Amateur Radio Extra Class License Class Syllabus

Valid for license exams given July 1, 2020 thru June 30, 2024

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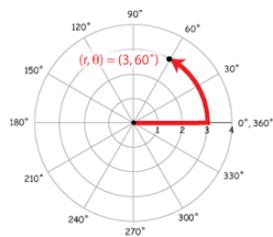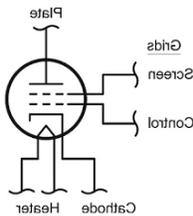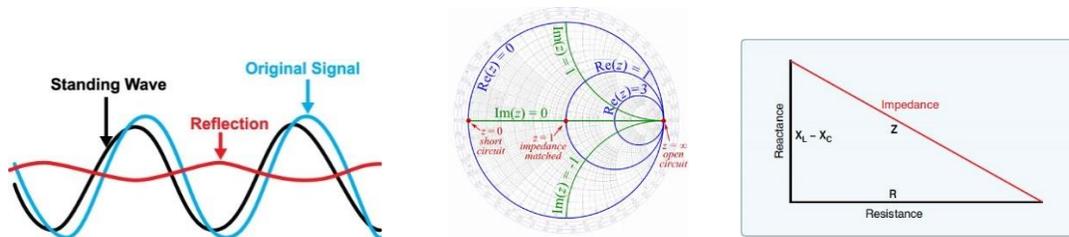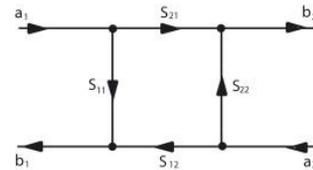*Based on July 1, 2020 Public Release Amateur Extra License Question Pool*
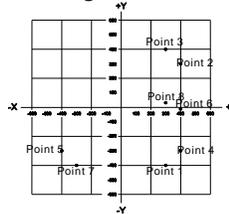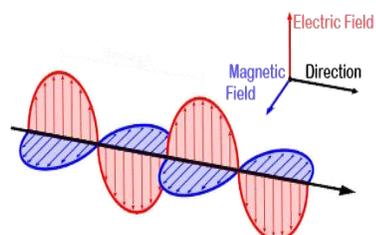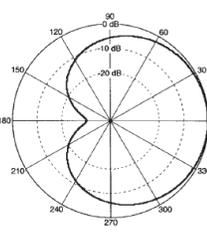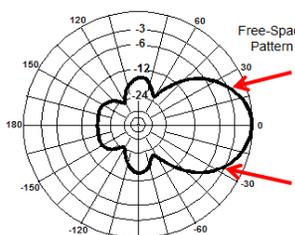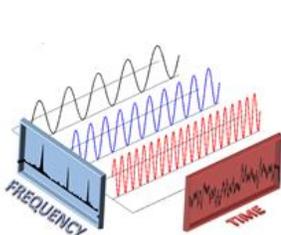
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Check the authors web site www.ad7fo.com to make sure you have the latest revision

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Overview

All questions in this syllabus are shown exactly as they will appear in the License exam, with only the correct answer shown (**in green bold text**).   This in the author's view makes it easier when you see the other choices in your exam to identify the correct answer.   Question numbers have been included so you can go to the ARRL Extra Class License Manual, or the question pool itself to see the additional choices in the exam for each question. The actual July 1, 2020 license question pool with all the answer choices can be found at http://www.ncvec.org/downloads/2020ExtraClassPoolJan22.txt

This material is based on the above published 2020 Extra Class License question pool. Additional information added by the author (***in bold italicized blue text***).

You do not need a copy of the current ARRL Extra Class License Manual or any other License Study Guide. All the questions that could possibly be in the exam are contained in this syllabus. Additional information is in the authors "***Reference Materials for FCC Amateur Extra License Study***" at the back of this syllabus and on my web site www.ad7fo.com . It is suggested for more in-depth explanations of the technical areas that you acquire a copy of the ARRL Handbook available for the ARRL at www.arrl.org or book sellers like Amazon and Barnes and Noble.

Frequently, used ARRL Handbooks are available at hamfests for significantly less than a new one. The Handbook will serve as a useful technical reference to help you understand the technical areas covered in this syllabus and for Ham Radio in general. You do not need the latest edition of the ARRL Handbook, any edition within the past few years is adequate, since the technical content changes very little from year to year.

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While every effort was made to ensure the accuracy of the material herein, this material was prepared by an ordinary human being and it is likely that some typographical, spelling or other errors remain.   The author can be contacted at *ad7fo@arrl.net*. Corrections are always welcome and appreciated.

Additional information and resources to help you study for the Extra Class License can be found on the ARRL web site www.arrl.org .   The ARRL site has articles and resources for reference materials on all aspects of the exam questions and Amateur Radio in general.

There are several on-line Exam practice sites with practice exams you can take with real exam questions. Listed below are some sites where you can find practice exams:

http://aa9pw.com/radio/   **http://www.arrl.org/exam-practice**

http://www.eham.net/exams   **http://www.hamradionation.com**

http://www.qrz.com/hamtest   **http://www.hamexam.org**

http://www.hamstudy.org   **http://www.hamradiolicenseexam.com**

About the Author

Education:
Electrical Engineering, Pennsylvania State University

Work Experience:
Hewlett Packard Company: Thirty-four years filling various positions (retired in 2004)

RF Products Division in Spokane WA -1981 to 2004

- New Product Introduction planning
- Product Management
- Systems Development
- Worldwide Sales Management
- Regional Sales Support
- Military program sales development

Field Sales Office in Valley Forge PA - from 1969 until 1981

- Engineering Technical Support
- Technical Customer Training
- Field Sales Engineer

American Electronics Laboratories (AEL) in Colmar PA 1961 to 1970
Working in and managing a Metrology (Calibration Standards) Laboratory

responsible for maintaining test instruments and their calibration accuracy traceable to the National Bureau of Standards (NBS) now called National Institute of Standards and Technology (NIST)

Jerrold Electronics, Hatboro PA: 1959 to 1961
Technician in the R&D Laboratory working on Cable TV system products and Cable TV RF test equipment

Hobbies:

- Amateur Radio
- Test Equipment
- Electronics in general

Amateur Radio Activities:

- Teaching amateur radio License classes with training materials I have developed. Over 50 classes taught, and 431 new hams licensed.
- Writing and presenting 30 to 60-minute technical talks on Amateur Radio topics for local clubs. They are available for others to use and are on my web site www.ad7fo.com
- Developed and presented a power point version class for the ARRL 4th Edition EMCOMM course. This class requires two 7-hour days and one 4-hour day followed with the ARRL EMCOM Exam. Available on my web site www.ad7fo.com under the training tab.
- Author provides a radio and general-purpose test table every year at the ARRL Washington State Convention and Hamfest in Spokane WA for folks to test their radios and other electronic Hamfest treasures.
- Attending as many hamfests as I can: Swaptoberfest in Rickreall OR, Mike and Key Hamfest in Puyallup WA, Yakima WA Hamfest, KARS Hamfest Post Falls ID, Spokane Hamfest, Spokane WA

ARRL Appointments:

- ARRL Eastern Washington Section Manager
- ARRL Technical Specialist
- ARRL VE (Volunteer Examiner)
- ARRL Registered Instructor
- ARRL Certified EMCOMM Instructor

Other:

- Member of the Inland Empire VHF Club (past President)
- Member of the Spokane County ARES/RACES (past AEC)

2020-2024 Extra Class Outline
FCC Element 4 Question Pool Syllabus
Effective July 1, 2020

SUBELEMENT E1 — COMMISSION RULES [*6 Exam Questions — 6 Groups*]
75 Questions

SUBELEMENT E2 - OPERATING PROCEDURES [*5 Exam Questions - 5 Groups*]
61 Questions

SUBELEMENT E3 - RADIO WAVE PROPAGATION [*3 Exam Questions - 3 Groups*]
41 Questions

SUBELEMENT E4 - AMATEUR PRACTICES [*5 Exam Questions - 5 Groups*]
60 Questions

SUBELEMENT E5 - ELECTRICAL PRINCIPLES [*4 Exam Questions - 4 Groups*]
55 Questions

SUBELEMENT E6 - CIRCUIT COMPONENTS [*6 Exam Questions - 6 Groups*]
70 Questions

SUBELEMENT E7 - PRACTICAL CIRCUITS [*8 Exam Questions - 8 Groups*]
108 Questions

SUBELEMENT E8 - SIGNALS AND EMISSIONS [*4 Exam Questions - 4 Groups*]
45 Questions

SUBELEMENT E9 - ANTENNAS AND TRANSMISSION LINES [*8 Exam Questions - 8 Groups*] 96 Questions

SUBELEMENT E0 – SAFETY [*1 exam question – 1 group*]
11 Questions

There are 50 questions in the Amateur Extra Exam from 20 sub element groups, only one question will come from each sub-element group. You must have 37 correct answers to pass your extra class license exam.

SUBELEMENT E1 — COMMISSION RULES [6 Exam Questions — 6 Groups]

E1A Operating Standards: frequency privileges; automatic message forwarding; stations aboard ships or aircraft; power restriction on 630 and 2200 meter bands

E1A01 [97.305, 97.307(b)]
Which of the following carrier frequencies is illegal for LSB AFSK emissions on the 17 meter band RTTY and data segment of 18.068 to 18.110 MHz? **18.068 MHz**
A Lower Sideband transmission would be 18.065 and below the18.068 MHz lower band limit.

17 Meters (18 MHz)

E,A,G

18.068   18.110   18.168 MHz
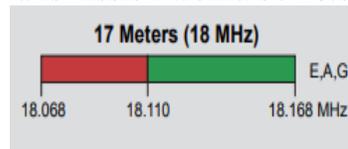
E1A02 [97.301, 97.305]
When using a transceiver that displays the carrier frequency of phone signals, which of the following displayed frequencies represents the lowest frequency at which a properly adjusted LSB emission will be totally within the band? **3 kHz above the lower band edge**
A LSB signal could be as much as 3 KHz below the carrier frequency setting on the transmitter.

E1A03 [97.305, 97.307(b)]
What is the maximum legal carrier frequency on the 20 meter band for transmitting USB AFSK digital signals having a 1 kHz bandwidth? **14.149 MHz**
Since the USB signal would have upper sidebands up to 1 KHz, the highest carrier frequency allowed would be 1 KHz below the upper band edge or 14.350 MHz – 1 KHz would be 14.149 MHz.

20 Meters (14 MHz)

14.000   14.150   14.350 MHz

E
A
G

14.175
14.025   14.150 14.225
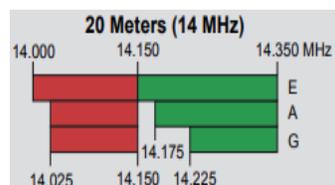
E1A04 [97.301, 97.305]
With your transceiver displaying the carrier frequency of phone signals, you hear a DX station calling CQ on 3.601 MHz LSB. Is it legal to return the call using lower sideband on the same frequency? **No, the sideband will extend beyond the edge of the phone band segment**
A 3.601 LSB signal will occupy a 3 KHz bandwidth (3.598 to 3.601 MHz). This is 2 KHz below the lower edge of the phone band.

80 Meters (3.5 MHz)

3.500 3.600   3.700   4.000 MHz

E
A
G
N,T
(200 W)

3.800

3.525 3.600
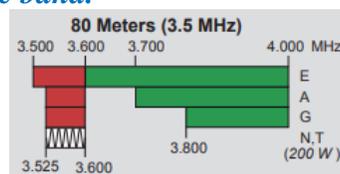
E1A05 [97.313]
What is the maximum power output permitted on the 60 meter band?
100 watts PEP effective radiated power relative to the gain of a half-wave dipole
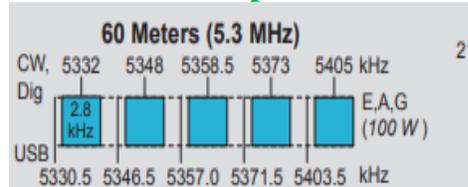
E1A06 [97.303(h)(1)]
Where must the carrier frequency of a CW signal be set to comply with FCC rules for 60 meter operation?   **At the center frequency of the channel**
See graphic for E1A05 above.

E1A07 [97.313(k)]
What is the maximum power permitted on the 2200 meter band? **1 watt EIRP (Equivalent isotropic radiated power)**
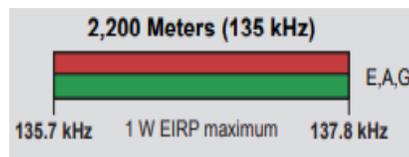
E1A08 [97.219]
If a station in a message forwarding system inadvertently forwards a message that is in violation of FCC rules, who is primarily accountable for the rules violation?   **The control operator of the originating station**

E1A09 [97.219]
What action or actions should you take if your digital message forwarding station inadvertently forwards a communication that violates FCC rules? **Discontinue forwarding the communication as soon as you become aware of it**

E1A10 [97.11]
If an amateur station is installed aboard a ship or aircraft, what condition must be met before the station is operated? **Its operation must be approved by the master of the ship or the pilot in command of the aircraft**

E1A11 [97.5]
Which of the following describes authorization or licensing required when operating an amateur station aboard a U.S.-registered vessel in international waters? **Any FCC-issued amateur license**

E1A12
What special operating frequency restrictions are imposed on slow scan TV transmissions?
They are restricted to phone band segments

E1A13 [97.5]
Who must be in physical control of the station apparatus of an amateur station aboard any vessel or craft that is documented or registered in the United States? **Any person holding an FCC issued amateur license or who is authorized for alien reciprocal operation**

E1A14 [97.313(l)]
Except in some parts of Alaska, what is the maximum power permitted on the 630 meter band?
5 watts EIRP
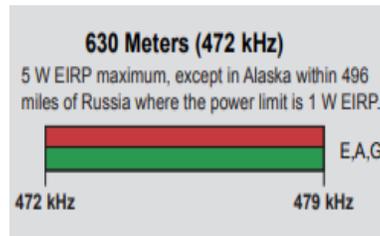
E1B Station restrictions and special operations: restrictions on station location; general operating restrictions; spurious emissions; antenna structure restrictions; RACES operations

E1B01 [97.3]
Which of the following constitutes a spurious emission? **An emission outside the signal's necessary bandwidth that can be reduced or eliminated without affecting the information transmitted**

E1B02 [97.307(f)(2)]
Which of the following is an acceptable bandwidth for Digital Radio Mondiale (DRM) based voice or SSTV digital transmissions made on the HF amateur bands? **3 kHz**
Digital Radio Mondiale is a set of digital audio broadcasting technologies designed to work over the bands currently used for analogue radio broadcasting including AM broadcasting, particularly shortwave, and FM broadcasting. DRM is more spectrally efficient than AM and FM, allowing more stations, at higher quality, into a given amount of bandwidth.

E1B03 [97.13]
Within what distance must an amateur station protect an FCC monitoring facility from harmful interference? **1 mile**
The FCC Monitoring stations that remain in operation include Atlanta; Baltimore; Boston; Chicago; Dallas; Denver; Detroit; Kansas City, MO; L.A.; New Orleans; New York; Philadelphia; San Diego; San Francisco; Seattle; and Tampa,

E1B04 [97.13, 1.1305-1.1319]
What must be done before placing an amateur station within an officially designated wilderness area or wildlife preserve, or an area listed in the National Register of Historic Places?
An Environmental Assessment must be submitted to the FCC

E1B05 [97.3]
What is the National Radio Quiet Zone? **An area surrounding the National Radio Astronomy Observatory**
There is a zone in the Pacific Northwest in Brewster WA. Check online for the location of other sites in the US.

E1B06 [97.15]
Which of the following additional rules apply if you are installing an amateur station antenna at a site at or near a public use airport? **You may have to notify the Federal Aviation Administration and register it with the FCC as required by Part 17 of the FCC rules**

E1B07 [97.15]
To what type of regulations does PRB-1 apply? **State and local zoning**
PRB-1 refers to the rule that Local governments are required to "reasonably accommodate Amateur Radio installations".

E1B08 [97.121]
What limitations may the FCC place on an amateur station if its signal causes interference to domestic broadcast reception, **assuming** that the receivers involved are of good engineering design? **The amateur station must avoid transmitting during certain hours on frequencies that cause the interference**

E1B09 [97.407]
Which amateur stations may be operated under RACES rules? **Any FCC-licensed amateur station certified by the responsible civil defense organization for the area served**
Races is the "Radio Amateur Civil Emergency Service"

E1B10 [97.407]
What frequencies are authorized to an amateur station operating under RACES rules? **All amateur service frequencies authorized to the control operator**

E1B11 [97.15]
What does PRB-1 require of regulations affecting amateur radio? **Reasonable accommodations of amateur radio must be made**

E1B12 [97.303(b)]
What must the control operator of a repeater operating in the 70 cm band do if a radiolocation system experiences interference from that repeater? **Cease operation or make changes to the repeater to mitigate the interference**
Radio location systems include VOR, TACAN, DME, Radar, etc.

E1C Rules pertaining to automatic and remote control; band-specific regulations; operating in, and communicating with foreign countries; spurious emission standards; HF modulation index limit; bandwidth definition

E1C01 [97.303]
What is the maximum bandwidth for a data emission on 60 meters? **2.8 kHz**
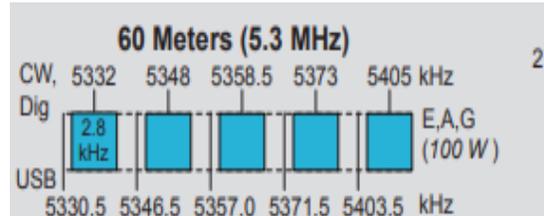
E1C02 [97.117]
Which of the following types of communications may be transmitted to amateur stations in foreign countries? **Communications incidental to the purpose of the amateur service and remarks of a personal nature**

E1C03 [97.109(d)]
How do the control operator responsibilities of a station under automatic control differ from one under local control? **Under automatic control the control operator is not required to be present at the control point**
They must, however, be able to control the station from a remote point.

E1C04
What is meant by IARP? **An International Amateur Radio Permit that allows U.S. amateurs to operate in certain countries of the Americas**
Application for an international amateur radio permit is available on the ARRL web site. Go to http://www.arrl.org/iarp.

E1C05 [97.221(c)(1), 97.115(c)]
When may an automatically controlled station originate third party communications? **Never**

E1C06
Which of the following is required in order to operate in accordance with CEPT rules in foreign countries where permitted? **You must bring a copy of FCC Public Notice DA 16-1048**
You can obtain a copy by searching the web for "FCC Public Notice DA 16-1048".

