

# **Extra Class. FCC License Preparation Element 4B**

To go to an explanation press the Search button and select the required question designator.

E1A01

Extra Class operators have privileges across the 80 meter band, 40 meter band, 20 meter band and 15 meter band. Generally this means exclusive privileges on the bottom 25 kHz of each band as well as some exclusive areas in the middle of each band. [\[97.301\]](#)

E1A02

This is a segment of the 75 - 80 meter band that is exclusive to Extra Class operators.

[97.301]

E1A03

The bottom 25 kHz of the 40 meter band is reserved exclusively for Extra Class operators.

[97.301]

E1A04

The Extra Class operator has two exclusive operating areas on the 20 meter band. [\[97.301\]](#)

E1A05

The Extra Class operator has two exclusive operating areas on the 15 meter band. [\[97.301\]](#)

E1A06

The originator and first forwarding station is responsible for making sure that the message does not violate FCC rules. Other forwarding stations are not accountable for inadvertently forwarding messages that violate the rules. However, they must not forward such messages if they become aware of the violation. [97.219]

E1A07

Message forwarding stations are not accountable for inadvertently forwarding messages that violate FCC rules. However, they must not forward such messages if they become aware of the violation. [97.219]



E1A08

Spurious emissions are radiated when your transmitter is faulty, badly adjusted or being used incorrectly. The most common cause of spurious emissions on SSB is overdriving and excessive speech processing. [\[97.307\]](#)

E1A09

Normally Radio Amateurs communicate with other Radio Amateurs. Other transmissions permitted include:

Communications with other FCC regulated stations in an emergency.

Communication with other US government stations for RACES purposes.

Communications with stations authorized by the FCC to communicate with amateur stations.

[97.111]

E1A10

The 219 - 220 MHz segment of this band is reserved for packet radio communications. Stations using this segment are also required to register their location with the ARRL. Some geographic restrictions also apply. [\[97.303\]](#)

E1A11

Written notice of 30 days or more is given by the FCC unless there is a threat to life or property. [97.27]

E1A12

You are bound by FCC rules if the vessel you are on flies the American flag in international waters. [97.5] There are some extra rules concerning operation of Amateur Radio stations aboard ships or aircraft. [97.11]

E1A13

You are bound by FCC rules if the vessel you are on flies the American flag in international waters. [97.5] There are some extra rules concerning operation of Amateur Radio stations aboard ships or aircraft. [97.11]

E1A14

This is an exception to the normal rule governing secret codes. A space telecommand station is also allowed to transmit one-way communications to the space station. [97.211]

E1B01

There are also some geographical restrictions. [\[97.13\]](#)



E1B02

A list is available showing the locations of the FCC monitoring facilities. [\[97.13\]](#)

E1B03

The actions that may be required are prescribed in FCC rules S1.1301 - 1.1319. [\[97.13\]](#)

E1B04

What constitutes a "well-engineered" receiver is not defined by the FCC Part 97 Rules.

[97.121]

E1B05

Restricted operation may involve keeping off particular amateur bands during the prescribed times. What constitutes a "well-engineered" receiver is not defined by the FCC Part 97 Rules. [\[97.121\]](#)

E1B06

This rule is designed to encourage the teaching of Amateur Radio in educational institutions.

[97.113]

E1B07

This rule is designed to encourage the teaching of Amateur Radio in educational institutions.

[97.113]

E1B08

This is a rule to help Radio Amateurs! Its purpose is to prevent State and local regulations from making it impossible to erect a reasonable antenna system. [\[97.15\]](#)

E1B09

This is unfortunate if you happen to live in a canyon since the antenna height is measured using local ground level. You may, however, erect an antenna 20 feet above an existing building regardless of the building height (provided that building safety and airport regulations are met.) [97.15]



E1B10

Repeaters, beacons, and auxiliary station antennas are subject to the same regulations as regular amateur radio station antenna systems. [\[97.15\]](#)

E1B11

Paragraph (c) of the relevant rule grants exemption for antennas less than 20 feet high.

[97.15]

E1B12

Although there are no FCC imposed restrictions there will be obvious considerations of road safety and the safety of third parties! The vehicle manufacturer and local authorities may impose or recommend restrictions but these are not under the remit of the FCC. [\[97.15\]](#)

E1C01

Licensed amateur operators from other countries may apply for a reciprocal permit to operate in the US. [\[97.17\]](#)

E1C02

Licensed amateur operators from other countries may apply for a reciprocal permit to operate in the US. [\[97.17\]](#)

E1C03

For example, if a foreign operator has VHF privileges in his/her own country then he/she will have VHF privileges in the US (unless the FCC specifies otherwise). [97.107]

E1C04

An alien operator uses a letter/numeral indicating location followed by his/her call sign (issued by his/her country). The station location must be given at least once per communication.

[97.119]

E1C05

US citizens are not eligible for reciprocal permits even though they may hold a call sign from another country. [97.17]



E1C06

Use FCC Form 610 for a new operator license.

Use FCC Form 610-A for a reciprocal permit.

Use FCC Form 610-B for a new club license.

[97.17]

E1C07

The person must be a citizen of the country that issued the amateur service license. [\[97.17\]](#)

E1C08

A Canadian government issued license is acceptable in place of a reciprocal permit. [\[97.17\]](#)

E1C09

Many young people enjoy Ham radio as a hobby. [97.17]

E1C10

An amateur license is good for ten years. A reciprocal permit is good for one year. [97.25]

E1C11

The rule that applies is: "No person who has been granted an amateur license is eligible for a reciprocal permit for alien and amateur licensee." [\[97.17\]](#)

E1D01

You may operate a Radio Amateur Civil Emergency Service (RACES) station if you hold an FCC issued operator license and are enrolled in a civil defense organization. [97.3]

E1D02

You may operate a Radio Amateur Civil Emergency Service (RACES) station if you hold an FCC issued operator license and are enrolled in a civil defense organization. [\[97.407\]](#)



E1D03

You may operate a Radio Amateur Civil Emergency Service (RACES) station if you hold an FCC issued operator license and are enrolled in a civil defense organization. [\[97.407\]](#)

E1D04

You may operate a Radio Amateur Civil Emergency Service (RACES) station if you hold an FCC issued operator license and are enrolled in a civil defense organization. [\[97.407\]](#)

E1D05

You may operate a Radio Amateur Civil Emergency Service (RACES) station if you hold an FCC issued operator license and are enrolled in a civil defense organization. [\[97.21\]](#)

E1D06

You may operate a Radio Amateur Civil Emergency Service (RACES) station if you hold an FCC issued operator license and are enrolled in a civil defense organization. [\[97.407\]](#)

E1D07

No extra bands or band segments are available to RACES stations. [\[97.407\]](#)

E1D08

No extra bands or band segments are available to RACES stations. [\[97.407\]](#)

E1D09

The frequencies available under such an emergency are listed in [\[97.407\]](#).

E1D10

Normally, Radio Amateurs communicate with other Radio Amateurs. Other transmissions permitted include:

Communications with other FCC regulated stations in an emergency.

Communication with other US government stations for RACES purposes.

Communications with stations authorized by the FCC to communicate with amateur stations.

[97.407]



E1D11

Normally, Radio Amateurs communicate with other Radio Amateurs. Other transmissions permitted include:

Communications with other FCC regulated stations in an emergency.

Communication with other US government stations for RACES purposes.

Communications with stations authorized by the FCC to communicate with amateur stations.

[97.407]

E1E01

Radio Amateurs may use the Amateur satellite service just like any other Amateur service.  
Most Amateur Radio satellites are used as orbiting repeaters. [97.207]

E1E02

The bands and band segments available for space stations are listed in [\[97.207\]](#).

E1E03

The bands and band segments available for space stations are listed in [\[97.207\]](#).

E1E04

Telecommand operation is distinct from normal usage of a space station as a repeater.  
[97.207].

E1E05

The telecommand station is subject to the privileges of the control operator. [97.207].

E1E06

The telemetry may relate to communications by way of the spacecraft or it may relate to other functions of the craft. [97.207].

E1E07

An altitude higher than 50 km above the earth's surface is considered to be space. Below this altitude is considered to be Earth. [\[97.3\]](#)



E1E08

The telecommand station must be operated within the license privileges of the control operator. [97.207].

E1E09

A further notification is required once the station is in operation. Notice must also be given when the station ceases operation. [97.207]

E1E10

Once the space station begins operation you have seven days to give the FCC written notice.

[97.207]

E1E11

After the space station ceases operation, the licensee should give notice to the FCC within three months of shut down. [97.207]

E1E12

An altitude higher than 50 km above the surface of the earth is considered to be space.  
Below this altitude, a station is considered to be an Earth station. [97.3] (Paragraph 38)

E1F01

The ARRL/VEC offers monthly examinations throughout the US. [\[97.521\]](#)

E1F02

This question is checking that you know the difference between a VE (Volunteer Examiner) and a VEC (Volunteer Examiner Coordinator). [\[97.519\]](#)

E1F03

A VEC must NOT be engaged in the manufacture or distribution of amateur station equipment or amateur license preparation materials without FCC approval. [\[97.521\]](#)



E1F04

A VEC must NOT be engaged in the manufacture or distribution of amateur station equipment or amateur license preparation materials without FCC approval. [\[97.521\]](#), [\[97.523\]](#)

E1F05

A VEC must NOT be engaged in the manufacture or distribution of amateur station equipment or amateur license preparation materials without FCC approval. [\[97.521\]](#), [\[97.523\]](#)

E1F06

This question is checking that you understand the function of a VEC (Volunteer Examiner Coordinator). [\[97.519\]](#)

E1F07

A VE must NOT be engaged in the manufacture or distribution of amateur station equipment or amateur license preparation materials without FCC approval. Approval may be granted so long as the VE is not involved with that part of the company that manufactures such equipment and materials. [\[97.521\]](#), [\[97.523\]](#)

E1F08

The examination candidates may be asked to pay an examination fee to reimburse the VE and the VEC for out of pocket expenses. Currently, up to \$6 is a typical amount (1996).

[97.527]

E1F09

To become accredited by a VEC a person must be:

Eighteen or more years old,

Competent to perform the duties of a VE,

Acceptable to the FCC,

A person who has been granted an FCC amateur operator license.

The person must not be

A person who has ever had a license revoked or suspended,

Involved in an activity that could result in a conflict of interest.

[97.509], [97.525]

E1F10

The FCC is advised of any discredited VE's. [97.527]

E1F11

Any question that you may be asked in your examination must be drawn from the FCC question pools. These are the same question pools that are used by NuTest. [\[97.523\]](#)



E1G01

To become accredited by a VEC a person must be:

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A person who has ever had a license revoked or suspended,

Involved in an activity that could result in a conflict of interest.

[97.5259], [97.527]

E1G02

To become accredited by a VEC a person must be:

Eighteen or more years old,

Competent to perform the duties of a VE,

Acceptable to the FCC,

A person who has been granted an FCC amateur operator license.

The person must not be

A person who has ever had a license revoked or suspended,

Involved in an activity that could result in a conflict of interest.

[97.509], [97.525]

E1G03

To become accredited by a VEC a person must be:

Eighteen or more years old,

Competent to perform the duties of a VE,

Acceptable to the FCC,

A person who has been granted an FCC amateur operator license.

The FCC amateur operator license class determines which classes of examination can be administered by the person. [\[97.509\]](#) contains further details. [\[97.525\]](#)

E1G04

Any amateur that has ever had his/her license suspended or revoked may not be an accredited volunteer examiner. [\[97.509\]](#)

E1G05

VEs must keep records of out-of-pocket expenses and reimbursements and forward them to the VEC annually on or before January 15 of the following year. The VEC must then forward them to the FCC by January 31 of that year. [97.527]

E1G06

VEs must keep records of out-of-pocket expenses and reimbursements and forward them to the VEC annually on or before January 15 of the following year. The VEC must then forward them to the FCC by January 31 of that year. The records must be kept for 3 years. [97.527]

E1G07

VEs must keep records of out-of-pocket expenses and reimbursements and forward them to the VEC annually on or before January 15 of the following year. The VEC must then forward them to the FCC by January 31 of that year. The records must be kept for 3 years. [97.527]

E1G08

The correct answer is almost a direct quotation from paragraph 97.527 of the Part 97 rules.



E1G09

Reimbursement for out-of-pocket expenses is the only payment allowed. [97.527] of the Part 97 rules apply.

#### E1G10

An Extra Class accredited VE may prepare code and theory exams for all license classes including Extra Class. A code or theory exam must be prepared or obtained by an accredited VE who has an FCC operator license at least one class above the candidate. However, this is not the case for the Extra class exam. Only Extra class Hams may prepare an Extra class examinations. A test properly pre-prepared by a qualified supplier on computer disk or cassette tape would be acceptable if the VEC permits this. [\[97.507\]](#)

#### E1G11

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## E1G12

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E1G13

The administering VEs are coordinated by the VEC. Section [\[97.509\]](#) of the FCC Part 97 rules lists the qualifications for an administering VE.

E1H01

VEs should make sure the candidate understands the importance of safekeeping of the CSCE. This is the proof that they have passed an examination element until their higher grade FCC license arrives in the mail. The successful applicant in possession of a CSCE can begin using new privileges immediately provided he/she appends specific letters to the existing call sign as follows:

AG General Class  
AA Advanced Class  
AE Extra Class.

[97.505]

E1H02

The observing should not be so obtrusive as to distract the candidates! [97.509]

E1H03

This is explained in Paragraph [\[97.509\]](#) of the Part 97 FCC Rules.



E1H04

Only the individual candidates' examination need be terminated, not the whole examination.

[97.509]

E1H05

After completion, the examination is immediately graded by a VE. [97.509]

E1H06

After completion, the examination is immediately graded by a VE. If the applicant failed to achieve a passing grade then he/she must be informed and the application form returned.

[97.509]

E1H07

After completion, the examination is immediately graded by a VE. If the applicant achieves a pass grade then he/she must be informed and the qualification is certified. [97.509]

E1H08

Volunteer examiners have 10 days after the administering examinations to submit applications and test papers to the VEC. [97.509]

E1H09

A code or theory exam must be prepared or obtained by an accredited VE who has an FCC operator license at least one class above the candidate. However, this is not the case for the Extra class exam. Only Extra class Hams may prepare an Extra class examinations.

[97.509]

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AG General Class  
AA Advanced Class  
AE Extra Class.

[97.505]

E2A01

When describing satellite orbits, the North Pole is assumed to be at the top. So a satellite with a tilted orbit will sometimes be "ascending" from South to North and sometimes "descending" from North to South.

E2A02

When describing satellite orbits, the North Pole of the Earth is assumed to be at the top. So a satellite with a tilted orbit will sometimes be "ascending" from South to North and sometimes "descending" from North to South.

E2A03

The "period" of an amateur satellite is the amount of time that it takes to make one complete orbit of the Earth.

