use thermistors as temperature sensors, or to control the power in a circuit when the operating temperature rises above safe operating levels.

T4A11 What is the term used to describe opposition to current flow in ordinary conductors such as wires?
Resistance.

G6A01 What will happen to the resistance if the temperature of a carbon resistor is increased?
It will change depending on the resistor's temperature coefficient rating.

G6A13 What type of component is a thermistor?
A device having a controlled change in resistance with temperature variations.

Ohm Law.

The first and fundamental formula to be familiar with is Ohm Law. This formula describes the relationship between the voltage, current, and resistance in a circuit. This equation is at the heart of the definitions of what a volt, an ohm, and an ampere are. One volt will cause a current of one ampere to flow through a resistance of one ohm.

$E = I \cdot R$ to find for voltage $\qquad R = \frac{E}{I}$ to find for resistance $\qquad I = \frac{E}{R}$ to find for current

In all of these formulas E is Volts, I is current in Amps, and R is resistance in Ohms. You will want to work the problems in the questions below to be sure you have a solid understanding of Ohms Law. In later sections we will be building on this to calculate answers for other more complicated problems.

T4D01 What formula is used to calculate current in a circuit?
Current (I) equals voltage (E) divided by resistance (R).

T4D02 What formula is used to calculate voltage in a circuit?
Voltage (E) equals current (I) multiplied by resistance (R).

T4D03 What formula is used to calculate resistance in a circuit?
Resistance (R) equals voltage (E) divided by current (I).

T4D04 What is the resistance of a circuit when a current of 3 amperes flows through a resistor connected to 90 volts?
30 ohms.

T4D05 What is the resistance in a circuit where the applied voltage is 12 volts and the current flow is 1.5 amperes?
8 ohms.

T4D06 What is the current flow in a circuit with an applied voltage of 120 volts and a resistance of 80 ohms?
1.5 amperes.

T4D07 What is the voltage across the resistor if a current of 0.5 amperes flows through a 2 ohm resistor?
1 volt.

T4D08 What is the voltage across the resistor if a current of 1 ampere flows through a 10 ohm resistor?
10 volts.

T4D09 What is the voltage across the resistor if a current of 2 amperes flows through a 10 ohm resistor?
20 volts.

T4D10 What is the current flowing through a 100 ohm resistor connected across 200 volts?
2 amperes.

T4D11 What is the current flowing through a 24 ohm resistor connected across 240 volts?
10 amperes.

Reactance.

Reactance is the opposition to AC caused by inductors and capacitors in a circuit. Reactance in an inductor (coil) or in a capacitor varies as a function of frequency. Reactance values are expressed in Ohms. We don't get into the formulas for calculating reactance for the radio exams, but we will shortly be doing some equations that take reactance into consideration as one factor of the answer. In formulas reactance is represented by the letter X_L for inductive reactance or X_C for capacitive reactance.

G5A02 What is reactance?
Opposition to the flow of alternating current caused by capacitance or inductance.

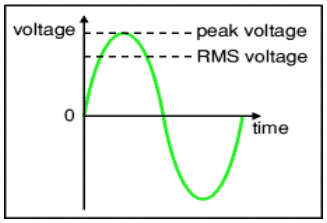
G5A03 Which of the following causes opposition to the flow of alternating current in an inductor?
Reactance.

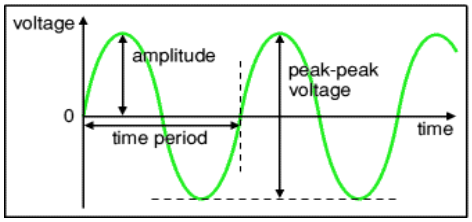
G5A09 What unit is used to measure reactance?
Ohm.

Root-Mean-Square (RMS) Values.

Any time we begin discussing reactances, we need to also address the differences between AC and DC voltage measurements. In some cases, we will measure a voltage as a 'peak' voltage or a 'peak to peak' value. It is important to know what measurement we are calculating with to get the correct answer. When we refer to the voltage at a wall outlet as 120 volts, we are actually saying that it does the work of 120 volts DC. In truth, the peak voltage at the outlet is over 169 volts. If we are talking about peak to peak voltage we are measuring the span between the largest positive going and largest negative going points of the waveform. That outlet voltage is over 339 volts peak to peak. If you multiply the peak voltage by **0.707** you will have the RMS voltage, which is the power equivalent DC voltage. If you multiply the RMS voltage by **1.414** you get the peak voltage.

$E_{Peak} \times 0.707 = E_{RMS}$ or $E_{RMS} \times 1.414 = E_{Peak}$ Remember peak voltage is always the larger number.





The peak to peak voltage is double the peak voltage. Be careful in calculating the answer to the exam questions, and don't forget to convert peak to RMS voltage.

G5B07 Which measurement of an AC signal is equivalent to a DC voltage of the same value?
The RMS value.

G5B08 What is the peak-to-peak voltage of a sine wave that has an RMS voltage of 120 volts?
339.4 volts.

G5B09 What is the RMS voltage of sine wave with a value of 17 volts peak?
12 volts.

Inductance.

The reactance of a coil or inductor **increases** as the frequency of the applied AC increases. An inductor stores energy in a magnetic field. When the magnitude or direction of the current flow is changing, the resulting change in the magnetic field opposes the change in current. This opposition to change is the value we refer to as inductive reactance. The reactance of an inductor is measured in ohms but the value will change as the frequency changes, so we label it in formulas as X_L to identify this as a frequency dependent value. The unit of inductance is the Henry. Because the definition of the Henry results in a unit of very large size, we usually use values expressed in millihenries (mH) or microhenries (µH). In formulas, inductance is represented by the letter L.

This frequency related change in value is a useful property and can be employed for blocking high frequency noise from passing between circuits operating at DC or low frequencies. This application is called a 'filter choke'.

Because of the magnetic field around an inductor, we have to be careful when placing them in a circuit, as the magnetic field of one will interact with the magnetic field of another. The result may not be a desirable effect on the overall performance of the circuit. To avoid this coupling effect, the inductors should be placed with their axis at right angles, or placed inside shielding boxes to minimize coupling. Sometimes however we intentionally arrange inductors in a way that allows the transfer of signals from one section of a circuit to another. This allows a tuned transformer effect where only signals at certain frequencies are able to pass.

When an inductor of a larger value is required, a magnetically permeable core is placed inside of the wire coil to contain a greater magnetic field. If the core is movable, the resulting value of the inductor can be changed. If the current through the coil is too large however the core material will hit a limit where the intensity of the magnetic field cannot increase further. This is called core saturation. Because the core behaves in a non-linear way at this point, core saturation of a conventional impedance matching transformer should be avoided because harmonics and distortion could result.

Large values of inductance may be obtained by use of ferrite toroidal inductors. The core in this type of inductor is a donut shape, and the wire is would through the hole. The toroid does not suffer the same issues with core saturation as other inductors so the toroidal inductor may be used in applications where core saturation is desirable. Most of the magnetic field is contained in the core material, so a toroidal inductor is considered to be 'self-shielding' and will have little effect on other circuit components.

We also need to be aware that other circuit components can 'look' like a coil to the circuit. Large resistors are often constructed with wire that has a large resistance per foot, wound onto a non-conductive core. It would not be a good idea to use a wire-wound resistor in a resonant circuit because the resistor's inductance would detune the circuit. A wire wound resistor acts like an inductor (coil) in a circuit, and it's inductance must be considered as a part of the overall circuit design.

Another design issue with inductors is that the instantaneous differences in voltage from one turn of the coil to the next will cause the wire turns to begin to look like the plates of a capacitor. This inter turn capacitance can result in the coil becoming self-resonant at some frequency. This will cause unpredictable things to happen in your circuit.

G6A12 What is the common name for an inductor used to help smooth the DC output from the rectifier in a conventional power supply?
Filter choke.

G5A05 How does a coil react to AC?
As the frequency of the applied AC increases, the reactance increases.

G6A06 What is the main disadvantage of using a conventional wire-wound resistor in a resonant circuit?
The resistor's inductance could detune the circuit.

G6A07 What is an advantage of using a ferrite core with a toroidal inductor?
A. Large values of inductance may be obtained
B. The magnetic properties of the core may be optimized for a specific range of frequencies
C. Most of the magnetic field is contained in the core
D. **All of these choices are correct.**

G6A10 What is an effect of inter-turn capacitance in an inductor?
The inductor may become self resonant at some frequencies.

G6A08 How should two solenoid inductors be placed so as to minimize their mutual inductance?
With their winding axes at right angles to each another.

G6A09 Why might it be important to minimize the mutual inductance between two inductors?
To reduce or eliminate unwanted coupling.

Capacitance.

The reactance of a capacitor **decreases** as the frequency of the applied AC increases. A capacitor stores energy as electrons on one of two conductive plates or surfaces separated by air or an insulation medium. DC current will not flow through a capacitor. In many ways it resembles a very small battery in how it stores charge, and then feeds it back into the circuit. The reactance of a capacitor is measured in ohms but the value will change as the frequency changes, so we label it in formulas as X_C to identify this as a frequency dependent value. The unit of capacitance is the Farad. Because the definition of the Farad, the unit of capacitance is so large, we typically use values expressed in microfarads (µF) and picofarads (pF) in our circuits.

There are may different types of capacitor, and each of them are optimized for certain applications. The type of capacitor often used in power-supply circuits to filter the rectified AC is an electrolytic. The electrolytic capacitor combines very large values of capacity in a relatively small package. The possible problem with this device is that the device is polarized and connecting it into a circuit in reverse will cause it to fail, sometimes with a spectacularly loud bang.

Capacitors are often used to absorb surges and spikes in a circuit. This suppressor capacitor dissipates the energy of the surge by effectively shorting out the high frequency surge or spike to reduce the chances of damaging the circuit components.

The most commonly used capacitors are built with a small ceramic chip as the insulator. Metal areas are plated onto each side of this chip to create the structure of a capacitor. Wire leads are attached to the plates and the whole assembly is coated with an insulating material. This type of construction gives a device with a very low construction cost combined with good high voltage capability. In very high frequency circuits the chip is often used with no wire leads attached, as they begin to look like inductors in series with the capacitor and tend to reduce the effective value of the capacitance.

G5A06 How does a capacitor react to AC?
As the frequency of the applied AC increases, the reactance decreases.

G6A11 What is the common name for a capacitor connected across a transformer secondary that is used to absorb transient voltage spikes?
Suppressor capacitor.

G6A02 What type of capacitor is often used in power-supply circuits to filter the rectified AC?
Electrolytic.

G6A03 Which of the following is the primary advantage of ceramic capacitors?
Comparatively low cost.

G6A04 Which of the following is an advantage of an electrolytic capacitor?
High capacitance for given volume.

G5A04 Which of the following causes opposition to the flow of alternating current in a capacitor?
Reactance.

G6A05 Which of the following is one effect of lead inductance in a capacitor used at VHF and above?
Effective capacitance may be reduced.

Resistors, capacitors, and inductors in series and parallel.

Now we start to get into the interesting math. When doing Ohms Law calculations, we are usually faced with something a little more complicated than a single resistor to work with. Knowing how to total up the values of the components in a circuit is essential to arriving at the correct answer. The currents in branches of the circuit will add up to equal the total current. The total value of the resistance, capacitance, and/or inductance may not be so easy to understand without the formulas listed below.

G5B02 How does the total current relate to the individual currents in each branch of a parallel circuit?
It equals the sum of the currents through each branch.

Resistors in series is simple addition.

$$R_{Total} = R1 + R2 + R3 + ... + Rx$$

Resistors when connected in parallel divide the current between themselves. The formula gets a little more complicated. The total current will equal the sum of the current through each branch of the circuit.

$$R_{Total} = \frac{1}{(\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + ... + \frac{1}{Rx})}$$

A quick check to see if you did this right is to remember that R total will be smaller than the smallest individual resistance.

G5C04 What is the total resistance of three 100-ohm resistors in parallel?
33.3 ohms.

G5C05 What is the value of each resistor if three equal value resistors in parallel produce 50 ohms of resistance, and the same three resistors in series produce 450 ohms?
150 ohms.

G5C15 What is the total resistance of a 10 ohm, a 20 ohm, and a 50 ohm resistor in parallel?
5.9 ohms.

G5C16 What component should be added to an existing resistor in a circuit to increase circuit resistance?
A resistor in series.

When using these formulas it can get very confusing when there are a lot of values to consider. The value of a small section of the overall circuit can be calculated separately and the results inserted into the place of R1, R2, R3 etc in the final calculation. In the formulas shown above Rx is meant to represent that the number of values being calculated can extend to as large of a list as is needed.

Capacitance adds up in parallel. Each individual capacitor is able to store its full capacity of electrons from the circuit. A way to visualize this is to imagine the area of the conducting plates of each capacitor being added up to form a larger set of plates. In this case the total AC current will be equal to the AC current in each branch of the circuit.

$$C_{Total} = C1 + C2 + C3 + ... + Cx$$

Capacitors in series behave very differently. The capacity of each device is limited by the amount of electrons that flow from the next connected capacitor. Remember, DC current will not flow through a capacitor.

$$C_{Total} = \frac{1}{(\frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3} + ... + \frac{1}{Cx})}$$

Once again, the value of C total will be smaller than the smallest individual value. The most practical use for this concept is to construct very small capacitance values that may not be possible to produce in a single device.

G5C08 What is the equivalent capacitance of two 5000 picofarad capacitors and one 750 picofarad capacitor connected in parallel?
10750 picofarads.

G5C09 What is the capacitance of three 100 microfarad capacitors connected in series?
33.3 microfarads.

G5C12 What is the capacitance of a 20 microfarad capacitor in series with a 50 microfarad capacitor?
14.3 microfarads.

G5C13 What component should be added to a capacitor in a circuit to increase the circuit capacitance?
A capacitor in parallel.

Inductances total up just like resistors provided that there is **no mutual coupling** between the magnetic fields of the inductors. If the magnetic fields are interacting, the combination becomes a transformer and the basic formulas do not give the correct answer.

Inductors in series..

$$L_{Total} = L1 + L2 + L3 + ... + Lx$$

And in parallel..

$$L_{Total} = \frac{1}{(\frac{1}{L1} + \frac{1}{L2} + \frac{1}{L3} + ... + \frac{1}{Lx})}$$

And again, L total will be smaller than the smallest individual value.

G5C10 What is the inductance of three 10 millihenry inductors connected in parallel?
3.3 millihenrys.

G5C11 What is the inductance of a 20 millihenry inductor in series with a 50 millihenry inductor?
70 millihenrys.

G5C14 What component should be added to an inductor in a circuit to increase the circuit inductance?
An inductor in series.

Impedance.

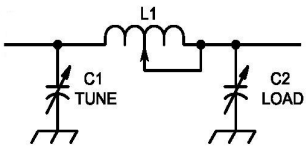
Impedance is the opposition to the flow of AC in a circuit and is the **total of all** of the reactances and resistances in a circuit. Impedance values are expressed in Ohms, and labeled as Z in formulas.

When specifying an impedance value we need to know what frequency the value was calculated for. An antenna system for example may have a 50 ohm impedance at 14 MHz. but have another value that is totally unusable at 7 MHz. When the impedance of an electrical load is equal to the internal impedance of the power source the source delivers maximum power to the load. In many antenna system designs it is necessary to transform from one impedance to another to effect that transfer of power.

There are several different ways to transform an impedance from one value to another. One is with a simple transformer. This is often used in antenna systems to convert from the 50 ohm feedline impedance to a different value that matches the feed point impedance of the antenna. In matching feedlines to antennas it is essential that the components be designed for the power levels expected in the system, as the core material may become 'saturated' or arrive at a point where the magnetic field can not increase in magnitude. At this point the actual reactance of the inductor becomes unpredictable and serious harmonics and distortion may occur.

Another method of matching feedlines to loads of differing impedance is with a short section of a different feedline. This is usually done with coaxial cable where external influences can be controlled to give a reliable result. A full technical discussion of how these are used is beyond the scope of this study guide.

The third method which is used more often inside circuits is the insertion of an LC network between stages of the circuit. A commonly used LC network is the pi network, so named because the schematic representation resembles the Greek letter 'pi' as shown below.



G5A01 What is impedance?
The opposition to the flow of current in an AC circuit.

G5A07 What happens when the impedance of an electrical load is equal to the internal impedance of the power source?
The source can deliver maximum power to the load.

G5A08 Why is impedance matching important?
So the source can deliver maximum power to the load.

G5A10 What unit is used to measure impedance?
Ohm.

G5A11 Why should core saturation of a conventional impedance matching transformer be avoided?
Harmonics and distortion could result.

G5A12 What is one reason to use an impedance matching transformer?
To maximize the transfer of power.

G5A13 (D) Which of the following devices can be used for impedance matching at radio frequencies?
A. A transformer
B. A Pi-network
C. A length of transmission line
D. **All of these choices are correct**.

G5A14 Which of the following describes one method of impedance matching between two AC circuits?
Insert an LC network between the two circuits.

Power calculations.

The basic unit of power is the Watt. Watts are a measure of actual work done. This work may be in the form of launching your signal around the world, or just heating up a resistor or your lunch. We use the label P to indicate watts in equations. The basic formula to calculate watts is..

$$P = I \cdot E$$

The following examples are based on questions directly from the exam pool. Shown below each question example is the formula used to calculate the answer. Remember when taking the exam to choose the answer **closest** to the correct answer. The answer values on the exam are often rounded off to one or two decimal places.

The voltage across a 50-ohm dummy load dissipating 1200 watts would be about 245 volts. This calculation is related to Ohm's law. When we know the power and the resistance, the formula to calculate this would be..

$$E = \sqrt{P \times R}$$

If the output PEP (peak envelope power) from a transmitter displayed on an oscilloscope measures 200 volts peak-to-peak across a 50-ohm resistor connected to the transmitter output, the transmitter output is 100 watts. We know voltage and resistance..

First convert to RMS volts $E_{RMS} = \frac{E_{PtoP}}{2} x .707$ then find the power $P = \frac{E^2}{R}$

Now same equations, different numbers..

If the output PEP from a transmitter if displayed on an oscilloscope measures 500 volts peak-to-peak across a 50-ohm resistor connected to the transmitter output, the transmitter output is 625 watts.

Remember, Peak-to-Peak voltage describes the difference between the maximum positive going voltage and the maximum negative going voltage. To use this in the basic power equations you must convert it to RMS volts.

If 7.0 milliamps is flowing through a resistance of 1.25 kilohms the power being dissipated is 61 milliwatts. We know the current and the resistance. Remember those metric prefixes?

$$P = I^2 \cdot R \qquad \text{or} \qquad P = (0.007_{Amps})^2 x\ 1250_{Ohms}$$

If the output of an unmodulated carrier transmitter shown on an average-reading wattmeter connected to the transmitter output indicates 1060 watts the PEP output is also 1060 watts. The averaging function of these meters is used to calculate the average PEP output of a modulated RF output. There is no calculation for this one. When the output of a transmitter is unmodulated, the the modulation ratio is 1.00, and peak envelope power and the average power are the same.