E1C07 [97.3(a)(8)]
At what level below a signal's mean power level is its bandwidth determined according to FCC rules? **26 dB**

E1C08 [97.213]
What is the maximum permissible duration of a remotely controlled station's transmissions if its control link malfunctions? **3 minutes**

E1C09 [97.307]
What is the highest modulation index permitted at the highest modulation frequency for angle modulation below 29.0 MHz? **1.0**
The modulation index (or modulation depth) of a modulation scheme describes by how much the modulated variable of the carrier signal varies around its unmodulated level. It is defined differently in each modulation type.

E1C10 [97.307]
What is the permitted mean power of any spurious emission relative to the mean power of the fundamental emission from a station transmitter or external RF amplifier installed after January 1, 2003 and transmitting on a frequency below 30 MHz? **At least 43 dB below**
For a 100 watt transmitter this is 5 milliwatts.
Ratio from dB = 10^(-43÷10) or 0.00005. Power allowed would be (0.00005)(100) or 0.005 watts or 5 milliwatts

E1C11 [97.5]
Which of the following operating arrangements allows an FCC-licensed U.S. citizen to operate in many European countries, and alien amateurs from many European countries to operate in the U.S.?   **CEPT agreement**

The European Conference of Postal and Telecommunications Administrations (CEPT) was established on June 26, 1959, as a coordinating body for European state telecommunications and postal organizations. The acronym comes from the French version of its name Conférence européenne des administrations des postes et des télécommunications. The CEPT was responsible for the creation of the European Telecommunications Standards Institute (ETSI) in 1988.

E1C12 [97.305(c)]
On what portion of the 630 meter band are phone emissions permitted? **The entire band**

E1C13 [97.303(g)]
What notifications must be given before transmitting on the 630 meter or 2200 meter bands?
Operators must inform the Utilities Telecom Council of their call sign and coordinates of the station

E1C14 [97.303(g)]
How long must an operator wait after filing a notification with the Utilities Telecom Commission before operating on the 2200 meter or 630 meter band? **Operators may operate after 30 days, providing they have not been told that their station is within 1 km of PLC systems using those frequencies**
The UTC maintains the national Power Line Carrier (PLC) database for the coordination of PLC use with licensed government radio services in the 10-490 kHz band.

E1D Amateur space and Earth stations; telemetry and telecommand rules; identification of balloon transmissions; one-way communications

E1D01 [97.3]
What is the definition of telemetry?   **One-way transmission of measurements at a distance from the measuring instrument**
One example would be one way transmissions from an amateur radio satellite to a ground station to report satellite problems and status,

E1D02 [97.211(b)]
Which of the following may transmit special codes intended to obscure the meaning of messages? **Telecommand signals from a space telecommand station**

E1D03 [97.3(a)(45)]
What is a space telecommand station?   **An amateur station that transmits communications to initiate, modify or terminate functions of a space station**

E1D04 [97.119(a)]
Which of the following is required in the identification of transmissions from a balloon-borne telemetry station? **Call sign**

E1D05 [97.213(d)]
What must be posted at the station location of a station being operated by telecommand on or within 50 km of the earth's surface?
A. A photocopy of the station license
B. A label with the name, address, and telephone number of the station licensee
C. A label with the name, address, and telephone number of the control operator
D. All these choices are correct

E1D06 [97.215(c)]
What is the maximum permitted transmitter output power when operating a model craft by telecommand? **1 watt**
You cannot operate your "Drone" or model from 100 miles away.

E1D07 [97.207]
Which HF amateur bands have frequencies authorized for space stations? **Only the 40, 20, 17, 15, 12, and 10 meter bands**

E1D08 [97.207]
Which VHF amateur bands have frequencies authorized for space stations? **2 meters**
There are three VHF Bands 6, 2 and 1.25 meter. Only 2 meter is authorized for satellite communications.

E1D09 [97.207]
Which UHF amateur bands have frequencies authorized for space stations? **70 cm and 13 cm**

E1D10 [97.211]
Which amateur stations are eligible to be telecommand stations of space stations (subject to the privileges of the class of operator license held by the control operator of the station)?
Any amateur station so designated by the space station licensee

E1D11 [97.209]
Which amateur stations are eligible to operate as Earth stations?   **Any amateur station, subject to the privileges of the class of operator license held by the control operator**

E1D12 [97.207(e), 97.203(g)]
Which of the following amateur stations may transmit one-way communications?   **A space station, beacon station, or telecommand station**

E1E Volunteer examiner program: definitions; qualifications; preparation and administration of exams; accreditation; question pools; documentation requirements

E1E01 [97.527]
For which types of out-of-pocket expenses do the Part 97 rules state that VEs and VECs may be reimbursed? **Preparing, processing, administering, and coordinating an examination for an amateur radio operator license**

E1E02 [97.523]
Who does Part 97 task with maintaining the pools of questions for all U.S. amateur license examinations? **The VEC's**

E1E03 [97.521]
What is a Volunteer Examiner Coordinator? **An organization that has entered into an agreement with the FCC to coordinate, prepare, and administer amateur operator license examinations**

E1E04 [97.509, 97.525]
Which of the following best describes the Volunteer Examiner accreditation process? **The procedure by which a VEC confirms that the VE applicant meets FCC requirements to serve as an examiner**

E1E05 [97.503]
What is the minimum passing score on all amateur operator license examinations? **Minimum passing score of 74%**

E1E06 [97.509]
Who is responsible for the proper conduct and necessary supervision during an amateur operator license examination session? **Each administering VE**
Every VE involved in conducting the test session is responsible.

E1E07 [97.509]
What should a VE do if a candidate fails to comply with the examiner's instructions during an amateur operator license examination? **Immediately terminate the candidate's examination**

E1E08 [97.509]
To which of the following examinees may a VE **_not_** administer an examination? **Relatives of the VE as listed in the FCC rules**
A Volunteer Examiner (VE) may not administer an examination to his or her spouse, children, grandchildren, stepchildren, parents, grandparents, stepparents, brothers, sisters, stepbrothers, stepsisters, aunts, uncles, nieces, nephews, and in-laws.

E1E09 [97.509]
What may be the penalty for a VE who fraudulently administers or certifies an examination?
Revocation of the VE's amateur station license grant and the suspension of the VE's amateur operator license grant

E1E10 [97.509(h)]
What must the administering VEs do after the administration of a successful examination for an amateur operator license? **They must submit the application document to the coordinating VEC according to the coordinating VEC instructions**

E1E11 [97.509(m)]
What must the VE team do if an examinee scores a passing grade on all examination elements needed for an upgrade or new license? **Three VEs must certify that the examinee is qualified for the license grant and that they have complied with the administering VE requirements**

E1E12 [97.509(j)]
What must the VE team do with the application form if the examinee does not pass the exam?
Return the application document to the examinee

E1F Miscellaneous rules: external RF power amplifiers; prohibited communications; spread spectrum; auxiliary stations; Canadian amateurs operating in the U.S.; special temporary authority; control operator of an auxiliary station

E1F01 [97.305]
On what frequencies are spread spectrum transmissions permitted? **Only on amateur frequencies above 222 MHz**

E1F02 [97.107]
What privileges are authorized in the U.S. to persons holding an amateur service license granted by the government of Canada?   **The operating terms and conditions of the Canadian amateur service license, not to exceed U.S. Amateur Extra Class license privileges**

E1F03 [97.315]
Under what circumstances may a dealer sell an external RF power amplifier capable of operation below 144 MHz if it has not been granted FCC certification? **It was purchased in used condition from an amateur operator and is sold to another amateur operator for use at that operator's station**

E1F04 [97.3]
Which of the following geographic descriptions approximately describes "Line A"?
 A line roughly parallel to and south of the border between the U.S. and Canada

E1F05 [97.303]
Amateur stations may not transmit in which of the following frequency segments if they are located in the contiguous 48 states and north of Line A? **420 MHz - 430 MHz**
Line A is an imaginary line within the US, approximately paralleling the US-Canadian border. To the north of Line A, FCC coordination with Canadian authorities is generally required in the assignment of frequencies in this frequency range.

E1F06 [1.931]
Under what circumstances might the FCC issue a Special Temporary Authority (STA) to an amateur station? **To provide for experimental amateur communications**

E1F07 [97.113]
When may an amateur station send a message to a business?   **When neither the amateur nor his or her employer has a pecuniary interest in the communications**
Pecuniary interest means monetary interest.

E1F08 [97.113(c)]
Which of the following types of amateur station communications are prohibited?
Communications transmitted for hire or material compensation, except as otherwise provided in the rules

E1F09 [97.311]
Which of the following conditions apply when transmitting spread spectrum emissions?
A. A station transmitting SS emission must not cause harmful interference to other stations employing other authorized emissions
B. The transmitting station must be in an area regulated by the FCC or in a country that permits SS emissions
C. The transmission must not be used to obscure the meaning of any communication
D. All these choices are correct

Spread Spectrum emission transmissions by an amateur station are authorized only for communications between points within areas where the amateur service is regulated by the FCC and between an area where the amateur service is regulated by the FCC and an amateur station in another country that permits such communications. SS emission transmissions must not be used for the purpose of obscuring the meaning of any communication.

Stations must maintain a record, convertible to the original information (voice, text, image, etc.) of all spread spectrum communications transmitted.

E1F10 [97.201]
Who may be the control operator of an auxiliary station? **Only Technician, General, Advanced or Amateur Extra Class operators**
When an amateur station, such as a repeater, is remotely controlled over a radio link, there is another station involved, the station doing the controlling. This "control" station is, under the FCC rules, called an auxiliary station defined by the FCC.

E1F11 [97.317]
Which of the following best describes one of the standards that must be met by an external RF power amplifier if it is to qualify for a grant of FCC certification? **It must satisfy the FCC's spurious emission standards when operated at the lesser of 1500 watts or its full output power**

SUBELEMENT E2 - OPERATING PROCEDURES [5 Exam Questions - 5 Groups]

E2A Amateur radio in space: amateur satellites; orbital mechanics; frequencies and modes; satellite hardware; satellite operations

E2A01
What is the direction of an ascending pass for an amateur satellite? **From south to north**

E2A02
Which of the following occurs when a satellite is using an inverted linear transponder?
A. Doppler shift is reduced because the uplink and downlink shifts are in opposite directions
B. Signal position in the band is reversed
C. Upper sideband on the uplink becomes lower sideband on the downlink, and vice versa
D. All these choices are correct

E2A03
How is the signal inverted by an inverting linear transponder? **The signal is passed through a mixer and the difference rather than the sum is transmitted**
a mixer, or frequency mixer, is a nonlinear electrical circuit that creates new frequencies from two signals applied to it. In its most common application, two signals are applied to a mixer, and it produces new signals at the sum and difference of the original frequencies.

E2A04
What is meant by the term "mode" as applied to an amateur radio satellite? **The satellite's uplink and downlink frequency bands**

E2A05
What do the letters in a satellite's mode designator specify? **The uplink and downlink frequency ranges**
The mode designator U/V means the satellite uplink is on UHF and the down link is on VHF. The mode designator V/U means the satellite uplink is on VHF and the down link is on UHF. The mode designator L/U means the satellite uplink is on L-Band (2,268 MHz) and the down link is on UHF.

E2A06
What are Keplerian elements? **Parameters that define the orbit of a satellite**

Satellite	P.	Next Pass	Rise	Length	Azimuth	Elevation	ΔE	Max E	Latitude	Longitude
AO-92	4	00:00:00	10:07:53	00:07:55	46.49	5.49	+	12.8	53.71	-57.84
FO-29	7	00:00:00	10:07:52	00:01:18	321.31	3.09	-	3.1	60.54	-114.55
AO-07	5	00:27:42	10:35:35	00:05:01	87.48	-44.61	+	0.9	-4.70	19.09
AO-73	5	00:30:25	10:38:18	00:10:48	23.49	-66.77	+	16.1	-2.04	84.58
AO-91	4	02:00:55	12:08:47	00:12:13	140.70	-66.56	+	14.1	-54.03	-4.86
SO-50	2	04:13:46	14:21:39	00:09:20	298.65	-48.82	-	7.8	10.81	161.64
AO-85	4	10:48:26	20:56:18	00:08:42	237.80	-2.08	-	7.1	24.29	-106.12
ISS	4	12:54:19	23:03:12	00:08:58	140.70	-54.49	-	12.5	-60.63	-111.14

E2A07
Which of the following types of signals can be relayed through a linear transponder?
A. FM and CW
B. SSB and SSTV
C. PSK and packet
D. All these choices are correct

E2A08
Why should effective radiated power to a satellite that uses a linear transponder be limited?
To avoid reducing the downlink power to all other users
The output power of the satellite is divided among all the users. the stronger the received signal the stronger the transmit signal, reducing power to other users. A transponder in a satellite receives an uplink signal and then retransmits what it hears via its downlink transmitter … much like your local FM repeater does. However, unlike your local FM repeater. Most of our so-called "linear" satellite transponders (sometimes also called "analog" transponders) receive and then retransmit a whole band of frequencies commonly called a passband.

E2A09
What do the terms "L band" and "S band" specify regarding satellite communications?
The 23 centimeter and 13 centimeter bands
 The 23 cm band is the1,300 MHz, the 13 cm band is the 2300 MHz
Microwave Frequency Bands are frequently designated by letters

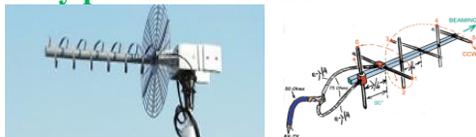| Band	Frequency
L	1-2 GHz
S	2-4 GHz
C	4-8 GHz
X	8-12 GHz

E2A10
What type of satellite appears to stay in one position in the sky?   **Geostationary**
 Like those used for Satellite Radio, Satellite TV and GPS to name a few.

E2A11
What type of antenna can be used to minimize the effects of spin modulation and Faraday rotation?   **A circularly polarized antenna**

E2A12
What is the purpose of digital store-and-forward functions on an amateur radio satellite?
To store digital messages in the satellite for later download by other stations

E2A13
Which of the following techniques is normally used by low Earth orbiting digital satellites to relay messages around the world?   **Store-and-forward**

E2B Television practices: fast scan television standards and techniques; slow scan television standards and techniques

E2B01
How many times per second is a new frame transmitted in a fast-scan (NTSC) television system? **30**
NTSC is the National Television Standards Committee who set the standards for all commercial fast scan TV (the old analog TV system).
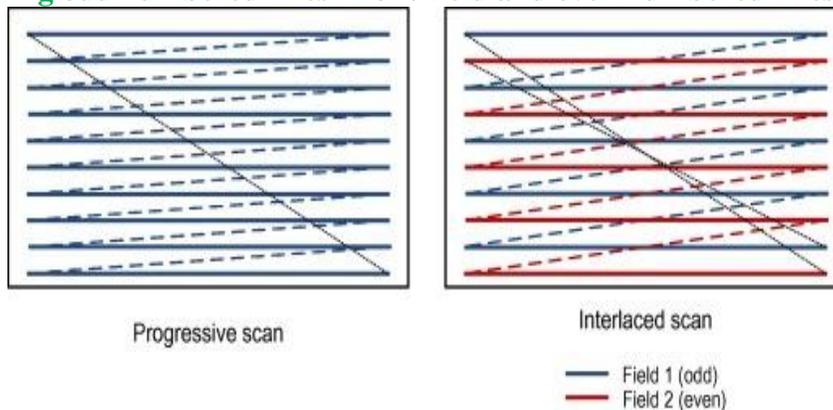
E2B02
How many horizontal lines make up a fast-scan (NTSC) television frame? **525**

E2B03
How is an interlaced scanning pattern generated in a fast-scan (NTSC) television system?
**By scanning odd numbered lines in one field and even numbered lines in the next**

Progressive scan   Interlaced scan

—— Field 1 (odd)
—— Field 2 (even)

E2B04
How is color information sent in analog SSTV?   **Color lines are sent sequentially**

E2B05
Which of the following describes the use of vestigial sideband in analog fast-scan TV transmissions? **Vestigial sideband reduces bandwidth while allowing for simple video detector circuitry**
Fast scan Tv uses AM modulation for the video signal. To reduce the bandwidth one of the sidebands is partly cut off or suppressed, this is called a vestigial sideband.
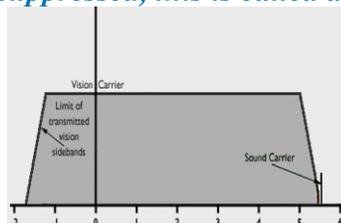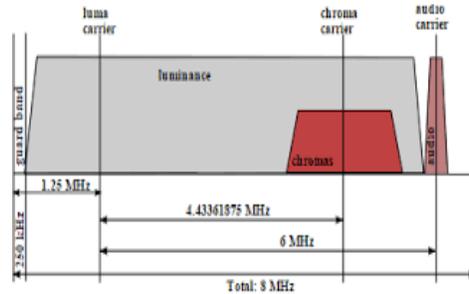

E2B06
What is vestigial sideband modulation? **Amplitude modulation in which one complete sideband and a portion of the other are transmitted**

E2B07
What is the name of the signal component that carries color information in NTSC video?
Chroma

E2B08
What technique allows commercial analog TV receivers to be used for fast-scan TV operations on the 70 cm band? **Transmitting on channels shared with cable TV**

E2B09
What hardware, other than a receiver with SSB capability and a suitable computer, is needed to decode SSTV using Digital Radio Mondiale (DRM)?   **No other hardware is needed**

E2B10
What aspect of an analog slow-scan television signal encodes the brightness of the picture?
Tone frequency

E2B11
What is the function of the Vertical Interval Signaling (VIS) code sent as part of an SSTV transmission?   **To identify the SSTV mode being used**

E2B12
What signals SSTV receiving software to begin a new picture line?
Specific tone frequencies

E2C Operating methods: contest and DX operating; remote operation techniques; Cabrillo format; QSLing; RF network connected systems

E2C01

What indicator is required to be used by U.S.-licensed operators when operating a station via remote control and the remote transmitter is located in the U.S.? **No additional indicator is required**

E2C02

Which of the following best describes the term "self-spotting" in connection with HF contest operating? **The often-prohibited practice of posting one's own call sign and frequency on a spotting network**

E2C03

From which of the following bands is amateur radio contesting generally excluded? **30 meters**

E2C04

Which of the following frequencies are sometimes used for amateur radio mesh networks? **Frequencies shared with various unlicensed wireless data services**

AREDN (Amateur Radio Emergency Data Network) was an outgrowth of the ARRL working group on High-Speed Multimedia (HSMM). It has evolved over the past 10-12 years from its first implementation by Broadband Hamnet (BBHN). Over the years the AREDN Project has developed software support for nearly 70 commercial wireless routers---moving them from their Part 15 allocation into adjacent Part 97 allocations in the .9, 2, 3, and 5 GHz bands---providing an inexpensive and easy way for hams to implement high-speed (up to 144 Mbps) data networks in support of Emergency Operations Centers (EOCs), Non-governmental Agencies (NGOs) and first responders.