E2A04

You need operating privileges on the relevant bands just like any other amateur repeater.

E2A05

In Mode B both input and output frequencies are VHF with the output on 2 meters. Mode B frequencies are reversed in Mode J where it is the output that is on 70 cm.

E2A06

In Mode B both input and output frequencies are VHF with the output on 2 meters. Mode B frequencies are reversed in Mode J where it is the output that is on 70 cm.

E2A07

In Mode L the satellite receives on 23 cm and re-transmits on 70 cm.



E2A08

A linear transponder is like a mixer. It re-transmits input signals in the output band exactly as they were received except for the frequency change. If the conversion involved a frequency difference then the output band will be inverted.

E2A09

As a satellite is approaching your receiving station, the Doppler effect will make its frequencies several hundred hertz higher. As a satellite moves away the signals will decrease in frequency.

E2A10

Satellites rotate to evenly distribute heat from solar radiation.

E2A11

A circularly polarized antenna minimizes fading due to changes in received signal polarization. However, it has a loss of approximately 3 dB gain over a correctly oriented dipole.

E2B01

A frame refresh rate of 30 times per second is similar to domestic TV. Domestic television receivers can be easily adapted for fast scan amateur TV service.

E2B02

The total lines are scanned in two passes, each one of 262.5 lines. This technique is called interlacing and helps reduce visible flicker.

E2B03

The total lines are scanned in two passes, each one of 262.5 lines. This technique is called interlacing and helps reduce visible flicker.

E2B04

If the signal is not blanked then the extra "flyback" lines will be visible. The frame "flyback" line can sometimes be seen on a faulty or maladjusted television set as one or more diagonal lines across the picture.



E2B05

One volt peak to peak is the standard video voltage.

E2B06

Fast scan television requires a wide bandwidth and therefore is only used on 432 MHz and above.

E2B07

At 0.7 volts the standard TV signal is at black level.

E2B08

At 0.125 volts the standard TV signal is at white level.

E2B09

At 0.75 volts the signal is at blanking or "blacker than black" level.

E2B10

Deep fading will result in a noisy picture. FM TV is not immune from fading.

E2B11

A separate audio link on another band, such as the 2-meter band, is the most common method of providing accompanying audio.

## E2C01

The 20 meter band is open mainly during daylight hours during a solar minimum. Due to the phenomena of gray line propagation, dawn and dusk are especially good times to operate DX. Near a solar minimum, openings on 28 MHz tend to be infrequent. So, this band is not a good choice for DX contest use. The 160 - 40 meter bands benefit from reduced D-layer absorption during the evening especially during years of low solar activity.



E2C02

A full DX operating code is published in the ARRL Radio Amateurs Handbook.

E2C03

The fundamental purpose of Amateur Radio is summarized in Paragraph [\[97.1\]](#) of the FCC rules. Of course, contests are great fun as well!

E2C04

The DX station may issue instructions such as "10U" meaning "call me 10 kHz up from this frequency."

E2C05

In the worldwide "Maidenhead" system the first two letters constitute a  $20^\circ \times 10^\circ$  field. This is followed by two numbers designating a  $2^\circ \times 1^\circ$  square. To indicate location more precisely, two final letters are used to indicate the  $5' \times 2.5'$  sub-square.

E2C06

In the worldwide "Maidenhead" system the first two letters constitute a  $20^\circ \times 10^\circ$  field. This is followed by two numbers designating a  $2^\circ \times 1^\circ$  square. To indicate location more precisely, two final letters are used to indicate the  $5' \times 2.5'$  sub-square.

E2C07

This is the basic "rubber stamp" QSO.

E2C08

By tradition, the lower parts of the amateur bands have been reserved for weak or esoteric signals.

E2C09

By tradition, the lower parts of the amateur bands have been reserved for weak or esoteric signals.



E2C10

By tradition, the lower parts of the amateur bands have been reserved for weak or esoteric signals. A frequency of 1,832 kHz is in the lower frequency segment of the 160 meter amateur band.

E2C11

The MUF will decrease as the amount of ionization in the ionosphere decreases due to lack of solar flux.

E2D01

RTTY is still a common method of data transmission.

E2D02

Each character is transmitted twice and the received character pairs must match to be flagged as error free.

E2D03

Each character is transmitted twice and the received character pairs must match to be flagged as error free. There is no handshaking involved. The receiving station does not acknowledge correct receipt of the data.

E2D04

The "CMD:" prompt is analogous to the "C:>" DOS prompt on a PC screen.

E2D05

The ASCII 7 bit code allows upper and lower case text to be transmitted whereas the Baudot 5 bit code uses uppercase letters only.

E2D06

Selective fading can introduce a deep notch into the signal passband that can attenuate the mark or space signal.



E2D07

Facsimile is similar to slow scan TV except that the output image is printed as "hard copy".

E2D08

Facsimile is similar to slow scan TV except that the output image is printed as "hard copy". The sending rate of the image must be slow enough to keep the bandwidth down to the equivalent voice transmission. This restriction also applies to slow scan TV.

E2D09

AMTEX is a system that W1AW uses to transmit bulletins to radio amateurs. Each bulletin has a special message header containing information about the source and type of bulletin. This information, combined with a two-digit serial number, allows AMTEX receiving equipment to ignore bulletins that have already been received.

## E2D10

Packet Clusters are groups of packet stations sharing a common local channel for distribution and sharing of information. The stations in the cluster typically share a common interest, such as DX working.

E2D11

Packet radio is open to all operators within their License class privileges.

E3A01

Moon bounce is a marginal, but exciting, communication method. Both stations need high power transmitters and high gain antennas. The main modulation method used in moon bounce is CW. The distance between stations is not relevant so long as both stations can see the Moon.

E3A02

Multiple radio paths will exist due to multiple reflections from the irregular lunar surface. As the Moon "wobbles" (libation) the signals alternately combine and cancel.

E3A03

The moon's orbit is not perfectly circular; it is an ellipse. Perigee is the time when the moon is closest to the earth.



E3A04

For EME operation, it is mandatory to use a receiver with front end transistors that have extremely high gain and low noise.

E3A05

Because EME contacts are rather marginal and subject to fading experience has shown that two minute sequencing gives the best chance of successful contacts on 144 MHz.

E3A06

Because EME contacts are rather marginal and subject to fading experience has shown that two and one half minute sequencing gives the best chance of successful contacts on 432 MHz.

E3A07

EME contacts are rather marginal and certainly qualify as weak signals. They are therefore found at the bottom end of the amateur bands.

E3A08

EME contacts are rather marginal and certainly qualify as weak signals. They are therefore found at the bottom end of the amateur bands.

### E3A09

The ionized trails from meteors persist for seconds or tens of seconds and can be used for communications purposes. During a heavy meteor shower MS communication on CW and SSB is possible for minutes at a time. Unlike moon bounce communications, meteor shower communication can be achieved with relatively modest radio equipment.

### E3A10

The ionized trails from meteors persist for seconds or tens of seconds and can be used for communications purposes. During a heavy meteor shower MS communication on CW and SSB is possible for minutes at a time. Unlike moon bounce communications, meteor shower communication can be achieved with relatively modest radio equipment.

### E3A11

The ionized trails from meteors persist for seconds or tens of seconds and can be used for communications purposes. During a heavy meteor shower MS communication on CW and SSB is possible for minutes at a time. Usually, however, the signal path will exist for ten seconds or so and 15 second time sequences have been found to be the optimum.



E3B01

Transequatorial propagation is thought to occur by the F2 layer. Both CW and SSB are the normal modes for TE on VHF and UHF bands.

E3B02

The maximum distance for a TE (transequatorial) contact is 5000 miles.

E3B03

The best time of day for TE propagation is mid afternoon or early evening. This is the time when the level of ionization has had chance to build up during the day.

E3B04

Normally two stations will attempt to communicate by a great circle "short path". However, due to the position of the sun, a "long path" signal (in the opposite direction from the "short path") may offer better propagation conditions.

E3B05

Normally two stations will attempt to communicate by a great circle "short path". However, due to the position of the sun, a "long path" signal (in the opposite direction from the "short path") may offer better propagation conditions. Long path propagation will not occur on the VHF bands (above 6 meters).

E3B06

Normally two stations will attempt to communicate by a great circle "short path". However, due to the position of the sun, a "long path" signal (in the opposite direction from the "short path") may offer better propagation conditions. Long path signals are most common on the 20 meters band.

E3B07

The echo delay can be appreciable. It can last a fraction of a second and be noticeable. The echo delay is due to the difference in distance between the direct path and the long path..

E3B08

Enhanced gray line propagation may be present during a time window of 30 minutes.  
Propagation will be North and South and at dusk and dawn.



E3B09

Enhanced gray line propagation may be present during a time window of 30 minutes.  
Propagation will be North and South and at dusk and dawn.

### E3B10

Enhanced gray line propagation may be present during a time window of 30 minutes. Propagation will be North and South and at dusk and dawn. Most signal absorption occurs in the D-layer and this rapidly disappears at twilight. The E and F layers take longer to weaken and so excellent propagation is likely for a short period.

### E3B11

Enhanced gray line propagation may be present during a time window of 30 minutes. Propagation will be North and South and at dusk and dawn. Most signal absorption occurs in the D-layer and this rapidly disappears at twilight. The E and F layers take longer to weaken and so excellent propagation is likely for a short period.

E4A01

The horizontal axis in an oscilloscope usually represents time. In a spectrum analyzer the horizontal axis represents frequency. Spectrum analyzers are great for observing transmitter output signals. Spurious emissions and the effect of various adjustments can be clearly seen. A spectrum analyzer is required to tune most modern solid state amplifiers.

E4A02

The display of a spectrum analyzer is a graph of signal strength versus frequency. The horizontal axis represents frequency. The frequency range to be observed can be adjusted.

E4A03

The display of a spectrum analyzer is a graph of signal strength versus frequency. The vertical axis represents the amplitude of the signal.

E4A04

Spectrum analyzers are great for observing transmitter output signals. Spurious emissions and the effect of various adjustments can be clearly seen. A spectrum analyzer is required to tune most modern solid state amplifiers.

E4A05

Spectrum analyzers are great for observing transmitter output signals. Spurious emissions and the effect of various adjustments can be clearly seen. A spectrum analyzer is required to tune most modern solid state amplifiers.



E4A06

This is a time measurement and an oscilloscope would be the best measuring instrument.

E4A07

Spectrum analyzers are great for observing transmitter output signals. Spurious emissions and the effect of various adjustments can be clearly seen. A spectrum analyzer is required to tune most modern solid state amplifiers.

#### E4A08

A logic probe indicates points in a circuit that are in either a logic low or a logic high state. This is a quick way to determine logic circuit operation. There are two variations of logic circuits that may require different types of logic probe (dual purpose probes are also available). The TTL device family has nominal logic levels of 0 and +5 volts. The CMOS device family has nominal logic levels of  $\pm V(\text{supply})$ .

#### E4A09

A logic probe indicates points in a circuit that are in either a logic low or a logic high state. This is a quick way to determine logic circuit operation. There are two variations of logic circuits that may require different types of logic probe (dual purpose probes are also available). The TTL device family has nominal logic levels of 0 and +5 volts. The CMOS device family has nominal logic levels of  $\pm V(\text{supply})$ .

#### E4A10

A logic probe indicates points in a circuit that are in either a logic low or a logic high state. This is a quick way to determine logic circuit operation. There are two variations of logic circuits that may require different types of logic probe (dual purpose probes are also available). The TTL device family has nominal logic levels of 0 and +5 volts. The CMOS device family has nominal logic levels of  $\pm V(\text{supply})$ .

#### E4A11

A logic probe indicates points in a circuit that are in either a logic low or a logic high state. This is a quick way to determine logic circuit operation. There are two variations of logic circuits that may require different types of logic probe (dual purpose probes are also available). The TTL device family has nominal logic levels of 0 and +5 volts. The CMOS device family has nominal logic levels of +/-V(supply). Very short logic pulses might not be directly seen, but most logic probes have a feature that allows short pulses to be detected and indicated in some way.

E4B01

The noise figure will determine the level of the weakest signal that can be heard. The bandwidth will affect the noise figure. As the bandwidth increases, the noise figure will increase.

E4B02

The noise floor will determine the level of the weakest signal that can be heard.



E4B03

A preselector with a fairly narrow passband helps reduce reception of image signals.

E4B04

A ringing CW filter will blur the "dits" and "dahs" into each other making copy difficult.

E4B05

An RTTY signal often has a bandwidth of less than 300 Hz, but setting the filter bandwidth to exactly the required bandwidth would make tuning of these signals extremely difficult.

E4B06

A 2.4 kHz filter is good for communications voice quality. If the filter is more narrow than this, the audio quality will be degraded. Speech will be difficult to understand.

E4B07

As well as the desired signal, other signals on adjacent frequencies will be heard.

E4B08

Filter bandwidth should be slightly greater than the received signal bandwidth.

E4B09

This is because FM modulation produces a wider bandwidth signal than AM modulation.

E4B10

High Q filters have good out of band rejection and a steep skirt slope.



#### E4B11

The bottom end of the blocking dynamic range is determined by the receiver noise floor. The top end of the range is often determined by the "1 dB blocking level". This is the level where receiver desensitization of 1 dB occurs in the presence of a strong signal 20 kHz away from the test signal. A typical 1 dB blocking level is 30 dB. You want this level to be as high as possible.

#### E4B12

The top end of the dynamic range is determined by the "1 dB blocking level". This is the level where receiver desensitization of 1 dB occurs in the presence of a strong signal 20 kHz away from the test signal. A typical 1 dB blocking level is 30 dB. You want this level to be as high as possible to avoid cross modulation effects.

#### E4B13

The noise floor is the noise level generated by the receiver itself. This noise originates mainly from the receiver first stage with a small contribution from the mixer. It is vital that low noise active devices are used in the receiver first stage at VHF frequencies and above. At high frequencies, receiver noise is the largest contribution to total noise.

#### E4C01

Ignition noise is a big problem with mobile high-frequency installations. The main method of reducing this is at source by adding filters and replacing ignition components with low noise equivalent units.. Be aware that modern high performance vehicle ignition systems may not react well to the addition of RF filtering.

#### E4C02

The main method of reducing ignition noise is at source by adding filters and replacing ignition components with low noise equivalent units.. Be aware that modern high performance vehicle ignition systems may not react well to the addition of RF filtering. Careful shielding and bonding of the vehicle metalwork can also help.

E4C03

Primary and secondary ignition leads radiate strong electromagnetic pulses that create ignition noise. Ferrite beads fitted on these leads may help reduce RF noise.

E4C04

Bonding the body work components of a car will tend to lower the resonant frequency and, with luck, make them less efficient radiators of RF in the amateur bands.

E4C05

Connect your mobile set to an independent circuit that is fed directly from your car battery using the shortest leads possible. Also, install capacitors in the alternator leads.