T4E01 What unit is used to describe electrical power?
Watt.

T4E02 What is the formula used to calculate electrical power?
Power (P) equals voltage (E) multiplied by current (I).

T4E03 How much power is represented by a voltage of 13.8 volts and a current of 10 amperes?
138 watts.

T4E04 How much power is being used in a circuit when the voltage is 120 volts and the current is 2.5 amperes?
300 watts.

T4E05 How can you determine how many watts are being drawn by your transceiver when you are transmitting?
Measure the DC voltage at the transceiver and multiply by the current drawn when you transmit.

T4E06 How many amperes are flowing in a circuit when the applied voltage is 120V and the load is 1200 watts?
10 amperes.

G5B06 What is the output PEP from a transmitter if an oscilloscope measures 200 volts **peak-to-peak** across a 50-ohm dummy load connected to the transmitter output?
100 watts.

G5B03 How many watts of electrical power are used if 400 VDC is supplied to an 800-ohm load?
200 watts.

G5B11 What is the ratio of peak envelope power to average power for an unmodulated carrier?
1.00.

G5B12 What would be the voltage across a 50-ohm dummy load dissipating 1200 watts?
245 volts.

G5B14 What is the output PEP from a transmitter if an oscilloscope measures 500 volts peak-to-peak across a 50-ohm resistor connected to the transmitter output?
625 watts.

G5B15 What is the output PEP of an unmodulated carrier if an average reading wattmeter connected to the transmitter output indicates 1060 watts?
1060 watts.

G5B04 How many watts of electrical power are used by a 12-VDC light bulb that draws 0.2 amperes?
2.4 watts.

G5B05 How many watts are being dissipated when a current of 7.0 milliamperes flows through 1.25 kilohms?
Approximately 61 milliwatts.

Transformers.

A transformer is just two inductors configured so that energy is coupled from one to the other by mutual inductance. Usually the coil windings are placed on a common core to maximize the transfer. The source of energy is connected to the primary winding in a transformer. If no load is attached to the secondary winding of a transformer, the current in the primary winding is called the magnetizing current. This magnetizing current is the the energy used to overcome losses in the magnetic core material, and appears as heat in the core.

Most of the calculations you might do for a transformer are simple ratio problems. If we know the turns ratio, we can calculate the output voltage when we have a known input voltage. For example..

$$\frac{Secondary_{Turns}}{Primary_{Turns}} = \frac{Output_{Volts}}{Input_{Volts}} \quad \text{or with numbers} \quad \frac{500_{Secondary\,Turns}}{2250_{Primary\,Turns}} = 0.222_{Turns\,ratio} \quad \text{then} \quad 0.222_{ratio}\, x\, 120_{Volts\,input} = 26.66_{Volts\,output}$$

Sometimes a transformer is used to convert from one impedance to another. This is still a ratio problem, although a bit more complicated. We assume here that the rated impedance is for the entire audio frequency range. We are matching the output of an audio amplifier with a speaker. We have the impedance values, so we use the following..

$$Turns_{Ratio} = \frac{Turns_{Primary}}{Turns_{Secondary}} \quad \text{or} \quad \sqrt{\frac{Z_{Primary}}{Z_{Secondary}}} \quad \text{so with numbers} \quad \sqrt{\frac{600_{Ohms}}{4_{Ohms}}} \quad \text{which is} \quad \sqrt{150} = 12.247 \quad \text{or a 12.2 :1 Turns ratio}$$

That wasn't so bad was it?

G5C01 What causes a voltage to appear across the secondary winding of a transformer when an AC voltage source is connected across its primary winding?
Mutual inductance.

G5C02 Where is the source of energy normally connected in a transformer?
To the primary winding.

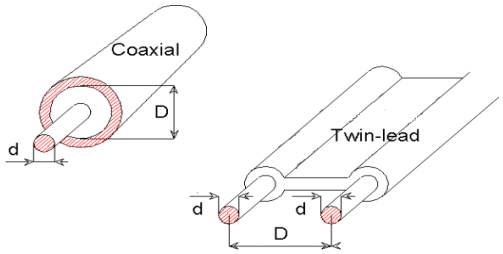
G5C03 What is current in the primary winding of a transformer called if no load is attached to the secondary?
Magnetizing current.

G5C06 What is the voltage across a 500-turn secondary winding in a transformer if the 2250-turn primary is connected to 120 VAC?
26.7 volts.

G5C07 What is the turns ratio of a transformer used to match an audio amplifier having a 600-ohm output impedance to a speaker having a 4-ohm impedance?
12.2 to 1.

Feedline Types.

Feedline is the stuff between your transmitter and your antenna. OK, it's a little more complex than that. There are many different types of feedline used in amateur radio. One of the most common is 50 ohm coaxial cable, but in some applications we also use 75 ohm cable. Coaxial cable carries the power on a center wire surrounded by an insulating medium that is then shielded with a second conductor that completely surrounds the inner wire and insulator. The outer shield is usually surrounded by a black insulating jacket to protect the cable from the effects of ultraviolet light. Because of the shielded structure of coaxial cable, there is no need to maintain specific distances from conductive items like there is with other feedline types. Coaxial cable is also much more flexible which makes it desirable for applications where movement is expected in the antenna system. Cable TV cable is a good example of coaxial cable you may have seen. When coaxial cable is contaminated or deteriorated by age, the loss increases dramatically. The lost energy is converted to heat in the cable. The most common cause of failure in coaxial cable is contamination by moisture.



Another type of feedline commonly used in amateur stations is balanced line. This is two parallel conductors held at a fixed distance apart by some form of insulating material of structures. An example of balanced line would be TV twin lead cable. The distance between the centers of the conductors and the radius or diameter of the conductors are factors that determine the characteristic impedance of a parallel-conductor antenna feed-line. The insulation between the conductors may be air or plastic. In the case of air insulated lines, spacers will be used at regular intervals to hold the wires at the correct distance apart. The characteristic impedance of flat-ribbon TV-type twin-lead is 300 ohms.

T9C05 What happens to the power lost in a feed line?
It is converted into heat by losses in the line.

T9C07 What is the primary reason for failure in coaxial cables?
Moisture contamination.

T9C09 What can happen to older coaxial cables that are exposed to weather and sunlight for several years?
Losses can increase dramatically.

T9C10 Why is the outer sheath of most coaxial cables black in color?
Black provides better protection against ultraviolet damage.

T9C11 What is the impedance of the most commonly used coaxial cable in typical amateur radio installations?
50 Ohms.

T9C12 Why is coaxial cable used more often than any other feed line for amateur radio antenna systems?
It is easy to use and requires few special installation considerations.

G9A01 Which of the following factors help determine the characteristic impedance of a parallel conductor antenna feedline?
The distance between the centers of the conductors and the radius of the conductors.

G9A02 What is the typical characteristic impedance of coaxial cables used for antenna feedlines at amateur stations?
50 and 75 ohms.

G9A03 What is the characteristic impedance of flat ribbon TV type twin lead?
300 ohms.

The Decibel.

The decibel is a comparative measurement. When we are examining the performance of an antenna system we might compare it to a dipole antenna for reference. If we say the antenna has 3 dB of gain when referenced to a dipole, the antenna is effectively doubling the radiated power in the direction we want it to go. A two-times increase in power results in a change of 3 dB. The dB scale is logarithmic, so a change of 1 dB is a change of 20.6%, while a change of 3dB is very close to a 100% change. The loss in a feedline may also be expressed in dB.

G5B01 A two-times increase or decrease in power results in a change of how many dB?
3 dB.

G5B13 What percentage of power loss would result from a transmission line loss of 1 dB?
20.5 %.

Standing Wave Ratio and Feedline Losses.

VSWR or SWR (Standing Wave Ratio) is a term used to describe the match or mismatch of antenna feedlines and feedpoints and/or the reflection of energy from an antenna that is operating off its resonant frequency. When all other considerations are removed and the system is operating at resonance the SWR will be expressed as a ratio of the impedance values being connected to each other.

The typical cause of power being reflected back down an antenna feed-line is a difference between feed line impedance and antenna feed-point impedance. To prevent standing waves of voltage and current on an antenna feed-line the antenna feed-point impedance must be matched to the characteristic impedance of the feed-line. On a dipole antenna fed with parallel-conductor feed line you would use an inductively coupled matching network to match the unbalanced transmitter output to the balanced parallel-conductor feed line.

SWR can be measured with a specialized SWR meter or by comparing the forward and reflected power readings of a directional wattmeter. If the SWR reading is erratic, it may indicate a defective connection in the antenna/feedline system. A high SWR in a coaxial cable feedline increases loss in the line, so we want to keep the SWR low by matching the feedline to the load correctly.

RF feed line losses are usually expressed dB/100 ft. As the frequency increases, the loss value will increase. If a 160-meter signal and a 2-meter signal pass through the same coaxial cable, the attenuation will be greater at 2 meters.

The connection of a 50-ohm feed line to a resonant antenna having a 200-ohm feed-point impedance would be a 4:1 SWR.

The connection of a 50-ohm feed line to a resonant antenna having a 10-ohm feed-point impedance would be a 5:1 SWR.

The connection of a 50-ohm feed line to a resonant antenna having a 50-ohm feed-point impedance would be a 1:1 SWR.

The SWR if you feed a vertical antenna that has a 25-ohm feed-point impedance with 50-ohm coaxial cable would be 2:1.

The SWR if you feed a folded dipole antenna that has a 300-ohm feed-point impedance with 50-ohm coaxial cable would be 6:1.

When writing the SWR value, the larger number is always first.

For the most efficient transfer of energy, the source, feedline, and load impedances should all be equal. When the feedline and antenna impedance are equal, the SWR is a 1:1 ratio. Most modern amateur transmitters can tolerate an SWR of up to 2:1 in the antenna system.

T9C01 What is standing wave ratio (SWR)?
The ratio of load impedance to feedline impedance.

T9C02 What reading on a SWR meter reading indicates a perfect impedance match between the antenna and the feed line?
1 to 1.

T9C03 What might be indicated by erratic changes in SWR readings?
A loose connection in your antenna or feedline.

T9C04 What is the SWR value where the protection circuits in most solid-state transmitters begin to reduce transmitter power?
2 to 1.

T9C06 What instrument other than a SWR meter could you use to determine if your feedline and antenna are properly matched?
Directional wattmeter.

T9C08 Why is it important to have a low SWR in an antenna system that uses coaxial cable feedline?
To allow the efficient transfer of power and reduce losses.

G9A04 What is a common reason for the occurrence of reflected power at the point where a feedline connects to an antenna?
A difference between feedline impedance and antenna feed point impedance.

G9A05 What must be done to prevent standing waves on an antenna feedline?
The antenna feed point impedance must be matched to the characteristic impedance of the feedline.

G9A06 Which of the following is a reason for using an inductively coupled matching network between the transmitter and parallel conductor feed line feeding an antenna?
To match the unbalanced transmitter output to the balanced parallel conductor feedline.

G9A07 How does the attenuation of coaxial cable change as the frequency of the signal it is carrying increases?
It increases.

G9A08 In what values are RF feed line losses usually expressed?
dB per 100 ft.

G9A09 What standing-wave-ratio will result from the connection of a 50-ohm feed line to a non-reactive load having a 200-ohm impedance?
4:1.

G9A10 What standing-wave-ratio will result from the connection of a 50-ohm feed line to a non-reactive load having a 10-ohm impedance?
5:1.

G9A11 What standing-wave-ratio will result from the connection of a 50-ohm feed line to a non-reactive load having a 50-ohm impedance?
1:1.

G9A12 What would be the SWR if you feed a vertical antenna that has a 25-ohm feed-point impedance with 50-ohm coaxial cable?
2:1.

G9A13 What would be the SWR if you feed a folded dipole antenna that has a 300-ohm feed-point impedance with 50-ohm coaxial cable?
6:1.

G9A14 If the SWR on an antenna feedline is 5 to 1, and a matching network at the transmitter end of the feedline is adjusted to 1 to 1 SWR, what is the resulting SWR on the feedline?
5 to 1.

Rectifiers, Solid State Diodes.

The two major ratings that must not be exceeded for silicon-diode rectifiers used in power-supply circuits are peak inverse voltage, the maximum voltage the rectifier will handle in the non-conducting direction, and average forward current.

Another rating that is also important is the internal capacitance of the diode junction. This internal capacitance can interfere with the tuning of circuits, as the absolute value will change based on the voltages applied to the diode. In many circuits Schottky diodes are used because their internal capacitance is lower than standard silicon diodes.

The last thing to consider about a diode is the voltage drop caused by the internal resistances of the diode junction. Silicon diodes typically have a 0.7 volt drop, meaning that they do not begin to conduct current until the voltage applied to them rises above 0.7 volts. Germanium diodes which are usually used in receiver detector stages, have a voltage drop of only 0.3 volts.

A half-wave rectifier conducts during 180 degrees of each cycle. A full-wave rectifier conducts during 360 degrees of each cycle. The output waveform of an unfiltered full-wave rectifier connected to a resistive load will be a series of pulses at twice the frequency of the AC input.

When two or more diodes are connected in parallel to increase the current-handling capacity of a power supply, a ballast resistor must be connected in series with each diode to ensure that one diode doesn't take most of the current and burn up due to overload. The resistor value is selected to limit the current through the diode to a safe operating level.

G6B01 What is the peak-inverse-voltage rating of a rectifier?
The maximum voltage the rectifier will handle in the non-conducting direction.

G6B02 What are the two major ratings that must not be exceeded for silicon-diode rectifiers?
Peak inverse voltage; average forward current.

G6B03 What is the approximate junction threshold voltage of a germanium diode?
0.3 volts.

G6B04 When two or more diodes are connected in parallel to increase current handling capacity, what is the purpose of the resistor connected in series with each diode?
The resistors ensure that one diode doesn't carry most of the current.

G6B05 What is the approximate junction threshold voltage of a silicon diode?
0.7 volts.

G6B06 Which of the following is an advantage of using a Schottky diode in an RF switching circuit as compared to a standard silicon diode?
Lower capacitance.

Tubes and Transistors.

Early amateur radio equipment was all built around vacuum tubes. The higher voltages required for these devices made portable and mobile equipment difficult to impossible to produce. Now most of our equipment is based on transistors or their more advanced descendants the integrated circuit or IC.

Some of the older equipment you will encounter is still tube based, as are most of the high power amplifiers you might use in your station. The operating characteristics of tubes are determined by the shape, size, and spacing of the internal elements. In addition to the expected cathode, anode, and grid structures, there may be screens to control the inter-element capacitance of the tube or grids to control the flow of current through the tube. The biggest disadvantages to using tubes in your equipment is the large amount of power they waste as heat, and the fact that they are getting somewhat rare and expensive. Some of the older tube based rigs will use 10 to 20 tubes. The prices for those tubes is $20 to $70 each, or more for high power amplifier tubes. This means that restoring one of these old rigs to new condition can cost as much as a new solid state rig.

The operating characteristics of field effect transistors is similar to the tubes they often replace. The main issues in using FET devices is that they are susceptible to damage from static and over voltage conditions. MOSFETs are a type of FET that is capable of amazing gain when amplifying a signal, but they are even more sensitive to static charges when being handled. The control gate is separated from the source and drain of the transistor by a thin layer of metal oxide which is easily damaged if the surrounding circuitry does not protect it properly.

Because of the large amount of power that may be handled by a power transistor, the case is often insulated to prevent short circuiting of the device to ground.

Simple bipolar transistors are often used as switches in our circuits. The stable operating points for a bipolar transistor that is used as a switch in a logic circuit would be in its saturation and cut-off regions. As a switch, saturation is where the transistor conducts the maximum possible current, meaning the switch is turned on, and cutoff is where no current flows, and the switch is turned off. The region between saturation and cutoff is where amplification is done.

G6B07 What are the stable operating points for a bipolar transistor that is used as a switch in a logic circuit?
Its saturation and cut-off regions.

G6B08 Why is it often necessary to insulate the case of a large power transistor?
To avoid shorting the collector or drain voltage to ground.

G6B09 Which of the following describes the construction of a MOSFET?
The gate is separated from the channel with a thin insulating layer.

G6B10 Which element of a triode vacuum tube is used to regulate the flow of electrons between cathode and plate?
Control grid.

G6B11 Which of the following solid state devices is most like a vacuum tube in its general characteristics?
An FET.

G6B12 What is the primary purpose of a screen grid in a vacuum tube?
To reduce grid-to-plate capacitance.

Batteries.

Batteries are one of the most misunderstood subjects in amateur radio circles. Any time you are working with batteries, you need to keep a few safety concepts in mind. Batteries store a lot of energy in a small space, and some types will self destruct violently if shorted or damaged. All batteries contain corrosive chemicals in some form or another, and many types may allow their electrolytes to spill if tilted too far. When exhausted beyond recharging, they still contain hazardous substances that should be recycled rather than being dumped in the landfill. Excessive charge or discharge current will cause electrolytes to overheat and/or change to potentially explosive gases, so proper ventilation is required, especially for large storage batteries. When shorted, batteries will deliver extremely high currents that may cause wiring to melt, and fires to start, so proper fusing is essential.

All that having been said, batteries also make portable and hand held equipment possible, so it is a good idea to be familiar with their use and care.

We use many types of batteries to power our equipment. The old reliable standard is the deep cycle lead acid battery similar to a car battery. These are usually 12 volts and may have the spill proof structure of a gel-cell battery. 12 volt lead acid batteries should not be discharged below 10.2 volts, as this will shorten their life. To extend battery life as much as possible, you should draw power from the battery at the lowest possible rate.

Nickel cadmium batteries are often used in hand held radios, because they give good power density and long recharge life at a reasonable cost. Their low internal resistance allows them to provide very large discharge currents without damaging the cell. Nickel metal hydride batteries share the same characteristics, but with about double the capacity of the original NiCd battery. The normal cell voltage of NiCd and NiMH batteries is 1.2 volts, so a standard battery holder intended for alkaline cells when filled with these cells results in a lower total voltage.

Alkaline cells are good for one use, and have the advantage of long storage life which makes them good to have for emergency operations. Like the old carbon/zinc battery, you should not attempt to recharge an alkaline cell. It may overheat and/or explode if recharged.

A new battery making its way into our equipment is the lithium ion battery. These little wonders pack an amazing amount of energy into a very small space, giving them the longest service life when compared to other battery types of the same size. The only problem with the lithium ion battery is that it does not recharge well if fully discharged, and if shorted or damaged it may self destruct in a fiery explosion. This is generally not an issue with properly designed equipment that is configured to use lithium ion batteries.

All batteries should be inspected regularly and recharged and/or replaced when defective. Storage temperatures are a consideration. Batteries like cool dry locations. For emergency preparedness, it is a good idea to do this check at least every 6 months.

T4C06 Which of the battery types listed below offers the longest life when used with a hand-held radio, assuming each battery is the same physical size?
A. Lead-acid
B. Alkaline
C. Nickel-cadmium
D. Lithium-ion.

T4C07 What is the nominal voltage per cell of a fully charged nickel-cadmium battery?
1.2 volts.