E2C05

What is the function of a DX QSL Manager? **To handle the receiving and sending of confirmation cards for a DX station**

E2C06

During a VHF/UHF contest, in which band segment would you expect to find the highest level of SSB or CW activity? **In the weak signal segment of the band, with most of the activity near the calling frequency**

E2C07

What is the Cabrillo format?   **A standard for submission of electronic contest logs**
The Cabrillo Specification was originally developed by Trey Garlough, N5KO to provide a method for consistent data formatting that sponsors could use in the submission of contest logs. This is an example:

```
CONTEST: NAQP-CW
LOCATION: CA
CALLSIGN: N5KO
CATEGORY-OPERATOR: SINGLE-OP
CATEGORY-TRANSMITTER: ONE
CATEGORY-ASSISTED: NON-ASSISTED
CATEGORY-BAND: ALL
CATEGORY-POWER: LOW
CATEGORY-MODE: CW
CATEGORY-STATION: FIXED
CLAIMED-SCORE: 404670
NAME: Trey Garlough
SOAPBOX:
QSO: 28048 CW 2014-01-11 1800 N5KO          TREY      CA  N4PN          PAUL      GA
QSO: 28048 CW 2014-01-11 1800 N5KO          TREY      CA  VE3NZ         BEN       ON
QSO: 28048 CW 2014-01-11 1801 N5KO          TREY      CA  K6DGW         SKIP      CA
QSO: 28048 CW 2014-01-11 1801 N5KO          TREY      CA  AA4LR         BILL      GA
QSO: 28048 CW 2014-01-11 1802 N5KO          TREY      CA  K6RB          ROB       CA
QSO: 28048 CW 2014-01-11 1802 N5KO          TREY      CA  WA1S          ANN       GA
END-OF-LOG:
```

E2C08

Which of the following contacts may be confirmed through the U.S. QSL bureau system?
Contacts between a U.S. station and a non-U.S. station

E2C09

What type of equipment is commonly used to implement an amateur radio mesh network?
A wireless router running custom firmware

E2C10

Why might a DX station state that they are listening on another frequency?
A. Because the DX station may be transmitting on a frequency that is prohibited to some responding stations
B. To separate the calling stations from the DX station
C. To improve operating efficiency by reducing interference
D. All these choices are correct

E2C11

How should you generally identify your station when attempting to contact a DX station during a contest or in a pileup?   **Send your full call sign once or twice**

E2C12

What technique do individual nodes use to form a mesh network? **Discovery and link establishment protocols**

E2D Operating methods: VHF and UHF digital modes and procedures; APRS; EME procedures; meteor scatter procedures

E2D01
Which of the following digital modes is designed for meteor scatter communications?
MSK144
Minimum-shift keying (MSK) is a type of continuous-phase frequency shift keying. **MSK144** *supports short-form messages that can be used after QSO partners have exchanged both call signs.*

E2D02
Which of the following is a good technique for making meteor scatter contacts?
A. 15-second timed transmission sequences with stations alternating based on location
B. Use of special digital modes
C. Short transmissions with rapidly repeated call signs and signal reports
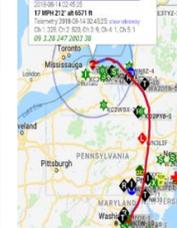**D. All these choices are correct**

E2D03
Which of the following digital modes is especially useful for EME communications?   **JT65**

E2D04
What technology is used to track, in real time, balloons carrying amateur radio transmitters?
APRS

E2D05
What is one advantage of the JT65 mode?   **The ability to decode signals which have a very low signal-to-noise ratio**

E2D06
Which of the following describes a method of establishing EME contacts?   **Time synchronous transmissions alternately from each station**

E2D07
What digital protocol is used by APRS?   **AX.25**

E2D08

What type of packet frame is used to transmit APRS beacon data?   **Unnumbered Information**
On a router each interface requires a unique IP address so it can install an entry in the routing table and process IP packets. IP unnumbered allows you to process IP packets without configuring a unique IP address on an interface, this works by "borrowing" an IP address from another interface.

E2D09

What type of modulation is used for JT65 contacts?   **Multi-tone AFSK**

Audio frequency-shift keying (AFSK) is a modulation technique by which digital data is represented by changes in the frequency (pitch) of an audio tone, yielding an encoded signal suitable for transmission via radio.

E2D10

How can an APRS station be used to help support a public service communications activity?
An APRS station with a Global Positioning System unit can automatically transmit information to show a mobile station's position during the event

E2D11

Which of the following data are used by the APRS network to communicate station location?
Latitude and longitude

E2E Operating methods: operating HF digital modes

E2E01
Which of the following types of modulation is common for data emissions below 30 MHz?
FSK
Frequency-shift keying (FSK) is the frequency modulation system in which digital information is transmitted through the discrete frequency change of a carrier wave.
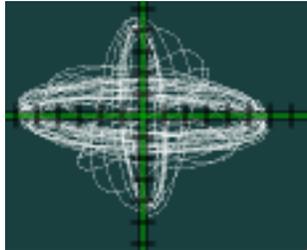
E2E02
What do the letters FEC mean as they relate to digital operation?   **Forward Error Correction**

E2E03
How is the timing of FT4 contacts organized?   **Alternating transmissions at 7.5 second intervals**

E2E04
What is indicated when one of the ellipses in an FSK crossed-ellipse display suddenly disappears?   **Selective fading has occurred**

E2E05
Which of these digital modes does not support keyboard-to-keyboard operation?   **PACTOR**

E2E06
What is the most common data rate used for HF packet?   **300 baud**

E2E07
Which of the following is a possible reason that attempts to initiate contact with a digital station on a clear frequency are unsuccessful?
A. Your transmit frequency is incorrect
B. The protocol version you are using is not supported by the digital station
C. Another station you are unable to hear is using the frequency
D. All these choices are correct

E2E08
Which of the following HF digital modes can be used to transfer binary files?   **PACTOR**

E2E09
Which of the following HF digital modes uses variable-length coding for bandwidth efficiency?
PSK31
PSK31 is distinguished from other digital modes in that it is specifically tuned to have a data rate close to typing speed, and has an extremely narrow bandwidth, allowing many conversations in the same bandwidth as a single voice channel. Variable length codes are used for each character based on frequency of usage. More commonly used characters have shorter codes (Similar to Morse code)

E2E10
Which of these digital modes has the narrowest bandwidth?   **PSK31**

E2E11
What is the difference between direct FSK and audio FSK? **Direct FSK applies the data signal to the transmitter VFO, while AFSK transmits tones via phone**

E2E12
How do ALE stations establish contact?   **ALE constantly scans a list of frequencies, activating the radio when the designated call sign is received**
An Automatic Link Establishment station (ALE) is a feature in an HF communications radio transceiver system that enables the radio station to make contact, or initiate a circuit, between itself and another HF radio station or network of stations.

E2E13

Which of these digital modes has the fastest data throughput under clear communication conditions? **300 baud packet**
The baud rate is the rate at which information is transferred in a communication channel. In the serial port context, "300 baud" means that the serial port can transfer a maximum of 300 bits per second.

SUBELEMENT E3 - RADIO WAVE PROPAGATION [3 Exam Questions - 3 Groups]

E3A Electromagnetic waves; Earth-Moon-Earth communications; meteor scatter; microwave tropospheric and scatter propagation; aurora propagation; ionospheric propagation changes over the day; circular polarization

E3A01
What is the approximate maximum separation measured along the surface of the Earth between two stations communicating by EME?   **12,000 miles, if the moon is visible by both stations**

E3A02
What characterizes libration fading of an EME signal?   **A fluttery irregular fading**

E3A03
When scheduling EME contacts, which of these conditions will generally result in the least path loss? **When the moon is at perigee**
Perigee is when the moons orbit is closest to earth.

E3A04
What do Hepburn maps predict? **Probability of tropospheric propagation**
The troposphere is the lowest portion of the earth's atmosphere, extending from the earth's surface to approximately 4 to 12 miles above it. Under certain conditions signals in the VHF and UHF frequency bands can propagate over great distances through the troposphere due to a phenomenon called tropospheric ducting. A Canadian meteorologist, William R. Hepburn, has developed a method for predicting tropospheric ducting and provides forecasts (available on the Internet) using this method, which predicts signal strength propagation as a result of the ducting phenomenon.

E3A05
Tropospheric propagation of microwave signals often occurs in association with what phenomenon? **Warm and cold fronts**

E3A06
What might help to restore contact when DX signals become too weak to copy across an entire HF band a few hours after sunset? **Switch to a lower frequency HF band**

E3A07
Atmospheric ducts capable of propagating microwave signals often form over what geographic feature? **Bodies of water**
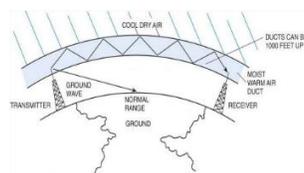
E3A08
When a meteor strikes the Earth's atmosphere, a cylindrical region of free electrons is formed at what layer of the ionosphere? **The E layer**

E3A09
Which of the following frequency ranges is most suited for meteor scatter communications?
28 MHz - 148 MHz

E3A10
Which type of atmospheric structure can create a path for microwave propagation?
Temperature inversion
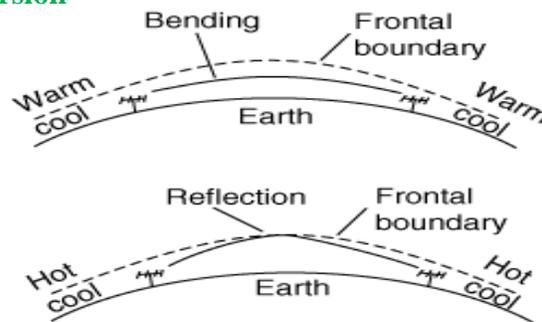
E3A11
What is a typical range for tropospheric propagation of microwave signals? **100 miles to 300 miles**

E3A12
What is the cause of auroral activity? **The interaction in the E layer of charged particles from the Sun with the Earth's magnetic field**

E3A13
Which of these emission modes is best for auroral propagation? **CW**

E3A14
What is meant by circularly polarized electromagnetic waves? **Waves with a rotating electric field**

E3B Transequatorial propagation; long-path; grayline; ordinary and extraordinary waves; chordal hop; sporadic E mechanisms

E3B01
What is transequatorial propagation?   **Propagation between two mid-latitude points at approximately the same distance north and south of the magnetic equator**
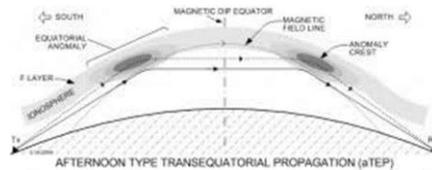
E3B02
What is the approximate maximum range for signals using transequatorial propagation?
5000 miles

E3B03
What is the best time of day for transequatorial propagation?   **Afternoon or early evening**

E3B04
What is meant by the terms "extraordinary" and "ordinary" waves?   **Independent waves created in the ionosphere that are elliptically polarized**
Caused by the scattering of electromagnetic radiation during propagation through the ionosphere.

E3B05
Which amateur bands typically support long-path propagation?   **160 meters to 10 meters**
The higher HF frequencies above 20 meters are dependent on solar cycle and solar activity.

E3B06
Which of the following amateur bands most frequently provides long-path propagation?   **20 meters**
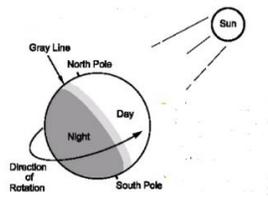*14 MHz.*

E3B07
What happens to linearly polarized radio waves that split into ordinary and extraordinary waves in the ionosphere?   **They become elliptically polarized**

E3B08
What is the term for the long path opening that exists between two points on the Earth which are simultaneously near sunrise and sunset?   **Grayline**

E3B09

At what time of year is sporadic E propagation most likely to occur?   **Around the solstices, especially the summer solstice**
Occurs either of the two times in the year, the summer solstice and the winter solstice, when the sun reaches its highest or lowest point in the sky at noon, marked by the longest and shortest days.

E3B10

Why is chordal hop propagation desirable?   **The signal experiences less loss compared to multi-hop using Earth as a reflector**
Chordal hop propagation is a propagation mode involving the daylight F2 layer and night time F layer where the signal does not touch Earth's surface but reflects off the F-layer

E3B11

At what time of day can sporadic E propagation occur?   **Any time**

E3B12

What is the primary characteristic of chordal hop propagation?   **Successive ionospheric refractions without an intermediate reflection from the ground**

E3C Radio horizon; ground wave; propagation prediction techniques and modeling; effects of space weather parameters on propagation

E3C01
What does the radio communication term "ray tracing" describe?   **Modeling a radio wave's path through the ionosphere**
Ray tracing is a method for calculating the path of waves or particles through a system with regions of varying propagation velocity, absorption characteristics, and reflecting surfaces.

E3C02
What is indicated by a rising A or K index?   **Increasing disruption of the geomagnetic field**
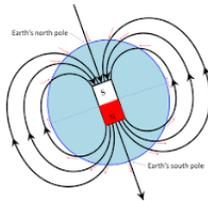
Earth's magnetic field, also known as the geomagnetic field, is the magnetic field that extends from the Earth's interior out into space, where it interacts with the solar wind, a stream of charged particles emanating from the Sun.

E3C03
Which of the following signal paths is most likely to experience high levels of absorption when the A index or K index is elevated?   **Polar**

E3C04
What does the value of Bz (B sub Z) represent?   **Direction and strength of the interplanetary magnetic field**

E3C05
What orientation of Bz (B sub z) increases the likelihood that incoming particles from the sun will cause disturbed conditions? **Southward**
South-pointing B_z's often herald widespread auroras, triggered by solar wind gusts or coronal mass ejections that can inject energy into our planet's magnetosphere.

E3C06
By how much does the VHF/UHF radio horizon distance exceed the geometric horizon?
By approximately 15 percent of the distance

E3C07
Which of the following descriptors indicates the greatest solar flare intensity?   **Class X**

Class	Intensity (erg cm^{-2} s^{-1})	I (W m^{-2})
A	10^{-5}	10^{-8}
B	10^{-4}	10^{-7}
C	10^{-3}	10^{-6}
M	10^{-2}	10^{-5}
X	10^{-1}	10^{-4}

E3C08

What does the space weather term "G5" mean?   **An extreme geomagnetic storm**
Geomagnetic Storms are disturbances in the geomagnetic field caused by gusts in the solar wind that blows by Earth and are measured n a scale from 1 (minor) to 5 (extreme)

E3C09

How does the intensity of an X3 flare compare to that of an X2 flare?   **50 percent greater**
A solar flare is a sudden flash of increased brightness on the Sun.   An X2 flare is twice the strength of an X1 flare, an X3 flare is three times as powerful as an X1, and only 50% more powerful than an X2.

E3C10

What does the 304A solar parameter measure?   **UV emissions at 304 angstroms, correlated to the solar flux index**
304A can be thought of as 304 Angstroms) in the Ultraviolet Light Spectrum which is 100 to 4,000 angstroms.   Solar Flux Index (SFI) is measured in solar flux units (SFUs). SFI is defined as the amount of flux (radio noise) emitted at 2800 MHz.

E3C11

What does VOACAP software model? **HF propagation**
VOACAP (Voice of America Coverage Analysis Program) is free professional high-frequency (HF) propagation prediction software from NTIA/ITS, originally developed for Voice of America. NTIA/ITS .   National Telecommunications and Information Administration, ITS is the Institute for Telecommunication Sciences.

E3C12 (C)

How does the maximum range of ground-wave propagation change when the signal frequency is increased? **It decreases**

E3C13

What type of polarization is best for ground-wave propagation?   **Vertical**

E3C14

Why does the radio-path horizon distance exceed the geometric horizon? **Downward bending due to density variations in the atmosphere**

E3C15

What might be indicated by a sudden rise in radio background noise across a large portion of the HF spectrum? **A solar flare has occurred**

## SUBELEMENT E4 - AMATEUR PRACTICES [5 Exam Questions - 5 Groups]

E4A Test equipment: analog and digital instruments; spectrum analyzers; antenna analyzers; oscilloscopes; RF measurements; computer-aided measurements

E4A01
Which of the following limits the highest frequency signal that can be accurately displayed on a digital oscilloscope?   **Sampling rate of the analog-to-digital converter**

E4A02
Which of the following parameters does a spectrum analyzer display on the vertical and horizontal axes?   **RF amplitude and frequency**
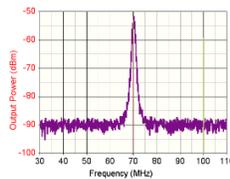
E4A03
Which of the following test instruments is used to display spurious signals and/or intermodulation distortion products generated by an SSB transmitter?   **A spectrum analyzer**

E4A04
How is the compensation of an oscilloscope probe typically adjusted?   **A square wave is displayed, and the probe is adjusted until the horizontal portions of the displayed wave are as nearly flat as possible**
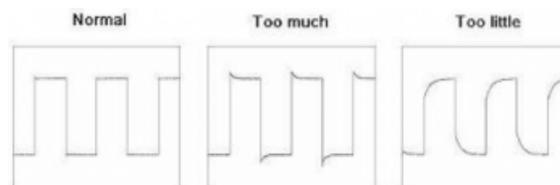
E4A05
What is the purpose of the prescaler function on a frequency counter?   **It divides a higher frequency signal so a low-frequency counter can display the input frequency**

E4A06
What is the effect of aliasing on a digital oscilloscope caused by setting the time base too slow?
A false, jittery low-frequency version of the signal is displayed
Aliasing is an undesired effect in which the sampling frequency is too low to accurately reproduce the original analog content, resulting in signal distortion. Frequency aliasing is a common problem in signal conversion systems whose sampling rate is too slow to read input signals of a much higher frequency.