E4C06

Connect your mobile set to an independent circuit that is fed directly from your car battery. It should use the shortest leads possible. Also, install capacitors in the alternator leads.

E4C07

Lightening strokes can be heard up to a thousand miles away on some amateur bands.

E4C08

Common offenders are heating thermostats, televisions, faulty plugs and sockets and washing machines. If you find that electrical noise is being generated in your home then use a portable radio to "sniff out" the source.

E4C09

An AC-line filter contains capacitors and inductors to present a low shunt impedance and a high series impedance to high frequency pulses.

E4C10

"Common mode" means that the RF voltage is in the same phase on each conductor.

E4C11

An FM receiver that is not tuned to a radio signal will produce a constant noise signal at the output. The signal cannot be used for direction finding since it will not vary as the antenna is rotated.

E4D01

There is always some ambiguity when using a wire lop antenna. The ambiguity can be resolved by using triangulation methods.

E4D02

A light weight Yagi or quad antenna makes a good DF antenna on 2 meters and 70 centimeters.



#### E4D03

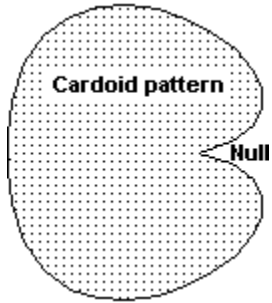
A triangle is formed by two beam headings when drawn on a map with a baseline drawn between them. The crossing point of the beam headings indicates the approximate location of the radio source. Extra headings may help give a more accurate location. Usually extra sets of headings are taken as the target is approached.

E4D04

As the RF source is approached the field strength will become too high for the receiver to respond properly. For example, the S-meter will be "hard over" to the right of the scale. The correct heading cannot be found unless extra attenuation is provided at the receiver input.

E4D05

This is to remove the directional ambiguities caused by the bi-directional properties of a loop antenna. It allows direction as well as bearing to be obtained. A cardoid pattern means "heart-shaped" and the sharp null in this pattern is used to obtain the bearing.



E4D06

An Adcock antenna is a 4 element antenna that uses phasing information to determine signal direction. By altering the phasing to the elements the field pattern can be rotated without physically moving the antenna.

E4D07

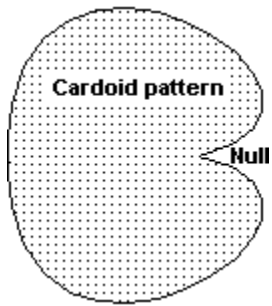
A wire loop antenna is used for direction finding. If there is sufficient signal strength it is better to use the null points to obtain a bearing because they are sharper.

E4D08

Making the loop larger increases the "capture area".

E4D09

A cardioid pattern means "heart-shaped" and the sharp null in this pattern is used to obtain the bearing.



E4D10

Mountains and valleys obstruct radio signals and cause them to be reflected.



E4D11

The hidden transmitter represents the fox.

E5A01

Most semiconductor junctions are affected by light. Usually light is excluded from them, but some devices are designed to exploit the photoelectric effect. Examples are simple photocells to detect light beam interruption and optoisolators (optocouplers) for coupling parts of a circuit at widely differing voltages.

E5A02

The increase in conductivity is due to the release of charge carriers in the depletion region of the junction.

E5A03

The increase in conductivity is due to the release of charge carriers in the depletion region of the junction.

E5A04

The increase in conductivity is due to the release of charge carriers in the depletion region of the junction.

E5A05

Optocouplers (optoisolators) are used to provide a signal path between two circuits at widely different voltages. Typical isolation voltages are 2 kV.

E5A06

Optocouplers (optoisolators) are used to provide a signal path between two circuits at widely different voltages. Typical isolation voltages are 2 kV.

E5A07

In an optical shaft encoder a rotating wheel with slots cut in it allows differing light patterns to fall on to an array of semiconductor junctions. The output from the junctions is a binary code representing the shaft position.



E5A08

This change in resistance is produced by a similar mechanism to that in semiconductor junctions.

E5A09

The change in resistance is produced by a similar mechanism to that in semiconductor junctions. Cadmium sulfide was used in photoelectric devices before semiconductor junction devices became available.

E5A10

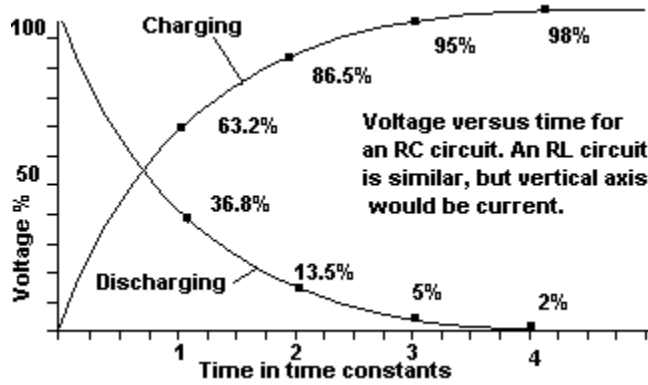
The change in resistance is produced by a similar mechanism to that in semiconductor junctions. Lead Sulfide infrared detectors are used in passive infrared alarm systems.

E5A11

The increase in conductivity is due to the release of charge carriers in the depletion region of the junctions that will be present in a crystalline semiconductor. The materials in the other options do not contain semiconductor junctions.

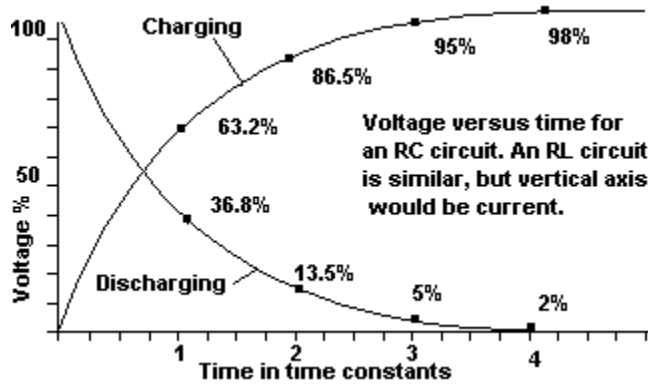
### E5B01

The discharge time of a CR circuit is also determined by the time constant. With large amounts of capacitance and high resistance the time constant can be several hours, so beware of large capacitors in electronics equipment. In an RC circuit assuming there is no initial charge on the capacitor it takes a time of  $R \times C$  seconds to charge a capacitor to 63.2% of its final value.



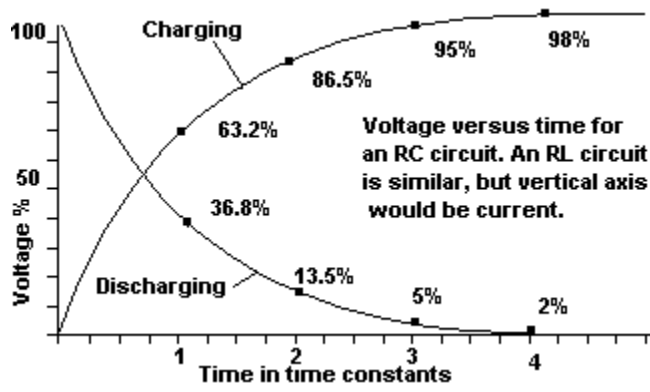
E5B02

In an RL circuit the coil will develop a back EMF that will oppose the flow of current and cause it to build up more slowly. In an RL circuit assuming there is no initial current through the inductance it takes  $L \times R$  seconds for the current to build up to 63.2 % of its final value.



E5B03

In an RC circuit it takes a time of  $R \times C$  seconds to discharge a capacitor to 36.8% of its final value.

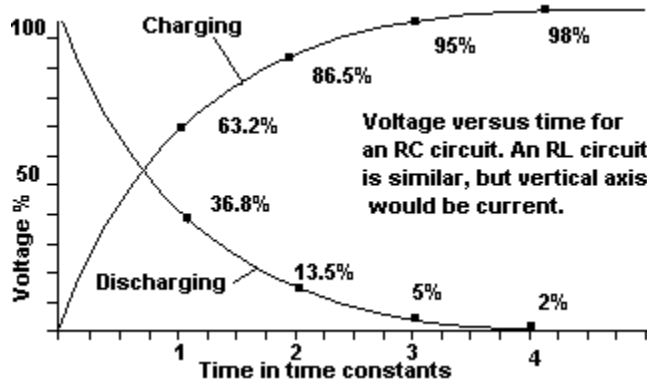


E5B04

During the first time constant period the voltage will reach 0.632 of the final value, this leaves 0.368 to go.

During the next time constant period the voltage will rise by 0.632 of the remaining voltage. This is  $0.632 \times 0.368 = 0.232$ .

We now add the two voltage rises together to obtain  $0.632 + 0.232 = 0.865$ , or 86.5%

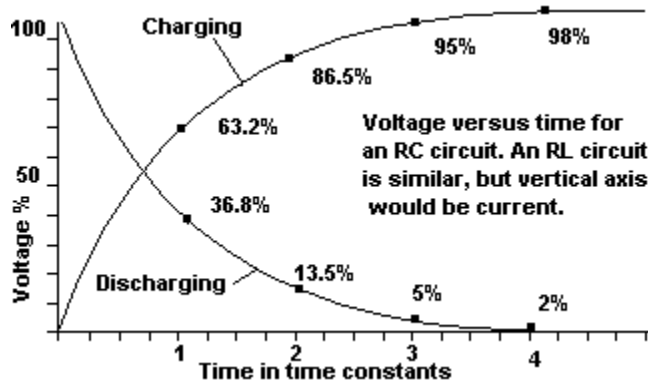




E5B05

During the first time constant period the voltage will drop to 0.368 of the original value.

During the next time constant period the voltage will drop to 0.368 of the remaining voltage.  
This is  $0.368 \times 0.368 = 0.135 = 13.5\%$

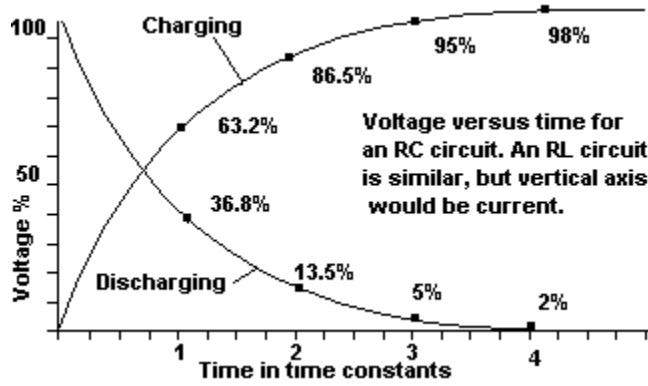


E5B06

We need to obtain total C and total R. For the special case of 2 equal capacitors C1 and C2 in series the total capacitance is C1/2 so we have C = 50 microfarads.

Resistors in series add up, so total resistance R = 470E3 + 470E3 = 940E3 ohms

Time constant of an RC circuit is  $R \times C = 940E3 \times 50E-6 = 47$  seconds

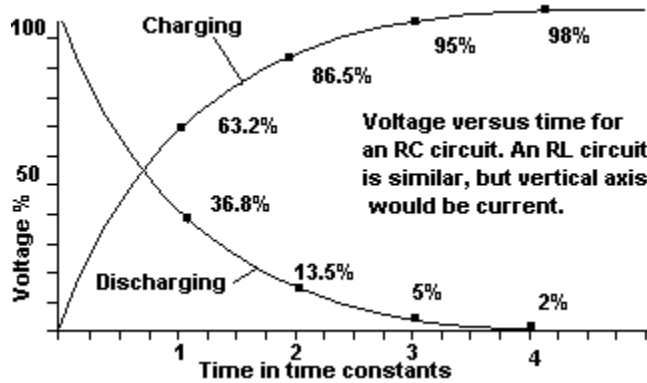


E5B07

We need to obtain total C. For the case of 2 capacitors C1 and C2 in parallel the total capacitance is  $C_1 + C_2$  so we have  $C = 440$  microfarads.

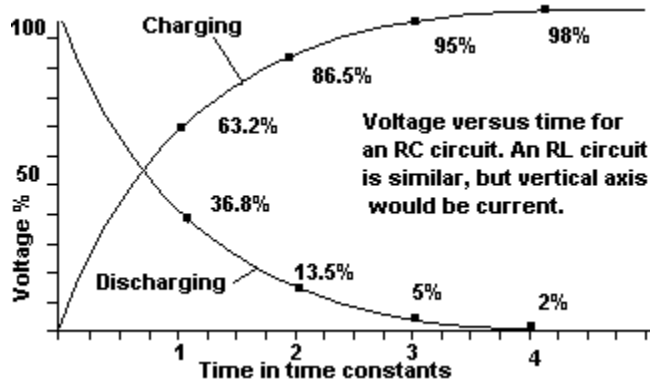
For the special case of two equal resistors R1 and R2 in parallel we have  $R = R_1/2$ , so total resistance  $R = 1E6/2 = 500E3$  ohms

Time constant of an RC circuit is  $R \times C = 500E3 \times 440E-6 = 220$  seconds



E5B08

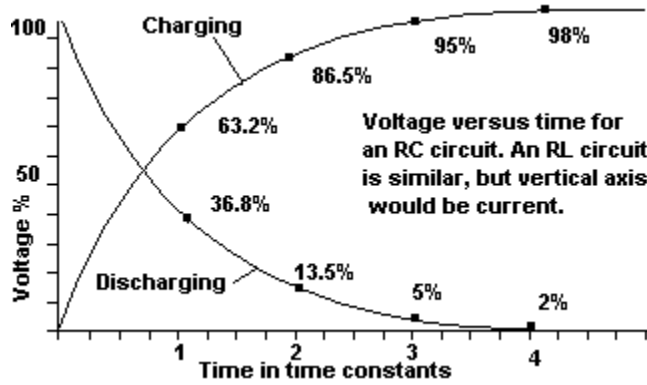
Time constant of an RC circuit is  $R \times C = 470E3 \times 220E-6 = 103$  seconds



E5B09

Time constant of an RC circuit is  $R \times C = 2E6 \times 0.01E - 6 = 0.02$  seconds

In 0.02 seconds this circuit will discharge to 36.8% of the starting voltage. So, after 0.02 seconds the voltage will be  $20 \times 0.368 = 7.36$  volts. This matches the required voltage in the question, so the time for discharge is 0.02 seconds.