T4C08 What battery type on this list is not designed to be re-charged?
Carbon-zinc.

T4C09 What is required to keep rechargeable batteries in good condition and ready for emergencies?
A. They must be inspected for physical damage and replaced if necessary
B. They should be stored in a cool and dry location
C. They must be given a maintenance recharge at least every 6 months
D. All of these answers are correct.

T4C10 What is the best way to get the most amount of energy from a battery?
Draw current from the battery at the slowest rate needed.

G6B13 What is an advantage of the low internal resistance of Nickel Cadmium batteries?
High discharge current.

G6B14 What is the minimum allowable discharge voltage for maximum life of a standard 12 volt lead acid battery?
10.5 volts.

G6B15 When is it acceptable to recharge a carbon-zinc primary cell?
Never.

G6B16 Which of the following is a rechargeable battery?
Nickel Metal Hydride.

Analog and Digital Integrated Circuits (ICs); Microprocessors; Memory; I/O devices; Display Devices.

For some, this is just a review of things you already know. Just as vacuum tubes faded into the history of radio, the transistor is starting to become more of a rare item. The increasing demand for more sophisticated equipment that can monitor 42 frequencies, browse the Web, make a hot cup of coffee, and fit in a shirt pocket, has led to the use of integrated circuits in most of our equipment. The boundary between our computers and our radios has become extremely hard to define. At some point you will encounter the need to understand what all those little little boxes with all the hundreds of wire legs are, and how they work. Fortunately, you don't need to know that much for the radio exams.

Integrated circuits can be broadly separated into two groups, devices that deal with analog signals, meaning signals where the signal level varies continuously, and devices that deal with logic. The inputs and outputs are represented by 1s and 0s or the on/off states of the circuits.

Examples of an analog IC would be things like a linear voltage regulator, or an operational amplifier. One special device that is of great interest to amateurs is the MMIC or monolithic microwave integrated circuit. This device is a nearly complete amplifier on a single chip. The use of MMIC chips allows amateurs who might not have been able to master the design and manufacturing process of UHF and microwave radios to experiment with designs that are the technical equal of anything coming out of the research labs of the big corporations and universities.

Logic ICs are a much larger group of devices, as so many of the things that use electronics are, internally at least, run by digital logic. The first logic chips were based on a method call transistor-transistor logic or TTL. TTL chips have a disadvantage of being a little power hungry. Then some clever fellows invented complimentary metal oxide semiconductors or CMOS ICs. Every chip function that was available in a TTL chip is now offered in CMOS as well. CMOS circuits only use a fraction of the power required by TTL chips, which make them the preferred choice for new designs. Most of the electronic devices you use every day are based on CMOS components.

Logic circuits can be very complex. The largest logic chips would be the microprocessor chip, which is at the heart of your personal computer, but is also found in places that might surprise you. There is a microprocessor chip in every cell phone. Most newer cars have entire networks of specialized microprocessor chips in their control systems. Video games, talking toys, fancy two way radios, traffic signals, industrial tools, exercise equipment, cameras, and the list goes on and on. It grows much faster than you can read.

As more and more things rely on microprocessors there came a need for support devices to help the processor chips do their jobs. Specialized memory chips like RAM or random access memory, and ROM meaning read only memory are used to store information in the form of lots of 1s and 0s. To allow equipment to save settings when the power is off, non-volatile memory devices were created that do not lose their saved information at shutdown.

Specialized interface devices were also required. Most of you have seen a digital clock or the timer on a microwave oven. These are examples of interface devices. Display devices can be broken down into two basic groups, light emitting devices and transmissive devices like liquid crystal displays. Light emitting devices can be as simple as a single light emitting diode that emits photons when forward biased with a DC voltage to complex arrays of LEDs arranged to present letters and numbers. LEDs are also a little power hungry and were replaced in most applications with LCD displays. The first digital watches used LEDs and would only show the time when you pressed a button to light them up. They were large and used batteries at an alarming rate. Contrast that to the LCD watch hanging beside my computer monitor that is and has been displaying the time for 4 years now on the same tiny battery. The only disadvantage to using an LCD display is that it does require a light source to be readable. The main advantage is that arrays of LCD cells can be built into large panels capable of showing video images like in laptop computers, some desktop monitors, and in some living rooms the new HDTV displays that are 3 to 4 feet across.

G6C01 Which of the following is most often provided as an analog integrated circuit?
Linear voltage regulator.

G6C02 Which of the following is the most commonly used digital logic family of integrated circuits?
CMOS.

G6C03 Which of the following is an advantage of CMOS Logic integrated circuits compared to TTL logic circuits?
Low power consumption.

G6C04 What is meant by the term ROM?
Read Only Memory.

G6C05 What is meant when memory is characterized as "non-volatile"?
The stored information is maintained even if power is removed.

G6C06 Which type of integrated circuit is an operational amplifier?
Analog.

G6C07 What is one disadvantage of an incandescent indicator compared to a LED?
High power consumption.

G6C08 How is an LED biased when emitting light?
Forward Biased.

G6C09 Which of the following is a characteristic of a liquid crystal display?
It requires ambient or back lighting.

G6C10 What is meant by the term MMIC?
Monolithic Microwave Integrated Circuit.

G6C11 What is a microprocessor?
A miniature computer on a single integrated circuit chip.

Digital Circuits (gates, flip-flops, shift registers).

There are some new questions in the General class pool about digital logic circuits. These devices may be TTL or CMOS, or in some cases other more exotic chip types. The essential information you need to know is mostly definitions of some of the basic building blocks of logic circuitry. As mentioned above, digital logic represents the binary 1s and 0s with the on/off states of the chip inputs and outputs.

The first 'block' is a simple flip-flop circuit. This circuit is so simple it is sometimes built with discrete components instead of using an IC chip. As pulses enter the input line of the flip-flop, the output lines change to one of two stable states. Usually this is 2 lines alternating between logic 'low' (0) and logic 'high' (1).

The operational sections in a logic circuit are referred to as 'gates' and there are many terms to describe the function of those gates. The basic types are the AND and the OR gates. When the logic lines into these gates go to high or low states the output is driven to a high or low depending on the type of gate it is. When the inputs of an AND gate are both 'high', the output goes 'high'. When one or the other input, or both, of an OR gate go 'high', the output goes 'high'.

The basic gates have counterparts that operate the opposite. These **N**egative **AND** gates or NAND will give an output 'low' when the inputs are both 'high'. The NOR gate is similarly reversed in output. When one or both inputs are 'high' the output would be 'low'.

Another logic chip you need to know about is a binary counter. This is a collection of gates configured so that incoming pulses cause the outputs to count through the binary number sequence in a pattern as shown below.

count	bit 3	bit 2	bit 1
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1
6	1	1	0
7	1	1	1

Note that it takes just 3 bits or output lines to represent numbers 0 to 7, or 8 unique states. This is the same way data is stored in a computer, though with a great many more bits.

The last logic circuit to look at is a shift register. The function of a shift register is to store or delay data bits for a series of clock pulse cycles. A shift register may have as many stages as your design needs and may be as wide (how many bits in parallel) as you need. There are single chips that perform this function, as well as chips that can be ganged together to construct very large shift register arrays.

G7B01 Which of the following describes a "flip-flop" circuit?
A digital circuit with two stable states.

G7B02 Why do digital circuits use the binary number system?
Binary "ones" and "zeros" are easy to represent with an "on" or "off" state.

G7B03 What is the output of a two-input NAND gate, given both inputs are "one"?
Zero.

G7B04 What is the output of a NOR gate given that both inputs are "zero"?
One.

G7B05 How many states are there in a 3-bit binary counter?
8.

G7B06 What is a shift register?
A clocked array of circuits that passes data in steps along the array.

Power Supplies.

To operate our equipment, we need power. To be usable, that power must be at the correct voltage and clean filtered DC. To obtain the clean output we require power supplies to incorporate a filter network into their design. The power-supply filter network is a circuit made up of capacitors and inductors that removes AC noise from the DC output of the power supply. One design issue we need to consider with any power supply but especially with high voltage supplies used on high power transmitters and amplifiers is the energy that is stored in the capacitors in that filter network. If you open the cabinet of a supply, even with the power disconnected, the capacitors inside will still be holding a charge, just like a battery. In the case of a high voltage system, that charge can be large enough to be DEADLY! A safety feature that should be used in high voltage power supplies is a bleeder resistor across the terminals of the filter capacitors to provide a discharge path for the energy stored there. The value of that bleeder resistor is high enough that the current flowing through it will be very small. The supply of stored electrons is not infinite however, and after a while the stored charge in the filter capacitors will be dissipated.

When, as amateurs often do, we design or build a power supply, we need to consider the ratings of components used in that supply. The minimum peak-inverse-voltage rating of the rectifier in a full-wave power supply should be double the normal peak output voltage of the power supply. The rectifier in a full wave power supply circuit could be subjected to higher reverse voltage if one leg of the rectifier bridge fails. If the PIV rating of the diode is too low the entire device will fail, and often in a 'shorted' mode which will subject following components to the unrectified AC current. The resulting cascade failure of components will render your power supply into a doorstop in a delightful cloud of noxious fumes and an amazing display of flashing lights and showers of sparks.

In a half wave power supply, the rectifier diode can not be exposed to voltages larger than the output voltage, so the minimum peak-inverse-voltage rating of the rectifier in a half-wave power supply should be one to two times the normal peak output voltage of the power supply. A larger PIV rating does add a safety margin to the supply design, so it is better to be much larger than the voltages expected in the circuit.

To protect the equipment attached to a power supply, a crowbar circuit is often used to provide over voltage protection at the output of a power supply. This can be a complex system that automatically resets when the overload is remove, or it can be something as simple as a circuit that will draw a sudden excessive current and cause the fuse to fail, thus cutting off the power to the protected equipment.

In a switched-mode power supply, the first step in converting the 120 volt AC input voltage to a 12 volt DC output voltage is that the 120 volt AC is first rectified and filtered. The 120 volt DC is then switched by a high frequency oscillator and delivered to the step-down transformer. An advantage of a switched-mode power supply as compared to a linear power supply is that the relatively high frequency power oscillator allows the use of small, lightweight and low-cost transformers in the switched-mode supply. Capacitors with low equivalent series resistance should be used to filter the rectified DC output of a switching power supply due to the high frequency of the switching circuit.

T4C04 What device is used to convert the alternating current from a wall outlet into low-voltage direct current?
Power Supply.

G7A01 What safety feature does a power-supply bleeder resistor provide?
It discharges the filter capacitors.

G7A02 What components are used in a power-supply filter network?
Capacitors and inductors.

G7A03 What should be the minimum peak-inverse-voltage rating of the rectifier in a full-wave power supply?
Double the normal peak output voltage of the power supply.

G7A04 What should be the approximate minimum peak-inverse-voltage rating of the rectifier in a half-wave power supply?
Two times the normal peak output voltage of the power supply.

G7A14 Which of the following is a desirable characteristic for capacitors used to filter the DC output of a switching power supply?
Low equivalent series resistance.

G7A15 Which of the following is an advantage of a switched-mode power supply as compared to a linear power supply?
High frequency operation allows the use of smaller components.

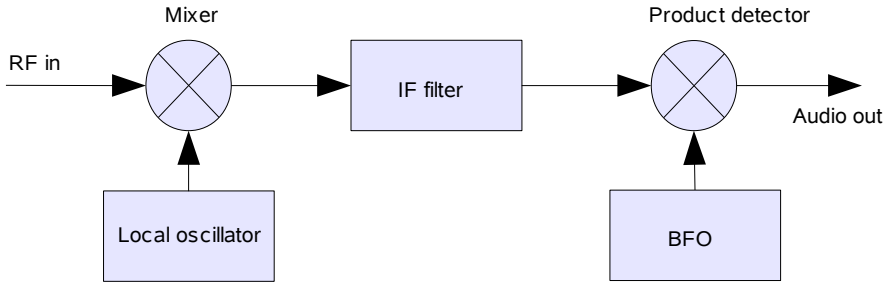
G7A16 What portion of the AC cycle is converted to DC by a half-wave rectifier?
180 degrees.

G7A17 What portion of the AC cycle is converted to DC by a full-wave rectifier?
360 degrees.

G7A18 What is the output waveform of an unfiltered full-wave rectifier connected to a resistive load?
A series of DC pulses at twice the frequency of the AC input.

Receivers.

All good amateur radio stations start with a receiver. The receiver is the piece of equipment that converts a radio signal into sounds we can hear. To perform this conversion the receiver mixer stage combines an input RF signal with a local oscillator signal to produce an intermediate frequency (IF) signal. This process of mixing 2 RF signals is called heterodyning. This IF signal would then be passed to the next stage of the receiver for additional processing and eventual conversion to output audio.



In any heterodyning process you start with 2 frequencies, and the mixer output will contain those 2 frequencies and the SUM and DIFFERENCE of those 2 frequencies. Inter-stage filtering only allows the desired signal to pass into the next circuit stage. The next statement built from a question in the question pool illustrates this process with frequencies listed so you can see how this works.

The receiver mixer stage combines a 14.250-MHz input signal with a 13.795-MHz oscillator signal to produce a 455-kHz intermediate frequency (IF) signal.

$$RF_{Frequency} - Local_{frequency} = IF_{Frequency} \quad \text{or} \quad 14.250_{MHz} - 13.795_{MHz} = 455_{kHz}$$

The problem with this scheme in a simple receiver is that it can also respond to undesired signals. If the receiver mixes a 13.795-MHz VFO with a 14.250-MHz received signal to produce a 455-kHz intermediate frequency (IF) signal, it will also produce an Image response of a signal on 13.340-MHz in the receiver. Notice that the Image signal is on the other side of the VFO frequency by the same distance, in this case 455-kHz.

$$RF_{Frequency} + Local_{frequency} = IF_{Frequency} \quad \text{or} \quad 13.340_{MHz} + 13.795_{MHz} = 455_{kHz}$$

Any signal converted to the IF frequency will be processed by the next stage in the receiver. Better receiver designs use several of these frequency conversions to prevent reproduction of these undesired Image signals, as well as good interstage filters to reject signals that are not desired in the output. In Heterodyning, the characteristics of the original signal are reproduced unchanged at the output frequency.

In an FM or frequency modulation receiver, the product detector stage is replaced by a frequency discriminator. In most other respects the receiver works the same as described above.

S Meters, found on the better receivers, are useful as indicators of signal tuning and as an indication of the strength and quality of a received signal. The indication is not as accurate as a calibrated field strength meter, but can be useful for comparing the effect of station adjustments. The reading is not linear especially at the top of the scale where a difference from S9 to 20dB over S indicates a 100 times increase in signal on a well calibrated meter.

T4C01 What is used to convert radio signals into sounds we can hear?
Receiver.

G4D04 What does an S-meter measure?
Received signal strength.

G4D05 How does an S-meter reading of 20 db over S-9 compare to an S-9 signal, assuming a properly calibrated S meter?
It is 100 times stronger.

G4D06 Where is an S-meter generally found?
In a receiver.

G7A09 What circuit is used to process signals from the IF amplifier and BFO and send the result to the AF amplifier in a single-sideband phone superheterodyne receiver?
Product detector.

G7A11 What is the simplest combination of stages that can be combined to implement a superheterodyne receiver?
HF oscillator, mixer, detector.

G8B12 What is another term for the mixing of two RF signals?
Heterodyning.

G7A12 What type of receiver is suitable for CW and SSB reception but does not require a mixer stage or an IF amplifier?
A direct conversion receiver.

G7A13 What type of circuit is used in many FM receivers to convert signals coming from the IF amplifier to audio?
Discriminator.

G7A08 What circuit is used to process signals from the RF amplifier and local oscillator and send the result to the IF filter in a superheterodyne receiver?
Mixer.

G8B01 What receiver stage combines a 14.250 MHz input signal with a 13.795 MHz oscillator signal to produce a 455 kHz intermediate frequency (IF) signal?
Mixer.

G8B02 If a receiver mixes a 13.800 MHz VFO with a 14.255 MHz received signal to produce a 455 kHz intermediate frequency (IF) signal, what type of interference will a 13.345 MHz signal produce in the receiver?
Image response.

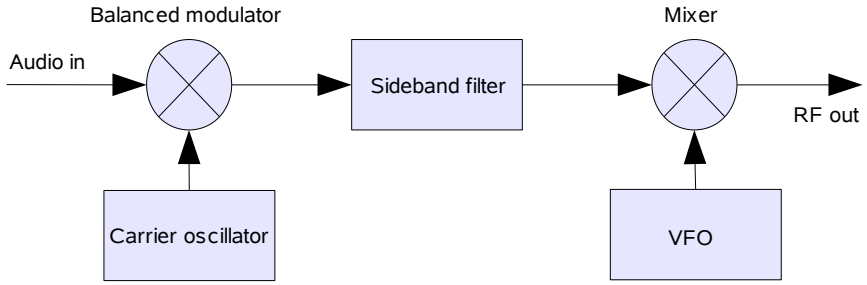
An S-Meter

And a very good signal!

Transmitters.

Receivers are more fun when you combine them with a transmitter. If you put both systems in a single box it would be called a transceiver. Most of the transmissions we would make on the HF bands are based on some form of amplitude modulation. The amplitude modulation system changes the amplitude of an RF wave for the purpose of conveying information. The instantaneous amplitude (envelope) of the RF signal will vary in accordance with the modulating audio. Modulation on any RF carrier causes the resulting signal to occupy a larger bandwidth, and since the amateur bands are only so big we want to use as little bandwidth as possible. Amateur operators usually use single sideband transmissions to get maximum performance out of the power we are allowed to use. The benefit of SSB emission is that it uses the narrowest frequency bandwidth by removing the carrier and the unwanted duplicate sideband so all the RF power is used to move information from one place to another.

In its simplest form, the transmitter converts our voices to a radio frequency so it can be sent out to be received by other stations. Heterodyning is also used in transmitter circuits. For example, the Mixer stage in a transmitter would change a 5.3-MHz input signal to 14.3 MHz. by processing it with a 9.0 MHz. VFO output. This is done to allow expensive components like sideband filters to be used at a fixed frequency so they can be shared on all bands and frequencies, and the resulting signal to be converted to the desired output frequency. For the best stability a crystal controlled oscillator is used to set the frequencies around filter stages.



In a single-sideband phone transmitter, the balanced modulator processes signals from the carrier oscillator and the speech amplifier and sends double sideband signals to the sideband filter. Both upper and lower sidebands would be found at the output of a properly adjusted balanced modulator, but the carrier frequency is not. The filter processes signals from the balanced modulator to select the desired sideband and sends signals to the mixer. At this point all the transmitter power can be applied to the single sideband instead of sending two copies of a modulation envelope that contain the same information. The mixer stage translates the modulation envelope to the desired output frequency by processing it along with the output of the variable frequency oscillator. The resulting signal is passed on to the next stage for possible conversion to another frequency or amplification to be delivered to the antenna. The essential speech envelope is 2-3 kHz in bandwidth, so a correctly adjusted SSB transmitter will produce an RF envelope with a bandwidth of just 2-3 kHz.