E4A07
Which of the following is an advantage of using an antenna analyzer compared to an SWR bridge to measure antenna SWR? **Antenna analyzers do not need an external RF source**
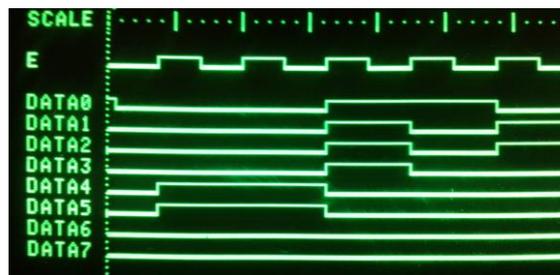

E4A08
Which of the following measures SWR? **An antenna analyzer**

E4A09
Which of the following is good practice when using an oscilloscope probe? **Keep the signal ground connection of the probe as short as possible**

E4A10
Which of the following displays multiple digital signal states simultaneously? **Logic analyzer**

E4A11
How should an antenna analyzer be connected when measuring antenna resonance and feed point impedance? **Connect the antenna feed line directly to the analyzer's connector**
Before connecting a feed line to an antenna analyzer short circuit the feed line to eliminate anystatic charge that could damage the analyzer

E4B Measurement technique and limitations: instrument accuracy and performance limitations; probes; techniques to minimize errors; measurement of Q; instrument calibration; S parameters; vector network analyzer

E4B01
Which of the following factors most affects the accuracy of a frequency counter?   **Time base accuracy**
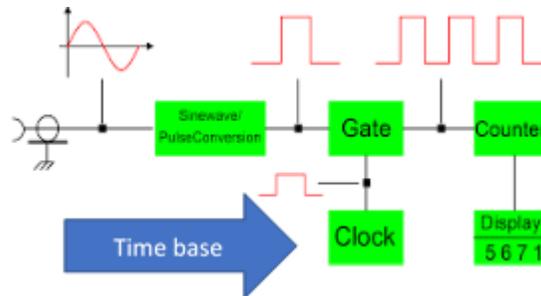
*The gate open time is determined by the time base, which determines the time over which the incoming signal is counted.*

E4B02
What is the significance of voltmeter sensitivity expressed in ohms per volt?   **The full scale reading of the voltmeter multiplied by its ohms per volt rating will indicate the input impedance of the voltmeter**
A 1,000 ohm per volt voltmeter will have an input resistance of 100K ohms on the 100 volt full scale range and an input resistance of 10K ohms on the 10 volt full scale range .

E4B03
Which S parameter is equivalent to forward gain?   **S21**
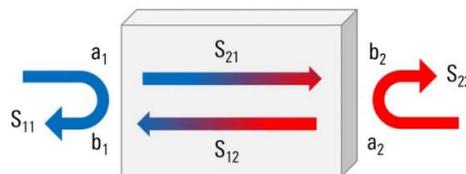
E4B04
Which S parameter represents input port return loss or reflection coefficient (equivalent to VSWR)?   **S11**

E4B05
What three test loads are used to calibrate an RF vector network analyzer? **A Short circuit, open circuit, and 50 ohms**

E4B06
How much power is being absorbed by the load when a directional power meter connected between a transmitter and a terminating load reads 100 watts forward power and 25 watts reflected power?   **75 watts**
Power to load is the forward power minus returned power or 100 watts minus 25watts or 75 watts

E4B07
What do the subscripts of S parameters represent?   **The port or ports at which measurements are made**
S11 is the input impedance, S22 is the output impedance, S21 is the output relative to the input (Gain), S12 is input relative to the output (reflected energy from the load). See graphic for E4B03

E4B08
Which of the following can be used to measure the Q of a series-tuned circuit?   **The bandwidth of the circuit's frequency response**
A circuit with a center frequency of 7.3 MHz and 3 dB bandwidth of 30,000 Hz would have a Q of: Q = center frequency ÷ Δ 3dB Bandwidth or 7,300,000 ÷ 30,000 or 243

E4B09
What is indicated if the current reading on an RF ammeter placed in series with the antenna feed line of a transmitter increases as the transmitter is tuned to resonance?   **There is more power going into the antenna**
Basic Power law. P = E ÷ I, since the antenna is a fixed impedance as the current increases there is more power flowing into the antenna.

E4B10
Which of the following methods measures intermodulation distortion in an SSB transmitter?
Modulate the transmitter using two AF signals having non-harmonically related frequencies and observe the RF output with a spectrum analyzer
Typical test tones are approx. 700 Hz and 1,900 Hz.

E4B11
Which of the following can be measured with a vector network analyzer?
A. Input impedance
B. Output impedance
C. Reflection coefficient
D. All these choices are correct

E4C Receiver performance characteristics: phase noise, noise floor, image rejection, MDS, signal-to-noise ratio, noise figure, reciprocal mixing; selectivity; effects of SDR receiver non-linearity; use of attenuators at low frequencies

E4C01
What is an effect of excessive phase noise in a receiver's local oscillator? **It can combine with strong signals on nearby frequencies to generate interference**
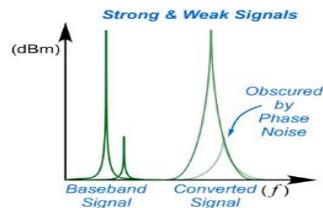
When the local oscillator (LO) in a receiver has excessive Phase Noise the down converted signal may be obscured by the LO Phase Noise.

E4C02
Which of the following receiver circuits can be effective in eliminating interference from strong out-of-band signals? **A front-end filter or pre-selector**
This is a narrow band fixed or tunable filter placed just after the antenna in a receiver

E4C03
What is the term for the suppression in an FM receiver of one signal by another stronger signal on the same frequency? **Capture effect**

E4C04
What is the noise figure of a receiver?   **The ratio in dB of the noise generated by the receiver to the theoretical minimum noise**
Theoretical Noise power is a function of temperature and receiver bandwidth at 290° Kelvin (62° Fahrenheit) the theoretical noise floor is -174 dBm in a 1 Hz bandwidth. This means a perfect receiver would not be able to receive a signal below this value. A receiver with a 3 KHz bandwidth (a 34.7 dB wider bandwidth than 1 Hz) would have a theoretical noise floor of − 139 dBm (.02 μV).

E4C05
What does a receiver noise floor of -174 dBm represent?   **The theoretical noise in a 1 Hz bandwidth at the input of a perfect receiver at room temperature**

The noise power available in 1 Hz bandwidth from a source is −174 dBm (174 dB below the one milliwatt level taken as a reference) at temperature of + 290° Kelvin (17° Celsius or 62° Fahrenheit). Using this value and knowing the bandwidth of our receiver and its noise figure we can determine the smallest signal level that we could expect to receive.

E4C06
A CW receiver with the AGC off has an equivalent input noise power density of -174 dBm/Hz. What would be the level of an unmodulated carrier input to this receiver that would yield an audio output SNR of 0 dB in a 400 Hz noise bandwidth?   **-148 dBm**
Difference in dB from 1 Hz to 400 Hz is 10(log)(400 ÷ 1)) or   10 (2.602) or +26.02 dB. Therefore, the noise floor would be -174 + 26.02 or – 147.98 dBm.

E4C07
What does the MDS of a receiver represent?   **The minimum discernible signal**
 In other words, the smallest signal that can be detected or received.

E4C08
An SDR receiver is overloaded when input signals exceed what level?   **The reference voltage of the analog-to-digital converter**
ADCs convert analog inputs that can vary from zero volts on up to a maximum voltage level that is called the reference voltage. The reference voltage that determines the ceiling of what the Analog to Digital Converter can convert.

E4C09
Which of the following choices is a good reason for selecting a high frequency for the design of the IF in a superheterodyne HF or VHF communications receiver?   **Easier for front-end circuitry to eliminate image responses**
This is because the Image frequencies will be higher (further away).

E4C10
What is an advantage of having a variety of receiver IF bandwidths from which to select?
Receive bandwidth can be set to match the modulation bandwidth, maximizing signal-to-noise ratio and minimizing interference
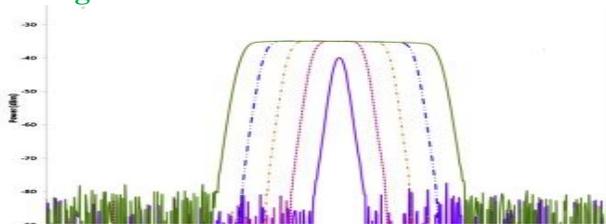
E4C11
Why can an attenuator be used to reduce receiver overload on the lower frequency HF bands with little or no impact on signal-to-noise ratio?   **Atmospheric noise is generally greater than internally generated noise even after attenuation**

E4C12
Which of the following has the largest effect on an SDR receiver's dynamic range?   **Analog-to-digital converter sample width in bits**

E4C13

How does a narrow-band roofing filter affect receiver performance?   **It improves dynamic range by attenuating strong signals near the receive frequency**

A Roofing filter is a type of filter used in a HF radio receiver. It is usually found after the first receiver mixer. The goal of a roofing filter is to limit the passband of the first intermediate frequency (IF) stage. Additional filters for specific modulation types follow the roofing filter stage.

E4C14

What transmit frequency might generate an image response signal in a receiver tuned to 14.300 MHz and that uses a 455 kHz IF frequency?

A. 13.845 MHz

B. 14.755 MHz

C. 14.445 MHz

D. 15.210 MHz

A mixer will generate a 455 KHz difference frequency from a 14.300 signal with an LO of 14.750 MHz and with a frequency of 14.300. The 14.750 is the image frequency
This example assumes the Local Oscillator is <u>above </u>the receive frequency.

E4C15

What is reciprocal mixing?   **Local oscillator phase noise mixing with adjacent strong signals to create interference to desired signals**

E4D Receiver performance characteristics: blocking dynamic range; intermodulation and cross-modulation interference; third-order intercept; desensitization; preselector

E4D01
What is meant by the blocking dynamic range of a receiver? **The difference in dB between the noise floor and the level of an incoming signal that will cause 1 dB of gain compression**

E4D02
Which of the following describes problems caused by poor dynamic range in a receiver?
Spurious signals caused by cross-modulation and desensitization from strong adjacent signals

E4D03
How can intermodulation interference between two repeaters occur? **When the repeaters are in close proximity and the signals mix in the final amplifier of one or both transmitters**
Placing a circulator in the transmitter output will prevent signals from coming back from the antenna into the transmitter output. A circulator is a one way path for the transmit signal.

E4D04
Which of the following may reduce or eliminate intermodulation interference in a repeater caused by another transmitter operating in close proximity? **A properly terminated circulator at the output of the repeater's transmitter**
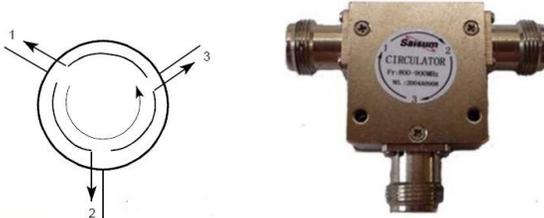
E4D05
What transmitter frequencies would cause an intermodulation-product signal in a receiver tuned to 146.70 MHz when a nearby station transmits on 146.52 MHz? **146.34 MHz and 146.61 MHz**
IM interference = ((145.52)(2)) – (146.70) or (293.04) - (146.70) or 146.34 also
IM interference = ((146.70 + 146.52) ÷ (2)) or (293.220) ÷ (2) or 146.61

E4D06
What is the term for spurious signals generated by the combination of two or more signals in a non-linear device or circuit? **Intermodulation**
Intermodulation (IM) or intermodulation distortion (IMD) is the amplitude modulation of signals containing two or more different frequencies, caused by nonlinearities in a system.

E4D07
Which of the following reduces the likelihood of receiver desensitization?   **Decrease the RF bandwidth of the receiver**
Desensitization of a receiver is caused by overload to the receiver from strong nearby transmitters. Reducing the bandwidth may eliminate nearby interfering signals.

E4D08
What causes intermodulation in an electronic circuit? **Nonlinear circuits or devices**

E4D09
What is the purpose of the preselector in a communications receiver?   **To increase rejection of signals outside the desired band**

E4D10
What does a third-order intercept level of 40 dBm mean with respect to receiver performance?
A pair of 40 dBm input signals will theoretically generate a third-order intermodulation product that has the same output amplitude as either of the input signals
The third-order intercept point is an extrapolated convergence – not directly measurable – of intermodulation distortion products in the desired output. It indicates how well a device (for example an amplifier) or a system (for example, a receiver) performs in the presence of strong signals.
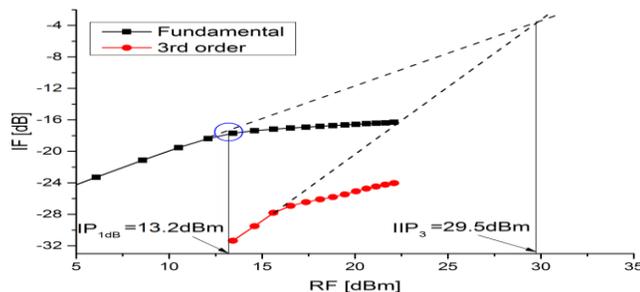
E4D11
Why are odd-order intermodulation products, created within a receiver, of particular interest compared to other products? **Odd-order products of two signals in the band of interest are also likely to be within the band**

E4D12
What is the term for the reduction in receiver sensitivity caused by a strong signal near the received frequency? **Desensitization**

E4E Noise suppression and interference: system noise; electrical appliance noise; line noise; locating noise sources; DSP noise reduction; noise blankers; grounding for signals; common mode currents

E4E01
What problem can occur when using an automatic notch filter (ANF) to remove interfering carriers while receiving CW signals?   **Removal of the CW signal as well as the interfering carrier**

E4E02
Which of the following types of noise can often be reduced with a digital signal processing noise filter?
A. Broadband white noise
B. Ignition noise
C. Power line noise
D. All these choices are correct

E4E03
Which of the following signals might a receiver noise blanker be able to remove from desired signals? **Signals that appear across a wide bandwidth**
In radio receivers, a noise blanker is a circuit intended to reduce the effect of certain kinds of radio noise on a received signal. It is often used on shortwave receivers or communications receivers   The noise blanker is only effective on impulse-type noise such as from lightning or from automotive ignition systems, and cannot improve performance on wideband noise.

E4E04
How can conducted and radiated noise caused by an automobile alternator be suppressed?
By connecting the radio's power leads directly to the battery and by installing coaxial capacitors in line with the alternator leads

E4E05
How can radio frequency interference from an AC motor be suppressed?   **By installing a brute-force AC-line filter in series with the motor leads**
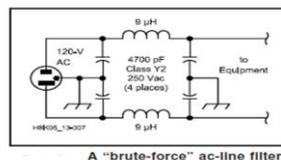
E4E06
What is one type of electrical interference that might be caused by a nearby personal computer?
The appearance of unstable modulated or unmodulated signals at specific frequencies

E4E07
Which of the following can cause shielded cables to radiate or receive interference? **Common-mode currents on the shield and conductors**

E4E08
What current flows equally on all conductors of an unshielded multi-conductor cable?
Common-mode current
Common-mode current **is** *current* **that is not opposed or counteracted by an equal and opposite phase** *current* **flowing at every point along the line in closely-spaced conductor or conductors, and the outside of the shield has** *current* **flowing in a coaxial line. This is an unwanted current**

E4E09
What undesirable effect can occur when using an IF noise blanker?   **Nearby signals may appear to be excessively wide even if they meet emission standards**
To detect sharp noise pulses, the nose blanker must detect signals over a wide bandwidth and therefore can not be protected by narrow receive filters. The noise blanker can be fooled by strong signals as if they were noise pulses causing the receiver to shut down. This can cause distortion of the desired signals even of no noise was present. This might sound as if the strong signal is very wide with lots of spurious signals.

E4E10
What might be the cause of a loud roaring or buzzing AC line interference that comes and goes at intervals?
A. Arcing contacts in a thermostatically controlled device
B. A defective doorbell or doorbell transformer inside a nearby residence
C. A malfunctioning illuminated advertising display
D. All these choices are correct

E4E11
What could cause local AM broadcast band signals to combine to generate spurious signals in the MF or HF bands? **Nearby corroded metal joints are mixing and re-radiating the broadcast signals**
The corroded joints act as a diode causing the mixing of signals and generating harmonics and mixing products.

SUBELEMENT E5 – ELECTRICAL PRINCIPLES [4 Exam Questions - 4 Groups]

E5A Resonance and Q: characteristics of resonant circuits: series and parallel resonance; definitions and effects of Q; half-power bandwidth; phase relationships in reactive circuits

E5A01
What can cause the voltage across reactance's in a series RLC circuit to be higher than the voltage applied to the entire circuit?   **Resonance**
Resonance occurs when the capacitive reactance and inductive reactance of components in parallel or series have equal values of reactance.

E5A02
What is resonance in an LC or RLC circuit?   **The frequency at which the capacitive reactance equals the inductive reactance**

E5A03
What is the magnitude of the impedance of a series RLC circuit at resonance?   **Approximately equal to circuit resistance**
Because the net value of capacitive and inductive reactance is zero, then the only limit to current flow is the circuit resistance.

E5A04
What is the magnitude of the impedance of a parallel RLC circuit at resonance? **Approximately equal to circuit resistance**
Because the net value of capacitive and inductive reactance is zero, then the only circuit resistance is the DC resistance of the components.

E5A05
What is the result of increasing the Q of an impedance-matching circuit? **Matching bandwidth is decreased**

E5A06
What is the magnitude of the circulating current within the components of a parallel LC circuit at resonance?   **It is at a maximum**
Circulating current is the exchange of energy between the capacitor and the inductor.

E5A07
What is the magnitude of the current at the input of a parallel RLC circuit at resonance? **Minimum**

E5A08
What is the phase relationship between the current through and the voltage across a series resonant circuit at resonance? **The voltage and current are in phase**

E5A09
How is the Q of an RLC parallel resonant circuit calculated?   **Resistance divided by the reactance of either the inductance or capacitance**
Q = Resistance ÷ Reactance (X_L or X_C)
Example: *The Q of a parallel resonant circuit with 50 ohms reactance and 1,000 ohms resistance is: Q = 1,000 ÷ 50 or Q = 20*

E5A10
How is the Q of an RLC series resonant circuit calculated?   **Reactance of either the inductance or capacitance divided by the resistance**
Q = Reactance (X_L or X_C) ÷ Resistance
Example: *The Q of series resonant circuit with 500 ohms reactance and 5 ohms resistance is: Q = 500 ÷ 5 or Q= 100*

E5A11
What is the half-power bandwidth of a resonant circuit that has a resonant frequency of 7.1 MHz and a Q of 150?   **47.3 kHz**
Bandwidth = Frequency ÷ Q or 7,100,000 kHz ÷ 150 or 47.3 kHz

E5A12
What is the half-power bandwidth of a resonant circuit that has a resonant frequency of 3.7 MHz and a Q of 118?   **31.4 kHz**
Bandwidth = Frequency ÷ Q or 3,700,000 kHz ÷ 118 or 31.356 kHz

E5A13
What is an effect of increasing Q in a series resonant circuit**?   Internal voltages increase**
High Q circuits can generate very high voltages.