E5B10

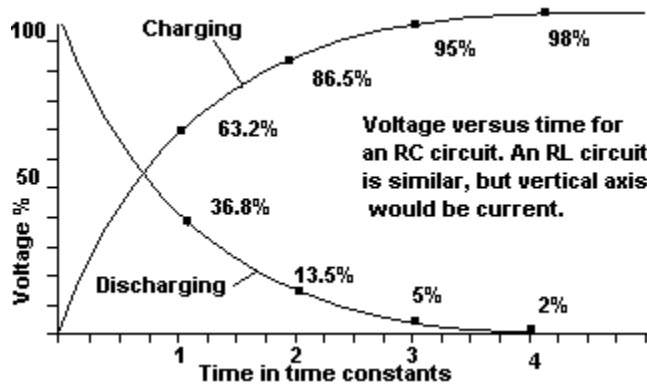
Time constant of an RC circuit is  $R \times C = 2E6 \times 0.01E - 6 = 0.02$  seconds.

In 0.02 seconds this circuit will discharge to 36.8% of the starting voltage. So, after 0.02 seconds the voltage will be  $20 \times 0.368 = 7.36$  volts. The voltage is more than the required voltage, so we wait for 0.02 seconds.

After 0.04 seconds the voltage is  $7.36 \times 0.368 = 2.71$  volts (approximately). This voltage is more than the required voltage, so we wait for another 0.02 seconds.

After 0.06 seconds the voltage is  $2.71 \times 0.368 = 1$  volts (approximately). This voltage is more than the required voltage, so we wait for another 0.02 seconds.

After 0.08 seconds the voltage is  $1 \times 0.368 = 0.37$  volts (approximately). This matches the required voltage in the question, so the time for discharge is 0.08 seconds.

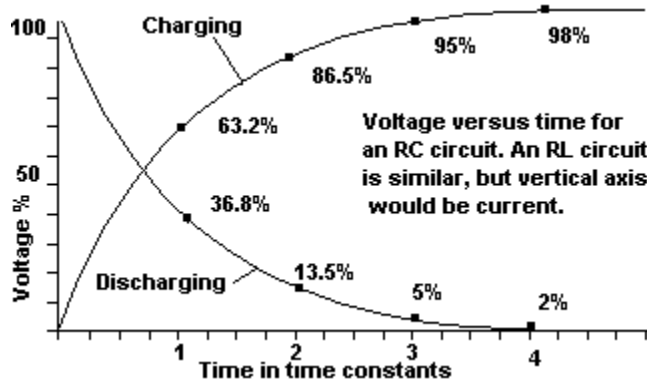


E5B11

Time constant of an RC circuit is  $R \times C = 1E6 \times 450E - 6 = 450$  seconds.

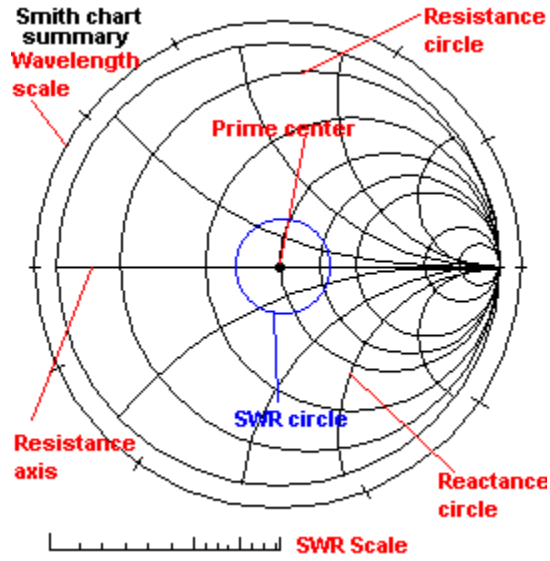
After a time of 450 seconds the circuit will discharge to 36.8% of its original voltage.

$800 \times 0.368 = 294$ . This matches the voltage in the question and so the time for discharge is 450 seconds.



E5C01

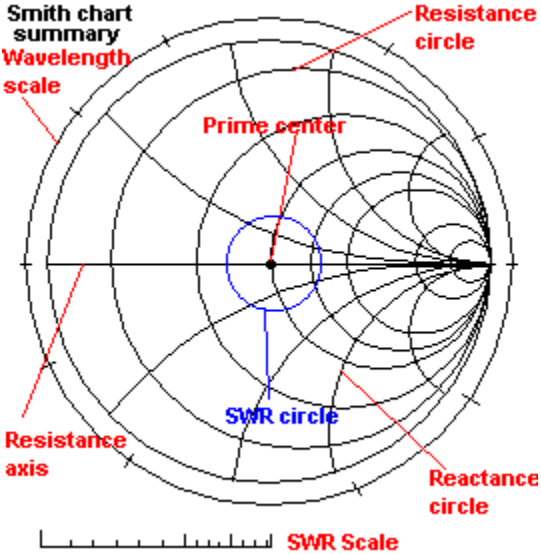
The Smith chart is a graph for calculation of impedance along radio transmission lines. Given nominal line impedance and length plus a measured input impedance to the transmission line the SWR and node positions can be calculated as well as the impedance at the load (antenna) end.





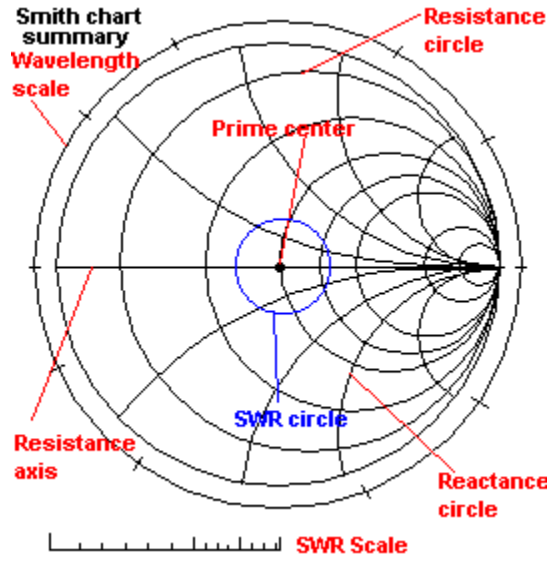
E5C02

A Smith chart has a number of curved resistance and reactance lines.



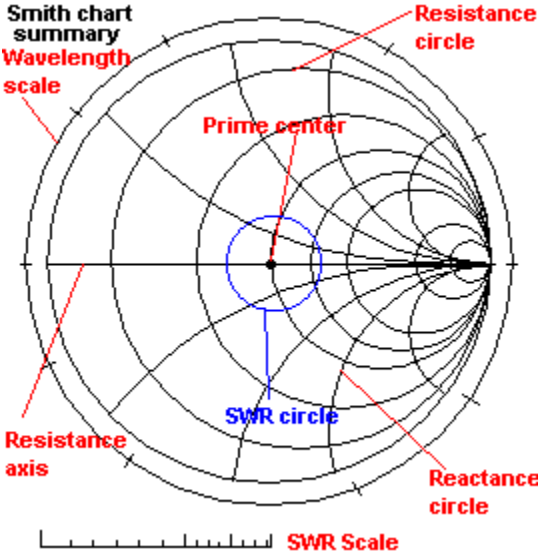
E5C03

The Smith chart is a graph for calculation of impedance along radio transmission lines. Given nominal line impedance and length plus a measured input impedance to the transmission line the SWR and node positions can be calculated as well as the impedance at the load (antenna) end.



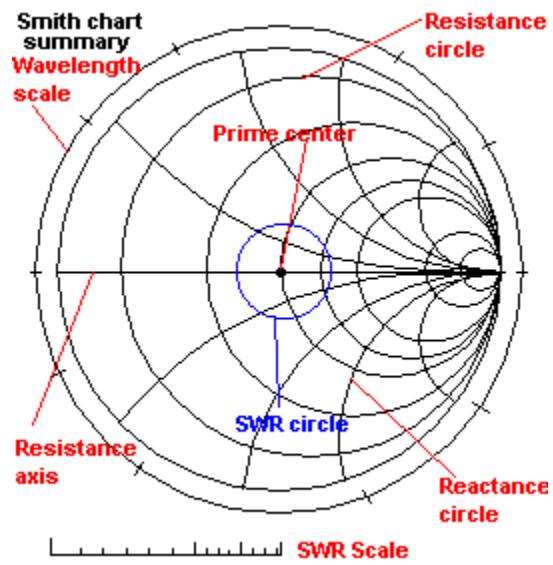
E5C04

A Smith chart has a number of curved resistance and reactance lines.



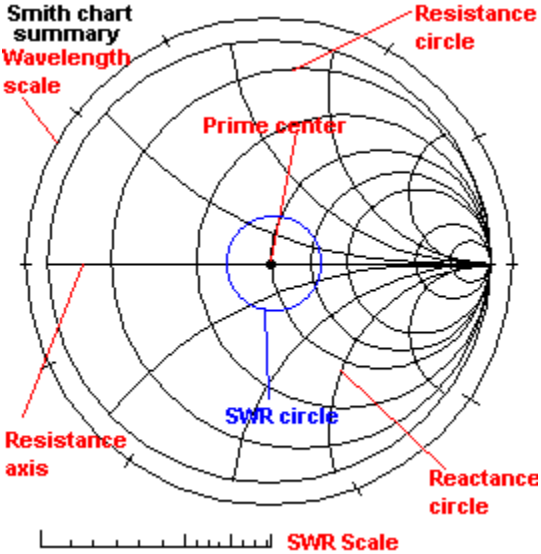
E5C05

The curved segments on a Smith chart are portions of reactance circles. The straight line is the resistance axis. The complete circles are resistance circles.



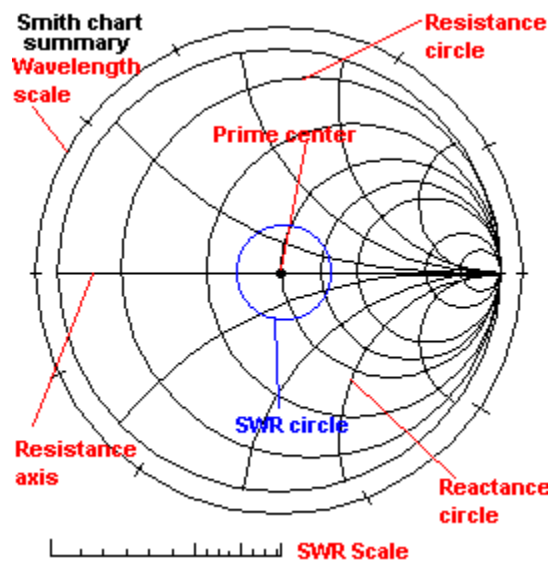
E5C06

A Smith chart has a number of curved resistance and reactance lines.



E5C07

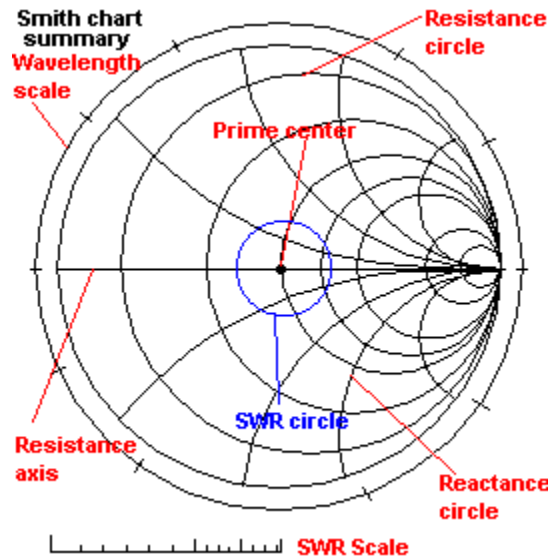
The single straight line is the resistance axis.



E5C08

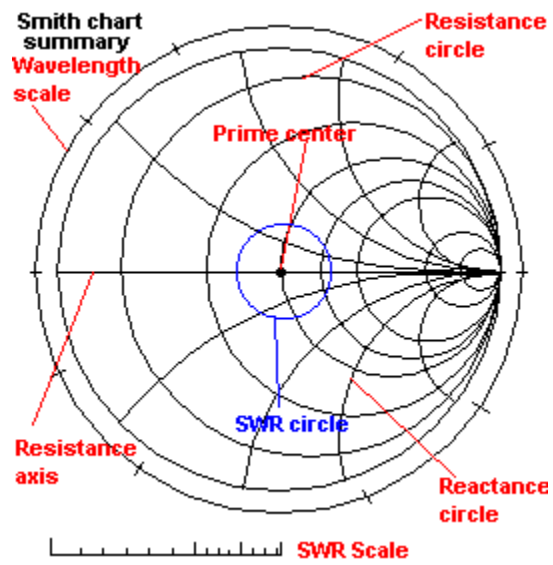
A Smith chart is designed for lines with a characteristic impedance of 1 ohm. The "prime center" of a Smith chart is at 1 ohm resistive. No real transmission lines have such an impedance, but we can divide the measured impedance of any line by the characteristic impedance to use the Smith chart. This is called normalization.

After using the chart to obtain the required normalized results, we multiply them by the characteristic impedance of the real line to get the actual results.



E5C09

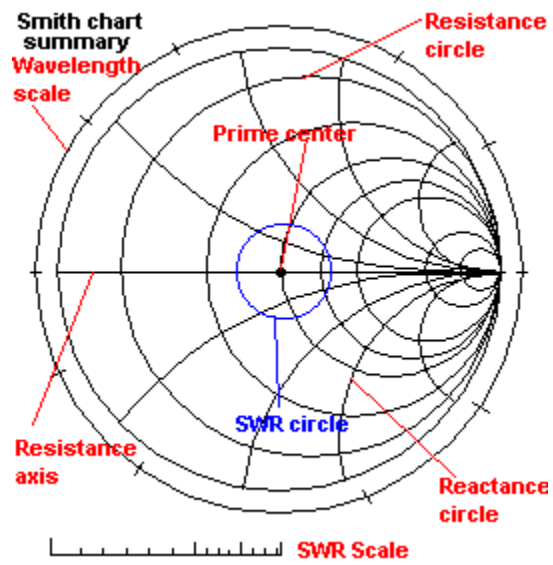
The curved segments on a Smith chart are portions of reactance circles. The straight line is the resistance axis. The complete circles are resistance circles.





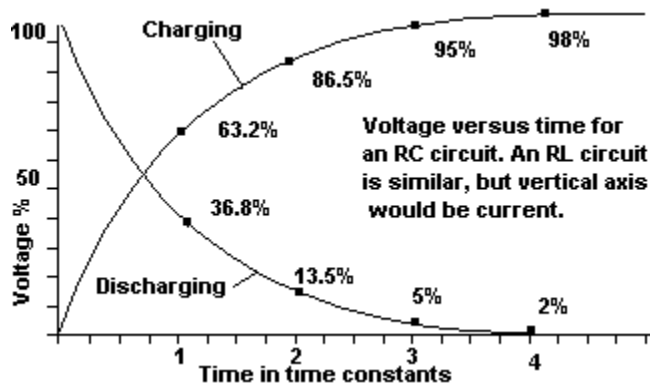
E5C10

SWR circles will be centered on the prime center of the chart. The radius of these circles is read off on an auxiliary scale to give SWR readings.