If the signal of single-sideband or double-sideband phone transmitter is over modulated, the output becomes distorted and occupies more bandwidth. This condition, known as flat-topping, in a single-sideband phone transmission is signal distortion caused by excessive drive. To adjust for correct modulation the microphone gain control should be adjusted on a single-sideband phone transmitter for slight movement of the ALC (automatic level control) meter on modulation peaks.

T4C02 What is used to convert sounds from our voice into radio signals?
Transmitter.

T4C03 What two devices are combined into one unit in a transceiver?
Receiver, transmitter.

T6A08 What is the primary advantage of single sideband over other voice modes?
SSB signals use much less bandwidth than FM signals.

T6A09 What is the approximate bandwidth of a single-sideband voice signal?
Between 2 and 3 kHz.

T6A02 Which of the following is a form of amplitude modulation?
A. Frequency modulation
B. Phase modulation
C. Single sideband
D. Phase shift keying

G2A06 Which of the following is an advantage when using single sideband as compared to other voice modes on the HF amateur bands?
Less bandwidth used and high power efficiency.

G2A07 Which of the following statements is true of the single sideband (SSB) voice mode?
Only one sideband is transmitted; the other sideband and carrier are suppressed.

G2A08 Which of the following statements is true of single sideband (SSB) voice mode?
It is a form of amplitude modulation in which one sideband and the carrier are suppressed.

G7A06 Which of the following might be used to process signals from the balanced modulator and send them to the mixer in a single-sideband phone transmitter?
Filter.

G7A07 Which circuit is used to combine signals from the carrier oscillator and speech amplifier and send the result to the filter in a typical single-sideband phone transmitter?
Balanced modulator.

G7A10 What is an advantage of a crystal controlled transmitter?
Stable output frequency.

G8A01 What is the name of the process that changes the envelope of an RF wave to convey information?
Amplitude modulation.

G8A05 What type of transmission varies the instantaneous power level of the RF signal to convey information?
Amplitude modulation.

G8A06 What is one advantage of carrier suppression in a single-sideband phone transmission?
More transmitter power can be put into the remaining sideband.

G8A07 Which of the following phone emissions uses the narrowest frequency bandwidth?
Single sideband.

G8A08 What happens to the signal of an over-modulated single-sideband phone transmitter?
It becomes distorted and occupies more bandwidth.

G8A09 What control is typically adjusted for proper ALC setting on an amateur single sideband transceiver?
Audio or microphone gain.

G8A10 What is meant by flat-topping of a single-sideband phone transmission?
Signal distortion caused by excessive drive.

G8A12 What signal(s) would be found at the output of a properly adjusted balanced modulator?
Both upper and lower sidebands.

G8B03 What stage in a transmitter would change a 5.3 MHz input signal to 14.3 MHz?
A mixer.

Speech Processors.

A speech processor is used to increase the average power level of the modulation envelope of human speech. The reason for using a properly adjusted speech processor with a single-sideband phone transmitter is to improve signal intelligibility at the receiver. If a single-sideband phone transmitter is 100% modulated, a speech processor will add nothing to the output PEP.

Properly adjusted speech clipping prevents overdriving of the transmitter's modulator stage.

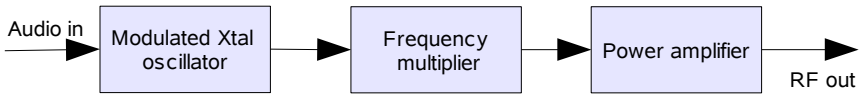
G4D01 What is the reason for using a properly adjusted speech processor with a single sideband phone transmitter?
It improves signal intelligibility at the receiver.

G4D02 Which of the following describes how a speech processor affects a transmitted single sideband signal?
It increases the average power.

G4D03 (D) Which of the following can be the result of an incorrectly adjusted speech processor?
A. Distorted speech
B. Splatter
C. Excessive background pickup
D. **All of these answers are correct.**

Frequency Modulation Transmitter.

So far we have looked at a single sideband transmitter and how it works. All of this is done a little differently in a VHF -FM system. A VHF -FM transmitter uses a circuit called a Multiplier that selects a harmonic of an HF signal to reach the desired operating frequency. A small deviation of the original signal is multiplied along with the frequency to result in the desired deviation (modulation) of the output signal.



The 12.21-MHz oscillator of an FM-phone transmitter is reactance modulated plus and minus 416.7 Hz and when multiplied by 12 results in a signal at 146.52 MHz with a modulation deviation of plus or minus 5-kHz.

$12.21_{MHz} x 12 = 146.52_{MHz}$ while at the same time the modulation does $\pm 416.7_{Hz} x 12 = \pm 5_{kHz}$ 5 to 15 kHz. is a typical deviation value for FM.

A phase modulation system changes the phase of an RF wave for the purpose of conveying information. Phase modulation is produced by a reactance modulator connected to an RF power amplifier.

Frequency modulation changes the frequency of an RF wave for the purpose of conveying information. The RF carrier frequency changes proportionally to the instantaneous amplitude of the modulating signal.

Both of these signals look identical to the receiver. There are advantages to either system, but most newer FM gear with frequency synthesis instead of channel crystals uses phase modulation. Notice that the modulation is in fact the output RF carrier sliding up and down the spectrum in step with the modulating signal. Because this does in fact require a great deal of bandwidth, FCC rules forbid FM modulation below 29.5 MHz.

T6A10 What is the approximate bandwidth of a frequency-modulated voice signal?
Between 5 and 15 kHz.

G8B04 What is the name of the stage in a VHF FM transmitter that selects a harmonic of an HF signal to reach the desired operating frequency?
Multiplier.

G8B05 Why isn't frequency modulated (FM) phone used below 29.5 MHz?
The bandwidth would exceed FCC limits.

G8B06 What is the total bandwidth of an FM-phone transmission having a 5 kHz deviation and a 3 kHz modulating frequency?
16 kHz.

G8B07 What is the frequency deviation for a 12.21-MHz reactance-modulated oscillator in a 5-kHz deviation, 146.52-MHz FM-phone transmitter?
416.7 Hz.

G8A02 What is the name of the process that changes the phase angle of an RF wave to convey information?
Phase modulation.

G8A03 What is the name of the process which changes the frequency of an RF wave to convey information?
Frequency modulation.

G8A04 What emission is produced by a reactance modulator connected to an RF power amplifier?
Phase modulation.

G8A11 What happens to the RF carrier signal when a modulating audio signal is applied to an FM transmitter?
The carrier frequency changes proportionally to the instantaneous amplitude of the modulating signal.

Modulation Modes, Descriptions and Bandwidth (AM, FM, SSB).

You have seen so far many passing references to various modes of transmitting. Each of the various emission types we are able to use in amateur radio has a place and purpose, and each also has a loyal following of eager hams who think everybody should love their favorite mode.

We have talked some about Morse code or CW. For a long time this was considered to be the narrowest form of modulation possible, and is still the simplest. CW or continuous wave telegraphy, is simply communicating by switching the transmitter carrier on and off. Depending on the character rate, this can be a very spectrum efficient method of communication, occupying typically about 50-60 Hz of band per signal. The human ear however has trouble discerning the tones of CW when they are this closely packed. For practical use CW contacts should be spaced out about 200 Hz apart on the band.

The winner right now for spectrum efficiency is PSK31, a phase shift keyed data system that occupies only 31 Hz of spectrum for each signal. Because PSK31 is decoded by a computer, the on the air signals can be packed very closely, needing only 20-30 Hz of space between signals. This would allow as many as 1000 signals to fit in the same space as is required for a voice signal on HF.

Each mode has a required bandwidth, and to allow communications without interference, there is a spacing that should be observed between signals. Knowing what type of modulation to use for a given activity is part of following the established band plan. You should check the band plan for the frequency you are about to use before transmitting.

There are a few generalities you can rely on. FM is the mode used for talking through repeaters on 2 meters and 70 centimeters. The frequency modulation is less effected by the pulse noise of vehicle ignition systems and therefore is better for mobile operations.

SSB is the type of voice modulation that is most often used for long distance and weak signal contacts on the VHF and UHF bands. Upper sideband is normally used for VHF, UHF, and SSB communications.

The primary advantage of single sideband over FM for voice transmissions is SSB signals use much less bandwidth than FM signals, so the power is used more efficiently and contact over longer distances or under extreme conditions are possible.

The normal bandwidth required for a conventional fast-scan TV transmission using combined video and audio on the 70-centimeter band is about 6 MHz. Obviously this would not fit in the lower frequency bands where the signal bandwidth would exceed the width of the entire band allocated to amateur radio.
When comparing FM voice, SSB voice, CW, or Slow-scan TV, CW has the narrowest bandwidth.

Phone transmissions are voice transmissions by radio.

T6A01 What are phone transmissions?
Voice transmissions by radio.

T6A04 Which type of voice modulation most often used for long distance and weak signal contacts on the VHF and UHF bands?
A. FM
B. AM
C. SSB.
D. PM

T6A05 Which type of modulation is most commonly used for VHF and UHF voice repeaters?
FM.

T6A06 Which emission type has the narrowest bandwidth?
A. FM voice
B. SSB voice
C. CW.
D. Slow-scan TV

T6A07 Which sideband is normally used for VHF and UHF SSB communications?
Upper sideband.

T6A11 What is the normal bandwidth required for a conventional fast-scan TV transmission using combined video and audio on the 70-centimeter band?
About 6 MHz.

Questions about Common Connectors.

Amateur radio stations use a lot of different types of interconnecting devices. Each has its designed purpose and using the wrong connector in the wrong place can cause some serious problems. Collected here are the questions about connections that are in the exam pools. Most of you are familiar with the computer USB connector. Many amateur radios have interfaces that allow them to interact various ways with computer equipment.

When dealing with UHF and microwave frequencies, the quality of the RF connector you use is extremely important. At these frequencies, the best connector to use is the type N connector because it has a flat impedance characteristic and low loss over the whole of its operating range which extends all the way to 10 GHz.

At lower frequencies in the HF range, the UHF connector or PL-259 is usually used due to its relatively low cost.

For audio connections the RCA phone jack is best and when connecting serial ports on your computer the d-sub connectors like the DB-9 are the best to use.

When possible you should used keyed connectors for all your equipment to prevent damage caused by reversed connections.

G6C12 What two devices in an amateur radio station might be connected using a USB interface?
Computer and transceiver.

G4D07 Which of the following describes a Type-N connector?
A moisture resistant RF connector useful to 10 GHz.

G4D08 Which of the following connectors would be a good choice for a serial data port?
DB-9.

G4D09 Which of these connector types is commonly used for RF service at frequencies up to 150 MHz?
UHF.

G4D10 Which of these connector types is commonly used for audio signals in amateur radio stations?
RCA Phono.

G4D11 What is the main reason to use keyed connectors over non-keyed types?
Reduced chance of damage due to incorrect mating.


A DB-9 Connector


UHF or PL-259 Connector

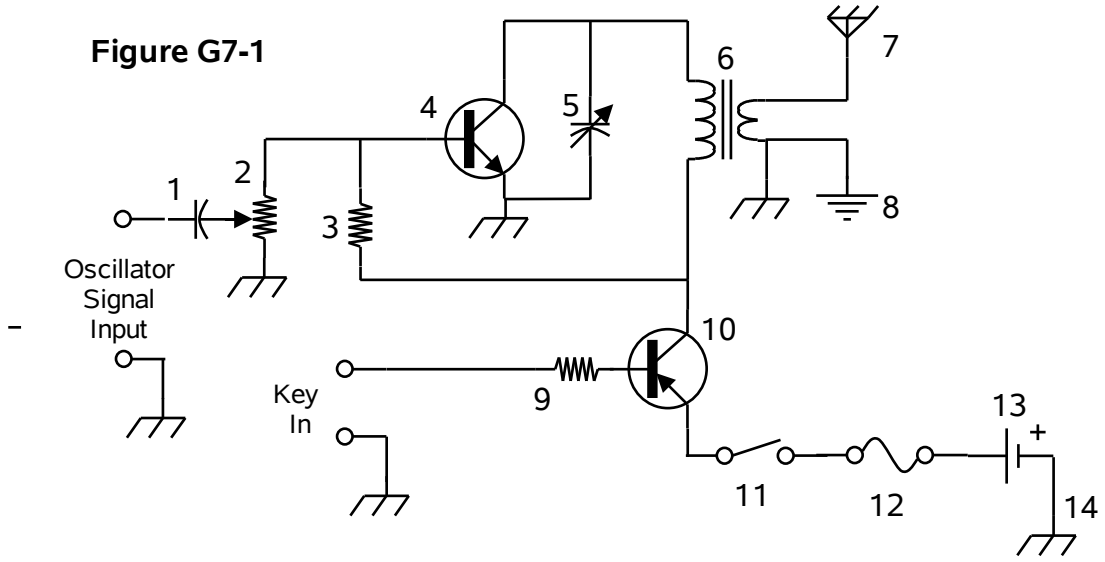

Type N Connector


RCA Phono Plugs


Anderson Power Poles, a very high quality keyed power connector

Schematic Symbols.

And now for the hieroglyphics..
Well, not really, but electronics does have a symbolic language all its own. Schematic symbols are recognized representations of the components used to build a circuit. Knowing a little about them is a good idea if you are ever faced with repairing your own equipment or building something from a kit or plans. For the exam, you might be asked to identify some schematic symbols from a diagram shown below.



The best way to handle this section is to let the questions speak for themselves.

G7A19 Which symbol in figure G7-1 represents a fixed resistor?
Symbol 3.

Editor note: Symbol 9 is also a fixed resistor, but is not in the list of choices offered with the question.

G7A20 Which symbol in figure G7-1 represents a single cell battery?
Symbol 13.

G7A21 Which symbol in figure G7-1 represents a NPN transistor?
Symbol 4.

Editor note: There are two transistor symbols in the diagram. The memory trick that helps is to remember “NPN means not pointing in.”

G7A22 Which symbol in figure G7-1 represents a variable capacitor?
Symbol 5.

G7A23 Which symbol in figure G7-1 represents a transformer?
Symbol 6.

G7A24 Which symbol in figure G7-1 represents a single pole switch?
Symbol 11.

Amplifiers.

An amplifier is a device that makes a signal stronger. In our radio systems we use all kinds of amplifiers; from very small signal types that boost the level of incoming signals from the antenna to the big power amps that raise your output signal up to the legal maximum power allowed for transmitting. Generally we want our amplifiers to be linear in function, meaning the shape of the input signal and the output signal are the same. Amplifier circuits are described by several 'type' letters. The best type for low distortion is class A amp. Class A amps are not as efficient as class C amps, but because of the possibility of distortion to a modulated signal a class C amp is best used for CW signals only. To determine the efficiency of an amplifier, you divide the RF output power by the DC input power. Please take note that doing this measurement involves measuring the voltage and current in a possibly high voltage environment. For safety, keep one hand behind your back at all times when measuring.

T4C05 What device is used to increase the output of a 10 watt radio to 100 watts?
Amplifier.

G7B10 Which of the following is a characteristic of a Class A amplifier?
Low distortion.

G7B11 For which of the following modes is a Class C power stage appropriate for amplifying a modulated signal?
CW.

G7B12 Which of the following is an advantage of a Class C amplifier?
High efficiency.

G7B13 How is the efficiency of an RF power amplifier determined?
Divide the RF output power by the DC input power.

G7B14 Which of the following describes a linear amplifier?
An amplifier whose output preserves the input waveform.

Oscillators.

In many ways an oscillator can be described as an amplifier with feedback. If the components are chosen correctly, the frequency of an oscillator circuit will be a stable sine wave output. The frequency of operation is determined either by a combination of inductor and capacitor in an LC circuit, or by the phase shift of a resistor and capacitor in an RC circuit.

G7B07 What are the basic components of virtually all oscillators?
A filter and an amplifier operating in a feedback loop.

G7B08 What determines the frequency of an RC oscillator?
The phase shift of the RC feedback circuit.

G7B09 What determines the frequency of an LC oscillator?
The inductance and capacitance in the tank circuit.

Radio Fundamentals.

Propagation by Line of Sight.

VHF and UHF signals are usually not reflected by the ionosphere and so are not normally heard over long distances. Because of this, these frequencies are best for local communications. When we hear VHF signals from long distances it may be sporadic E reflection from a layer in the ionosphere, or atmospheric ducting taking place.

VHF and UHF radio signals usually travel about a third farther than the visual line of sight distance between 2 stations because the Earth seems less curved to radio waves than to light. The point where radio signals between two points are blocked by the curvature of the Earth is the radio horizon. In open flat areas this is usually about 80 miles from the transmitting station. The effective radio horizon at VHF and UHF frequencies may be much shorter due to hills or mountains in the path.

UHF signals often work better inside buildings than VHF signals because the shorter wavelength of UHF signals allows them to more easily penetrate urban areas and buildings. The wavelength is often shorter than the size of the windows, allowing the signal to enter the building.

If the antennas at opposite ends of a VHF or UHF line of sight radio link are not using the same polarization the signals could be as much as 100 times weaker. Most repeater operations are done with vertically polarized antennas. This is why you want to make sure the antenna of your hand held radio is vertical when talking into a repeater, to match the orientation of the repeater antenna.

The advantage of 5/8 wavelength over 1/4 wavelength vertical antennas is their radiation pattern concentrates energy at lower angles. The 1/4 wave antenna launches most of its power at about 45 degrees above the horizon, which is fine if you are trying to talk to an airplane. To maximize your range down on the ground where the other amateur stations are, you want an antenna that radiates its energy as close to the horizon as possible.

A way to reach a distant repeater if buildings or obstructions are blocking the direct line of sight path might be to try using a directional antenna to find a path that reflects signals to the repeater. At VHF and UHF frequencies, the sides of buildings and even mountainsides can serve as reflectors to the signal.

Picket fencing is commonly used to describe the rapid fluttering sound sometimes heard from mobile stations that are moving while transmitting. This effect is caused by the signal arriving at the receiver via two slightly different paths. As the length of those two paths change in relation to each other, the signal alternately cancels and reinforces itself, causing the familiar fluttering of the signal.

T9B01 Why are VHF/UHF signals not normally heard over long distances?
VHF and UHF signals are usually not reflected by the ionosphere.

T9B02 What might be happening when we hear a VHF signal from long distances?
A possible cause is sporadic E reflection from a layer in the ionosphere.

T9B04 What is the radio horizon?
The point where radio signals between two points are blocked by the curvature of the Earth.

T9B05 What should you do if a station reports that your signals were strong just a moment ago, but now they are weak or distorted?
Try moving a few feet, random reflections may be causing multi-path distortion.

T9B06 Why do UHF signals often work better inside of buildings than VHF signals?
The shorter wavelength of UHF signals allows them to more easily penetrate urban areas and buildings.

T9B07 What is a good thing to remember when using your hand-held VHF or UHF radio to reach a distant repeater?
Keep the antenna as close to vertical as you can.

T9B08 What can happen if the antennas at opposite ends of a VHF or UHF line of sight radio link are not using the same polarization?
Signals could be as much as 100 times weaker.