E5A14
What is the resonant frequency of an RLC circuit if R is 22 ohms, L is 50 microhenries and C is 40 picofarads? **3.56 MHz**
Resonant Frequency = 1 ÷ ((2 π) ($\sqrt{}$ ($L_{Microhenries}$) ($C_{Microfarads}$)) or
1 ÷ ((2 π) ($\sqrt{}$ (50) (40^-6)) or 1 ÷ ((2 π) ($\sqrt{}$ (.0020)) or 1 ÷ ((6.283) (.04472)) or
* 1 ÷ (0.281) or 3.558 MHz*

E5A15
Which of the following increases Q for inductors and capacitors?   **Lower losses**
Lower resistive losses.

E5A16
What is the resonant frequency of an RLC circuit if R is 33 ohms, L is 50 microhenries and C is 10 picofarads?   **7.12 MHz**
RF = 1 ÷ ((2) (π)) ($\sqrt{}$ ($L_{Microhenries}$) ($C_{Microfarads}$)) or RF = 1 ÷ ((2) (π) (($\sqrt{}$ (50) (10^-6))) or
RF = 1 ÷ ((2) (3.1415)) $\sqrt{}$ (0.00050)) or RF = 1 ÷ ((6.283) (.02236)) or RF = 1 ÷ 0.1405 or
Resonant Frequency = 7.117 MHz

E5B Time constants and phase relationships: RL and RC time constants; phase angle in reactive circuits and components; admittance and susceptance

E5B01
What is the term for the time required for the capacitor in an RC circuit to be charged to 63.2% of the applied voltage or to discharge to 36.8% of its initial voltage?   **One time constant**
Time constant (τ) in seconds = R x C with capacity in µF and R in Megohms. For example, a 1 meg ohm resistor connected to a 10 µF capacitor will have a time constant of 10 Seconds: τ = 1 meg ohm x 10 µF =10 Seconds.

E5B02
What letter is commonly used to represent susceptance?   **B**
Susceptance, mathematically, it is equal to 1/reactance, or the reciprocal of reactance. It is measured in Siemens. Its mathematical symbol is "B".

E5B03
How is impedance in polar form converted to an equivalent admittance?
Take the reciprocal of the magnitude and change the sign of the angle
An impedance of 5 Ω at 37° would be an admittance of 0.2 at -37•

E5B04
What is the time constant of a circuit having two 220 microfarad capacitors and two 1 megohm resistors, all in parallel?   **220 seconds**
τ$_{(time constant)}$ = (1 megohm ÷ 2) (220) (2) or τ = (.5) (440) or τ =220 seconds

E5B05
What happens to the magnitude of a pure reactance when it is converted to a susceptance?
It becomes the reciprocal
A positive reactance becomes a negative susceptance and a negative reactance becomes a positive susceptance.

E5B06
What is susceptance? **The imaginary part of admittance**
Susceptance is one divided by the reactance.

E5B07
What is the phase angle between the voltage across and the current through a series RLC circuit if XC is 500 ohms, R is 1 kilohm, and XL is 250 ohms? **14.0 degrees with the voltage lagging the current**
Tangent of Θ = Y ÷ X or Tangent of Θ = (50 - 25) ÷ 100 or Tangent of Θ= -.25 or Θ = +14.04°
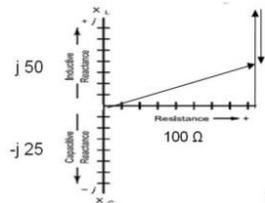
E5B08
What is the phase angle between the voltage across and the current through a series RLC circuit if XC is 100 ohms, R is 100 ohms, and XL is 75 ohms?
14 degrees with the voltage lagging the current

Tangent of Θ = Y ÷ X or Tangent of Θ = (-100 +75) ÷ 100 or arc Tangent of Θ = -25÷100 or arc Tangent of Θ = -0 .25 or Θ = -14.04°

100 Ω

100 Ω

75 Ω
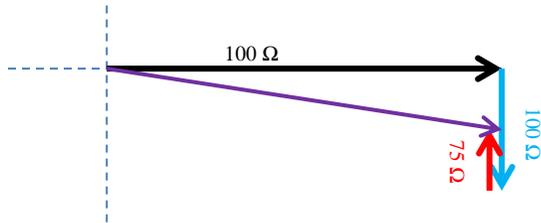
E5B09
What is the relationship between the AC current through a capacitor and the voltage across a capacitor? **Current leads voltage by 90 degrees**
Because initially the capacitor looks like a very low impedance.

E5B10
What is the relationship between the AC current through an inductor and the voltage across an inductor? **Voltage leads current by 90 degrees**
Initially the inductor looks like a very High impedance.

E5B11
What is the phase angle between the voltage across and the current through a series RLC circuit if XC is 25 ohms, R is 100 ohms, and XL is 50 ohms? **14 degrees with the voltage leading the current**

Tangent of Θ = Y ÷ X or Tangent of Θ = (50 – 25) ÷ 100 or arc Tangent of Θ = 0 .25 or Θ = +14.04°

E5B12
What is admittance? **The inverse of impedance**
Admittance is measured in the unit of Siemens, and its symbol is "Y". Like impedance, admittance is a complex quantity rather than a scalar (X,Y value).

E5C Coordinate systems and phasors in electronics: Rectangular Coordinates; Polar Coordinates; Phasors

E5C01
Which of the following represents capacitive reactance in rectangular notation? **–jx**

E5C02
How are impedances described in polar coordinates?   **By phase angle and magnitude**
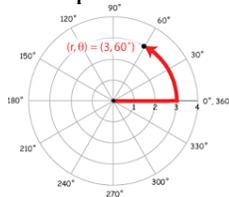
E5C03
Which of the following represents an inductive reactance in polar coordinates?   **A positive phase angle**

E5C04
What coordinate system is often used to display the resistive, inductive, and/or capacitive reactance components of impedance?   **Rectangular coordinates**
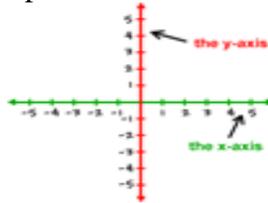
E5C05
What is the name of the diagram used to show the phase relationship between impedances at a given frequency?   **Phasor diagram**
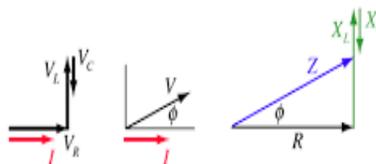
E5C06
What does the impedance 50 –j25 represent? **50 ohms resistance in series with 25 ohms capacitive reactance**

E5C07
Where is the impedance of a pure resistance plotted on rectangular coordinates? **On the horizontal axis**

E5C08
What coordinate system is often used to display the phase angle of a circuit containing resistance, inductive and/or capacitive reactance? **Polar coordinates**
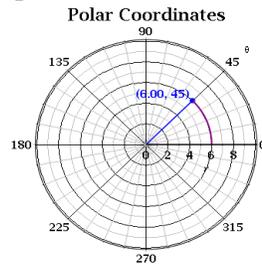
Polar Coordinates

E5C09
When using rectangular coordinates to graph the impedance of a circuit, what do the axes represent? **The X axis represents the resistive component and the Y axis represents the reactive component**
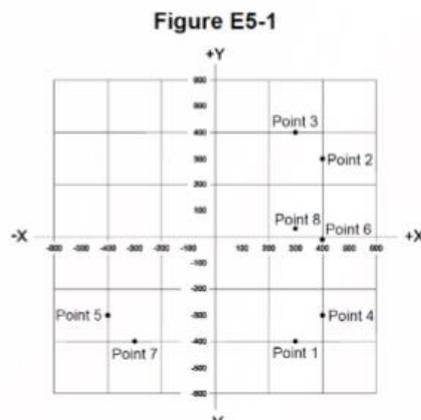
Figure E5-1

E5C10
Which point on Figure E5-1 best represents the impedance of a series circuit consisting of a 400-ohm resistor and a 38-picofarad capacitor at 14 MHz? **Point 4**
$X_c = 1 \div ((2)(\pi)(F)(C))$ or $X_c = 1 \div ((6.28)(14)(0.000038))$ or $X_c = -299\,\Omega$
In rectangular coordinates 400Ω (X Axis) and -299 Ω (Y axis)

E5C11
Which point in Figure E5-1 best represents the impedance of a series circuit consisting of a 300-ohm resistor and an 18-microhenry inductor at 3.505 MHz?   **Point 3**

$X_L = ((2)(\pi)(F)(L))$ or $X_L = (6.28)\,(3.505)\,(18))$ or $X_L = +396.4\,\Omega$
In rectangular coordinates 300Ω (X Axis) and -+396Ω (Y axis)

E5C12 Which point on Figure E5-1 best represents the impedance of a series circuit consisting of a 300-ohm resistor and a 19-picofarad capacitor at 21.200 MHz? **Point 1**

$X_c = 1 \div ((2)(\pi)(F)(C))$ or $X_c = 1 \div ((6.28)\,(21.2)\,(0.000019))$ or $X_c = -395\,\Omega$
In rectangular coordinates 300Ω (X Axis) and -395 Ω (Y axis)

E5D AC and RF energy in real circuits: skin effect; electromagnetic fields; reactive power; power factor; electrical length of conductors at UHF and microwave frequencies; microstrip

E5D01

What is the result of skin effect?   **As frequency increases, RF current flows in a thinner layer of the conductor, closer to the surface**

Cross-sectional area of a round conductor available for conducting DC current

Cross-sectional area of the same conductor available for conducting low-frequency AC

Cross-sectional area of the same conductor available for conducting high-frequency AC
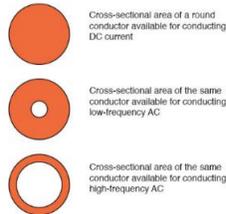
E5D02

Why is it important to keep lead lengths short for components used in circuits for VHF and above?   **To avoid unwanted inductive reactance**

E5D03

What is microstrip?   **Precision printed circuit conductors above a ground plane that provide constant impedance interconnects at microwave frequencies**
Impedance is a function of conductor width and distance above the ground plane.

conductor

W   L

h   dielectric (ε,)

ground
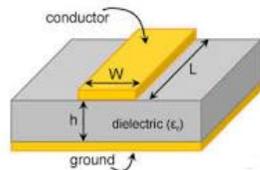
E5D04

Why are short connections used at microwave frequencies?   **To reduce phase shift along the connection**

E5D05

What is the power factor of an RL circuit having a 30-degree phase angle between the voltage and the current?   **0.866**
Power factor is the cosine of the phase angle or cosine of 30° or 0.866

E5D06

In what direction is the magnetic field oriented about a conductor in relation to the direction of electron flow? **In a circle around the conductor**
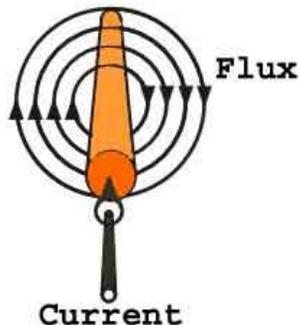
E5D07

How many watts are consumed in a circuit having a power factor of 0.71 if the apparent power is 500VA?   **355 W**

Watts consumed = (apparent power) (power Factor) or W= (500) (.71) or 355

E5D08

How many watts are consumed in a circuit having a power factor of 0.6 if the input is 200VAC at 5 amperes? **600 watts**

W= (Volts) (Current) (Power factor) or W= (200) (5) (.6) or W= 600

E5D09

What happens to reactive power in an AC circuit that has both **ideal inductors** and **ideal capacitors**?   **It is repeatedly exchanged between the associated magnetic and electric fields, but is not dissipated**

E5D10

How can the true power be determined in an AC circuit where the voltage and current are out of phase? **By multiplying the apparent power by the power factor**

E5D11

What is the power factor of an RL circuit having a 60-degree phase angle between the voltage and the current? **0.5**

Power factor = Cosine (angle) or Cosine 60°) or 0.500

E5D12

How many watts are consumed in a circuit having a power factor of 0.2 if the input is 100 VAC at 4 amperes? **80 watts**

W= (Volts) (Current) (Power factor) or W= (100) (4) (.2) or W = 80

E5D13
How many watts are consumed in a circuit consisting of a 100-ohm resistor in series with a 100-ohm inductive reactance drawing 1 ampere? **100 watts**
 Power = (Current) (Voltage) **or** *Power = (1) (100)* **or** *Power = 100 watts*

E5D14
What is reactive power? **Wattless, nonproductive power**

E5D15
What is the power factor of an RL circuit having a 45-degree phase angle between the voltage and the current? **0.707**
Power factor = Cosine (angle) **or** *Cosine (45°)* **or** *0.707*
The power factor would be the Cosine of the angle which is 45° or .707

SUBELEMENT E6 - CIRCUIT COMPONENTS [6 Exam Questions - 6 Groups]

E6A Semiconductor materials and devices: semiconductor materials; germanium, silicon, P-type, N-type; transistor types: NPN, PNP, junction, field-effect transistors: enhancement mode; depletion mode; MOS; CMOS; N-channel; P-channel

E6A01
In what application is gallium arsenide used as a semiconductor material? **In microwave circuits**
GaAs components are useful at ultra-high radio frequencies and in fast electronic switching applications. The benefit of using GaAs in devices is that it generates less noise than most other types of semiconductor components and, as a result, is useful in weak-signal amplification applications.

E6A02
Which of the following semiconductor materials contains excess free electrons? **N-type**

E6A03
Why does a PN-junction diode not conduct current when reverse biased? **Holes in P-type material and electrons in the N-type material are separated by the applied voltage, widening the depletion region**
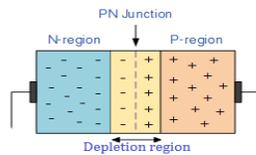
E6A04
What is the name given to an impurity atom that adds holes to a semiconductor crystal structure? **Acceptor impurity**

E6A05
How does DC input impedance at the gate of a field-effect transistor compare with the DC input impedance of a bipolar transistor? **An FET has higher input impedance**

E6A06
What is the beta of a bipolar junction transistor? **The change in collector current with respect to base current**
This is the gain of the transistor. A transistors current gain is given the Greek symbol Beta (β).

E6A07
Which of the following indicates that a silicon NPN junction transistor is biased on? **Base-to-emitter voltage of approximately 0.6 to 0.7 volts**
This is the normal silicon diode junction forward voltage drop which is approx. 0.7 volts.

E6A08
What term indicates the frequency at which the grounded-base current gain of a transistor has decreased to 0.7 of the gain obtainable at 1 kHz? **Alpha cutoff frequency**
Transistor α(alpha) is the gain of a transistor, ß, at a higher frequency compared to the ß of the transistor at 1 KHz, then increasing the frequency till ß is 0.7 of the 1 KHZ ß. This is the alpha cut off frequency.

E6A09
What is a depletion-mode FET? **An FET that exhibits a current flow between source and drain when no gate voltage is applied**
This device requires a bias voltage to stop the current flow, opposite of a normal FET where a bias voltage is required to cause current to flow.

E6A10
In Figure E6-1, what is the schematic symbol for an N-channel dual-gate MOSFET? **4**
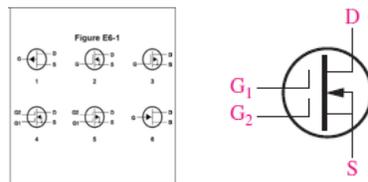
E6A11
In Figure E6-1, what is the schematic symbol for a P-channel junction FET? **1**
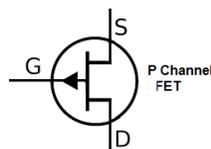
E6A12
Why do many MOSFET devices have internally connected Zener diodes on the gates?
To reduce the chance of static damage to the gate

E6B Diodes

E6B01
What is the most useful characteristic of a Zener diode? **A constant voltage drop under conditions of varying current**
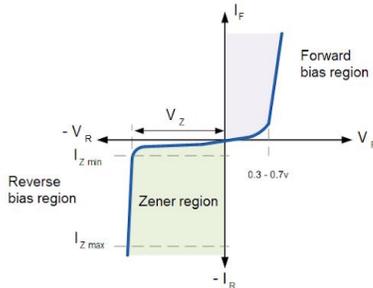
A Zener diode is a diode that when reverse biased will have a constant breakdown voltage vs current flow over a wide range of current. The current must be limited in the Zener region to prevent too much current from flowing which would result in failure of the diode.

E6B02
What is an important characteristic of a Schottky diode as compared to an ordinary silicon diode when used as a power supply rectifier? **Less forward voltage drop**
A Schottky Diode is a metal-semiconductor diode with a low forward voltage drop (Between 0.3 to 0.5 volts) and a very fast switching speed.

E6B03
What type of bias is required for an LED to emit light?   **Forward bias**

E6B04
What type of semiconductor device is designed for use as a voltage-controlled capacitor?
Varactor diode
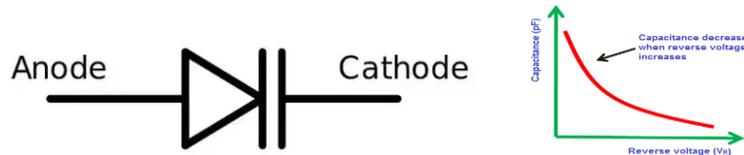
E6B05
What characteristic of a PIN diode makes it useful as an RF switch? **Low junction capacitance**
The PIN diode is used as an ideal radio frequency switch. The intrinsic layer among the P & N layers increases the space between them. This also reduces the capacitance between both the regions, thus raising the level of isolation when the PIN diode is reverse biased.

E6B06
Which of the following is a common use of a Schottky diode? **As a VHF/UHF mixer or detector**

E6B07
What is the failure mechanism when a junction diode fails due to excessive current? **Excessive junction temperature**

E6B08

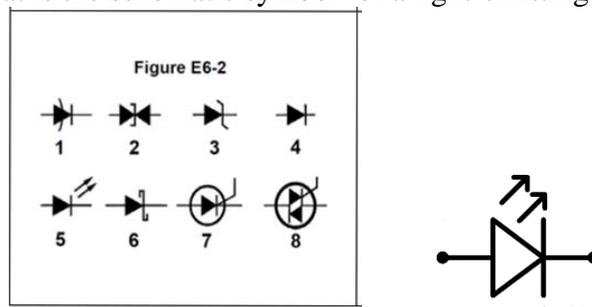Which of the following is a Schottky barrier diode?   **Metal-semiconductor junction**
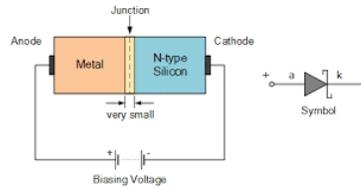
E6B09

What is a common use for point-contact diodes?   **As an RF detector**
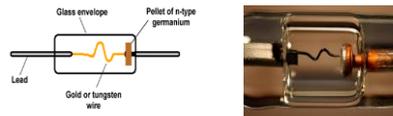
E6B10

In Figure E6-2, what is the schematic symbol for a light-emitting diode?   **5**

E6B11

What is used to control the attenuation of RF signals by a PIN diode?   **Forward DC bias current**

A PIN diode is a diode with a wide, undoped intrinsic semiconductor region between a p-type semiconductor and an n t-type semiconductor region. The p-type and n-type regions are typically heavily doped because they are used for ohmic contacts.