E5C11

A complete rotation of the wavelength scale is 0.5 transmission line electrical wavelengths.  
Electrical length is less than free space wavelength by a factor called the velocity factor.



E5D01

This is a rectangular coordinate question.

We have resistance and inductive reactance in the circuit. The resistance contributes to the real part of the result and is 20 ohms. (Without any calculations we see that the correct answer must be either  $20+j19$  or  $20-j19$  !)

The inductive reactance contributes to the "imaginary" part. Inductive reactance is always regarded as positive in sign. To signify that it is a reactance we add a "j" to the front of the number. You can now select the correct answer as  $20+j19$  because this one has a positive reactance. The following calculation is just a double check

Using the standard formula for inductive reactance gives:  $X_L = 2 \times \pi \times F \times L = 2 \times 3.141 \times 30E6 \times 0.1E - 6 = 18.846$  ohms

So the inductive reactance is approximately 19 Ohms. The total impedance is  $20 + j19$  ohms

E5D02

This is a rectangular coordinate question.

We have resistance and inductive reactance in the circuit. The resistance contributes to the real part of the result and is 30 ohms. (Without any calculations we see that the correct option must be either 30-j3 or 30+j3 !)

The inductive reactance contributes to the "imaginary" part. Inductive reactance is always regarded as positive in sign. To signify that it is a reactance we add a "j" to the front of the number. You can now select the correct answer as 30+j3 because this one has a positive reactance. The following calculation is just a double check

Using the standard formula for inductive reactance gives:  $X_L = 2 \times \pi \times F \times L = 2 \times 3.141 \times 5E6 \times 0.1E - 6 = 3.141 \text{ ohms.}$

So the inductive reactance is approximately 3 Ohms. The total impedance is 30 + j3 ohms

E5D03

This is a rectangular coordinate question.

We have resistance and inductive reactance in the circuit. The resistance contributes to the real part of the result and is 40 ohms. (Without any calculations we see that the correct option must be either  $40+j31400$  or  $40-j31400$  !)

The inductive reactance contributes to the "imaginary" part. Inductive reactance is always regarded as positive in sign. To signify that it is a reactance we add a "j" to the front of the number. You can now select the correct answer as  $40+j31400$  because this one has a positive reactance. The following calculation is just a double check

Using the standard formula for inductive reactance gives:  $X_L = 2 \times \pi \times F \times L = 2 \times 3.141 \times 500 \times 10^6 \times 10^{-6} = 31410$  ohms

So the inductive reactance is approximately 31400 Ohms. The total impedance is  $40 + j31400$  ohms

E5D04

This is a polar coordinate question.

The capacitive reactance is  $X_c = 1 / (2 \times \pi \times f \times C) = 1 / (2 \times 3.141 \times 500E3 \times 100E-12) = 3183$  ohms

Polar coordinates are given as impedance magnitude Z and an angle.

This is a parallel circuit with 2 components that we shall call Z1 (the resistor) and Z2 (the capacitor), so we use the "product over sum formula"

$$Z_{\text{total}} = (Z1 \times Z2) / (Z1 + Z2).$$

Z1 and Z2 are "complex" quantities. This means that they contain both resistance and reactance. Therefore, we must use vector multiplication and addition using the rules given in the polar coordinate help topic.

The resistor Z1 = 4000 ohms at 0 degrees. (Pure resistance has phase angle 0)

The capacitor Z2 = 3183 ohms at -90 degrees. (Pure capacitance has phase angle -90)

$$Z1 \times Z2 = (4000 \text{ at } 0) \times (3183 \text{ at } -90) = (4000 \times 3183) \text{ at } (0 - 90) = 12.732E6 \text{ ohms at } -90 \text{ degrees}$$

$$(Z1 + Z2) = \text{square root } (Z1^2 + Z2^2) \text{ ohms at INV Tan } (Z2/Z1) \text{ degrees}$$

This gives  $(Z1 + Z2) = \text{square root } (26.1E6) \text{ at INV tan } (0.795) = 5.1E3 \text{ ohms at } -38.5 \text{ degrees.}$

(INV tan means press the INV button on your calculator before pressing the tan button)

$$\text{So } Z_{\text{total}} = (12.732E6 \text{ ohms at } -90 \text{ degrees}) / (5.1E3 \text{ ohms at } -38.5 \text{ degrees})$$

Using vector division this gives

$$Z_{\text{total}} = (12.732E6 / 5.1E3) \text{ ohms at } (-90 - (-38.5)) \text{ degrees} = 2.493 \text{ kilohms at } -51.5 \text{ degrees.}$$

E5D05

This is a rectangular coordinate question.

We have resistance and capacitive reactance in the circuit. The resistance contributes to the real part of the result and is 400 ohms. (Without any calculations we see that the correct option must be either 400-j318 or 400+j318 !)

The capacitive reactance contributes to the "imaginary" part. Capacitive reactance is always regarded as negative in sign. To signify that it is a reactance we add a "j" to the front of the number. You can now select the correct answer as 400 - j318 because this one has a negative reactance. The following calculation is just a double check

Using the standard formula for capacitive reactance gives:  $X_c = 1/(2 \times \pi \times F \times C) = 1/(2 \times 3.141 \times 500E3 \times 0.001E-6) = 318$  ohms

So the capacitive reactance is approximately 318 ohms. The total impedance is 400 - j318 ohms.

E5D06

This is a rectangular coordinate question.

We have resistance and capacitive reactance in the circuit. The resistance contributes to the real part of the result and is 50 ohms. (Without any calculations we see that the correct option must be either 50-j162 or 50+j162 !)

The capacitive reactance contributes to the "imaginary" part and is always regarded as negative in sign. To signify that it is a reactance we add a "j" to the front of the number. You can now select the correct answer as 50-j162 because this one has a negative reactance. The following calculation is just a double check

Using the standard formula for capacitive reactance gives:  $X_c = 1/(2 \times \pi \times F \times C) = 1/(2 \times 3.141 \times 7E6 \times 140E-12) = 162 \text{ ohms}$

So the capacitive reactance is approximately 162 ohms. The total impedance is 50 - j162 ohms.



E5D07

This is a polar coordinate question.

The best approach is to first calculate the total reactance, which is the sum of each individual reactance. This gives:

capacitive reactance + inductive reactance =  $-1 + 4 = 3$  ohms.  
(Remember, capacitive reactance is a negative quantity)

Polar coordinates are given as impedance magnitude  $Z$  and an angle.

This is a series circuit and so we add the impedances using vector arithmetic to obtain:

$Z_{\text{total}}^2 = R^2 + X^2 = 4^2 + 3^2 = 25$

So  $Z_{\text{total}} = \text{square root}(25) = 5$  ohms

We find the angle

Angle =  $\text{INV tan}(X/R) = \text{INV tan}(3/4) = 37$  degrees.  
(INV tan means press the INV button on your calculator before pressing the tan button)

So the impedance in polar notation is:

5 ohms at 37 degrees

E5D08

On the diagram horizontal directions from the Y-axis represent resistance and vertical directions up and down from the X-axis represent reactance. Inductive reactance is positive (above the X-axis) and capacitive reactance is negative (below the X-axis).

We immediately know that the correct point must be either 2,6 or 4 since they are all at 400 ohms horizontally to the right of the Y-axis.

We know that capacitive reactance is regarded as negative so that narrows the options down to points 6 and 4.

Since a capacitor is present the capacitive reactance is not zero. This rules out point 6 and gives us the correct answer as point 4 without doing any calculations!

As a double check we can calculate the capacitive reactance.

Using the standard formula for capacitive reactance gives:  $X_c = 1/(2 \times \pi \times F \times C) = 1/(2 \times 3.141 \times 14E6 \times 38E-12) = -300$  ohms  
(Capacitive reactance is always regarded as negative)

So the correct answer is point 4, which is 300 units below the X-axis.

E5D09

On the diagram horizontal directions from the Y-axis represent resistance and vertical directions up and down from the X-axis represent reactance. Inductive reactance is positive (above the X-axis) and capacitive reactance is negative (below the X-axis).

We immediately know that the correct point must be either 3,8 or 1, since they are all at 300 ohms horizontally to the right of the Y-axis.

We know that inductive reactance is regarded as positive so that narrows the options down to points 3 and 8.

The value of the inductive reactance is given by the standard formula  
 $X_L = 2 \times \pi \times F \times L = 2 \times 3.141 \times 3.505E6 \times 18E - 6 = 396 \text{ ohms}$

So the correct answer is point 3, which is 400 units above the X-axis.

E5D10

On the diagram horizontal directions from the Y-axis represent resistance and vertical directions up and down from the X-axis represent reactance. Inductive reactance is positive (above the X-axis) and capacitive reactance is negative (below the X-axis).

We immediately know that the correct point must be either 3,8 or 1 since they are all at 300 ohms horizontally to the right of the Y-axis.

We know that capacitive reactance is regarded as negative so that narrows the options down to point 1 and gives us the correct answer without doing any calculations!

As a double check we can calculate the capacitive reactance.

Using the standard formula for capacitive reactance gives:  $X_c = 1/(2 \times \pi \times F \times C) = 1/(2 \times 3.141 \times 21200E3 \times 19E-12) = -400$  ohms  
(Capacitive reactance is always regarded as negative)

So the correct answer is point 1, which is 400 units below the X-axis.

E5D11

On the diagram horizontal directions from the Y-axis represent resistance and vertical directions up and down from the X-axis represent reactance. Inductive reactance is positive (above the X-axis) and capacitive reactance is negative (below the X-axis).

We immediately know that the correct point must be either 3,8 or 1 since they are all at 300 ohms horizontally to the right of the Y-axis.

Using the standard formula for capacitive reactance gives:  $X_c = 1/(2 \times \pi \times F \times C) = 1/(2 \times 3.141 \times 24900E3 \times 85E-12) = -75$  ohms  
(Capacitive reactance is always regarded as negative)

The value of the inductive reactance is given by the standard formula  
 $X_l = 2 \times \pi \times F \times L = 2 \times 3.141 \times 24900E3 \times 0.64E-6 = 100$  ohms

The total circuit reactance is  $100 - 75 = 25$  ohms.  
(an inductive reactance, since it is positive)

So the correct answer is point 8, which is 25 units above the X-axis.

E5E01

This is a polar coordinate question.

The impedances are in series and so we can add them (using vector arithmetic).

$$Z_{\text{total}}^2 = R^2 + X_L^2 = 100^2 + 100^2 = 20000$$

$$\text{So } Z_{\text{total}} = \sqrt{20000} = 141 \text{ ohms}$$

This is enough information to be able to select 141 ohms at 45 degrees as the correct answer.

As a double check we find the angle

$$\text{Angle} = \text{INV tan}(X_L/R) = \text{INV tan}(1) = 45 \text{ degrees.}$$

So the impedance in polar notation is

141 ohms at 45 degrees.

E5E02

This is a polar coordinate question.

There is a short cut here. The inductive and capacitive reactances are equal. Since they are of opposite sign they cancel each other. This means that the phase angle is 0 degrees so the correct answer is either 10 ohms at 0 degrees or 100 ohms at 0 degrees.

The resistance is 100 ohms and so the complete answer is 100 ohms at 0 degrees.

E5E03

This is a polar coordinate question.

The impedances are in series and so we can add them (using vector arithmetic).

$$Z_{\text{total}}^2 = R^2 + X_L^2 = 300^2 + (-400)^2 = 250E3$$

$$\text{So } Z_{\text{total}} = \sqrt{250E3} = 500 \text{ ohms}$$

We now find the angle:

$$\text{Angle} = \text{INV tan}(X_L/R) = \text{INV tan}(-400/300) = -53.1 \text{ degrees.}$$

So the impedance in polar notation is

500 ohms at -53.1 degrees



E5E04

This is a polar coordinate question.

The impedances are in series and so we can add them (using vector arithmetic).

The total reactance is  $X_L - X_C = 300$  ohms inductive.

$Z_{\text{total}}^2 = R^2 + X_C^2 = 400^2 + 300^2 = 250E3$

So  $Z_{\text{total}} = \text{square root}(250E3) = 500$  ohms

This is enough information to be able to select 500 ohms at 37 degrees as the correct answer.

As a double check we now find the angle

Angle =  $\text{INV tan}(X_C/R) = \text{INV tan}(300/400) = 37$  degrees.

So the impedance in polar notation is:

500 ohms at 37 degrees

E5E05

This is a polar coordinate question.

Polar coordinates are given as impedance magnitude Z and an angle.

This is a parallel circuit with 2 components that we shall call Z1 (the resistor) and Z2 (the inductor), so we use the "product over sum formula":

$$Z_{\text{total}} = (Z1 \times Z2) / (Z1 + Z2)$$

Z1 and Z2 are "complex" quantities. This means that they contain both resistance and reactance. Therefore, we must use vector multiplication and addition using the rules given in the polar coordinate Help topic.

The resistor Z1 = 300 ohms at 0 degrees. (A pure resistance has phase angle of 0)  
The inductor Z2 = 400 ohms at 90 degrees. (A pure inductance has phase angle of 90)

$$Z1 \times Z2 = (300 \text{ at } 0) \times (400 \text{ at } 90) = (300 \times 400) \text{ at } (0+90) = 120\text{E}3 \text{ ohms at } 90 \text{ degrees}$$

$$(Z1 + Z2) = \text{square root } (Z1 \text{ squared} + Z2 \text{ squared}) \text{ ohms at INV Tan } (Z2/Z1) \text{ degrees}$$

This gives  $(Z1 + Z2) = \text{square root } (90\text{E}3+160\text{E}3) \text{ at INV tan } (400/300) = 500 \text{ ohms at } 53.1 \text{ degrees.}$

(INV tan means press the INV button on your calculator before pressing the tan button)

$$\text{So } Z_{\text{total}} = (120\text{E}3 \text{ ohms at } 90 \text{ degrees}) / (500 \text{ ohms at } 53.1 \text{ degrees})$$

Using vector division this gives:

$$Z_{\text{total}} = (120\text{E}3 / 500) \text{ ohms at } (90 - 53.1) \text{ degrees} = 240 \text{ kilohms at } 36.9 \text{ degrees.}$$

E5E06

We have an inductive reactance, so it is positive.

The resistance is 200 ohms and so that gives  $200 + j188$  as the correct option.

As a check  $X_L = 2 \times \pi \times F \times L = 2 \times 3.141 \times 30E3 \times 1E-3 = 188$  Ohms giving  $Z = 200 + j188$ .

E5E07

We have an inductive reactance, so it is positive.

The resistance is 600 ohms that gives  $600+j628$  as the correct option.

As a check  $X_L = 2 \times \pi \times F \times L = 2 \times 3.141 \times 10E3 \times 10E-3 = 628$  Ohms giving  $Z = 600 + j628$ .