T9B09 What might be a way to reach a distant repeater if buildings or obstructions are blocking the direct line of sight path?
Try using a directional antenna to find a path that reflects signals to the repeater.

T9B10 What term is commonly used to describe the rapid fluttering sound sometimes heard from mobile stations that are moving while transmitting?
Picket fencing.

T9B11 Why do VHF and UHF Radio signals usually travel about a third farther than the visual line of sight distance between 2 stations?
The Earth seems less curved to radio waves than to light.

Propagation Over the Horizon.

Long range communication is only possible because at certain frequencies the signals reflect back to earth from the charged regions of the upper atmosphere known as the ionosphere.

There are 3 regions of the ionosphere that we are concerned with in amateur radio. The first is the D layer. The D layer is a daytime only region as it requires the energy from the Sun to maintain the ionization. The D layer is in many ways, the spoiler of daytime radio. This is where all the broadcast radio goes during the daytime. The D layer absorbs radio energy, converting it to heat in the air. The main reason the 160-, 80- and 40-meter amateur bands tend to be useful only for short-distance communications during daylight hours is because of D-region absorption. Daylight fading on the 40-meter band is associated most with the D layer. Ionospheric absorption will be minimum near the maximum usable frequency (MUF).

The next layer of interest is the E layer. The average height of maximum ionization of the E region is about 70 miles. The maximum distance along the Earth's surface that is normally covered in one hop using the E region is about 1200 miles. We make best use of the E layer during the periods when the sunspot number is high. During that time the sporadic E, or E_S phenomena occurs. This is when intensely ionized areas form in large clouds that will support communication between distinct geographic regions. The propagation effects of E_S may extend in frequency all the way into our UHF bands. This is the method of propagation that is observed on the Citizens Band around 27 MHz.

The last region we want to look at is the F layer. During the day the F layer splits into the F1 and F2 regions. The F2 region can be expected to reach its maximum height of about 250 miles at your location at noon during the summer. The F2 region is mainly responsible for the longest-distance radio wave propagation because it is the highest ionospheric region. The maximum distance along the Earth's surface that is normally covered in one hop using the F2 region is about 2500 miles.

The MUF is the highest frequency that will be refracted back to Earth. Above that frequency, signals are not refracted enough to return. The actual frequency where this change happens varies from moment to moment, as the charges in the ionosphere move and change. Atmospheric absorption will be lowest at or near the MUF.

The "critical angle" as used in radio-wave propagation is the highest takeoff angle that will return a radio wave to the earth under specific ionospheric conditions. At higher angles, the radio wave passes out into space. Below the critical angle, the radio wave is refracted back to earth. The actual angle where this change happens varies from moment to moment, as the charges in the ionosphere move and change. This effectively limits the shortest distance for normal skywave propagation. The distance where this wave reaches the Earth again will normally be beyond the longest distance of the ground wave. The area between these distances is called the 'skip zone' and can only be reached by specialized near vertical incidence skywave (NVIS) antennas, or by HF scatter.

The NVIS antenna is essentially a horizontal dipole placed between 1/8 and 1/4 wavelength above the ground to focus the radiation into the high angles. When done on the correct frequencies for the time of day, this gives reliable communications out to about 300-500 miles.

HF scatter signals are a usually weak, wavering sound caused by radio energy scattered into the skip zone through several radio-wave paths. This type of radio-wave propagation allows a signal to be detected at a distance too far for ground-wave propagation but too near for normal sky-wave propagation. Scatter propagation on the HF bands most often occurs when communicating on frequencies above the maximum usable frequency (MUF).

G3B03 Which of the following guidelines should be selected for lowest attenuation when transmitting on HF?
Select a frequency just below the MUF.

G3B09 What is the maximum distance along the Earth's surface that is normally covered in one hop using the F2 region?
2,500 miles.

G3B10 What is the maximum distance along the Earth's surface that is normally covered in one hop using the E region?
1,200 miles.

G3C01 Which of the following ionospheric layers is closest to the surface of the Earth?
The D layer.

G3C02 When can the F2 region be expected to reach its maximum height at your location?
At noon during the summer.

G3C03 Why is the F2 region mainly responsible for the longest distance radio wave propagation?
Because it is the highest ionospheric region.

G3C04 What does the term "critical angle" mean as used in radio wave propagation?
The highest takeoff angle that will return a radio wave to the Earth under specific ionospheric conditions.

G3C05 Why is long distance communication on the 40, 60, 80 and 160 meter bands more difficult during the day?
The D layer absorbs these frequencies during daylight hours.

G3C06 What is a characteristic of HF scatter signals?
They have a wavering sound.

G3C07 What makes HF scatter signals often sound distorted?
Energy is scattered into the skip zone through several radio wave paths.

G3C08 Why are HF scatter signals in the skip zone usually weak?
Only a small part of the signal energy is scattered into the skip zone.

G3C09 What type of radio wave propagation allows a signal to be detected at a distance too far for ground wave propagation but too near for normal sky wave propagation?
Scatter.

G3C10 Which of the following might be an indication that signals heard on the HF bands are being received via scatter propagation?
The signal is heard on a frequency above the maximum usable frequency.

G3C11 Which of the following is true about ionospheric absorption near the maximum usable frequency (MUF)?
Absorption will be minimum.

G3C12 Which ionospheric layer is the most absorbent of long skip signals during daylight hours on frequencies below 10 MHz?
The D layer.

G3C13 What is Near Vertical Incidence Sky-wave (NVIS) propagation?
Short distance HF propagation using high elevation angles.

G3C14 Which of the following antennas will be most effective for skip communications on 40 meters during the day?
A horizontal dipole placed between 1/8 and 1/4 wavelength above the ground.

Propagation Related Solar Events.

All of the skywave propagation is driven and controlled by activity on the Sun. Long range propagation is tied to the sunspot number. The sunspot number is a daily index of sunspot activity. When sunspot numbers are high, long-distance communication in the upper HF and lower VHF range is enhanced. The average sunspot number varies on an approximately 11- year cycle called the sunspot cycle.

Associated with increases in the sunspot number is an increase in the occurrence of solar flares. When a solar flare erupts from the surface of the Sun massive amounts of ultraviolet and X-ray radiation arrive at the Earth about 8 minutes later. This blast of radiation can cause a condition known as a Sudden Ionospheric Disturbance. The effect of a sudden ionospheric disturbance on the daytime ionospheric propagation of HF radio waves is the disruption of signals on lower frequencies more than those on higher frequencies. To continue communications during a sudden ionospheric disturbance try a higher frequency.

While the UV and X-ray radiation from coronal mass ejections (CME) associated with solar flares effect radio-wave propagation on the earth in about 8 minutes, the charged particles do not arrive until 20-40 hours later. This particle storm can cause a geomagnetic disturbance. A geomagnetic disturbance is a dramatic change in the earth's magnetic field over a short period of time. At latitudes greater than 45 degrees, propagation paths are more sensitive to geomagnetic disturbances. This can result in degraded high-latitude HF propagation during a major geomagnetic storm.

A solar coronal hole will effect radio communications by emitting charged particles that usually disrupt HF radio communications.

In a propagation forecast, the K- index is a measure of geomagnetic stability. The A- index is a daily value measured on a scale from 0 to 400 to express the range of disturbance of the geomagnetic field. During periods of high geomagnetic activity there might be a visible aurora. The aurora can be used to reflect VHF and sometimes UHF signals.

The effects of a solar flare can sometimes disrupt communications for days, but can also provide unique opportunities for unusual contacts by way of rare propagation modes.

The radio energy emitted by the sun is known as the solar flux. The solar-flux index is a measure of solar activity that is taken at a specific frequency. Known also as the 10.7 cm flux (the wavelength of the radio signals at 2800 MHz), this solar radio emission has been shown to be proportional to sunspot activity. When the solar flux number is higher, HF propagation should be good.

G3A01 What can be done at an amateur station to continue communications during a sudden ionospheric disturbance?
Try a higher frequency.

G3A02 What effect does a Sudden Ionospheric Disturbance (SID) have on the daytime ionospheric propagation of HF radio waves?
It disrupts signals on lower frequencies more than those on higher frequencies.

G3A03 How long does it take the increased ultraviolet and X-ray radiation from solar flares to affect radio-wave propagation on the Earth?
Approximately 8 minutes.

G3A04 What is measured by the solar flux index?
The radio energy emitted by the sun.

G3A05 What is the solar-flux index?
A measure of solar activity at 10.7 cm.

G3A06 What is a geomagnetic disturbance?
A significant change in the Earth's magnetic field over a short period of time.

G3A07 Which latitudes have propagation paths that are more sensitive to geomagnetic disturbances?
Those greater than 45 degrees North or South latitude.

G3A08 What can be an effect of a geomagnetic storm on radio-wave propagation?
Degraded high-latitude HF propagation.

G3A09 What is the effect on radio communications when sunspot numbers are high?
Long-distance communication in the upper HF and lower VHF range is enhanced.

G3A10 What is the sunspot number?
A measure of solar activity based on counting sunspots and sunspot groups.

G3A11 How long is the typical sunspot cycle?
Approximately 11 years.

G3A12 What is the K-index?
A measure of the short term stability of the Earth's magnetic field.

G3A13 What is the A-index?
An indicator of the long term stability of the Earth's geomagnetic field.

G3A14 How are radio communications usually affected by the charged particles that reach the Earth from solar coronal holes?
HF communications are disturbed.

G3A15 How long does it take charged particles from Coronal Mass Ejections to affect radio-wave propagation on the Earth?
20 to 40 hours.

G3A16 What is a possible benefit to radio communications resulting from periods of high geomagnetic activity?
Aurora that can reflect VHF signals.

Propagation Forecasting.

Knowing how to apply the knowledge about the ionosphere to make the radio contact you want, takes some forecasting. Just like fishing, you could just put a worm on the hook and toss it in the pond if you just want to make any contact. But to catch that trophy bass (or rare DX station) you need to know what kind of bait to use (antenna, frequency, and mode) and where and when to fish. It's really not too hard to take advantage of the things we know and can learn about conditions to improve your chances to make that special contact.

As was mentioned earlier, the MUF or maximum usable frequency is the frequency above which communication with a location is not possible. This frequency will change from minute to minute and will vary over different paths. When radio waves with frequencies below the maximum usable frequency (MUF) are sent into the ionosphere they are bent back to the earth. The factors that effect the maximum usable frequency (MUF) are path distance and locations, time of day, season, solar radiation, and ionospheric disturbances. The MUF has an opposite value known as the LUF or lowest usable frequency. Below the LUF, all radio waves are completely absorbed. When the lowest usable frequency (LUF) exceeds the maximum usable frequency (MUF) no HF radio frequency will support communications along an ionospheric signal path, and it's time to go mow the lawn or something.

If the maximum usable frequency (MUF) on the path from Minnesota to France is 24 MHz, the 15 meter band should offer the best chance for a successful contact. If the maximum usable frequency (MUF) on the path from Ohio to Germany is 17 MHz, the 20 meter band should offer the best chance for a successful contact.

One way to determine if the maximum usable frequency (MUF) is high enough to support 28-MHz propagation between your station and western Europe is to listen for signals on a 10-meter beacon frequency. These beacons operate from many locations world wide on a closely controlled schedule that allows you to check the propagation for the entire world by listening to a single frequency for about 15 minutes. Each beacon transmits in it's time slot with a series of 4 signals stepped to progressively lower power levels. If you can hear the last transmission from the beacon, the band is very good to that location because you just heard a transmission at 100 milliwatts! At times like this a strong signal might arrive at your station both via the direct path and the long path (around the world the other way) and will have a distinctive echo when heard. The IARU beacon frequencies are 14.100, 18.110, 21.150, 24.930, and 28.200 MHz. To hear beacons that would help you determine propagation conditions on the 20-meter band you would tune to 14.1 MHz.

Listening to where you hear signals coming from will tell you a lot about where you might be able to contact. This method is also good for finding the highest amateur band that is usable at any time. We will want to use the band that is just below the MUF at that time for our contacts.

Solar driven conditions tend to repeat at the same rate as the Solar rotation. If the HF radio wave propagation (skip) is generally good on the 24 MHz and 28 MHz bands for several days, you might expect a similar condition to occur 27- 28 days later because the conditions may have been caused by a group of sunspots that will re-appear on the next rotation of the Sun.

During periods of low solar activity, frequencies above 20 MHz are the least reliable for long-distance communication. At any point in the solar cycle the 20-meter band usually supports worldwide propagation during daylight hours.

A short distance hop on 10 meters might indicate that the MUF exceeds 50 Mhz. This would meant that long distance propagation may be possible on the 6 meter band.

G3A17 At what point in the solar cycle does the 20 meter band usually support worldwide propagation during daylight hours?
At any point in the solar cycle.

G3A18 If the HF radio-wave propagation (skip) is generally good on the 24-MHz and 28-MHz bands for several days, when might you expect a similar condition to occur?
28 days later.

G3A19 Which frequencies are least reliable for long distance communications during periods of low solar activity?
Frequencies above 20 MHz.

G3B01 Which band should offer the best chance for a successful contact if the maximum usable frequency (MUF) between the two stations is 22 MHz?
15 meters.

G3B02 Which band should offer the best chance for a successful contact if the maximum usable frequency (MUF) between the two stations is 16 MHz?
20 meters.

G3B04 What is a reliable way to determine if the maximum usable frequency (MUF) is high enough to support 28-MHz propagation between your station and Western Europe?
Listen for signals on a 28 MHz international beacon.

G3B05 What usually happens to radio waves with frequencies below the maximum usable frequency (MUF) when they are sent into the ionosphere?
They are bent back to the Earth.

G3B06 What usually happens to radio waves with frequencies below the lowest usable frequency (LUF)?
They are completely absorbed by the ionosphere.

G3B07 What does LUF stand for?
The Lowest Usable Frequency for communications between two points.

G3B08 What does MUF stand for?
The Maximum Usable Frequency for communications between two points.

G3B11 What happens to HF propagation when the lowest usable frequency (LUF) exceeds the maximum usable frequency (MUF)?
No HF radio frequency will support communications over the path.

G3B12 What factors affect the maximum usable frequency (MUF)?
A. Path distance and location
B. Time of day and season
C. Solar radiation and ionospheric disturbance
D. **All of these choices are correct.**

G3B13 How might a sky-wave signal sound if it arrives at your receiver by both short path and long path propagation?
A well-defined echo can be heard.

G3B14 Which of the following is a good indicator of the possibility of sky-wave propagation on the 6 meter band?
Short hop sky-wave propagation on the 10 meter band.

Radio Technical Practices.

This section is a collection of bits and bytes about hooking up your station equipment and knowing what buttons to push. The information here may seem really overly simple, but these items are in the Technician pool, and you need to know this to get your license. Some of this may seem so simple that it is almost insulting to make it part of the test, but remember that people from all walks of life are coming into amateur radio, and some of them have never been exposed to this kind of information before. If you are one of those people, don't worry, we won't tell anyone.

To best handle this information, we will change format slightly. The exam question will be followed by explanatory ***comments*** where the subject matter is not obvious to the casual reader..

Station hookup – microphone, speaker, headphones, filters, power source, connecting a computer.

T5A01 What does a microphone connect to in a basic amateur radio station?
The transmitter.

T5A02 Which piece of station equipment converts electrical signals to sound waves?
Speaker.

T5A03 What is the term used to describe what happens when a microphone and speaker are too close to each other?
Audio feedback.

T5A04 What could you use in place of a regular speaker to help you copy signals in a noisy area?
A set of headphones.

Just the same as you would do to listen to music from a CD player or Ipod.

T5A05 What is a good reason for using a regulated power supply for communications equipment?
To protect equipment from voltage fluctuations.

An unregulated supply (they do exist) may damage your equipment by providing voltages that are too high for the internal components.

T5A06 Where must a filter be installed to reduce spurious emissions?
At the transmitter.

This is the low pass filter referenced in earlier sections. To be effective it must trap the unwanted signal before it gets to your antenna.

T5A07 What type of filter should be connected to a TV receiver as the first step in trying to prevent RF overload from a nearby 2-meter transmitter?
Notch filter.

This is the other side of the interference filter solution. This device attaches between the TV set and its antenna to trap the unwanted signal before it enters the set.

T5A08 What is connected between the transceiver and computer terminal in a packet radio station?
Terminal Node Controller.

A terminal node controller or TNC is the specialized modem that connects your radio and your computer together for packet and APRS operations. This device assembles the message text into small blocks (packets) of information and surrounds those blocks with routing and error correction features to allow the message to arrive at it's destination with no errors in the text. The TNC connects in place of the microphone on most radio equipment.

T5A09 Which of these items is not required for a packet radio station?
Microphone.

T5A10 What can be used to connect a radio with a computer for data transmission?
Sound Card.

Most of the various data modes can be done with a computer and a sound card. The audio output from the radio is processed to extract the coded information and the result is sent to the screen. On transmit, the process is reversed with the audio being connected into the microphone input of the radio transmitter.

Operating controls.

T5B01 What may happen if a transmitter is operated with the microphone gain set too high?
It may cause the signal to become distorted and unreadable.

T5B02 What kind of information may a VHF/UHF transceiver be capable of storing in memory?
A. Transmit and receive operating frequency
B. CTCSS tone frequency
C. Transmit power level
D. All of these answers are correct.

These little wonders can do amazing things and store all the information about operating parameters that you can imagine. About the only thing they can't do is mow the lawn, and somewhere out there somebody is probably working on that too.

T5B03 What is one way to select a frequency on which to operate?
Use the keypad or VFO knob to enter the correct frequency.

T5B04 What is the purpose of the squelch control on a transceiver?
It is used to quiet noise when no signal is being received.

The squelch control cuts off the audio output until the signal level rises above a certain level. If you don't enjoy listening for voices in the roaring noise of a huge waterfall, the squelch control is your friend.

T5B05 What is a way to enable quick access to a favorite frequency on your transceiver?
Store the frequency in a memory channel.

See question T5B02 above.

T5B06 What might you do to improve the situation if the station you are listening to is hard to copy because of ignition noise interference?
Turn on the noise blanker.

The noise blanker circuit is designed to remove short high energy pulses from the received signal by momentarily shutting down the receiver RF amplifier during the time the pulse is occurring.

T5B07 What is the purpose of the buttons labeled "up" and "down" on many microphones?
To allow easy frequency or memory selection.

T5B08 What is the purpose of the "shift" control found on many VHF/UHF transceivers?
Adjust the offset between transmit and receive frequency.

This was explained in the earlier section about repeaters. The repeater can't receive and transmit on the same frequency at the same time.

T5B09 What does RIT mean?
Receiver Incremental Tuning.

RIT only shifts the receive frequency, leaving the transmitter where it was. Very useful when trying to hear someone who didn't zero beat to the net frequency, and you don't want to transmit on the wrong frequency yourself.

T5B10 What is the purpose of the "step" menu function found on many transceivers?
It sets the tuning rate when changing frequencies.

A larger step value will move through the frequencies faster.

T5B11 What is the purpose of the "function" or "F" key found on many transceivers?
It selects an alternate action for some control buttons.