The wide intrinsic region is in contrast to an ordinary p-n diode. The wide intrinsic region makes the PIN diode an inferior rectifier (one typical function of a diode), but it makes it suitable for attenuators, fast switches, photodetectors, and high voltage power electronics applications.

E6C Digital ICs: Families of digital ICs; gates; Programmable Logic Devices (PLDs)

E6C01

What is the function of hysteresis in a comparator? **To prevent input noise from causing unstable output signals**
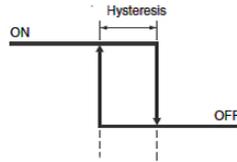
E6C02

What happens when the level of a comparator's input signal crosses the threshold? **The comparator changes its output state**

E6C03

What is tri-state logic? **Logic devices with 0, 1, and high-impedance output states**

E6C04

Which of the following is an advantage of BiCMOS logic? **It has the high input impedance of CMOS and the low output impedance of bipolar transistors**
Bipolar CMOS (BiCMOS) is a semiconductor technology that integrates two separate semiconductor technologies, those of the bipolar junction transistor and the CMOS (complementary metal-oxide-semiconductor) gate, in a single integrated circuit device.

E6C05

What is an advantage of CMOS logic devices over TTL devices? **Lower power consumption**
CMOS Logic control element (gate) is high impedance and does not draw any current. TTL logic requires a current flow to change state.

E6C06

Why do CMOS digital integrated circuits have high immunity to noise on the input signal or power supply? **The input switching threshold is about one-half the power supply voltage**
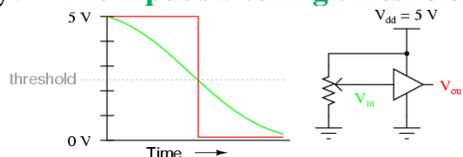
E6C07

What best describes a pull-up or pull-down resistor? **A resistor connected to the positive or negative supply line used to establish a voltage when an input or output is an open circuit**

E6C08
In Figure E6-3, what is the schematic symbol for a NAND gate? **2**

Figure E6-3

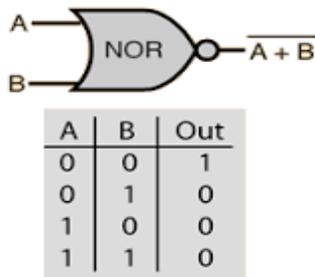| A	B	Out
0	0	1
0	1	1
1	0	1
1	1	0
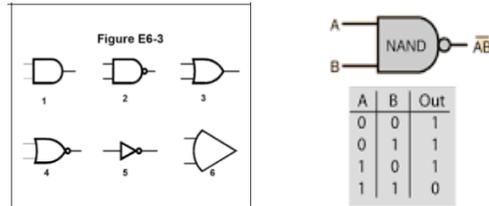
E6C09
What is a Programmable Logic Device (PLD)? **A programmable collection of logic gates and circuits in a single integrated circuit**
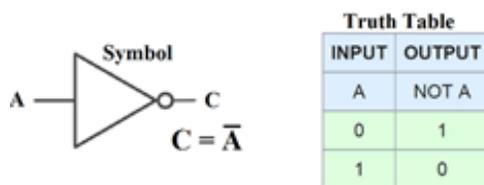
E6C10
In Figure E6-3, what is the schematic symbol for a NOR gate? **4**

A	B	Out
0	0	1
0	1	0
1	0	0
1	1	0

E6C11
In Figure E6-3, what is the schematic symbol for the NOT operation (inverter)? **5**

Symbol

$C = \overline{A}$

Truth Table

INPUT	OUTPUT
A	NOT A
0	1
1	0

E6D Toroidal and Solenoidal Inductors: permeability, core material, selecting, winding; transformers; piezoelectric devices

E6D01 (A)
Why should core saturation of an impedance matching transformer be avoided? **Harmonics and distortion could result**

E6D02
What is the equivalent circuit of a quartz crystal? **Motional capacitance, motional inductance, and loss resistance in series, all in parallel with a shunt capacitor representing electrode and stray capacitance**
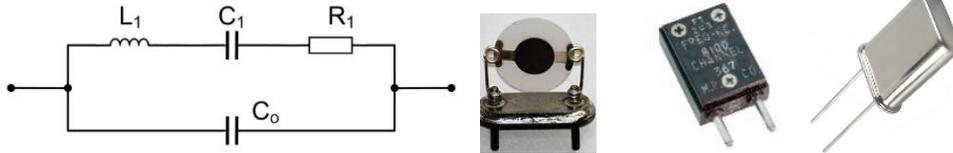
E6D03
Which of the following is an aspect of the piezoelectric effect? **Mechanical deformation of material by the application of a voltage**

E6D04
Which materials are commonly used as a core in an inductor? **Ferrite and brass**

E6D05
What is one reason for using ferrite cores rather than powdered iron in an inductor? **Ferrite toroids generally require fewer turns to produce a given inductance value**
Ferrite materials have a higher resistivity than powdered-iron materials, which permits them to operate more efficiently at higher frequencies. No two ferrite materials or powdered iron materials are alike when it comes to core-loss performance. In general, the less expensive the material, the higher the core losses.

E6D06
What core material property determines the inductance of an inductor? **Permeability**
Permeability is the measure of the resistance of a material against the formation of a magnetic field. Hence, it is the degree of magnetization that a material obtains in response to an applied magnetic field.

E6D07
What is current in the primary winding of a transformer called if no load is attached to the secondary? **Magnetizing current**

E6D08
What is one reason for using powdered-iron cores rather than ferrite cores in an inductor? **Powdered-iron cores generally maintain their characteristics at higher currents**

E6D09
What devices are commonly used as VHF and UHF parasitic suppressors at the input and output terminals of a transistor HF amplifier?   **Ferrite beads**

E6D10
What is a primary advantage of using a toroidal core instead of a solenoidal core in an inductor?
Toroidal cores confine most of the magnetic field within the core material
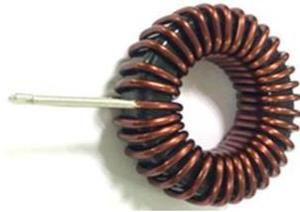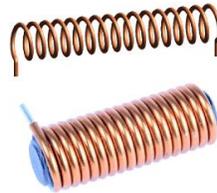
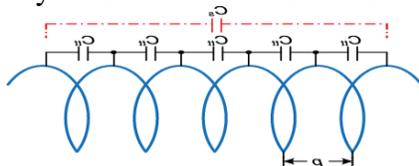**Toroidal Core**   **Solenoidal Core**

E6D11
Which type of core material decreases inductance when inserted into a coil?   **Brass**

E6D12
What is inductor saturation?   **The ability of the inductor's core to store magnetic energy has been exceeded**

E6D13
What is the primary cause of inductor self-resonance? **Inter-turn capacitance**

E6E Analog ICs: MMICs, IC packaging characteristics

E6E01
Why is gallium arsenide (GaAs) useful for semiconductor devices operating at UHF and higher frequencies? **Higher electron mobility**
Gallium arsenide is a type of semiconductor, with high electron mobility and a high saturated electron velocity compared to silicon, enabling transistors made of gallium arsenide to function at frequencies over 250 GHz.

E6E02

Which of the following device packages is a through-hole type? **DIP**

DIP is a Dual in-line package. Two rows of inline parallel pins.
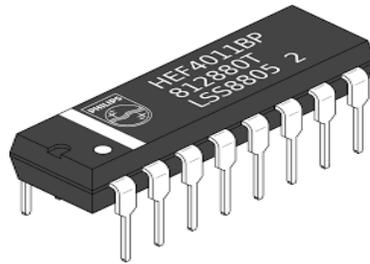
E6E03
Which of the following materials is likely to provide the highest frequency of operation when used in MMICs?   **Gallium nitride**
Monolithic microwave integrated circuit, or MMIC (sometimes pronounced "mimic"), is a type of integrated circuit (IC) device that operates at Microwave frequencies up to 300 GHz). These devices typically perform functions such as microwave Mixing power amplification, low-noise amplification, and high-frequency switching.

E6E04
Which is the most common input and output impedance of circuits that use MMICs? **50 ohms**
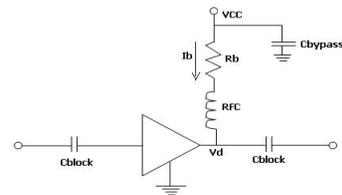
Biasing silicon Bipolar MMIC Amplifier

E6E05

Which of the following noise figure values is typical of a low-noise UHF preamplifier?   **2 dB**

The noise factor is defined as the ratio of the output noise power of a device to the portion thereof attributable to thermal noise in the input termination at standard noise temperature T_0 (usually 290 K (16° C). The noise factor is the ratio of actual output noise to that which would remain if the device itself did not introduce noise, or the ratio of input SNR (Signal to Noise Ratio) to output SNR. The noise figure is simply the noise factor expressed in decibels (dB).

E6E06

What characteristics of the MMIC make it a popular choice for VHF through microwave circuits?   **Controlled gain, low noise figure, and constant input and output impedance over the specified frequency range**

E6E07

What type of transmission line is used for connections to MMICs?   **Microstrip**
Microstrip is a type of electrical transmission line which can be fabricated using printed circuit board technology and is used to convey microwave-frequency signals. It consists of a conducting strip separated from a ground plane by a dielectric layer known as the substrate.

E6E08

How is power supplied to the most common type of MMIC?   **Through a resistor and/or RF choke connected to the amplifier output lead**
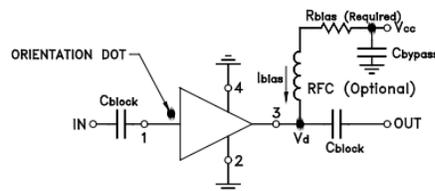
E6E09

Which of the following component package types would be most suitable for use at frequencies above the HF range?   **Surface mount**
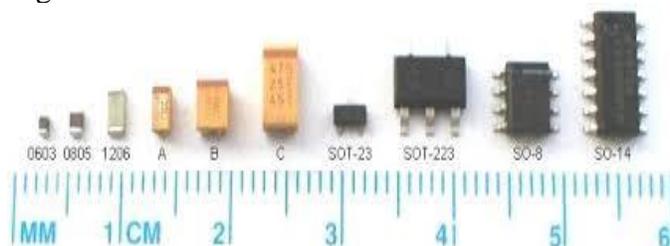
E6E10
What advantage does surface-mount technology offer at RF compared to using through-hole components?
A. Smaller circuit area
B. Shorter circuit-board traces
C. Components have less parasitic inductance and capacitance
D. All these choices are correct

E6E11
What is a characteristic of DIP packaging used for integrated circuits?   **A total of two rows of connecting pins placed on opposite sides of the package (Dual In-line Package)**
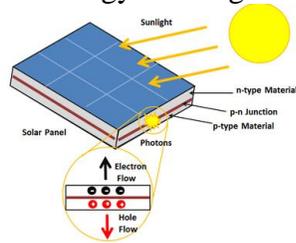
E6E12
Why are DIP through-hole package ICs not typically used at UHF and higher frequencies?
Excessive lead length

E6F Electro-optical technology: photoconductivity; photovoltaic devices; optical sensors and encoders; optical isolation

E6F01
What absorbs the energy from light falling on a photovoltaic cell?   **Electrons**

E6F02
What happens to the conductivity of a photoconductive material when light shines on it?
It increases

E6F03
What is the most common configuration of an optoisolator or optocoupler? **An LED and a phototransistor**
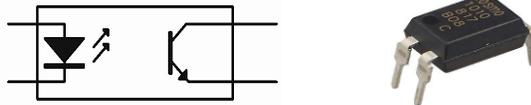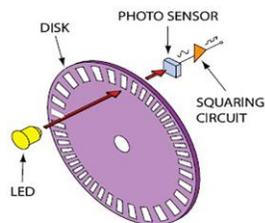
E6F04
What is the photovoltaic effect?   **The conversion of light to electrical energy**

E6F05
Which describes an optical shaft encoder? **A device that detects rotation of a control by interrupting a light source with a patterned wheel**
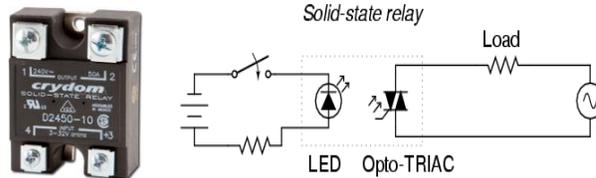
E6F06
Which of these materials is most commonly used to create photoconductive devices?
A crystalline semiconductor

E6F07
What is a solid-state relay?   **A device that uses semiconductors to implement the functions of an electromechanical relay**
Solid State Relays are used to switch AC Circuits on or off.

E6F08
Why are optoisolator often used in conjunction with solid-state circuits when switching 120-VAC?   **Optoisolators provide a very high degree of electrical isolation between a control circuit and the circuit being switched**

E6F09
What is the efficiency of a photovoltaic cell? **The relative fraction of light that is converted to current**

E6F10
What is the most common type of photovoltaic cell used for electrical power generation?
Silicon

E6F11
What is the approximate open-circuit voltage produced by a fully illuminated silicon photovoltaic cell? **0.5 V**
It takes a minimum of 24 Silicon Solar Cells to produce 12 volts DC in bright sunlight.

SUBELEMENT E7 - PRACTICAL CIRCUITS [8 Exam Questions - 8 Groups]

E7A Digital circuits: digital circuit principles and logic circuits; classes of logic elements; positive and negative logic; frequency dividers; truth tables

E7A01
Which circuit is bistable?   **A flip-flop**
The bistable multivibrator can be switched over from one stable state to the other by the application of an external trigger pulse thus, it requires two external trigger pulses before it returns to its original state.

E7A02
What is the function of a decade counter?   **It produces one output pulse for every 10 input pulses**
It divides an input frequency by 10. For 10 pulses in, only one output pulse is generated.
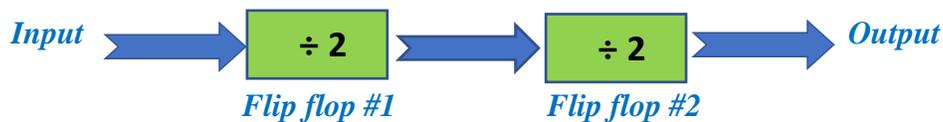
E7A03
Which of the following can divide the frequency of a pulse train by 2?   **A flip-flop**
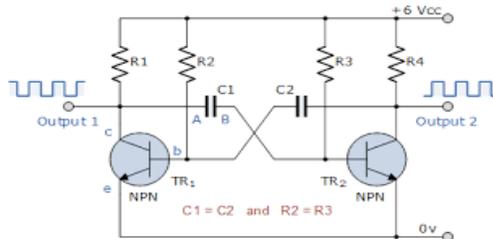*See explanation to E7A01.*

E7A04
How many flip-flops are required to divide a signal frequency by 4? **2**

E7A05
Which of the following is a circuit that continuously alternates between two states without an external clock? **Astable multivibrator**

E7A06
What is a characteristic of a monostable multivibrator?   **It switches momentarily to the opposite binary state and then returns to its original state after a set time**
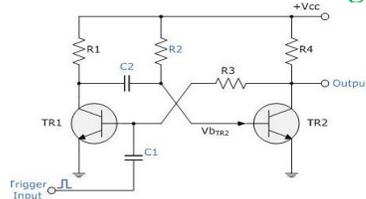
E7A07

What logical operation does a NAND gate perform? **It produces logic 0 at its output only when all inputs are logic 1**

NAND GATE

Truth Table		
INPUT		OUTPUT
A	B	A NAND B
0	0	1
0	1	1
1	0	1
1	1	0

E7A08

What logical operation does an OR gate perform? **It produces logic 1 at its output if any or all inputs are logic 1**
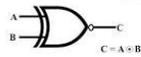
OR Gate

TRUTH TABLE		
INPUT		OUTPUT
A	B	A OR B
0	0	0
0	1	1
1	0	1
1	1	1

E7A09

What logical operation is performed by an exclusive NOR gate? **It produces logic 0 at its output if only one input is logic 1**

XNOR GATE Truth Table

$C = A \odot B$

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

E7A10

What is a truth table? **A list of inputs and corresponding outputs for a digital device**

NOR GATE

| TRUTH TABLE		
INPUT		OUTPUT
A	B	A NOR B
0	0	1
0	1	0
1	0	0
1	1	0

E7A11

What type of logic defines "1" as a high voltage? **Positive Logic**

E7B Amplifiers: Class of operation; vacuum tube and solid-state circuits; distortion and intermodulation; spurious and parasitic suppression; microwave amplifiers; switching-type amplifiers
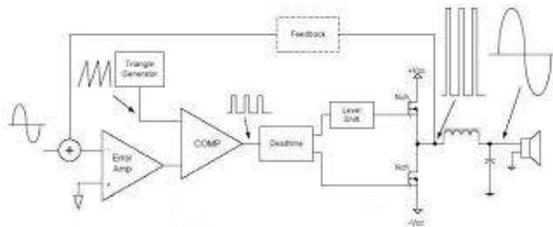
E7B01
For what portion of the signal cycle does each active element in a push-pull Class AB amplifier conduct? **More than 180 degrees but less than 360 degrees**
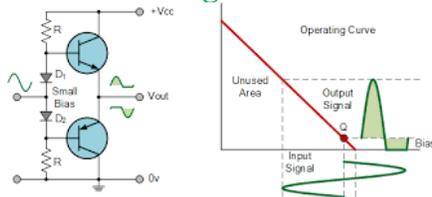
E7B02
What is a Class D amplifier? **A type of amplifier that uses switching technology to achieve high efficiency**
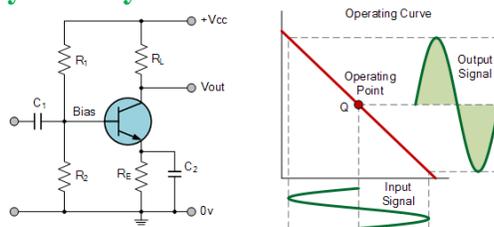
E7B03
Which of the following components form the output of a class D amplifier circuit?
 A low-pass filter to remove switching signal components

E7B04
Where on the load line of a Class A common emitter amplifier would bias normally be set?
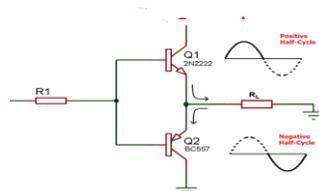**Approximately halfway between saturation and cutoff**

E7B05
What can be done to prevent unwanted oscillations in an RF power amplifier?
Install parasitic suppressors and/or neutralize the stage

E7B06
Which of the following amplifier types reduces even-order harmonics? **Push-pull**

E7B07
Which of the following is a likely result when a Class C amplifier is used to amplify a single-sideband phone signal?   **Signal distortion and excessive bandwidth**

E7B08
How can an RF power amplifier be neutralized?   **By feeding a 180-degree out-of-phase portion of the output back to the input**

E7B09
Which of the following describes how the loading and tuning capacitors are to be adjusted when tuning a vacuum tube RF power amplifier that employs a Pi-network output circuit?   **The tuning capacitor is adjusted for minimum plate current, and the loading capacitor is adjusted for maximum permissible plate current**

E7B10
In Figure E7-1, what is the purpose of R1 and R2?   **Voltage divider bias**
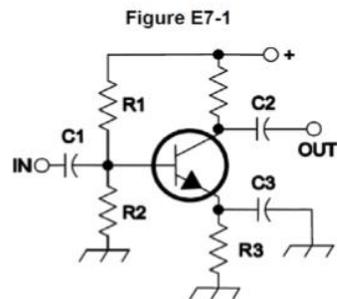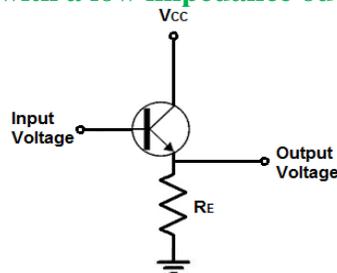

Figure E7-1

E7B11
In Figure E7-1, what is the purpose of R3?   **Self bias**

E7B12
What type of amplifier circuit is shown in Figure E7-1?   **Common emitter**

E7B13
Which of the following describes an emitter follower (or common collector) amplifier?
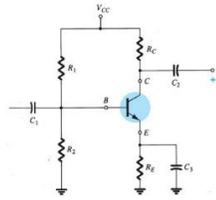**An amplifier with a low impedance output that follows the base input voltage**

E7B14
Why are switching amplifiers more efficient than linear amplifiers?   **The power transistor is at saturation or cutoff most of the time**

E7B15

What is one way to prevent thermal runaway in a bipolar transistor amplifier?
Use a resistor in series with the emitter

The series emitter resistor will limit the current flowing when the transistor is biased full on.