E5E08

We have a capacitive reactance, so it is negative.

The resistance is 40 ohms that gives  $40 - j32$  as the correct option.

As a check  $X_c = 1 / (2 \times \pi \times F \times C) = 1 / (2 \times 3.141 \times 50E3 \times 0.1E-6) = 32 \text{ Ohms}$  giving  $Z = 40 - j32$ .

E5E09

This is a polar coordinate question.

The impedances are in series and so we can add them (using vector arithmetic).

The total reactance  $X_c = -100$  ohms capacitive.

$Z_{\text{total squared}} = R^2 + X_c^2 = 100^2 + (-100)^2 = 20000$

So  $Z_{\text{total}} = \text{square root}(20000) = 141$  ohms

This is enough information to be able to select 141 ohms at -45 degrees as the correct answer.

As a double check we now find the angle:

Angle =  $\text{INV tan}(X_c/R) = \text{INV tan}(-100/100) = -45$  degrees.

So the impedance in polar notation is:

141 ohms at -45 degrees.

E5E10

This is a parallel circuit with 2 components that we shall call Z1 (the resistor) and Z2 (the capacitor), so we use the "product over sum formula":

$$Z_{\text{total}} = (Z1 \times Z2) / (Z1 + Z2)$$

Z1 and Z2 are "complex" quantities. This means that they contain both resistance and reactance. Therefore, we must use vector multiplication and addition using the rules given in the vector Help topic.

The resistor Z1 = 100 ohms at 0 degrees. (A pure resistance has phase angle of 0 degrees.)  
The capacitor Z2 = 100 ohms at -90 degrees. (A pure capacitance has phase angle of -90 degrees.)

$$Z1 \times Z2 = (100 \text{ at } 0) \times (100 \text{ at } -90) = (100 \times 100) \text{ at } (0 - 90) = 10E3 \text{ at } -90 \text{ degrees}$$

$$(Z1 + Z2) = \text{square root } (Z1^2 + Z2^2) \text{ ohms at INV Tan } (Z2/Z1) \text{ degrees}$$

This gives  $(Z1 + Z2) = \text{square root } (10000 + 10000) \text{ at INV tan } (-100/100) = 141 \text{ ohms at } -45 \text{ degrees.}$

(INV tan means press the INV button on your calculator before pressing the tan button)

$$\text{So } Z_{\text{total}} = (10E3 \text{ ohms at } -90 \text{ degrees}) / (141 \text{ ohms at } -45 \text{ degrees}).$$

Using vector division this gives:

$$Z_{\text{total}} = (10E3 / 141) \text{ ohms at } (-90 - (-45)) \text{ degrees} = 70.7 \text{ ohms at } -45 \text{ degrees.}$$

E5E11

This is a polar coordinate question.

The impedances are in series and so we can add them (using vector arithmetic).

$$Z_{\text{total}}^2 = R^2 + X_c^2 = 300^2 + 400^2 = 250E3$$

$$\text{So } Z_{\text{total}} = \text{square root } (250E3) = 500 \text{ ohms}$$

We now find the angle:

$$\text{Angle} = \text{INV tan } (X/R) = \text{INV tan}(300/400) = 37 \text{ degrees.}$$

So the impedance in polar notation is:

500 ohms at 37 degrees.



E5F01

Horizontal directions represent the resistive component. Vertical directions represent reactive component. The region above the X-axis represents positive reactance, or inductance. The region below the X-axis represents negative reactance, or capacitance. A graph like this is a visual representation of the rectangular coordinates system.

E5F02

Horizontal directions represent the resistive component. Vertical directions represent reactive component. The region above the X-axis represents positive reactance, or inductance. The region below the X-axis represents negative reactance, or capacitance. A graph like this is a visual representation of the rectangular coordinates system.

E5F03

Horizontal directions represent the resistive component. Vertical directions represent reactive component. The region above the X-axis represents positive reactance, or inductance. The region below the X-axis represents negative reactance, or capacitance. A graph like this is a visual representation of the rectangular coordinates system.

E5F04

Horizontal directions represent the resistive component. Vertical directions represent reactive component. The region above the X-axis represents positive reactance, or inductance. The region below the X-axis represents negative reactance, or capacitance. A graph like this is a visual representation of the rectangular coordinates system. A point on the horizontal axis represents pure resistance.

E5F05

Horizontal directions represent the resistive component. Vertical directions represent reactive component. The region above the X-axis represents positive reactance, or inductance. The region below the X-axis represents negative reactance, or capacitance. A graph like this is a visual representation of the rectangular coordinates system. The position of a point on the graph can also be determined by the distance from the crossing point of the axes plus a direction. This is the polar coordinate vector system.

E5F06

Horizontal directions represent the resistive component. Vertical directions represent reactive component. The region above the X-axis represents positive reactance, or inductance. The region below the X-axis represents negative reactance, or capacitance. A graph like this is a visual representation of the rectangular coordinates system. A point on the horizontal axis represents pure resistance.

E5F07

The position of a point on a graph can be determined by the distance from the crossing point of the axes plus a direction. This is the polar coordinate vector system.

E5F08

This is a polar coordinate question.

The impedances are in series and so we can add them (using vector arithmetic).

The total reactance  $X_c = -100$  ohms capacitive.

$Z_{\text{total}}^2 = R^2 + X_c^2 = 100^2 + (-100)^2 = 20000$

So  $Z_{\text{total}} = \text{square root}(20000) = 141$  ohms

This is enough information to be able to select 141 ohms at -45 degrees as the correct answer.

As a double check we now find the angle:

Angle =  $\text{INV tan}(X_c/R) = \text{INV tan}(-100/100) = -45$  degrees.

So the impedance in polar notation is:

141 ohms at -45 degrees.



E5F09

The siemen is the unit of admittance. To convert from ohms to siemens we just take the reciprocal of the magnitude of the impedance. If there is a reactive component we simply change the sign of the angle .

7.09 millisiemens at 45 degrees =  $1/(7.09E-3)$  ohms at -45 degrees =  
141 ohms at -45 degrees.

E5F10

The siemen is the unit of admittance. To convert from ohms to siemens we just take the reciprocal of the magnitude of the impedance. If there is a reactive component we simply change the sign of the angle .

5 millisiemens at -30 degrees =  $1/(5 \times 10^{-3})$  ohms at 30 degrees =  
200 ohms at 30 degrees.

This answer is in polar coordinates so we need to convert to rectangular coordinates using  
 $Z \text{ at angle} = Z \times \cos(\text{angle}) + j Z \times \sin(\text{angle})$

Giving

$$200 \times \cos(30) + j 200 \sin(30) =$$

$$173 + j 100 \text{ ohms}$$

E5F11

The siemen is the unit of admittance. To convert from ohms to siemens we just take the reciprocal of the magnitude of the impedance. If there is a reactive component we simply change the sign of the angle .

240 ohms at 36.9 degrees =  $1/(240)$  siemens at -36.9 degrees =  
4.16 millisiemens at -36.9 degrees.

This is in polar coordinates so we need to convert to rectangular coordinates using

$Z \text{ at angle} = Z \times \cos(\text{angle}) + j Z \times \sin(\text{angle})$

Giving

$4.16 \times \cos(-36.9) + j 4.16 \sin(-36.9)$  millisiemens=

$3.33 - j 2.50$  millisiemens

E6A01

The conduction channel is created by the gate voltage. Therefore, the output current is enhanced by the input bias. Under no bias conditions no current flows in the device.

E6A02

The conduction channel is reduced by the gate voltage. Under no bias conditions a constant current flows in the device. The device can be biased "off".

E6A03

In an N-channel MOSFET the arrow points **in**.

E6A04

In a P-channel MOSFET the arrow points **out**.

E6A05

In an N-channel dual-gate MOSFET the arrow points **in**.



E6A06

In a P-channel dual-gate MOSFET the arrow points **out**.

E6A07

In an N-channel FET the arrow points **in**. A FET has a gate, a drain and a source.

E6A08

A FET has a gate, a drain and a source.

E6A09

In a P-channel FET the arrow points **out**. A FET has a gate, a drain and a source.

#### E6A10

The gate electrode has no internal connection. It is insulated from the rest of the device by a very thin layer of oxide. The electric field of the gate is used to control the device. Because the oxide layer is so thin, static charges can easily destroy the gate insulation. To avoid this problem, small Zener diodes are often built in to MOSFET devices to protect them from high voltages.

E6A11

MOSFET devices use metal oxide as a very thin insulating layer between the gate and the rest of the device. Static charges can easily destroy this gate insulation. Complementary pairs of junctions are used to reduce power consumption of MOSFET based ICs to almost zero.

E6A12

FETs behave more like tube triode devices. They have a high input impedance and large dynamic range.

E6B01

Operational amplifiers are single chip devices that have inherently very high gain. In practice the gain is determined by external components. Operational amplifiers are direct coupled. The output is determined by differences between the two input terminals.



E6B02

High input impedance means no loading on the previous circuit. Low output impedance means that following components have little effect on the output. Infinite gain allows complete control of the gain by external components. Flat frequency response means that the actual frequency response can be set by external components.

E6B03

The inherent gain is very high. External feedback components are used to reduce the gain to practical levels. The frequency response can be tailored by putting frequency sensitive components in the feedback circuit.

E6B04

Ideally this should be zero. In practice it can be a few millivolts.

E6B05

High input impedance means no loading on the previous circuit.

E6B06

Low output impedance means that following components in a circuit have little effect on the output signal.

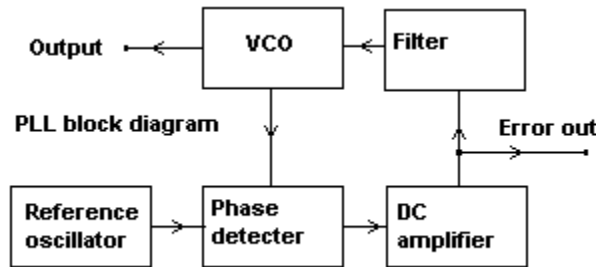
E6B07

All of the other symbols are for logic devices.

E6B08

A PLL is used for frequency synthesis. The synthesized frequency is locked to an accurate frequency standard.

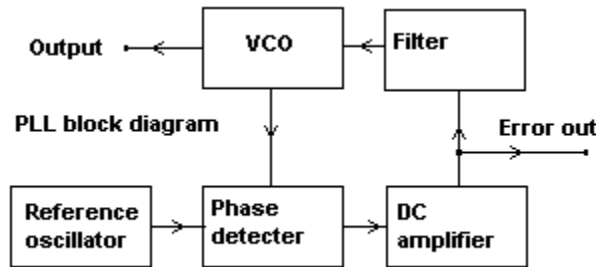
There is a feedback circuit in a PLL. The error signal in this feedback circuit is proportional to the frequency difference between the VCO output and the reference frequency. If an FM signal is substituted for the reference frequency then the error signal is a copy of the original modulating signal and the PLL functions as an FM demodulator.



E6B09

A PLL is used for frequency synthesis. The synthesized frequency is locked to an accurate frequency standard.

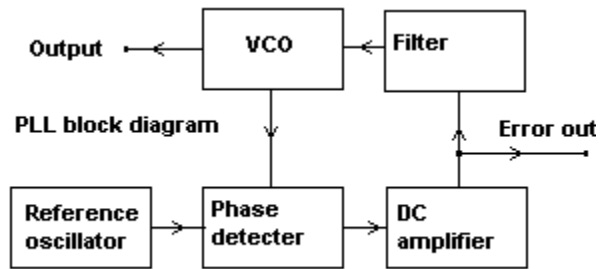
There is a feedback circuit in a PLL. The error signal in this feedback circuit is proportional to the frequency difference between the VCO output and the reference frequency. If an FM signal is substituted for the reference frequency then the error signal is a copy of the original modulating signal and the PLL functions as an FM demodulator.





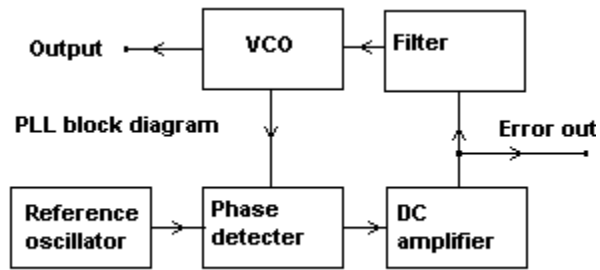
E6B10

In a phase locked loop circuit, the output frequency of a voltage controlled oscillator is locked to a highly stable reference frequency.



E6B11

In a phase locked loop circuit, the output frequency of a voltage controlled oscillator is locked to a highly stable reference frequency. The frequency range over which the VCO can remain locked to the reference is called the capture range.



E6C01

Transistor-transistor logic uses two logic levels. Nominally these are 0 and +5 volts.

E6C02

It is normal practice to fix unused TTL inputs to either supply rail by a "pull up" or "pull down" resistor.

E6C03

Although logic "high" is nominally +5 volts the actual voltage will be between +5 and +2 volts. The voltage will be lower if several TTL inputs are connected to a TTL output. This is an arrangement known as "fan out".

E6C04

Although logic "low" is nominally 0 volts the actual output can be between -0.6 and 0.8 volts.

E6C05

If complementary pairs of semiconductor junctions are used, both logic states consume very little current from the supply rail.

E6C06

Power supply noise transients or input transients have to be much larger for spurious switching to occur.



E6C07

There can be more than 2 inputs on an AND gate.

E6C08

The little circles represent negation. It is the output of the NAND gate that is negated (inverted).

E6C09

There can be more than 2 inputs on an OR gate.

E6C10

The little circles represent negation. It is the output of the NOR gate that is negated (inverted).

E6C11

The NOT gate will negate (invert) the input logic state. A 1 input will produce a 0 output and vice versa.

E6D01

A vidicon tube works like a television cathode ray tube in reverse.

E6D02

The electron beam is deflected by varying electromagnetic fields in coils surrounding the tube just like in a television cathode ray tube.

E6D03

In electromagnetic deflection systems coils are used to produce the required magnetic fields. These coils are inductive and the reactance will vary with frequency. It is difficult to drive the deflection coils consistently over a range of frequencies.



E6D04

Persistence is a function of the type of phosphor materials used to coat the front of the tube. This effect is similar to, but distinct from, the persistence that occurs in our eyes.

E6D05

The image will be smaller (and brighter) because the electrons will be traveling at higher speeds and will be more difficult to deflect. The X-rays produced by a CRT under such fault conditions are a health hazard.

E6D06

The image will be smaller (and brighter) because the electrons will be traveling at higher speeds and will be more difficult to deflect. The X-rays produced by a CRT under such fault conditions are a health hazard.

E6D07

The analog signals stored by a CCD are in response to incident light levels. There is no way to input an analog electrical signal to a CCD.

E6D08

The analogue signal passed on by the stage is based on the number of photons striking the junctions over a period of time.