Just like the shift key on your computer keyboard.

Digital Signal Processing.

A major advance in the art of radio has been the introduction of digital signal processing where the incoming signal is digitized and a microprocessor mathematically extracts the desired signal from the data stream. That signal is then converted back to a usable analog form and passed on to the next stage of the receiver or to the audio output. By doing this, all the undesirable noise can be reduced or eliminated. The exciting part about all of this is that it allows the IF filters to be changed and/or redesigned in software rather than requiring hardware changes. Filter characteristics that can not be constructed with physical components are possible as software constructs. Any receiver performance parameter can be adjusted or modified this way. With technology like this the future of radio is going to be a very exciting place to play.

G4A01 Which of the following is one use for a DSP in an amateur station?
To remove noise from received signals.

G4A03 (D) Which of the following is needed for a DSP IF filter?
A. An Analog to Digital Converter
B. Digital to Analog Converter
C. A Digital Processor Chip
D. **All of the these answers are correct.**

G4A04 Which of the following is an advantage of a receiver IF filter created with a DSP as compared to an analog filter?
A wide range of filter bandwidths and shapes can be created.

G4A05 How is DSP filtering accomplished?
By converting the signal from analog to digital and using digital processing.

G4A13 Which of the following performs automatic notching of interfering carriers?
A DSP filter.

Amplifier Tuning and Neutralization.

Neutralization is necessary for some vacuum-tube amplifiers to cancel self oscillation caused by the effects of inter electrode capacitance. An amplifier that is not neutralized will become a transmitter in its own right and usually **NOT** on a frequency you desire to operate on.

In a properly neutralized RF amplifier, enough negative feedback is introduced to cancel out the effects of positive feedback.

As a power amplifier is tuned, a minimum change in grid current on its grid-current meter as the output circuit is changed, indicates the best neutralization.

When tuning the amplifier for use, you must monitor the plate current while adjusting the 'load' control to insure that the maximum ratings for the amplifier are not exceeded. Plate tuning is indicated as correct by a pronounced dip in the measured grid current.

Amplifiers are nice to have, but are not the one and only answer to getting your signal around the world because in order to raise the S-meter reading on a receiver from S8 to S9, the power output of a transmitter must be increased approximately by a factor of 4. This means that your 100 watt transmitter must be raised to a 400 watt output to get that 1 S-unit on the other station's receiver.

G4A06 What reading on the plate current meter of a vacuum tube RF power amplifier indicates correct adjustment of the plate tuning control?
A pronounced dip.

G4A07 What is the correct adjustment for the "Load" or "Coupling" control of a vacuum tube RF power amplifier?
Maximum power output without exceeding maximum allowable plate current.

G4A08 Which of the following techniques is used to neutralize an RF amplifier?
Negative feedback.

G4A09 What does a neutralizing circuit do in an RF amplifier?
It cancels the effects of positive feedback.

G4A10 What is the reason for neutralizing the final amplifier stage of a transmitter?
To eliminate self oscillations.

G4B09 How much must the power output of a transmitter be raised to change the "S" meter reading on a distant receiver from S8 to S9?
Approximately 4 times.

Test and Monitoring Equipment.

There are many types of test equipment you may use in your station, but for the exam you should be familiar with the ones listed below.

An oscilloscope is an item of test equipment that contains horizontal and vertical channel amplifiers connected to a visual display. The amplitude of the input signal is usually displayed on the vertical axis plotted against time on the horizontal axis.

To test the amplitude linearity of a single-sideband phone transmitter, two audio-frequency sine waves that must be within the transmitter audio modulation passband and are not be harmonically related, are fed into the microphone input and the output is observed on an oscilloscope. A monitoring oscilloscope is the best instrument to use to check the signal quality of a CW or single-sideband phone transmitter.

A digital oscilloscope is an oscilloscope designed around digital technology rather than analog technology. These often use an LCD display rather than a CRT, and can run on battery power.

Oscilloscopes have a distinct advantage over digital voltmeters as they allow the analysis of complex waveforms. The digital voltmeter is superior to the analog meter because of its better accuracy. Any meter or measuring equipment you use should have a high impedance input to avoid loading the circuit under test and causing it to malfunction.

To check the quality of the RF output of the transmitter you would connect a sample of the signal to the vertical input of a monitoring oscilloscope. To check transmitter modulation using double trapezoidal patterns on an AM or SSB transmitter, you would couple the RF output signal to the vertical plates and external trigger input, and set the internal sweep to twice the modulating frequency.

A signal tracer can be used to identify an inoperative stage in a receiver. To use this device, a known reference signal is connected to the antenna input and the signal tracer is used to 'probe' different stages of the receiver to track the progression of the signal through the radio. Where the signal stops, is where the problem is located.

A noise bridge can be connected between a receiver and an antenna of unknown impedance and is tuned for minimum noise. This is helpful when pre-tuning an antenna tuner before beginning transmissions. A noise bridge can also be used to determine the characteristic impedance of an unknown length and type of transmission line, or the resonant frequency of an antenna system.

A dip meter can also determine the resonant frequency of a circuit or antenna As you tune the instrument across the frequency, there will be an indication of the coupled circuit accepting power as you approach the resonant frequency.

A field-strength meter is a simple instrument that may be used to monitor relative RF output during antenna and transmitter adjustments. A field strength meter can also provide a measure of the field pattern of an antenna, or for close-in radio direction finding (RDF) work.

The last piece of test equipment we will discuss, you must have. The SWR meter which we have referred to before is essential to the adjustment of transmitting antennas. This function may also be performed by a bidirectional wattmeter. The comparison of forward measured power to reflected power coming back from the feedline gives a direct indication of antenna resonance and/or the correct adjustment of any antenna tuner device you might be using.

One last item that is almost required is the dummy load. This device prevents the radiation of unwanted signals when testing your transmitting equipment.

T9A07 What is the primary purpose of a dummy load?
It does not radiate interfering signals when making tests.

G4A02 Which of the following instruments may be used to measure the output of a single-sideband transmitter when performing a two-tone test of amplitude linearity?
An oscilloscope.

G4A11 What type of transmitter performance does a two-tone test analyze?
Linearity.

G4A12 What type of signals are used to conduct a two-tone test?
Two non-harmonically related audio signals.

G4B01 What item of test equipment contains horizontal and vertical channel amplifiers?
An oscilloscope.

G4B02 Which of the following is an advantage of an oscilloscope versus a digital voltmeter?
Complex waveforms can be measured.

G4B03 How would a signal tracer normally be used?
To identify an inoperative stage in a receiver.

G4B04 How is a noise bridge normally used?
It is connected between a receiver and an antenna of unknown impedance and is adjusted for minimum noise.

G4B05 Which of the following is the best instrument to use to check the keying waveform of a CW transmitter?
A monitoring oscilloscope.

G4B06 What signal source is connected to the vertical input of a monitoring oscilloscope when checking the quality of a transmitted signal?
The attenuated RF output of the transmitter.

G4B07 What is an advantage of a digital voltmeter as compared to an analog voltmeter?
Significantly better precision for most uses.

G4B08 What instrument may be used to monitor relative RF output when making antenna and transmitter adjustments?
A field-strength meter.

G4B10 Which of the following can be determined with a field strength meter?
The radiation pattern of an antenna.

G4B11 Which of the following might be a use for a field strength meter?
Close-in radio direction-finding.

G4B12 What is one way a noise bridge might be used?
Pre-tuning an antenna tuner.

G4B13 What is one measurement that can be made with a dip meter?
The resonant frequency of a circuit.

G4B14 Which of the following must be connected to an antenna analyzer when it is being used for SWR measurements?
Antenna and feedline.

G4B15 Which of the following can be measured with a directional wattmeter?
Standing Wave Ratio.

G4B16 Why is high input impedance desirable for a voltmeter?
It decreases the loading on circuits being measured.

HF Mobile Radio Installations.

As a licensed amateur, you can do anything in a mobile operation that you can do at your home station, except drive in your pajamas.

Some special considerations for mobile operating should be observed. A 100 watt transmitter will draw 20 amps on modulation peaks from a 12 volt source. It is best **NOT** to draw the DC power for a 100-watt HF transceiver from an automobile's cigarette lighter socket because the socket's wiring may not be adequate for the current being drawn by the transceiver. This is almost always the case in fact.

A direct, fused connection to the battery using heavy gauge wire would be best for a 100-watt HF mobile installation. The main fuse should be as close as possible to the battery to protect against shorts in damaged wiring. There is no reason that equipment can not share a DC buss installed expressly for the radio equipment. The main fuse would be selected to allow enough current to pass for all equipment to operate while cutting off in the event of wiring faults or accidental short circuits due to operator error. Then each individual piece of gear can be separately fused at values designed to protect it from shorts due to malfunctions. A switch panel can be added to allow easy management of station functions.

This type of power system would also allow a single filter solution to be applied if you experience alternator whine from you auto. Alternator whine is a buzz or tone in your transmitted signal that varies with engine speed, and can be removed the same way you remove the AC ripple and noise in an AD/DC power supply.

The main limit to the effectiveness of an HF mobile transceiver is the HF mobile antenna system. This is especially true when operating in the 160 or 75 meter bands. The physical size of the antenna is so small compared to the wavelength that an efficient radiator is very hard to construct.

G4E01 Which of the following emission types are permissible while operating HF mobile?
A. CW
B. SSB
C. FM
D. **All of these choices are correct.**

G4E02 What is alternator whine?
A tone or buzz in transmitted or received audio that varies with engine speed.

G4E03 Which of the following power connections would be the best for a 100-watt HF mobile installation?
A direct, fused connection to the battery using heavy gauge wire.

G4E04 Why is it best NOT to draw the DC power for a 100-watt HF transceiver from an automobile's cigarette lighter socket?
The socket's wiring may be inadequate for the current being drawn by the transceiver.

G4E05 Which of the following most limits the effectiveness of an HF mobile transceiver operating in the 75 meter band?
The HF mobile antenna system.

Emergency and Battery Powered Operation.

Emergency operations are a big part of what amateur radio exists for. To be prepared there are some things you need to know; so the thoughtful people of the Question Pool Committee have included a few items in the exams to check your knowledge.

There is no way around this simple fact, radio operations require power. We can obtain emergency power from portable generators, batteries, solar panels, or wind generators. Each of these methods has certain advantages and certain problems.

An emergency generator, either permanent or temporary, brings certain safety related issues. These will be addressed in a later section on safety

Solar power is a viable option for emergency power. To be effective you need to have the system installed well before the emergency. Photovoltaic conversion is the name of the process by which sunlight is directly changed into electricity. The approximate open-circuit voltage from a modern, well illuminated photovoltaic cell is 0.5 VDC. To determine the proper size solar panel to use in a solar-powered battery-charging circuit, you would need to consider the panel's voltage rating and maximum output current.

The biggest disadvantage to using wind power as the primary source of power for an emergency station is that a large electrical storage system is needed to supply power when the wind is not blowing. This is also true of solar power when the sun is not shining, which on average it does less than 50% of the time. Wind generators are by their nature not very portable, and involve fast moving parts that are not friendly to innocent bystanders.

Using solar or wind power does require a battery system as well. Batteries, especially large ones, give off explosive hydrogen gas when charging and so they require proper ventilation. Even if you are only using stored charge and not a solar or wind power system, you need to consider the safety issues associated with batteries. Electrolytes are corrosive. Short circuits can involve massive amounts of power so proper fusing is essential. If you need to relocate your station, batteries are very heavy and difficult to move around. They can however be recharged by connecting them temporarily to the charging system of your car.

T0A09 What is one way to recharge a 12-volt battery if the commercial power is out?
Connect the battery to a car's battery and run the engine.

G4E08 What is the name of the process by which sunlight is changed directly into electricity?
Photovoltaic conversion.

G4E09 What is the approximate open-circuit voltage from a modern, well illuminated photovoltaic cell?
0.5 VDC.

G4E10 Which of these materials is used as the active element of a solar cell?
Doped Silicon.

G4E11 Which of the following is a disadvantage to using wind power as the primary source of power for an emergency station?
A large energy storage system is needed to supply power when the wind is not blowing.

Basic Antennas.

Rubber Ducks?

The flexible antenna attached to a hand held radio is traditionally called a rubber duck antenna. Rubber duck antennas have the main advantage of being flexible and therefore very hard to damage. A disadvantage of the "rubber duck" antenna supplied with most hand held radio transceivers is it does not transmit or receive as effectively as a full sized antenna. Some hams also lovingly refer to the rubber duck antenna as a rubber dummy load for this reason.

A good reason not to use a "rubber duck" antenna inside your car is signals can be 10 to 20 times weaker than when you are outside of the vehicle. A good thing to remember when using your hand-held VHF or UHF radio to reach a distant repeater is to keep the antenna as close to vertical as you can. If a station reports that your signals were strong just a moment ago, but now they are weak or distorted you should try moving a few feet; random reflections may be causing multi-path distortion of your signal.

T9A04 What is a disadvantage of the "rubber duck" antenna supplied with most hand held radio transceivers?
It does not transmit or receive as effectively as a full sized antenna.

T9A10 What is a good reason not to use a "rubber duck" antenna inside your car?
Signals can be 10 to 20 times weaker than when you are outside of the vehicle.

Simple Antennas.

A magnet mount vertical antenna is one type of antenna that offers good efficiency when operating mobile and can be easily installed or removed. This is a much better solution than using a rubber duck inside the car. The 5/8 wave antenna is better than quarter wave vertical because it keeps the radiation lower to the horizon. This extends the range of your station.

The physical size of half-wave dipole or quarter wave vertical antenna becomes shorter as the frequency increases.

A vertical antenna is an antenna that consists of a single element mounted perpendicular to the Earth's surface.

19 inches is the approximate length, in inches, of a quarter-wavelength vertical antenna for 146 MHz. Remember that formula for wavelength?

A simple fixed station antenna that you can build for any band is the quarter wave ground plane antenna. Sloping the radials of a ground plane antenna downward increases the feedpoint impedance bringing it closer to 50 ohms. On VHF and UHF frequencies, these can be made from coat hanger wire or welding rods.

For lower frequencies the dimensions of the ground plane antennas become 'ponderous' at best. The radial wires of a ground-mounted vertical antenna system should be placed on the surface or buried a few inches below the ground. The vertical element may be supported by a tree, or tower, or maybe the tower itself.
Most HF stations use a simple horizontal antenna. A horizontal antenna is a simple dipole mounted so the elements are parallel to the Earth's surface. Supports for this antenna can be trees, towers, buildings, or whatever is handy. The biggest advantage to a horizontal antenna is the reduced ground reflection losses. Take care to be sure that the antenna is mounted high enough or is in a place that is not accessible, to avoid being a hazard to innocent bystanders.

If needed to fit the available space, the feedpoint may be moved away from the center, but the feedpoint impedance will rise by doing so. You will need a matching network of some type to correctly match this to your feedline.

The low-angle radiation pattern of an ideal half-wavelength dipole HF antenna installed a half-wavelength high, parallel to the earth is a figure-eight at right angles to the antenna. If the antenna is less than one-half wavelength high, the azimuthal pattern is almost omnidirectional, with the main lobe mostly pointing up. More on this idea in a later section! When you bring the antenna lower to the ground, the feedpoint impedance does change due to energy being absorbed into the Earth. The impedance will decrease, and you will need to compensate for that to properly match the system to the transmitter.

112 inches is the approximate length, in inches, of a 6-meter 1/2 wavelength wire dipole antenna. There's that pesky wavelength thing again. Remember in general that as the frequency rises, the wavelength gets shorter.

To find the length of an antenna in feet (or inches) you can use a slightly different formula. This one has been adjusted to give the length in feet instead of meters.

For half wave antennas $Length_{feet} = \frac{468}{F_{MHz}}$ and for quarter wave verticals $Length_{feet} = \frac{234}{F_{MHz}}$

Using these formulas, you can find the length in feet of any simple wire antenna. Remember to convert the answer to inches where applicable.

One type of multi band transmitting antenna that does NOT require a feed-line is an end-fed random-wire antenna. The wire is usually connected directly to an antenna tuner. The main disadvantage of this antenna is that you may experience RF feedback in your station. This is what you have when you get an electrical burn from touching any equipment while transmitting. This description alone should make you want to avoid this problem.

T9A02 What is an antenna that consists of a single element mounted perpendicular to the Earth's surface?
A vertical antenna.

T9A03 What type of antenna is a simple dipole mounted so the elements are parallel to the Earth's surface?
A horizontal antenna.

T9A05 How does the physical size of half-wave dipole antenna change with operating frequency?
It becomes shorter as the frequency increases.

T9A06 Why is a 5/8 wavelength vertical antenna popular for mobile use?
It's radiation pattern concentrates energy at lower angles.

T9A09 What is one type of antenna that offers good efficiency when operating mobile and can be easily installed or removed?
A magnet mount vertical antenna.

T9A11 What is the approximate length, in inches, of a quarter-wavelength vertical antenna for 146 MHz?
19 inches.

T9A12 What is the approximate length, in inches, of a 6-meter 1/2 wave wire dipole antenna?
112 inches.

G9B01 What is one disadvantage of a directly fed random-wire antenna?
You may experience RF burns when touching metal objects in your station.

G9B02 What is an advantage of downward sloping radials on a ground-plane antenna?
They can be adjusted to bring the feed-point impedance closer to 50 ohms.

G9B03 What happens to the feed-point impedance of a ground-plane antenna when its radials are changed from horizontal to downward-sloping?
It increases.

G9B04 What is the low angle azimuthal radiation pattern of an ideal half-wavelength dipole antenna installed 1/2 wavelength high and parallel to the earth?
It is a figure-eight at right angles to the antenna.

G9B05 How does antenna height affect the horizontal (azimuthal) radiation pattern of a horizontal dipole HF antenna?
If the antenna is less than 1/2 wavelength high, the azimuthal pattern is almost omnidirectional.

G9B06 Where should the radial wires of a ground-mounted vertical antenna system be placed?
On the surface or buried a few inches below the ground.

G9B07 How does the feed-point impedance of a 1/2 wave dipole antenna change as the antenna is lowered from 1/4 wave above ground?
It steadily decreases.

G9B08 How does the feed-point impedance of a 1/2 wave dipole change as the feed-point location is moved from the center toward the ends?
It steadily increases.

G9B09 Which of the following is an advantage of a horizontally polarized as compared to vertically polarized HF antenna?
Lower ground reflection losses.

G9B10 What is the approximate length for a 1/2-wave dipole antenna cut for 14.250 MHz?
32.8 feet.

G9B11 What is the approximate length for a 1/2-wave dipole antenna cut for 3.550 MHz?
131.8 feet.