E7B16

What is the effect of intermodulation products in a linear power amplifier? **Transmission of spurious signals**

E7B17

Why are odd-order rather than even-order intermodulation distortion products of concern in linear power amplifiers? **Because they are relatively close in frequency to the desired signal**

E7B18

What is a characteristic of a grounded-grid amplifier? **Low input impedance**
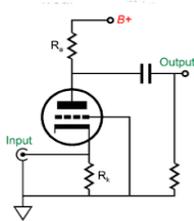
E7C Filters and matching networks: types of networks; types of filters; filter applications; filter characteristics; impedance matching; DSP filtering

E7C01
How are the capacitors and inductors of a low-pass filter Pi-network arranged between the network's input and output?   **A capacitor is connected between the input and ground, another capacitor is connected between the output and ground, and an inductor is connected between input and output**
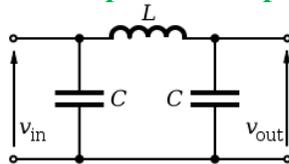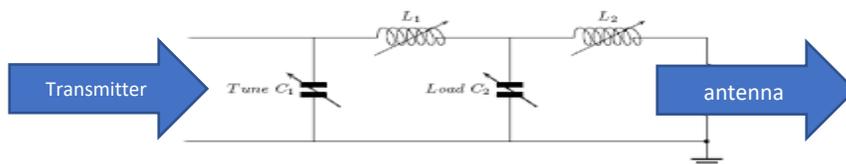
E7C02
Which of the following is a property of a T-network with series capacitors and a parallel shunt inductor? **It is a high-pass filter**
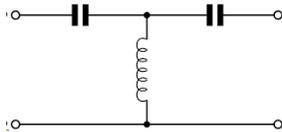
E7C03
What advantage does a series-L Pi-L-network have over a series-L Pi-network for impedance matching between the final amplifier of a vacuum-tube transmitter and an antenna?
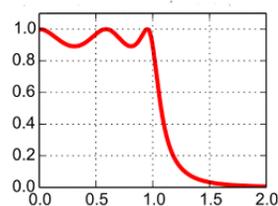**Greater harmonic suppression**

E7C04
How does an impedance-matching circuit transform a complex impedance to a resistive impedance? **It cancels the reactive part of the impedance and changes the resistive part to a desired value**
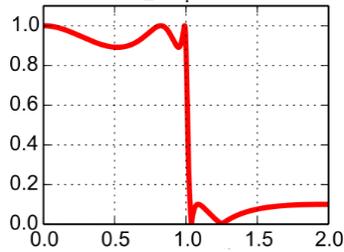
E7C05
Which filter type is described as having ripple in the passband and a sharp cutoff?
A Chebyshev filter

E7C06

What are the distinguishing features of an elliptical filter?   **Extremely sharp cutoff with one or more notches in the stop band**

E7C07

Which describes a Pi-L-network used for matching a vacuum tube final amplifier to a 50-ohm unbalanced output?   **A Pi-network with an additional series inductor on the output**
See graphic for E7C03

E7C08

Which of the following factors has the greatest effect on the bandwidth and response shape of a crystal ladder filter?   **The relative frequencies of the individual crystals**

E7C09

What is a crystal lattice filter?   **A filter with narrow bandwidth and steep skirts made using quartz crystals**
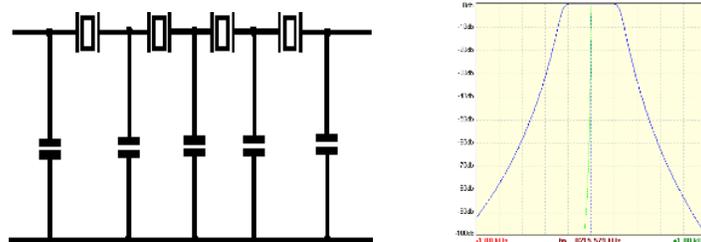
E7C10

Which of the following filters would be the best choice for use in a 2 meter band repeater duplexer?   **A cavity filter**
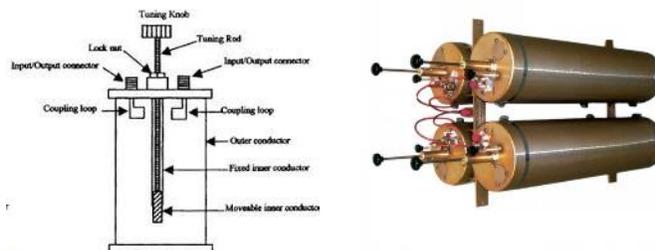
E7C11
Which of the following describes a receiving filter's ability to reject signals occupying an adjacent channel?   **Shape factor**
The sharper the filter (Narrower with steep skirts) the better it can reject nearby signals.

E7C12
What is one advantage of a Pi-matching network over an L-matching network consisting of a single inductor and a single capacitor?   **The Q of Pi-networks can be controlled**

E7D Power supplies and voltage regulators; Solar array charge controllers

E7D01
How does a linear electronic voltage regulator work?   **The conduction of a control element is varied to maintain a constant output voltage**

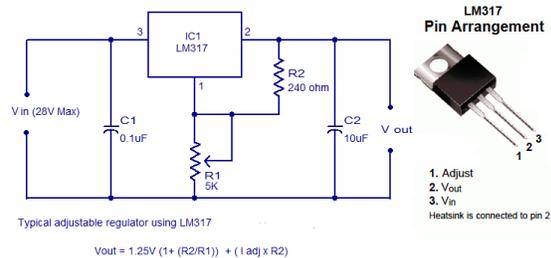Typical adjustable regulator using LM317

$$V_{out} = 1.25V (1+ (R2/R1)) + (I_{adj} \times R2)$$

E7D02
What is a characteristic of a switching electronic voltage regulator?   **The controlled device's duty cycle is changed to produce a constant average output voltage**

E7D03
What device is typically used as a stable voltage reference in a linear voltage regulator?
A Zener diode

E7D04
Which of the following types of linear voltage regulator usually make the most efficient use of the primary power source?   **A series regulator**
This is because the regulator circuit only dissipates power as a function of the load current. Power dissipated is the voltage drop across the regulator times the current.

E7D05
Which of the following types of linear voltage regulator places a constant load on the unregulated voltage source?   **A shunt regulator**
Since a shunt regulator always draws a constant power regardless of the load current.

E7D06
What is the purpose of Q1 in the circuit shown in Figure E7-2?   **It controls the current supplied to the load**
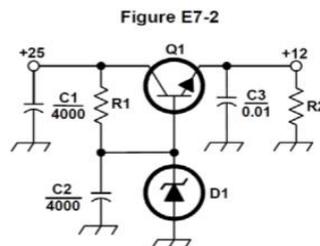
Figure E7-2

E7D07
What is the purpose of C2 in the circuit shown in Figure E7-2?   **It bypasses rectifier output ripple around D1**

E7D08
What type of circuit is shown in Figure E7-2?   **Linear voltage regulator**

E7D09
What is the main reason to use a charge controller with a solar power system?   **Prevention of battery damage due to overcharge**
The output voltage of a solar cell varies as a function of the intensity of the light hitting it. A 12 v solar array (24 each ½ volt solar cells in series) will produce as much as 17 volts DC in strong light and 0 volts with no light. A voltage regulator (charge controller) will prevent excessive charge voltage to the battery in strong light conditions and a series diode prevents discharge if the solar panel output drops below the battery voltage

E7D10
What is the primary reason that a high-frequency switching type high-voltage power supply can be both less expensive and lighter in weight than a conventional power supply?   **The high frequency inverter design uses much smaller transformers and filter components for an equivalent power output**
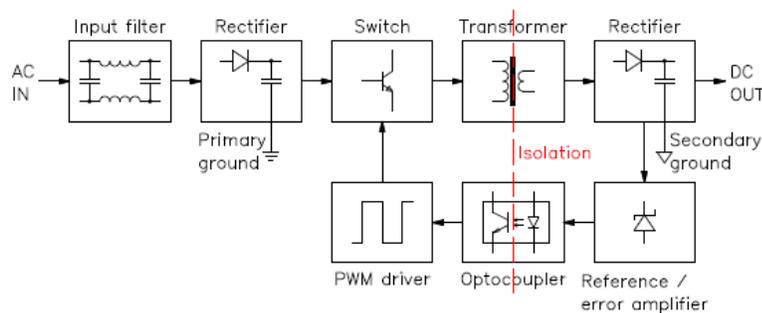
E7D11
What is the function of the pass transistor in a linear voltage regulator circuit?
Maintains nearly constant output voltage over a wide range of load current

E7D12
What is the dropout voltage of an analog voltage regulator?   **Minimum input-to-output voltage required to maintain regulation**

E7D13
What is the equation for calculating power dissipated by a series linear voltage regulator?
Voltage difference from input to output multiplied by output current
 Power dissipation is equal to the (input voltage – output voltage) (current).

E7D14
What is the purpose of connecting equal-value resistors across power supply filter capacitors connected in series?
A. Equalize the voltage across each capacitor
B. Discharge the capacitors when voltage is removed
C. Provide a minimum load on the supply
D. All these choices are correct
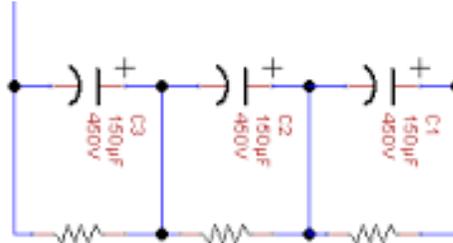
E7D15
What is the purpose of a step-start circuit in a high-voltage power supply?
To allow the filter capacitors to charge gradually
Step start is applying the high voltage to the filter capcitor(s) in steps allowing the capacitors to charge slower and less abruptly.

E7E Modulation and demodulation: reactance, phase and balanced modulators; detectors; mixer stages

E7E01
Which of the following can be used to generate FM phone emissions?   **A reactance modulator on the oscillator**
*In the oscillator circuit the output frequency is changed using the modulation signal to change the reactance of the oscillator inductor or capacitor to change its frequency or phase (FM or PM).*

E7E02
What is the function of a reactance modulator?   **To produce PM or FM signals by using an electrically variable inductance or capacitance**

E7E03
What is a frequency discriminator stage in a FM receiver?   **A circuit for detecting FM signals**
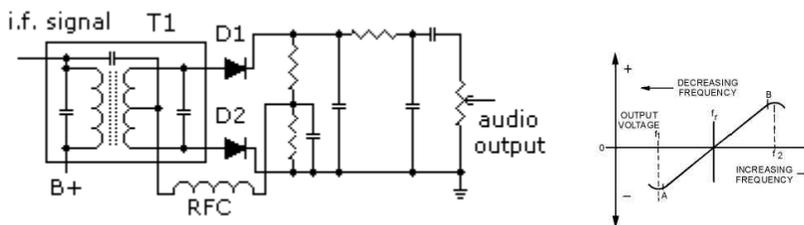
E7E04
What is one way a single-sideband phone signal can be generated?   **By using a balanced modulator followed by a filter**
The output of a balanced modulator would be the carrier and both the upper and lower sidebands. A band pass filter can be used to select only one sideband and not the carrier or the other sideband

E7E05
What circuit is added to an FM transmitter to boost the higher audio frequencies?
A pre-emphasis network
Pre-emphasis is the first part of a noise reduction technique in which a signal's weaker, audio higher frequencies are boosted before they are transmitted. Upon receiving, a de-emphasis filter is applied to the audio to reverse the process.
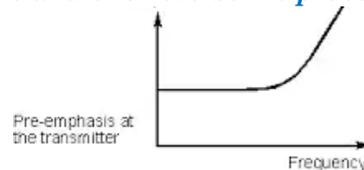
E7E06
Why is de-emphasis commonly used in FM communications receivers?   **For compatibility with transmitters using phase modulation**

E7E07
What is meant by the term "baseband" in radio communications?   **The frequency range occupied by a message signal prior to modulation**

E7E08
What are the principal frequencies that appear at the output of a mixer circuit?
The two input frequencies along with their sum and difference frequencies

E7E09
What occurs when an excessive amount of signal energy reaches a mixer circuit?
Spurious mixer products are generated

E7E10
How does a diode envelope detector function?   **By rectification and filtering of RF signals**

E7E11
Which type of detector circuit is used for demodulating SSB signals?   **Product detector**
A product detector is a type of demodulator used for AM and SSB signals. Rather than converting the envelope of the signal into the decoded waveform like an envelope detector, the product detector uses the product of the modulated signal and a local oscillator, hence the name. A product detector is basically a frequency mixer.

E7F DSP filtering and other operations; software defined radio fundamentals; DSP modulation and demodulation

E7F01
What is meant by direct digital conversion as applied to software defined radios?
Incoming RF is digitized by an analog-to-digital converter without being mixed with a local oscillator signal

E7F02
What kind of digital signal processing audio filter is used to remove unwanted noise from a received SSB signal?   **An adaptive filter**
The term adaptive filter implies changing the characteristic of a filter in some automated fashion to obtain the best possible signal quality despite changing signal/system conditions. Adaptive filters are usually associated with the broader topic of statistical signal processing.

E7F03
What type of digital signal processing filter is used to generate an SSB signal?
A Hilbert-transform filter
Digital Hilbert filters are a special class of digital filter whose characteristic is to introduce a π/2 radians phase shift of the input signal. In the ideal Hilbert transformer all the positive frequency components are shifted by –π/2 radians and all the negative frequency components are shifted by π/2 radians.

E7F04
What is a common method of generating an SSB signal using digital signal processing?
Signals are combined in quadrature phase relationship
"Quadrature" refers to two sinusoids that have the same frequency and are 90° out of phase.

E7F05
How frequently must an analog signal be sampled by an analog-to-digital converter so that the signal can be accurately reproduced? **At least twice the rate of the highest frequency component of the signal**
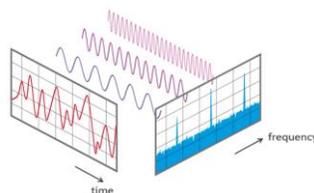*For a 10 MHz signal the sampling rate would need to be at least 20 MHz.*

E7F06
What is the minimum number of bits required for an analog-to-digital converter to sample a signal with a range of 1 volt at a resolution of 1 millivolt? **10 bits**

E7F07
What function is performed by a Fast Fourier Transform? **Converting digital signals from the time domain to the frequency domain**

E7F08
What is the function of decimation? **Reducing the effective sample rate by removing samples**

E7F09
Why is an anti-aliasing digital filter required in a digital decimator? **It removes high-frequency signal components that would otherwise be reproduced as lower frequency components**

E7F10
What aspect of receiver analog-to-digital conversion determines the maximum receive bandwidth of a Direct Digital Conversion SDR? **Sample rate**

E7F11
What sets the minimum detectable signal level for a direct-sampling SDR receiver in the absence of atmospheric or thermal noise? **Reference voltage level and sample width in bits**

E7F12
Which of the following is an advantage of a Finite Impulse Response (FIR) filter vs an Infinite Impulse Response (IIR) digital filter? **FIR filters can delay all frequency components of the signal by the same amount**
A finite impulse response (FIR) filter is a filter whose impulse response is of finite duration, because it decays to zero in finite time. This is in contrast to infinite impulse response (IIR) filters, which continue to respond indefinitely.