E6D09

CCD based cameras are much more sensitive than vidicon types.

E6D10

An LCD display has very low power consumption. No light is emitted by a LCD display.

E6D11

An LCD display has very low power consumption. No light is emitted by a LCD display.



E7A01

The circuit remains in one stable state until triggered to change to the other stable state; it has two stable states. One state represents the bit in the "off" state while the other state represents the bit in the "on" state.

E7A02

Each flip-flop divides by two. Connecting two of them in cascade divides by four.

E7A03

Each flip-flop divides by two. Connecting two of them in cascade divides by four.

E7A04

Each flip-flop divides by two. Connecting two of them in cascade divides by four.

E7A05

An astable multivibrator has no stable states. It constantly switches between its two unstable states. It is commonly called a "flip-flop" because it never stops changing states.

E7A06

A monostable multivibrator has one stable state. A trigger input will switch it to the unstable state. After a time period it will switch back to the stable state. The time period is set by external components.

E7A07

Here is a list of input-output states for a two input AND gate:

Input A	Input B	Output
1	0	0
0	1	0
0	0	0
1	1	1

E7A08

NAND means NOT AND. Here is a list of input-output states for a two input NAND gate:

Input A	Input B	Output
1	0	1
0	1	1
0	0	1
1	1	0



E7A09

Here is a list of input-output states for a two input OR gate:

Input A	Input B	Output
1	0	1
0	1	1
0	0	0
1	1	1

E7A10

The NOR gate produces a logic 0 at its output if any inputs are logic 1. Here is a list of input-output states for a two input NOR gate:

Input A	Input B	Output
1	0	0
0	1	0
0	0	1
1	1	0

E7A11

We use a truth table in digital circuitry to characterize the function of logic devices. The lists shown in some of the preceding logic device explanations are truth tables.

E7A12

In a positive logic circuit a logic 0 is a lower voltage and 1 is a higher voltage.

E7A13

In a negative logic circuit a logic 1 is a lower voltage and 0 is a higher voltage.

E7B01

A prescaler is a frequency divider circuit. It allows HF and VHF signals to be used with relatively inexpensive frequency counters designed to work at lower frequencies.

E7B02

Decade means powers of ten (like decimal). A decade counter gives one output pulse for every ten input pulses.

E7B03

Decade means powers of ten (like decimal). A decade counter gives one output pulse for every ten input pulses.



E7B04

Two flip-flops running at 50 kHz and 25 kHz would provide the 50 kHz and 25 kHz fundamental frequencies. The output of flip-flops is a square wave that is rich in harmonics. Therefore, signals would be present at 25 kHz and 50 kHz intervals.

E7B05

The prescaler circuit would output a 100 kHz square wave. Such a waveform is rich in regularly spaced harmonics.

E7B06

Normally the stable oscillator frequency is divided by a prescaler or flip-flop chain to give a low frequency square wave output that is rich in regularly spaced harmonics. The harmonics provide the "marks" at precisely defined frequencies.

E7B07

A pure sine wave has no harmonics. Only one frequency would be present in the output.

## E7B08

A marker oscillator is designed to output a low frequency square wave output that is rich in regularly spaced harmonics. The regularly spaced harmonics provide the "marks" at precisely defined frequencies. Typical fundamental output frequencies are 100 kHz, 50 kHz, and 25 kHz.

E7B09

All frequency counters will depend on an internal reference, usually a crystal oscillator. The internal reference is calibrated against other known frequency standards. Some frequency counters have a facility for making the internal reference lock to an external frequency standard.

E7B10

The internal reference sets the time period for the input pulse count. It must be accurate and is calibrated against other known frequency standards. Some frequency counters have a facility for making the internal reference lock to an external frequency standard.

E7B11

A frequency counter operates by counting the number of input pulses in a time period. If more than one signal is present the counter will, at best, count the pulses of the strongest signal. If several signals of similar magnitude are present then the displayed count may not bear any relationship to the correct frequency.



E7C01

The gain of an audio filter circuit containing an op-amp can be determined entirely by the external components. In a passive LC audio filter there will always be some loss.

E7C02

You would use a spectrum analyzer for looking at the frequency response of a filter.

E7C03

The gain of an audio filter circuit containing an op-amp can be determined entirely by the external components. In a passive LC audio filter there will always be some loss.

E7C04

Polystyrene capacitors have good temperature stability and have a high Q.

E7C05

High gain audio circuits are prone to "howling" and "ringing". An audio circuit that is close to oscillation gives a "speaking through a pipe" sound to the audio signal.

E7C06

Active op-amp filters can be designed for almost any frequency response and can also be made variable.

E7C07

A preselector with a fairly narrow passband helps reduce reception of image signals. However a preselector with a narrow bandwidth will have more insertion loss and will reduce the receiver front-end sensitivity.

E7C08

Standard value resistors are available for a wide range of values in small increments. Standard value capacitors have a more restricted range and the steps between standard values are larger.



E7C09

Standard value resistors are available for a wide range of values in small increments. Standard value capacitors have a more restricted range and the steps between standard values are larger.

E7C10

Op-amps are best used at fairly low signal levels. An example is in the low level audio stages of a receiver.

E7C11

Op-amps are best used at fairly low signal levels. An example is in the low level audio stages of a receiver.

E7D01

Op-amps have two signal inputs. One is inverting and the other one is non-inverting.

E7D02

Op-amps have two signal inputs. One is inverting and the other one is non-inverting.

E7D03

In the figure,  $\text{Gain} = R_f/R_1$ ,  
Where  $R_f$  is feedback resistance in ohms,  
and  $R_1$  is input resistance in ohms.

This gives  $\text{Gain} = 100\text{E}3 / 1000 = 100$   
This is an inverting op-amp circuit.

E7D04

In the figure,  $\text{Gain} = R_f/R_1$ ,  
Where  $R_f$  is feedback resistance in ohms,  
and  $R_1$  is input resistance in ohms.

This gives  $\text{Gain} = 68\text{E}3 / 1800 = 38$   
This is an inverting op-amp circuit.

E7D05

In the figure,  $\text{Gain} = R_f/R_1$ ,  
Where  $R_f$  is feedback resistance in ohms,  
and  $R_1$  is input resistance in ohms.

This gives  $\text{Gain} = 47\text{E}3 / 3,300 = 14$   
This is an inverting op-amp circuit.



E7D06

In the figure,  $\text{Gain} = R_f/R_1$ ,  
Where  $R_f$  is feedback resistance in ohms,  
and  $R_1$  is input resistance in ohms.

This gives  $\text{Gain} = 47\text{E}3 / 10 = 4700$   
This is an inverting op-amp circuit.

E7D07

An ideal op amp should have unlimited bandwidth. It should be the external components that determine the bandwidth of the op-amp circuit.

E7D08

The input impedance to the gate is very high since it is either a reverse biased junction in a JFET or an electrically isolated electrode in a MOSFET. So it is the biasing network that is effectively in parallel with the gate that will determine the input impedance.

E7D09

The output impedance is inherently very low and determined mainly by the drain resistor that is effectively in series with the output.

E7D10

In the figure,  $\text{Gain} = R_f/R_1$ ,  
Where  $R_f$  is feedback resistance in ohms,  
and  $R_1$  is input resistance in ohms.

This gives  $\text{Gain} = 1000 / 1000 = 1$

A gain of 1 indicates unity gain, the output signal amplitude will be the same as the input signal amplitude which is -10 millivolts. However this is an inverting op-amp circuit with the signal fed to the inverting input (the one with the minus sign) and so the output voltage will be of opposite sign to the input. Therefore the output signal will be  $-(-10 \text{ millivolts}) = 10$  Millivolts.

E7D11

In the figure,  $\text{Gain} = R_f/R_1$ ,  
Where  $R_f$  is feedback resistance in ohms,  
and  $R_1$  is input resistance in ohms.

This gives  $\text{Gain} = 10000 / 1000 = 10$   
Output signal amplitude =  $10 \times$  input signal amplitude = 23 volts.

However this is an inverting op-amp circuit with the signal fed to the inverting input (the one with the minus sign) and so the output voltage will be of opposite sign to the input. Therefore the output signal will be -23 volts.

E8A01

The duty cycle can be a lot less than 100% allowing a moderately rated transmitter to generate high pulse levels without overheating. High transient currents and voltages will be present in the output stages of a pulse transmitter.

E8A02

The modulating signal varies the duration of the pulses. It is easy to demodulate a pulse width signal by using a simple RC circuit.



E8A03

The pulse timing varies with the modulating signal.

E8A04

The modulating signal varies the duration of the pulses. It is easy to demodulate a pulse width signal by using a simple RC circuit.

E8A05

The modulating signal varies the duration of the pulses. It is easy to demodulate a pulse width signal by using a simple RC circuit.

E8A06

This gives a duty cycle of 1/1000.

E8A07

The duty cycle can be a lot less than 100% allowing a moderately rated transmitter to generate high pulse levels without overheating. High transient currents and voltages will be present in the output stages of a pulse transmitter.

E8A08

In a switching regulator the duty cycle is varied to control the output.

E8A09

In a switching regulator the duty cycle is varied to control the output.

E8B01

As we all know, "dahs" are three times the length of "dits".



E8B02

The ASCII 7 bit code allows upper and lower case text to be transmitted whereas the Baudot 5 bit code uses uppercase letters only.

E8B03

The ASCII 7 bit code allows upper and lower case text to be transmitted whereas the Baudot 5 bit code uses uppercase letters only.

E8B04

Meteor scatter propagation is sporadic. Short bursts of data are handled well by packet radio systems because each packet is of short duration and can be repeated many times.

E8B05

In mode A AMTOR if the signal is not received correctly the receiving system automatically requests a repeat of the frame.

E8B06

In mode B AMTOR characters are sent twice. There is no feedback from the receiving system. This is called forward error correction.

E8B07

The emission type is not relevant. The formula for Morse Code required bandwidth is:

Bandwidth = 4 x Words per minute.

This gives a bandwidth of  $4 \times 13 = 52$  Hz.

E8B08

The emission type is not relevant. The formula for required bandwidth of data transmissions is:

Bandwidth = baud rate + (1.2 x frequency shift).

This gives a bandwidth of  $300 + (1.2 \times 170) = 500$  Hz.

E8B09

The emission type is not relevant. The formula for required bandwidth of data transmissions is:

Bandwidth = baud rate + (1.2 x frequency shift).

This gives a bandwidth of  $1200 + (1.2 \times 1000) = 2,400$  Hz.



E8B10

The emission type is not relevant. The formula for required bandwidth of data transmissions is:

Bandwidth = baud rate + (1.2 x frequency shift).

This gives a bandwidth of  $9600 + (1.2 \times 4800) = 15,360$  Hz.

E8C01

Four 2.5 kHz ACSB transmissions take up the bandwidth of one 10 kHz FM transmission. This process allows more efficient use of transmitter power and band space.

E8C02

Four 2.5 kHz ACSB transmissions take up the bandwidth of one 10 kHz FM transmission. This process allows more efficient use of transmitter power and band space.

E8C03

The 3 kHz pilot tone facilitates automatic tuning of SSB signals. This is useful in mobile "hands free" operation.

E8C04

The 3 kHz pilot tone facilitates automatic tuning of SSB signals. This is useful in mobile "hands free" operation.

E8C05

Four 2.5 kHz ACSB transmissions take up the bandwidth of one 10 kHz FM transmission. The narrower bandwidth allows more efficient use of transmitter power and band space.

E8C06

In spread spectrum communications the signal moves around in a prearranged pseudo-random pattern. The receiver tracks the signal using the same pseudo-random sequence. Interference averages out while the required signal accumulates. SS transmission gives interference free private communications. Frequency hopping generally occurs at a low rate compared to the modulation information rate.

E8C07

In spread spectrum communications the signal moves around in a prearranged pseudo-random pattern. Interference averages out while the required signal accumulates. SS transmission gives interference free private communications. The receiver tracks the signal using the same pseudo-random sequence. Frequency hopping generally occurs at a low rate compared to the modulation information rate.



E8C08

The term direct sequence is used to describe shifts in the phase of an RF carrier to achieve spread spectrum communications. The carrier is phase shift keyed according to a pseudo-random code at a faster rate than the modulation information. The receiver tracks the signal using the same pseudo-random sequence.

E8C09

This is a technique that allows many pseudo random sequences to be generated by selection of feedback digits. A SS receiver must have the same sequence as the transmitter to receive information. Selection of pseudo random sequences effectively allows a number of private channels to be used.

E8C10

In spread spectrum communications, the signal moves around in a prearranged pseudo-random pattern. At the receiver interference averages out while the required signal accumulates.

E8C11

In spread spectrum communications, the signal moves around in a prearranged pseudo-random pattern. This has the effect of "smearing" the signal across a wide bandwidth. The energy at any given narrowband channel is very small.

E8D01

AC signals swing from one extreme to the other. The maximum positive excursion is called peak positive voltage.

E8D02

AC signals swing from one extreme to the other. The maximum negative excursion is called the peak negative voltage.

E8D03

It is easier to measure the peak to peak voltage and divide by two to get the peak voltage. This is because the negative and positive peaks are well defined but the zero axis may not be. This assumes that the waveform is symmetrical.

E8D04

Peak voltage is half the peak to peak voltage only if the waveform is symmetrical about the zero axis.



E8D05

The peak voltage is required to determine the electrical stresses in the amplifier circuitry. For example the capacitors and active device in the amplifier must be capable of withstanding the peak voltage .

E8D06

Peak envelope power (PEP) is the parameter used to express the maximum allowable power in the FCC rules. [\[97.313\]](#)

E8D07

To calculate peak envelope power:

Multiply the peak voltage by 0.707.

Square the result.

Divide by the load impedance.:

$$\text{Power} = ((V_p \times 0.707) \text{ squared})/R_L = ((30 \times 0.707) \text{ squared})/50 = 9$$

E8D08

To calculate average power over one RF cycle:

Multiply the peak voltage by 0.707.

Square the result.

Divide by the load impedance.:

$$\text{Power} = (V_p \times 0.707)^2 / R_L = ((35 \times 0.707)^2) / 50 = 12.2$$

E8D09

To calculate peak voltage we divide RMS voltage by 0.707.

$$65 / 0.707 = 92.$$

We now multiply the peak voltage by 2 to obtain the peak-to-peak voltage of 184.

E8D10

To calculate peak voltage we divide RMS voltage by 0.707.

$$34 / 0.707 = 48.$$

E8D11

Peak envelope power (PEP) is the parameter used to express the maximum allowable power in the FCC rules. [\[97.313\]](#)

E9A01

No real antenna radiates equally in all directions, but we can refer to a theoretical antenna that does. This antenna is known as an isotropic radiator. A dipole radiates equally in all directions in one plane only. When comparing antenna gain to an isotropic radiator we use dBi, a simple dipole has a gain of about 2.1 dBi. If we compare antenna gain to a simple dipole we use dBd.