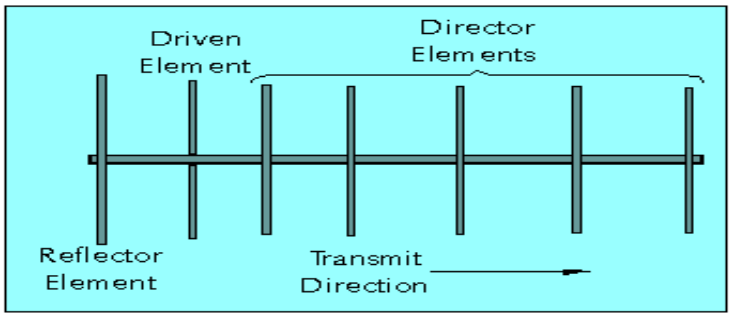
G9B12 What is the approximate length for a 1/4-wave vertical antenna cut for 28.5 MHz?
8.2 feet.

Directional Antennas.

If a slightly shorter parasitic element is placed 0.1 wavelength away and parallel to an HF dipole antenna mounted above ground, a major lobe will develop in the horizontal plane toward the parasitic element. If a slightly longer parasitic element is placed 0.1 wavelength away and parallel to an HF dipole antenna mounted above ground, a major lobe will develop in the horizontal plane, away from the parasitic element, toward the dipole. The combination of these is the basic design of the Yagi antenna. This is a good trick to remember when you are trying for that special contact with a rare DX station.

Most amateurs will at some time use a Yagi antenna. A Yagi is one type of beam antenna. A beam antenna is an antenna that concentrates signals in one direction. Examples of directional or beam antennas are the quad, Yagi, and dish antennas. A Yagi antenna is named for a Japanese professor who worked out all the math behind the phasing and parasitic elements. In our study for the exam, you need to know a few basic facts about a Yagi.

The Yagi is an array of dipole elements spaced along the supporting boom that holds it all together. Only one element is connected to the transmitter. Usually there is some form of matching device to connect a 50 ohm feedline. Often this device is a gamma match capacitor. The reflector element is located next to the driven element and is a little bit longer than the driven element. On the other side of the driven element is one or more director elements that are slightly shorter than it. When the RF energy is applied to the driven element, energy is inductively coupled to the other parasitic elements. Each one generates its own wave front, and the combined electromagnetic fields of the parasitic elements reinforce and cancel in a way that allows the power to go mostly in one direction.



Yagi antenna

The characteristics of the Yagi like it's front to back ratio, gain, and beamwidth can be changed by adding elements, changing the element spacing, and changing the length of the supporting boom. There is no need to insulate the elements from the boom, as the boom attachment is at a point on the element where the voltage is at or near zero.

The SWR bandwidth, or usable frequency range of the Yagi can be increased by using elements of a larger diameter.

The theoretical gain of a 3 element Yagi is 9.7dBi. That is the same effect as raising the 5 watt output of your radio to 40 watts. Best of all, the other guy's signal is that much stronger too, and it didn't take any power source to make it happen. Yagi antennas are very popular on the amateur bands from 20 meters and up because the front to back ratio allows you to reject unwanted signals by pointing the antenna in a different direction.

If the horizontal radiation pattern of an antenna shows a major lobe at 0 degrees and a minor lobe at 180 degrees, most of the signal would be radiated towards 0 degrees and a smaller amount would be radiated towards 180 degrees. Often when discussing antennas, we talk a lot about major and minor lobes. These are terms that identify where most of the RF energy is going. The major lobe is always the one that people are most interested in, but it is often important to know where the rest of the power is headed. These are the minor lobes. The comparative difference is known as the front to back ratio of the antenna.

On the HF bands, and especially below 20 meters, the directional antennas are more often made of wire loops supported on frames of wood, bamboo, or fiberglass. Most common loop antennas are based on a one wavelength wire supported on some type of frame. Cubical Quad antennas, so named because when made with two elements they outline a cubic space, use crossed poles to support the wire in a square. A Delta Loop supports the wire at 3 points in a triangle. A formula for these loops when adjusted for the velocity factor of the wire would be..

For a full wavelength of wire $Length_{feet} = \frac{936}{F_{MHz}}$ then divide the result by the number of sides.

The reflector element, just like in a Yagi antenna, is about 5% longer that a driven element and the director element 5% shorter than a driven element. Remember to select the answer on the exam that is closest to the value you have calculated. So using the numbers from exam questions we get the following.

A cubical-quad antenna driven element for 21.4 MHz will be 11.7 feet on each side.
A cubical-quad antenna driven element for 14.3 MHz will be 17.6 feet on each side.
A cubical-quad antenna reflector element for 29.6 MHz will be 8.7 feet on each side.
Remember that the reflector element is slightly larger than a driven element.

Each leg of a symmetrical delta-loop antenna driven element for 28.7 MHz will be 11.7 feet.
Each leg of a symmetrical delta-loop antenna driven element for 24.9 MHz will be 13.45 feet.
Each leg of a symmetrical delta-loop antenna reflector element for 14.1 MHz will be 24.35 feet.
Again, the reflector is slightly larger than a driven element.

Many operators choose a two-element quad antenna because its performance will compare favorably with a three-element Yagi. The directional radiation characteristics of a cubical-quad antenna have more directivity in both horizontal and vertical planes than a dipole antenna. Portions of the loop are in both the horizontal and the vertical planes.

Moving the feed point of a multielement quad antenna from a side parallel to the ground to a side perpendicular to the ground changes the antenna polarization from horizontal to vertical.

T9A01 What is a beam antenna?
An antenna that concentrates signals in one direction.

T9A08 What type of antennas are the quad, Yagi, and dish?
Directional or beam antennas.

G9C01 How can the SWR bandwidth of a Yagi antenna be increased?
Use larger diameter elements.

G9C02 What is the approximate length of the driven element of a Yagi antenna?
1/2 wavelength.

G9C03 Which statement about a three-element single-band Yagi antenna is true?
The director is normally the shortest parasitic element.

G9C04 Which statement about a Yagi antenna is true?
The reflector is normally the longest parasitic element.

G9C05 What is one effect of increasing the boom length and adding directors to a Yagi antenna?
Gain increases.

G9C06 Which of the following is a reason why a Yagi antenna is often used for radio communications on the 20 meter band?
It helps reduce interference from other stations to the side or behind the antenna.

G9C07 What does "front-to-back ratio" mean in reference to a Yagi antenna?
The power radiated in the major radiation lobe compared to the power radiated in exactly the opposite direction.

G9C08 What is meant by the "main lobe" of a directive antenna?
The direction of maximum radiated field strength from the antenna.

G9C09 What is the approximate maximum theoretical forward gain of a 3 Element Yagi antenna?
9.7 dBi.

G9C10 (D) Which of the following is a Yagi antenna design variable that could be adjusted to optimize forward gain, front-to-back ratio, or SWR bandwidth?
A. The physical length of the boom
B. The number of elements on the boom
C. The spacing of each element along the boom
D. **All of these choices are correct.**

G9C11 What is the purpose of a "gamma match" used with Yagi antennas?
To match the relatively low feed-point impedance to 50 ohms.

G9C12 (D) Which of the following describes a common method for insulating the driven element of a Yagi antenna from the metal boom when using a gamma match?
A. Support the driven element with ceramic standoff insulators
B. Insert a high impedance transformer at the driven element
C. Insert a high voltage balun at the driven element
D. **None of these answers are correct. No insulation is needed.**

G9C13 Approximately how long is each side of a cubical-quad antenna driven element?
1/4 wavelength.

G9C14 How does the forward gain of a 2-element cubical-quad antenna compare to the forward gain of a 3 element Yagi antenna?
About the same.

G9C15 Approximately how long is each side of a cubical-quad antenna reflector element?
Slightly more than 1/4 wavelength.

G9C16 How does the gain of a two element delta-loop beam compare to the gain of a two element cubical quad antenna?
About the same.

G9C17 Approximately how long is each leg of a symmetrical delta-loop antenna Driven element?
1/3 wavelengths.

G9C18 Which of the following antenna types consists of a driven element and some combination of parasitically excited reflector and/or director elements?
A Yagi antenna.

G9C19 What type of directional antenna is typically constructed from 2 square loops of wire each having a circumference of approximately one wavelength at the operating frequency and separated by approximately 0.2 wavelength?
A cubical quad antenna.
T0A09 What is one way to recharge a 12-volt battery if the commercial power is out?
Connect the battery to a car's battery and run the engine.

G9C20 What happens when the feed-point of a cubical quad antenna is changed from the center of the lowest horizontal wire to the center of one of the vertical wires?
The polarization of the radiated signal changes from horizontal to vertical.

G9C21 What configuration of the loops of a cubical-quad antenna must be used for the antenna to operate as a beam antenna, assuming one of the elements is used as a reflector?
The reflector element must be approximately 5% longer than the driven element.

Specialized Antennas.

We have saved the best for last. Or at perhaps the oddest for last?

In the section on radio propagation we mentioned the idea of intentionally launching your RF energy directly overhead. This is done with an NVIS or near vertical incidence skywave antenna. To construct an NVIS system, the simplest form uses a wire antenna mounted intentionally between 1/10 and 1/4 wave length off the ground. There may be a set of counterpoise wires laid out directly on the ground under the driven wire. These are a 'reflector' again so they will be about 5% longer than the driven wire. This antenna will provide good reliable communication in the area normally considered the 'skip zone' by bouncing the RF off the ionosphere directly over the transmitting station. In antenna restricted neighborhoods, this is a really good antenna to attach to the top rail of the backyard fence. The neighbors will never guess.

The next special antenna idea to consider is the stacked Yagi array. When you place 2 directional antennas together and correctly combine the feed system, the gain of the total system increases by 3dB. This is effectively doubling your output power, without using any more electronics to make it happen. Just like with the directional antennas mentioned above, this gain also improves the signal you are trying to receive as well. Stacking up very large arrays can achieve some very impressive system gain. This is the type of antenna system used for moon-bounce communications. Vertically stacked horizontal antennas reinforce the radiation pattern of each other by making the vertical beamwidth narrower. This effect can place more power down near the horizon where you need it.

Another directional antenna is the log periodic. This is an antenna that is designed to be very broad banded. This is accomplished by a logarithmic shortening of the elements as you move to the front of the antenna. The gain at any one frequency is about the same as a 3 element Yagi, because only about 3 elements are close enough in length to be active on any one frequency.

On the HF bands, when you need very high gain in a single direction, a Beverage Antenna is a good choice. This is really just a single wire several wavelengths long mounted close to the ground. Because of the odd feedpoint impedance you will encounter on a Beverage antenna, it is used mostly for receiving applications.

The last special antenna topic is the multiband trap antenna. These are built both as verticals and as horizontals. The 'traps' act like switches that disconnect the longer portion of the antenna as you move to higher bands. Only the resonant portion of the antenna is used on each band. If you can only put up one antenna, this might be the best choice. The disadvantage is that they are more responsive to harmonic radiation than other antenna types, so you need to pay special attention to running a clean station, and using filters to prevent harmonics from reaching the antenna.

G9D01 What does the term "NVIS" mean as related to antennas?
Near Vertical Incidence Skywave.

G9D02 Which of the following is an advantage of an NVIS antenna?
High vertical angle radiation for short skip during the day.

G9D03 At what height above ground is an NVIS antenna typically installed?
Between 1/10 and 1/4 wavelength.

G9D04 How does the gain of two 3-element horizontally polarized Yagi antennas spaced vertically 1/2 wave apart from each other typically compare to the gain of a single 3-element Yagi?
Approximately 3 dB higher.

G9D05 What is the advantage of vertical stacking of horizontally polarized Yagi antennas?
Narrows the main lobe in elevation.

G9D06 Which of the following is an advantage of a log periodic antenna?
Wide bandwidth.

G9D07 Which of the following describes a log periodic antenna?
Length and spacing of the elements increases logarithmically from one end of the boom to the other.

G9D08 Why is a Beverage antenna generally not used for transmitting?
It has high losses compared to other types of antennas.

G9D09 Which of the following is an application for a Beverage antenna?
Directional receiving for low HF bands.

G9D10 Which of the following describes a Beverage antenna?
A very long and low receiving antenna that is highly directional.

G9D11 Which of the following is a disadvantage of multiband antennas?
They have poor harmonic rejection.

G9D12 What is the primary purpose of traps installed in antennas?
To permit multiband operation.

Electrical and RF Safety.

Hazardous voltages.

30 volts is a commonly accepted value for the lowest voltage that can cause a dangerous electric shock. 100 milliamperes is the lowest amount of electrical current flowing through the human body that is likely to cause death. There is some disagreement as to the minimum current that can cause death. Some experts suggest as little as 50 milliamps passing across the heart can stop it. The exam takes a little stronger stance in claiming 100 milliamps is the correct value. The author will pass on this experiment if it's just the same to you.

T0A01 What is a commonly accepted value for the lowest voltage that can cause a dangerous electric shock?
30 volts.

T0A02 What is the lowest amount of electrical current flowing through the human body that is likely to cause death?
100 milliamperes.

Lightning protection.

When a lightning storm is expected, you should disconnect the antenna cables from your station and move them away from your radio equipment; unplug all power cords from AC outlets; and stop using your radio equipment and move to another room until the storm passes.

All of these steps are correct and can save your life! Lightning involves currents in the 100s of thousands of amps. See hazardous voltages above.

Fire prevention is the most important reason to have a lightning protection system for your amateur radio station. The most important item is a good single point grounding system. Do not expect soldered connections to withstand the energy of a lightning hit. The solder alloy will likely become vapor as the lightning bolt current passes through it.

T0A08 (D) What precautions should be taken when a lightning storm is expected?
A. Disconnect the antenna cables from your station and move them away from your radio equipment
B. Unplug all power cords from AC outlets
C. Stop using your radio equipment and move to another room until the storm passes
D. All of these answers are correct.

T0A12 What is the most important reason to have a lightning protection system for your amateur radio station?
Fire prevention.

G0B11 Which of the following is good engineering practice for lightning protection grounds?
They must be bonded together with all other grounds.

G0B09 Why is it not safe to use soldered joints with the wires that connect the base of a tower to a system of ground rods?
A soldered joint will likely be destroyed by the heat of a lightning strike.

Battery Safety.

One way to recharge a 12-volt battery if the commercial power is out is to connect the battery to a car's battery and run the engine. Keep in mind that the kind of hazards that are presented by a conventional 12-volt storage battery include the fact that it contains dangerous acid that can spill and cause injury, short circuits can damage wiring and possibly cause a fire, and explosive gas can collect if not properly vented. If a storage battery is charged or discharged too quickly the battery could overheat and give off dangerous gas or explode.

T0A10 (D) What kind of hazard is presented by a conventional 12-volt storage battery?
A. It contains dangerous acid that can spill and cause injury
B. Short circuits can damage wiring and possibly cause a fire
C. Explosive gas can collect if not properly vented
D. All of these answers are correct.

T0A11 What can happen if a storage battery is charged or discharged too quickly?
The battery could overheat and give off dangerous gas or explode.

G4E07 When might a lead-acid storage battery give off explosive hydrogen gas?
When being charged.

Generator Safety.

An emergency generator, either permanent or temporary should be located in a well ventilated area and the installation should be grounded. When using a gasoline-fueled generator to power your home station always ground the frame of the generator and use only generators that produce a clean sine wave output. Be sure that the engine is well lubricated. Extra fuel supplies, especially gasoline, should not be stored in an inhabited area.

You should **NOT** place a gasoline-fueled generator to power your station inside a building or outside an open window. CO (carbon monoxide) is a colorless, odorless gas that will kill you.

During a commercial power outage, it would be unwise to back feed the output of a gasoline generator into your house wiring by connecting the generator through an AC wall outlet for several reasons. This practice presents a hazard for electric company workers who are trying to restore power. Remember that transformers work both ways. Your generator set churning out 120 or 240 volts AC may be providing several thousand volts to power lines that should be disconnected according to the switches used on the power grid. This could really ruin some utility worker's whole day, or for that matter, the rest of his very short life. If you are back-feeding the power grid, all your neighbor's appliances and lights will try to draw power from your generator. Your generator may be good, but it's not that good. It will draw too much current, overloading your generator. If power is restored to your house before you disconnect the unit, it will damage your generator.

Think "**blue white fireball with flammable liquid attached**" in your carport. Do not reach for the hot dogs..

G4E06 Which of the following is true of an emergency generator installation?
The generator should be located in a well ventilated area.

G4E12 Which of the following is a primary reason for not placing a gasoline-fueled generator inside an occupied area?
Danger of carbon monoxide poisoning.

G4E13 Why would it be unwise to power your station by back feeding the output of a gasoline generator into your house wiring by connecting the generator through an AC wall outlet?
It might present a hazard for electric company workers.

Safety in the Ham Shack.

The most important thing to consider when installing an emergency disconnect switch at your station is everyone should know where it is and how to use it. It doesn't do much good to have a safety switch if people don't know where it is, or what it's for. Remember it's your life that they may be trying to save. It is also important to have people around who are trained in CPR if you are playing with high voltages and such in your hobby.

Be aware of the hazard that might exist in a power supply when it is turned off and disconnected. You might receive an electric shock from stored charge in large capacitors. See paragraph above. Again, it's your life we are talking about. Always take care with electrical hazards. It only takes a small current across your heart to cause the heart muscle to forget why it is here. The greatest hazard for this happening just happens to be at our powerline frequency of 60 Hz. Extended exposure to currents as small as 50 microamps may be hazardous.

Take proper care with chemicals and other substances used in your equipment or its repair. Amateurs do a lot of experimenting with new and old equipment. We often have things like etching solutions to make circuit boards or plating solutions around. Some older equipment can contain hazardous substances that you wouldn't want to get on you let alone ***in*** you. Carefully wash up before handling food after working with chemicals or solder. Some solder alloys contain lead, and the fluxing chemicals may be somewhat toxic as well.

T0A07 What is the most important thing to consider when installing an emergency disconnect switch at your station?
Everyone should know where it is and how to use it.

T0A13 What kind of hazard might exist in a power supply when it is turned off and disconnected?
You might receive an electric shock from stored charge in large capacitors.

G0B10 Which of the following is a danger from lead-tin solder?
Lead can contaminate food if hands are not washed carefully after handling.

G0B13 Which of the following is the most hazardous type of electrical energy?
60 cycle Alternating current.

G0B04 What is the mechanism by which electrical shock can be lethal?
Current through the heart can cause the heart to stop pumping.

G0B14 What is the maximum amount of electrical current flow through the human body that can be tolerated safely?
50 microamperes.

Grounding.

If your third-floor amateur station has a ground wire running 33 feet down to a ground rod, you might get an RF burn if you touch the front panel of your HF transceiver because the ground wire is a resonant length on several HF bands and acts more like an antenna than an RF ground connection. One good way to avoid stray RF energy in your amateur station is to keep the station's ground wire as short as possible. RF hot spots can occur in a station located above the ground floor if the equipment is grounded by a long ground wire. A good station ground will reduce electrical noise, reduce interference, and reduce the possibility of electrical shock, but for the exam you need to know that it will not reduce the cost of operating a station. Braid from RG-213 coaxial cable makes a good conductor to tie station equipment together into a station ground. According to the National Electrical Code, there should be only one grounding system in a building. The minimum length for a good ground rod is 8 feet. All station equipment needs to be tied into a station ground, not just the transceivers and power amplifiers. Severe, broadband radio frequency noise at an amateur radio station can be caused by an intermittent RF ground. To avoid creating a ground loop with all of it's problems be sure to connect all of your stations ground conductors to a single point.

Additional information about grounding requirements and procedures may be found in the National Electrical Code. The RF exposure limits of the human body however are not addressed by the National Electrical Code.

G4C09 Which of the following statements about station grounding is true?
RF hot spots can occur in a station located above the ground floor if the equipment is grounded by a long ground wire.

G4C05 What might be the problem if you receive an RF burn when touching your equipment while transmitting on a HF band, assuming the equipment is connected to a ground rod?
The ground wire is resonant.

G4C06 (D) Which of the following is an important reason to have a good station ground?
A. To reduce the likelihood of RF burns
B. To reduce the likelihood of electrical shock
C. To reduce interference
D. **All of these answers are correct.**

G4C07 What is one good way to avoid stray RF energy in an amateur station?
Keep the station's ground wire as short as possible.

G4C12 What is one cause of broadband radio frequency interference at an amateur radio station?
Arcing at a poor electrical connection.

G4C13 How can a ground loop be avoided?
Connect all ground conductors to a single point.

G0B05 Which of the following conditions will cause a Ground Fault Circuit Interrupter (GFCI) to disconnect the 120 or 240 Volt AC line power to a device?
Current flowing from the hot wire to ground.

G0B06 Why must the metal chassis of every item of station equipment be grounded (assuming the item has such a chassis)?
It ensures that hazardous voltages cannot appear on the chassis.

Fusing, Interlocks, Wiring, Electrical Code Compliance.

When installing a power plug on a line cord, you should twist the wire strands neatly and fasten them so they don't cause a short circuit. Be sure to observe the correct wire color conventions for plug terminals and use proper grounding. The green wire in a line cord is reserved for grounding. Never use it for any other purpose.

Only the "hot" (black and red) wires in a four-conductor line cord should be attached to fuses or switches in a 240-VAC primary (single phase) power supply. You do not want a fault in the power wiring in some piece of equipment to disconnect the ground (green) or neutral (white) wire because that could result in a voltage potential being present at the outside of the equipment. Switches and fuses must never disconnect the ground wire from your equipment.

The size of wire is normally used on a 20-ampere, 120-VAC household appliance circuit would be AWG number 12. AWG number 12 wiring should never be fused at a value larger than 20 amperes. AWG 14 wiring should never be fused at a rating higher than 15 amps. The purpose of a fuse in an electrical circuit is to interrupt power in case of overload. If you install a 20-ampere fuse in your transceiver in the place of a 5-ampere fuse the excessive current could cause a fire.

To guard against electrical shock at your station you should use 3-wire cords and plugs for all AC powered equipment, connect all AC powered station equipment to a common ground, and use a ground-fault interrupter at each electrical outlet. Cabinets for equipment that uses high voltage should be set up with a safety interlock switch that will disconnect the power when the cabinet is opened. This feature will help prevent you from reaching into that working amplifier to make that one little (and very final) adjustment.

Additional information about wiring requirements and procedures and electrical safety may be found in the National Electrical Code.

T0A03 What is connected to the green wire in a three-wire electrical plug?
Ground.

T0A04 What is the purpose of a fuse in an electrical circuit?
To interrupt power in case of overload.

T0A05 What might happen if you install a 20-ampere fuse in your transceiver in the place of a 5-ampere fuse?
Excessive current could cause a fire.

T0A06 What is a good way to guard against electrical shock at your station?
A. Use 3-wire cords and plugs for all AC powered equipment
B. Connect all AC powered station equipment to a common ground
C. Use a ground-fault interrupter at each electrical outlet
D. All of these answers are correct.

G4C10 Which of the following is covered in the National Electrical Code?
Electrical safety inside the ham shack.

G0B01 Which wire(s) in a four-conductor line cord should be attached to fuses or circuit breakers in a device operated from a 240-VAC single-phase source?
Only the "hot" (black and red) wires.

G0B02 What is the minimum wire size that may be safely used for a circuit that draws up to 20 amperes of continuous current?
AWG number 12.

G0B03 Which size of fuse or circuit breaker would be appropriate to use with a circuit that uses AWG number 14 wiring?
15 amperes.

G0B12 What is the purpose of a transmitter power supply interlock?
To ensure that dangerous voltages are removed if the cabinet is opened.

Antenna Installation.

The maximum allowed height with regard to nearby airports must be considered when erecting an antenna near an airport. Under normal circumstances you may erect towers and related antenna structures up to 200 feet tall without a requirement of FAA registration and anti-collision lighting. In locations near an airport, this height is substantially reduced.

The most important safety precaution to observe when putting up an antenna tower is to look for and stay clear of any overhead electrical wires. The minimum safe distance from a power line to allow when installing an antenna would be a location where if the antenna falls unexpectedly, no part of it can come closer than 10 feet to the power wires.

An important consideration when putting up an antenna is to make sure people cannot accidentally come into contact with it. If a person accidentally touched your antenna while you were transmitting they might receive a painful RF burn injury. Then you get a call from their attorney..

Stainless steel hardware is used on many antennas instead of other metals because stainless steel parts are much less likely to corrode. Corroded hardware is why antennas and towers fall over.

T0B08 What is a safe distance from a power line to allow when installing an antenna?
So that if the antenna falls unexpectedly, no part of it can come closer than 10 feet to the power wires.

T0B10 Why is stainless steel hardware used on many antennas instead of other metals?
Stainless steel parts are much less likely to corrode.

T0B04 What is an important consideration when putting up an antenna?
Make sure people cannot accidentally come into contact with it.

T0B05 [97.15(A)] What must be considered when erecting an antenna near an airport?
The maximum allowed height with regard to nearby airports.

T0C07 What could happen if a person accidentally touched your antenna while you were transmitting?
They might receive a painful RF burn injury.

Tower Safety.

You should wear a hard hat and safety glasses if you are on the ground helping someone work on an antenna tower to protect your head and eyes in case something accidentally falls from the tower. You will be standing there looking up to see what the other guy is doing when he loses his grip on that wrench, or drops that bolt.

A good precaution to observe before climbing an antenna tower is to put on your safety belt and safety glasses. Even if you are the one on the tower, things can still shake loose above you while you are climbing. It is hard to get off the tower when you are suddenly blind from a falling object, unless you forgot your safety belt, which will make the trip down the tower when you grab for your eye a very fast one. When using a safety belt, you want to connect the safety strap to the belt by attaching it to the D-rings with the opening of the clip away from the tower. You don't want the legs or struts of the tower to be opening the clip when you are not looking.

Before you climb a tower you should arrange for a helper or observer, inspect the tower for damage or loose hardware, and make sure there are no electrical storms nearby. Always make sure that electrical circuits on the tower have been shut off and locked out. It's really hard for your helper to do CPR on you while you are strapped to the side of a tower.

All of these steps are correct and can save your life!

The guy wires for an antenna tower should be installed in accordance with the tower manufacturer's instructions. It's always good to read the manual, and follow the instructions of the engineer that designed the equipment.

The most important safety rule to remember when using a crank-up tower is it should never be climbed unless it is in the fully lowered position. If it was designed to be climbed, it would not crank up. The cable that holds the tower in the up position might break, and there you are with your fingers and toes in the way of several hundred pounds of steel that is suddenly headed for the ground. It is very hard to hang on for your life with no fingers and toes..

Separate 8 foot long ground rods for each tower leg, bonded to the tower and each other are considered to be an adequate ground for a tower. Refer to the mention of lightning protection above. When lightning does strike you want to provide it with a nice easy path to a safe place to go, preferably not by way of the operating position.

T0B01 Why should you wear a hard hat and safety glasses if you are on the ground helping someone work on an antenna tower?
To protect your head and eyes in case something accidentally falls from the tower.

T0B02 What is a good precaution to observe before climbing an antenna tower?
Put on your safety belt and safety glasses.

T0B03 (D) What should you do before you climb a tower?
A. Arrange for a helper or observer
B. Inspect the tower for damage or loose hardware
C. Make sure there are no electrical storms nearby
D. All of these answers are correct.

T0B06 What is the most important safety precaution to observe when putting up an antenna tower?
Look for and stay clear of any overhead electrical wires.

T0B07 How should the guy wires for an antenna tower be installed?
In accordance with the tower manufacturer's instructions.

T0B09 What is the most important safety rule to remember when using a crank-up tower?
A crank-up tower should never be climbed unless it is in the fully lowered position.

T0B11 What is considered to be an adequate ground for a tower?
Separate 8 foot long ground rods for each tower leg, bonded to the tower and each other.

G0B07 Which of the following should be observed for safety when climbing on a tower using a safety belt or harness?
Always attach the belt safety hook to the belt "D" ring with the hook opening away from the tower.

G0B08 What should be done by any person preparing to climb a tower that supports electrically powered devices?
Make sure all circuits that supply power to the tower are locked out and tagged.

Radiation exposure.

We use the term 'radiation' a lot in radio discussions. This can and does cause some serious concern with some people. VHF and UHF radio signals are **non-ionizing** radiation. This is true for all radio as amateurs are involved with it. Radio waves cause injury to the human body **only** if the combination of signal strength and frequency cause excessive power to be absorbed.

T0C01 What type of radiation are VHF and UHF radio signals?
Non-ionizing radiation.

RF Heating Hazards.

Depending on the wavelength of the signal, the energy density of the RF field, and other factors, RF energy can heat body tissue. This is how your microwave oven gets your food hot. The frequency (or wavelength) of the energy has the most direct effect on the permitted exposure level of RF radiation. The body absorbs energy differently at different frequencies, and the safety limits take this into account.

Specific absorption rate (Watts/kg) best describes the biological effects of RF fields at frequencies used by amateur operators. Especially at VHF and UHF frequencies, we look like a collection of resonant antennas. For example RF radiation in the 1270-MHz range frequency ranges has the most effect on the human eyes. The spread arms are about a half wavelength at 2 meters. The head is resonant at about 300-400 MHz and the inside of the skull makes a good resonant cavity at several microwave frequencies. At the very-high-frequency (30-300-MHz) range the human body absorbs RF energy at a maximum rate.

The term "athermal effects" of RF radiation means biological effects from RF energy other than heating. There is still a great deal of debate over the question of safety here. It never hurts to be careful, but amateurs have been exposing themselves to RF energy for many years and there is no statistical evidence of harmful effect.

T0C02 When can radio waves cause injury to the human body?
Only if the combination of strength and frequency cause excessive power to be absorbed.

G0A01 What is one way that RF energy can affect human body tissue?
It heats body tissue.

G0A03 Which of the following has the most direct effect on the permitted exposure level of RF radiation?
The power level and frequency of the energy.

Recognized Safe Power Levels.

50 watts PEP at the antenna is the maximum power level that an amateur radio station may use at frequencies above 30 MHz before an RF exposure evaluation is required. Most amateurs use equipment that operates below this power level in these frequencies. If you are one of the few who have more powerful equipment, you will be wanting to keep your RF safety evaluation up to date for your own peace of mind.

T0C03 [97.13(C)(1)] What is the maximum power level that an amateur radio station may use at frequencies above 30 MHz before an RF exposure evaluation is required?
50 watts PEP at the antenna.

Exposure to Others.

The factors that affect the RF exposure of people near an amateur transmitter are the frequency and power level of the RF field, the distance from the antenna to a person, and the radiation pattern of the antenna. Duty cycle is one of the factors used to determine safe RF radiation exposure levels because it takes into account the amount of time the transmitter is operating. All exposure limits are calculated with time averaging to determine the total exposure to RF energy.

The frequency of an RF source must be considered when evaluating RF radiation exposure because the human body absorbs more RF energy at some frequencies than at others. The unit of measurement used to measure RF radiation exposure is milliwatts per square centimeter.

The body part and duration of its exposure, frequency and power density, and wave polarization are all factors that can affect the thermal aspects of RF energy exposure to human body tissues.

T0C04 (D) What factors affect the RF exposure of people near an amateur transmitter?
A. Frequency and power level of the RF field
B. Distance from the antenna to a person
C. Radiation pattern of the antenna
D. All of these answers are correct.

T0C05 Why must the frequency of an RF source be considered when evaluating RF radiation exposure?
The human body absorbs more RF energy at some frequencies than others.

T0C10 Which of the following units of measurement is used to measure RF radiation exposure?
Milliwatts per square centimeter.

T0C11 Why is duty cycle one of the factors used to determine safe RF radiation exposure levels?
It takes into account the amount of time the transmitter is operating.

G0A02 (B) Which property is NOT important in estimating if an RF signal exceeds the maximum permissible exposure (MPE)?
A. Its duty cycle
B. Its critical angle.
C. Its power density
D. Its frequency

G0A04 What does "time averaging" mean in reference to RF radiation exposure?
The total RF exposure averaged over a certain time.

G0A07 What effect does transmitter duty cycle have when evaluating RF exposure?
A lower transmitter duty cycle permits greater short-term exposure levels.

Routine station evaluation.

To determine that your station complies with FCC RF exposure regulations you could use calculations based on FCC OET Bulletin 65, calculations based on computer modeling, or measurement of field strength using calibrated equipment. You can make sure your station stays in compliance with RF safety regulations by re-evaluating the station whenever an item of equipment is changed. If your station is already compliant with RF safety standards, and you reduce operating power, no additional evaluation is required.

If you perform a routine RF evaluation on your station and determine that its RF fields exceed the FCC exposure limits in human-accessible areas, you are required to take action to prevent human exposure to the excessive RF fields. To prevent exposure to RF radiation in excess of FCC supplied limits amateur operators might alter antenna patterns, relocate antennas, and/or change station parameters such as frequency or power. For example if your neighbors would receive exposure exceeding the safe limits from your directional antenna, you might take measures to prevent the antenna from being aimed in their direction. If you install a ground mounted antenna, you need to take measures to insure that nobody can touch the antenna when you are operating the transmitter.

Take extra care if you are using an indoor antenna to make sure you and your family are not being exposed to unsafe levels of RF energy. If you are adjusting or repairing your antenna, it is a good idea to disconnect the feedline from the transmitter to prevent anyone from accidentally energizing the system. It only takes one curious push of a button to spoil your whole day. To measure the strength of the RF field around your station or antennas, you could use a calibrated field strength meter.

If you are involved with shared transmitter sites, like a mountain top repeater site, you should know that the owner of any transmitter that contributes 5% or more of the maximum permissible exposure level of RF at the site is equally responsible for site compliance with meeting RF safety standards.

T0C08 (D) What action might amateur operators take to prevent exposure to RF radiation in excess of FCC supplied limits?
A. Alter antenna patterns
B. Relocate antennas
C. Change station parameters such as frequency or power
D. All of these answers are correct.

T0C09 How can you make sure your station stays in compliance with RF safety regulations?
By re-evaluating the station whenever an item of equipment is changed.

T0C06 (D) [97.13(C)(1)] How can you determine that your station complies with FCC RF exposure regulations?
A. By calculation based on FCC OET Bulletin 65
B. By calculation based on computer modeling
C. By measurement of field strength using calibrated equipment
D. All of these choices are correct.

G0A05 What must you do if an evaluation of your station shows RF energy radiated from your station exceeds permissible limits?
Take action to prevent human exposure to the excessive RF fields.

G0A06 Which transmitter(s) at a multiple user site is/are responsible for RF safety compliance?
Any transmitter that contributes 5% or more of the MPE.

G0A08 Which of the following steps must an amateur operator take to ensure compliance with RF safety regulations?
Perform a routine RF exposure evaluation.

G0A09 What type of instrument can be used to accurately measure an RF field?
A calibrated field-strength meter with a calibrated antenna.

G0A10 What do the RF safety rules require when the maximum power output capability of an otherwise compliant station is reduced?
No further action is required.

G0A11 What precaution should you take if you install an indoor transmitting antenna?
Make sure that MPE limits are not exceeded in occupied areas.

G0A12 What precaution should you take whenever you make adjustments or repairs to an antenna?
Turn off the transmitter and disconnect the feedline.

G0A13 What precaution should be taken when installing a ground-mounted antenna?
It should be installed so no one can be exposed to RF radiation in excess of maximum permissible limits.

G0A14 What is one thing that can be done if evaluation shows that a neighbor might receive more than the allowable limit of RF exposure from the main lobe of a directional antenna?
Take precautions to ensure that the antenna cannot be pointed at their house.

G0A15 (D) [97.13(c)(1)] How can you determine that your station complies with FCC RF exposure regulations?
A. By calculation based on FCC OET Bulletin 65
B. By calculation based on computer modeling
C. By measurement of field strength using calibrated equipment
D. **All of these choices are correct.**

About the Exam.

Now you are ready for the fun part. First, relax! Be sure to take a rest break. Once you begin the exam you may not leave the room. Be sure to turn off cell phones, pagers, watches that make noise, and any two way radio equipment you may have with you. Place books and study materials on the floor or out of sight.

Each Exam is a simple 35 question multiple choice test, and you have been studying all the correct answers. You know this stuff. You are ready!

If you are working for your first license, you will start with exam Element 2, the Technician license exam.

Please follow the instructions of the Volunteer examiners carefully!

First there is a little paperwork that needs to be done.

The Volunteer Examiners will assist you in filling out the necessary application form NVEC-610. When this form is completed, they will ask to see your photo ID. This is required to verify that you are in fact the person you claim to be on the application form.

If you have copies of CSCE documents or previous licenses to be counted as credit for exam elements, be sure to inform the VE that checks your ID. The VE team will need photo copies of those documents to submit with your exam papers to the VEC.

They will now take your money. The exam processing fee on July 1 of 2007 is $14.00. This payment is to defray the actual costs of processing your application from the exam all the way to the FCC ULS Database.

Now you will receive the actual exam materials, and you may begin taking your exam.

When you are finished, return your exam materials including scratch pages you used for calculations to the examiners. They will grade your exam while you wait.

IMPORTANT!!! Do not leave the session until your exam has been graded.

Before you leave you should receive a CSCE document for any exam elements you have passed in this session. This is your only proof of passing this exam should the paperwork be lost in handling. Keep this CSCE in a safe place.

If you pass the Element 2 exam, you will be given an opportunity to take the Element 3 exam for the General class license. There is no additional charge for taking another exam element so long as you pass each previous element. If you need to re-take an exam element, there will be a new $14.00 fee required.

If you pass the Element 3 exam, you will be given an opportunity to take the Element 4 exam for the Extra class license. DO IT! You might end this exam session as an amateur Extra class operator.

If you have passed elements that qualify for a new license, you will be able to see your call sign in the ULS system typically in 5 to 10 days. As soon as your name and callsign appear in the ULS database you may go on the air with your new callsign.

If you are upgrading from Technician to General class, you may use your new privileges as soon as you have received your CSCE document, because you already have a callsign. Be sure to ad the “temporary AG” to your identification if you are on a General class frequency.

A hard copy document from the FCC will follow via US Mail to the address given on your application.

To search in the ULS for your new call sign, visit:

http://www.arrl.org/fcc/fcclook.php3

And enter your name in the name-search box just as you entered it onto the application form.