E9A02

No real antenna radiates equally in all directions, but we can refer to a theoretical antenna that does. This antenna is known as an isotropic radiator. A dipole radiates equally in all directions in one plane only. When comparing antenna gain to an isotropic radiator we use dBi, a simple dipole has a gain of about 2.1 dBi. If we compare antenna gain to a simple dipole we use dBd.

E9A03

No real antenna radiates equally in all directions, but we can refer to a theoretical antenna that does. This antenna is known as an isotropic radiator. A dipole radiates equally in all directions in one plane only. When comparing antenna gain to an isotropic radiator we use dBi, a simple dipole has a gain of about 2.1 dBi. If we compare antenna gain to a simple dipole we use dBd.

E9A04

No real antenna radiates equally in all directions, but we can refer to a theoretical antenna that does. This antenna is known as an isotropic radiator. A dipole radiates equally in all directions in one plane only. When comparing antenna gain to an isotropic radiator we use dBi, a simple dipole has a gain of about 2.1 dBi. If we compare antenna gain to a simple dipole we use dBd.

E9A05

No real antenna radiates equally in all directions, but we can refer to a theoretical antenna that does. This antenna is known as an isotropic radiator. A dipole radiates equally in all directions in one plane only. When comparing antenna gain to an isotropic radiator we use dBi, a simple dipole has a gain of about 2.1 dBi. If we compare antenna gain to a simple dipole we use dBd.

E9A06

When comparing antenna gain to an isotropic radiator we use dBi, a simple dipole has a gain of about 2.1 dBi. If we compare antenna gain to a simple dipole we use dBd.

E9A07

When comparing antenna gain to an isotropic radiator we use dBi, a simple dipole has a gain of about 2.1 dBi. If we compare antenna gain to a simple dipole we use dBd.

$$\text{Gain (dBd)} = \text{Gain (dBi)} - 2.1 = 6 - 2.1 = 3.9 \text{ dBd}$$

E9A08

When comparing antenna gain to an isotropic radiator we use dBi, a simple dipole has a gain of about 2.1 dBi. If we compare antenna gain to a simple dipole we use dBd.

$$\text{Gain (dBd)} = \text{Gain (dBi)} - 2.1 = 12 - 2.1 = 9.9 \text{ dBd}$$

E9A09

No real antenna radiates equally in all directions, but we can refer to a theoretical antenna that does. This antenna is known as an isotropic radiator and has no gain in any direction.



E9A10

No real antenna radiates equally in all directions, but we can refer to a theoretical antenna that does. This antenna is known as an isotropic radiator and has no gain in any direction, the radiation patterns is a sphere indicating that the radiation is the same in all directions.

E9A11

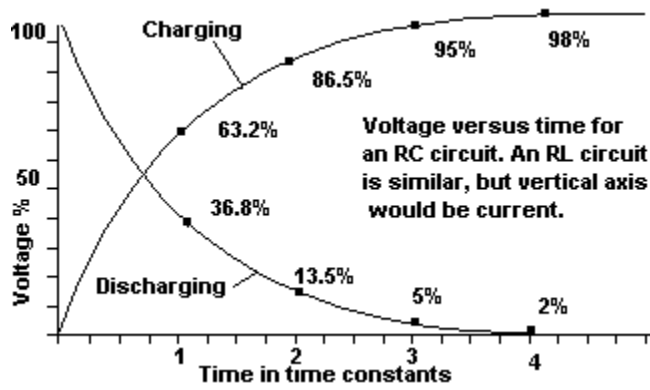
No real antenna radiates equally in all directions, but we can refer to a theoretical antenna that does. This antenna is known as an isotropic radiator and has no gain in any direction, the radiation patterns is a sphere indicating that the radiation is the same in all directions, that is, it has no directivity.

E9B01

Two quarter wavelength antennas spaced one half wavelength apart fed 180 degrees out of phase produces a figure eight pattern in line with the elements.

E9B02

Two quarter wave verticals spaced one quarter apart fed 90 degrees out of phase results in a unidirectional cardoid pattern. The sharp null is useful for direction finding.



E9B03

Two quarter wavelength antennas spaced one half wavelength apart fed in phase produces a figure eight pattern broadside to the line of the elements.

E9B04

Two quarter wavelength antennas spaced one quarter wavelength apart fed 180 degrees out of phase produces a figure eight pattern in line with the elements. However, if the elements are spaced more closely the pattern will start to resemble a single quarter wave vertical. It will be a less well defined figure of eight than a half wave spaced array.

E9B05

The two quarter wavelength vertical antennas spaced one eighth wavelength apart and fed 180 degrees out of phase produce an end fire figure eight pattern in line with the vertical elements. The pattern will be less well defined than a half wave spaced array.

E9B06

Two quarter wavelength verticals spaced one quarter wavelength apart and fed in phase will present a pattern part way between a figure of eight and a circular pattern. The result will be an elliptical pattern.



E9B07

A resonant rhombic has an open circuit at the end opposite to the feedline. Each side is one wavelength long. Resonant rhombic antennas are big!

E9B08

A non-resonant rhombic is unidirectional and has a terminating resistance at the end opposite to the feedline. They can work over a four to one frequency range.

E9B09

A non-resonant rhombic antenna works over a wide frequency range of up to four to one. It has plenty of gain (10-15 dB) and a good front to back ratio.

E9B10

Although it is non-resonant, the sides still need to be about one wavelength long.

E9B11

The terminating resistor should be around 800 ohms to match the characteristic impedance.

E9C01

The satellite transmitter power is one factor that will determine the strength of the received signals. The satellite transmitter antenna type will determine the strength and polarization of the received signals. The satellite height will influence signal strength and how long each pass will last.

E9C02

The satellite receive antenna gain will be one factor determining the earth station EIRP requirements as will the satellite receiver sensitivity. The satellite height defines the path lengths involved and this will also be a factor in determining EIRP requirements.

E9C03

The satellite receive antenna gain will be one factor determining the earth station EIRP requirements as will the satellite receiver sensitivity. The satellite height defines the path lengths involved and this will also be a factor in determining EIRP requirements.



E9C04

If you double the size of a dish the gain increases by four times, which is a 6 dB increase. If you halve the wavelength (double the frequency) the same thing happens. Parabolic antennas become feasible for most Radio Amateurs at frequencies of 1270 MHz and above.

E9C05

The greater the gain is, the narrower the beam width will be. The radiated signal is being focused in one direction.

E9C06

The beam width of a parabolic antenna is given by  
 $G = 203 / (3.16 \text{ to the power of } (\text{gain} / 10))$ .

This gives  $G = 203 / 3.162 \text{ to the power of } (20/10)$   
 $= 203 / 3.162 \text{ to the power of } 2$ .

"To the power of 2" means "squared".

So  $G = 203 / 10 = 20.3 \text{ degrees}$ .

E9C07

The beam width of a parabolic antenna is given by  
 $G = 203 / (3.16 \text{ to the power of } (\text{gain} / 10))$ .

This gives  $G = 203 / 3.162 \text{ to the power of } (30/10)$   
 $= 203 / 3.162 \text{ to the power of } 3$ .

"To the power of 3" means "cubed".

So  $G = 203 / 31.62 = 6.42 \text{ degrees}$ .

E9C08

The beam width of a parabolic antenna is given by  
 $G = 203 / (3.16 \text{ to the power of } (\text{gain} / 10))$ .

This gives  $G = 203 / 3.162 \text{ to the power of } (15/10)$   
 $= 203 / 3.162 \text{ to the power of } 1.5$ .

To calculate 3.162 to power 1.5 you need a calculator that has an exponent key. If you do not have one then you will have to estimate it. This can be considered to be half way between 3.162 to power of 1 (which is 3.162) and 3.162 to the power of 2 (which is 10). This will give you a value of 6.6 that will be close enough for you to select the correct option. The actual value of 3.162 to the power of 1.5 is 5.62

So  $G = 203 / 5.62 = 36.1$  degrees

E9C09

The beam width of a parabolic antenna is given by  
 $G = 203 / (3.16 \text{ to the power of } (\text{gain} / 10))$ .

This gives  $G = 203 / 3.162 \text{ to the power of } (12/10)$   
 $= 203 / 3.162 \text{ to the power of } 1.2$ .

To calculate 3.162 to power 1.2 you need a calculator that has an exponent key.

If you do not have such a calculator then here is a trick  
 $N \text{ to the power of } P = N \times P$  approximately, if  $P$  is close to 1

Using this trick gives an estimate of 3.8.

The actual value of 3.162 to the power of 1.2 is 3.98.

So  $G = 203 / 3.98 = 51$  degrees.

Using the estimate method gives  $203 / 3.8 = 53$  degrees.

E9C10

To get circular polarization using a pair of Yagis arrange them perpendicular to each other and feed them 90 degrees out of phase. The resulting array will have a gain 3 dB down on a single Yagi, but will not suffer from fades due to polarization changes.

E9C11

You need up/down nodding movement as well as side to side movement to track satellites because their path across the sky is rarely North-South or East-West.



E9D01

Delta means triangular. The matching sections form two sides of a triangle. Delta matching sections are used with balanced feedline.

E9D02

Gamma matches are popular because they match unbalanced coaxial feedline to a balanced driven element. They also provide impedance matching.

E9D03

A stub can be used to add small amounts of reactance to help matching.

E9D04

Use 7 picofarads per meter of wavelength:  $7 \times 20 = 140$  picofarads.

E9D05

Use 7 picofarads per meter of wavelength:  $7 \times 10 = 70$  picofarads.

E9D06

A  $\frac{1}{8}$  wavelength stub with the far end shorted will present inductive reactance at the near end.

E9D07

A  $\frac{1}{8}$  wavelength stub with the far end open will present capacitive reactance at the near end.

E9D08

A  $\frac{1}{4}$  wavelength stub with the far end shorted will present an open circuit at the near end.



E9D09

A  $\frac{1}{4}$  wavelength stub with the far end open will present a short circuit at the near end.

E9D10

A  $\frac{1}{2}$  wavelength stub with the far end shorted will present a short circuit at the near end.


E9D11

A  $\frac{1}{2}$  wavelength stub with the far end open will present an open circuit at the near end.

## Vector Arithmetic.

Suggestion:

Get yourself a scientific calculator for the Extra Class exam!

Check that it supports SIN, COS, TAN, and the inverses of these functions. These may be called ASIN, ACOS, ATAN, or there may be a separate key labeled INV. Also, some questions require you to raise numbers "to the power of" other numbers, so check that an exponent key is available. This will probably be labeled 

Vectors are quantities that have a magnitude (just like normal numbers) but they also have direction, or angle, and this means that we have to use special arithmetic when adding, subtracting, multiplying or dividing them.

Impedance is a "complex" vector quantity. This means that an impedance value contains two parts that are called the "real part" and the "imaginary" part.

The real part is contributed by the circuit resistance.

The imaginary part is contributed by the circuit reactance that can be either inductive or capacitive. If the total reactance is capacitive, then the reactance is regarded as being negative.

There are two ways of describing vector quantities:

**Rectangular notation.** The real and imaginary parts of an impedance Z are written:

$$Z = R + jXl.$$

This is the impedance of a series RL circuit containing resistance R and inductive reactance Xl. If the circuit has resistance R and capacitive reactance Xc then the impedance would be written

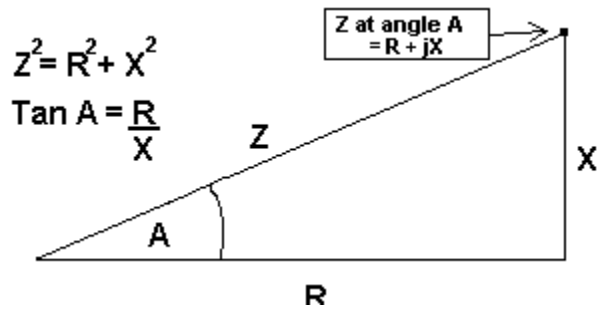
$$Z = R - jXc.$$

The "j" is **not** a quantity, it is a way of indicating that the following value is imaginary. Indicators like this are called operators.

**Polar notation.** The real and imaginary parts of an impedance Z are written:

Z at angle A.

The two notations are simply two different ways of describing the same thing. They can be demonstrated geometrically as follows



The diagram also shows how the two notations relate to each other. You will need to be able to convert an impedance from polar notation to vector notation and vice versa. Here are the relevant formulae:

Polar to rectangular conversion:

$$Z \text{ at angle } A = Z \times \cos(A) + jZ \times \sin(A).$$

Example:

$$\begin{aligned} &120 \text{ ohms at angle } 30 \text{ degrees} \\ &= 120 \times \cos(30) + j 120 \times \sin(30) \\ &= 120 \times 0.866 + 120 \times 0.5 \\ &= 104 + j60 \text{ ohms.} \end{aligned}$$

Rectangular to polar conversion:

$$R + jX = \text{square root}(R^2 + X^2) \text{ at angle } \text{INV Tan}(X/R).$$

Example:

$$\begin{aligned} &104 + j60 \text{ ohms} \\ &= \text{square root}(104^2 + 60^2) \text{ at angle } \text{INV Tan}(60/104) \\ &= 120 \text{ at angle } 30 \text{ degrees.} \end{aligned}$$

### Arithmetic.

Addition and subtraction is easiest with rectangular notation, so if the impedances are in polar notation then convert to rectangular first.

$$(A + jB) + (C + jD) = (A + C) + j(B + D).$$

Example:

$$\begin{aligned} &\text{If } Z_1 = 104 + j60 \text{ (A resistance of } 104 \text{ ohms and an inductor of reactance } 60 \text{ ohms)} \\ &Z_2 = 50 - j40 \text{ (A resistance of } 50 \text{ ohms and an capacitor of reactance } 40 \text{ ohms)} \\ &\text{Then to total series impedance is} \\ &Z_1 + Z_2 = (104 + j60) + (50 - j40) \\ &= (104 + 50) + j(60 - 40) \\ &= 54 + j10 \text{ ohms.} \end{aligned}$$

Multiplication and division is easier with polar notation. Therefore, if the impedances are in rectangular notation then convert to polar first:

$(Z_1 \text{ at angle } A) \times (Z_2 \text{ at angle } B) = Z_1 \times Z_2 \text{ at angle } (A + B),$

$(Z_1 \text{ at angle } A) / (Z_2 \text{ at angle } B) = Z_1 / Z_2 \text{ at angle } (A - B).$

Example:

$Z_1 = 120 \text{ ohms at angle } 30 \text{ degrees},$

$Z_2 = 60 \text{ ohms at angle } 45 \text{ degrees}.$

$Z_1/Z_2 = 120/60 \text{ at angle } (30 - 45),$

$Z_1/Z_2 = 2 \text{ ohms at angle } -15 \text{ degrees}.$