E7F13
What is the function of taps in a digital signal processing filter? **Provide incremental signal delays for filter algorithms**
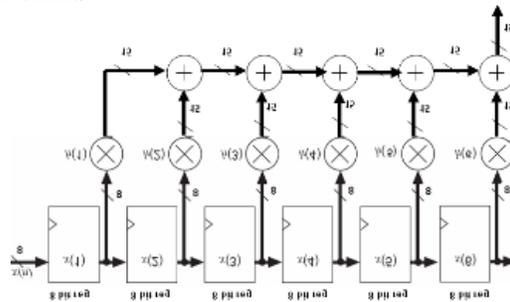
E7F14
Which of the following would allow a digital signal processing filter to create a sharper filter response? **More taps**
The number of FIR taps, (often designated as "N") is an indication of:
   1. The amount of memory required to implement the filter.
   2. The number of calculations required.
   3. The amount of "filtering" the filter can do.
   In effect, more taps means more stopband attenuation, less ripple, narrower filters, etc.
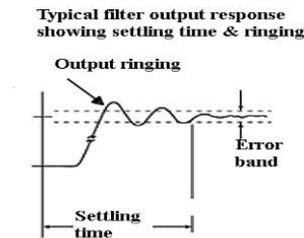
E7G Active filters and op-amp circuits: active audio filters; characteristics; basic circuit design; operational amplifiers

E7G01
What is the typical output impedance of an op-amp?   **Very low**

E7G02
What is ringing in a filter?   **Undesired oscillations added to the desired signal**

Typical filter output response
showing settling time & ringing

E7G03
What is the typical input impedance of an op-amp?   **Very high**

E7G04
What is meant by the term "op-amp input offset voltage"?   **The differential input voltage needed to bring the open loop output voltage to zero**

E7G05
How can unwanted ringing and audio instability be prevented in an op-amp RC audio filter circuit?   **Restrict both gain and Q**
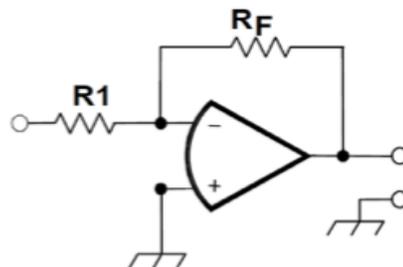
E7G06
What is the gain-bandwidth of an operational amplifier?   **The frequency at which the open-loop gain of the amplifier equals one**

E7G07
What magnitude of voltage gain can be expected from the circuit in Figure E7-3 when R1 is 10 ohms and RF is 470 ohms?   **47**

Figure E7-3

Gain = feedback resistor ÷ input resistor **or** *Gain = 470 ÷ 10 or 47*

E7G08
How does the gain of an ideal operational amplifier vary with frequency? **It does not vary with frequency**
Of course, there is no Ideal or perfect operational amplifiers so therefore there are some real limits.

E7G09
What will be the output voltage of the circuit shown in Figure E7-3 if R1 is 1000 ohms, RF is 10,000 ohms, and 0.23 volts DC is applied to the input? **-2.3 volts**
Output = (feedback resistor ÷ input resistor) (input voltage)(-1) or
(0.23V) (10,000 ÷ 1,000)(-1) or (0.23 v) (10) (-1) or – 2.3 volts

The multiply by (-1) is because this an inverting amplifier. If the input is positive, then the output will be negative and if the input is negative the output will be positive.

E7G10
What absolute voltage gain can be expected from the circuit in Figure E7-3 when R1 is 1800 ohms and RF is 68 kilohms?   **38**
Gain = feedback resistor ÷ input resistor or 68,000 ÷ 1,800 or 37.78

E7G11
What absolute voltage gain can be expected from the circuit in Figure E7-3 when R1 is 3300 ohms and RF is 47 kilohms?   **14**
Gain = feedback resistor ÷ input resistor or 47,000 ÷ 3300 or 14.24

E7G12
What is an operational amplifier?   **A high-gain, direct-coupled differential amplifier with very high input impedance and very low output impedance**

E7H Oscillators and signal sources: types of oscillators; synthesizers and phase-locked loops; direct digital synthesizers; stabilizing thermal drift; microphonics; high-accuracy oscillators

E7H01
What are three oscillator circuits used in amateur radio equipment?   **Colpitts, Hartley and Pierce**

E7H02
What is a microphonic?   **Changes in oscillator frequency due to mechanical vibration**

E7H03
How is positive feedback supplied in a Hartley oscillator?   **Through a tapped coil**
When you think of Hartley think "H" for Henries, or inductance.

E7H04
How is positive feedback supplied in a Colpitts oscillator?   **Through a capacitive divider**
When you think of Colpitts think "C" , or capacity

E7H05
How is positive feedback supplied in a Pierce oscillator?   **Through a quartz crystal**
When you think of Peirce think "P" for piezoelectric (quartz crystal)

E7H06
Which of the following oscillator circuits are commonly used in VFOs?   **Colpitts and Hartley**

E7H07
How can an oscillator's microphonic responses be reduced?   **Mechanically isolate the oscillator circuitry from its enclosure**
Mechanical vibration of the elements, especially a tuning capacitor will cause its value to change slightly.

E7H08
Which of the following components can be used to reduce thermal drift in crystal oscillators?
 NP0 capacitors
A NPO ceramic capcitor is an ultra-stable or temperature compensating capacitor. It is one of the most highly stable capacitors. It has very predictable temperature coefficients (TCs) and, in general, does not change value with time.

E7H09
What type of frequency synthesizer circuit uses a phase accumulator, lookup table, digital to analog converter, and a low-pass anti-alias filter?   **A direct digital synthesizer**
Direct digital synthesis (DDS) is a method of producing an analog waveform—usually a sine wave—by generating a time-varying signal in digital form and then performing a digital-to-analog conversion. Because operations within a DDS device are primarily digital, it can offer

fast switching between output frequencies, fine frequency resolution, and operation over a broad spectrum of frequencies.

E7H10
What information is contained in the lookup table of a direct digital synthesizer (DDS)?
Amplitude values that represent the desired waveform

E7H11
What are the major spectral impurity components of direct digital synthesizers? **Spurious signals at discrete frequencies**

E7H12
Which of the following must be done to ensure that a crystal oscillator provides the frequency specified by the crystal manufacturer? **Provide the crystal with a specified parallel capacitance**

E7H13
Which of the following is a technique for providing highly accurate and stable oscillators needed for microwave transmission and reception?
A. Use a GPS signal reference
B. Use a rubidium stabilized reference oscillator
C. Use a temperature-controlled high Q dielectric resonator
D. All these choices are correct
A rubidium reference is based on the molecular resonance frequency of a capsule of Rubidium gas which is precisely 6,834.682,610.904 Hz. This frequency is typically translated to a 10 MHz frequency

A dielectric resonator is a piece of dielectric (nonconductive) material, usually ceramic, that is designed to function as a resonator for radio waves, generally in the microwave bands.
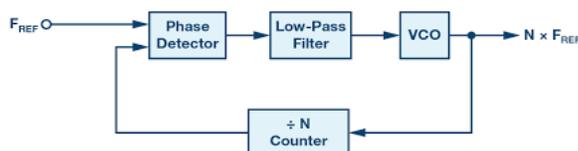
E7H14
What is a phase-locked loop circuit?   **An electronic servo loop consisting of a phase detector, a low-pass filter, a voltage-controlled oscillator, and a stable reference oscillator**
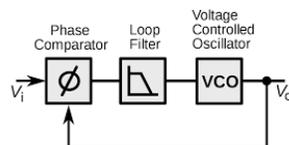
E7H15
Which of these functions can be performed by a phase-locked loop? **Frequency synthesis, FM demodulation**

SUBELE MENT E8 - SIGNALS AND EMISSIONS [4 Exam Questions - 4 Groups]

E8A AC waveforms: sine, square, and irregular waveforms; AC measurements; average power and PEP of RF signals; Fourier analysis; analog to digital conversion: digital to analog conversion; advantages of digital communications

E8A01
What is the name of the process that shows that a square wave is made up of a sine wave plus all its odd harmonics?   **Fourier analysis**
This an FFT (fast Frequency Fourier Transform) of a 1 KHz square wave showing it is made up of a fundamental and all the odd harmonics.
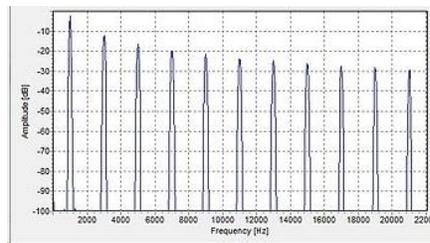
E8A02
Which of the following is a type of analog-to-digital conversion?   **Successive approximation**
A successive approximation ADC is a type of analog-to-digital converter that converts a continuous analog waveform into a discrete digital representation via a binary earch through all possible quantization levels before finally converging upon a digital output for each conversion. The A/D first compares the voltage the most significant digit to 0.1 steps of the reference voltage. Let's say it was between 2.0 and 2.9. we have the first digit a 2. The A/D then compares the input to a reference in 0.01 increments between 2.0 and 2.9 again let's say it was 2.8. We now have the second digit 8. This process continues in increasingly smaller steps until the desired resolution is obtained.

E8A03
What type of wave does a Fourier analysis show to be made up of sine waves of a given fundamental frequency plus all its harmonics?   **A sawtooth wave**
Various waveform converted by an FFT
Sine wave- fundamental at the sine wave frequency
Square wave- fundamental at the frequency and all the odd harmonics
Sawtooth wave- Fundamental at the frequency and all the harmonics

E8A04
What is "dither" with respect to analog-to-digital converters?   **A small amount of noise added to the input signal to allow more precise representation of a signal over time**
Dithering can be defined as intentional / deliberate adding of some noise to signal to prevent large-scale / low resolution errors that come from quantization or under sampling.

E8A05
What of the following instruments would be the most accurate for measuring the RMS voltage of a complex waveform?   **A true-RMS calculating meter**
These meters are frequently called "True RMS Voltmeters", where the voltage detector measures the True RMS Value of the AC signal. One type of true RMS Voltmeter uses a thermocouple on a heated element to measure the AC voltage.   Many non-true RMS voltmeters meters have an average responding detector that is calibrated in RMS. If the signal you are measuring has distortion, (and is not a perfect sine wave) there will be errors.

E8A06
What is the approximate ratio of PEP-to-average power in a typical single-sideband phone signal?   **2.5 to 1**
This means a 100 watt PEP SSB signal will have and average power of 40 watts
           100 watts ÷ 2.5 = 40 watts
The Peak to average power for a digital modulated signal is near 100%,

E8A07
What determines the PEP-to-average power ratio of a single-sideband phone signal?
Speech characteristics

E8A08
Why would a direct or flash conversion analog-to-digital converter be useful for a software defined radio?   **Very high speed allows digitizing high frequencies**
A Software Defined Radio (SDR) starts by digitizing the input signal with a high speed Analog to Digital converter (A/D.)

E8A09
How many different input levels can be encoded by an analog-to-digital converter with 8-bit resolution? **256**
               2^8 is 256

E8A10
What is the purpose of a low-pass filter used in conjunction with a digital-to-analog converter?
Remove harmonics from the output caused by the discrete analog levels generated

E8A11
Which of the following is a measure of the quality of an analog-to-digital converter?
Total harmonic distortion

E8B Modulation and demodulation: modulation methods; modulation index and deviation ratio; frequency and time division multiplexing; Orthogonal Frequency Division Multiplexing

E8B01
What is the modulation index of an FM signal?   **The ratio of frequency deviation to modulating signal frequency**
Modulation index is the deviation ÷ modulating frequency. For an FM signal with a deviation of 5 KHz and a modulation frequency of 2.5 KHz the modulation index would be:
*5,000 ÷ 2, 500 **or 2.0***

E8B02
How does the modulation index of a phase-modulated emission vary with RF carrier frequency?
It does not depend on the RF carrier frequency
See answer for E8B01 – Since Modulation Index is the deviation divided by the modulation rate the carrier frequency is not part of the equation. Only Deviation and modulation rate are in the calculation.

E8B03
What is the modulation index of an FM-phone signal having a maximum frequency deviation of 3000 Hz either side of the carrier frequency when the modulating frequency is 1000 Hz?   **3**
Modulation index is the deviation ÷ modulating frequency or 3,000 ÷ 1,000 or 3

E8B04
What is the modulation index of an FM-phone signal having a maximum carrier deviation of plus or minus 6 kHz when modulated with a 2 kHz modulating frequency? **3**
Modulation index is the deviation ÷ modulating frequency or 6,000 ÷ 2,000 or 3

E8B05
What is the deviation ratio of an FM-phone signal having a maximum frequency swing of plus-or-minus 5 kHz when the maximum modulation frequency is 3 kHz? **1.67**
Deviation ratio is the ratio of the <u>maximum </u>carrier frequency deviation to the <u>highest </u>audio modulating frequency. The deviation ratio of an FM-phone signal having a maximum frequency swing of plus-or-minus 5 kHz when the maximum modulation frequency is 3 kHz:
Deviation Ratio = the Max Deviation ÷ Max. Modulating Frequency or 5,000 ÷ 3,000 or 1.666

E8B06
What is the deviation ratio of an FM-phone signal having a maximum frequency swing of plus or minus 7.5 kHz when the maximum modulation frequency is 3.5 kHz? **2.14**
Deviation Ratio = the Max Deviation ÷ Max. Modulating Frequency or 7,500 ÷ 3,500 or 2.14

E8B07
Orthogonal Frequency Division Multiplexing is a technique used for which type of amateur communication?   **High-speed digital modes**
OFDM is a frequency division multiplexing (FDM) scheme used as a digital multi-carrier modulation method.   In OFDM, multiple closely spaced orthogonal (at 90°) subcarrier signals with overlapping spectra are transmitted to carry data in parallel. Demodulation is based on Fast Fourier Transform algorithms. Each subcarrier (signal) is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase shift keying) at a low symbol rate. This maintains total data rates like conventional single-carrier modulation schemes

E8B08
What describes Orthogonal Frequency Division Multiplexing? **A digital modulation technique using subcarriers at frequencies chosen to avoid intersymbol interference**

E8B09
What is deviation ratio? **The ratio of the maximum carrier frequency deviation to the highest audio modulating frequency**
Deviation Ratio = the Max Deviation ÷ Max. Modulating Frequency
The deviation ratio for a signal with 5 KHz of peak deviation at a max. 3 KHz rate would be 5 ÷ 3 or 1.33

E8B10
What is frequency division multiplexing?   **Two or more information streams are merged into a baseband, which then modulates the transmitter**
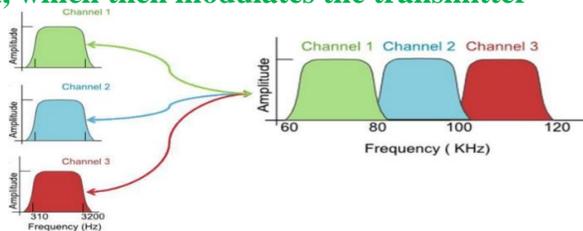
E8B11
What is digital time division multiplexing?   **Two or more signals are arranged to share discrete time slots of a data transmission**
Time-division multiple access (TDMA) is a channel access method for shared-medium networks. It allows several users to share the same frequency channel by dividing the signal into different time slots. The users transmit in rapid succession, one after the other, each using its own time slot.
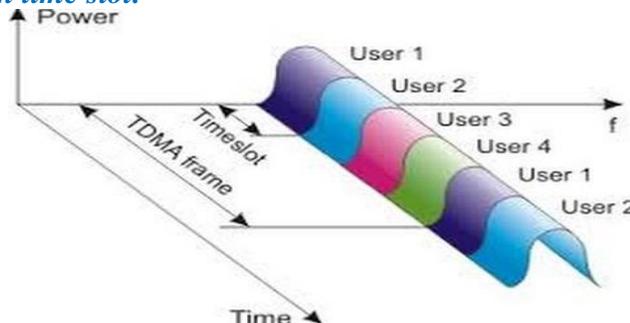
E8C Digital signals: digital communication modes; information rate vs. bandwidth; error correction

E8C01
How is Forward Error Correction implemented?   **By transmitting extra data that may be used to detect and correct transmission errors**

E8C02
What is the definition of symbol rate in a digital transmission?   **The rate at which the waveform changes to convey information**

E8C03
Why should phase-shifting of a PSK signal be done at the zero crossing of the RF signal?
To minimize bandwidth

E8C04
What technique minimizes the bandwidth of a PSK31 signal?   **Use of sinusoidal data pulses**

E8C05
What is the approximate bandwidth of a 13-WPM International Morse Code transmission?
52 Hz
Approximate CW bandwidth for 13 WPM: BW = (WPM) (4Hz) or (4 Hz)(13) or 52 Hz.
If the CW Rate was 20 WPM:
Approximate CW bandwidth for 20 WPM: BW = (WPM) (4Hz) or (4 Hz) (20) or 80 Hz

E8C06
What is the bandwidth of a 170-hertz shift, 300-baud ASCII transmission? **0.5 kHz**
Bandwidth =(1.2) (frequency shift) + (baud rate) or Bandwidth – ((1.2) (170)) +(300) or 504 Hz

E8C07
What is the bandwidth of a 4800-Hz frequency shift, 9600-baud ASCII FM transmission?
15.36 kHz
Bandwidth = ((1.2) (frequency shift))+ (baud rate) or Bandwidth = ((1.2) (4800)) +(9600) or (5760) + (9600) or 15,360 Hz or 15.36 KHz

E8C08
How does ARQ accomplish error correction? **If errors are detected, a retransmission is requested**

E8C09

Which digital code allows only one bit to change between sequential code values? **Gray code**
The Gray code is an ordering of the Binary numerical system such that two successive values differ in only one bit (binary digit). Gray code was originally designed to prevent spurious output from electromechanical switches. Today, Gray codes are widely used to facilitate error correction in digital communications.

E8C10

How may symbol rate be increased without increasing bandwidth? **Using a more efficient digital code**

E8C11

What is the relationship between symbol rate and baud? **They are the same**
Binary has two symbols, one for each bit 0 or 1, that represent voltage levels. In this case, the baud or symbol rate is the same as the bit rate.

E8C12

What factors affect the bandwidth of a transmitted CW signal? **Keying speed and shape factor (rise and fall time)**

E8D Keying defects and overmodulation of digital signals; digital codes; spread spectrum

E8D01
Why are received spread spectrum signals resistant to interference?   **Signals not using the spread spectrum algorithm are suppressed in the receiver**

E8D02
What spread spectrum communications technique uses a high-speed binary bit stream to shift the phase of an RF carrier?   **Direct sequence**
Direct-sequence spread spectrum (DSSS) is a spread-spectrum modulation technique primarily used to reduce overall signal interference. The direct-sequence modulation makes the transmitted signal wider in bandwidth than the information bandwidth. DSSS can also be used as a multiple access technique, whereby several different pseudo random spreading codes are being used simultaneously. This multiple access technique is better known as Direct Sequence CDMA (Code Division Multiple Access).

E8D03
How does the spread spectrum technique of frequency hopping work?   **The frequency of the transmitted signal is changed very rapidly according to a pseudorandom sequence also used by the receiving station**

Both the transmitter and receiver change frequency rapidly in a using a pseudo-random sequence. If you do not know the sequence and do not have the ability to accurately time synchronize the transmitter and the receiver you will not be able to recover the transmitted signal.

E8D04
What is the primary effect of extremely short rise or fall time on a CW signal?   **The generation of key clicks**

E8D05
What is the most common method of reducing key clicks? **Increase keying waveform rise and fall times**
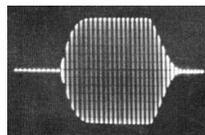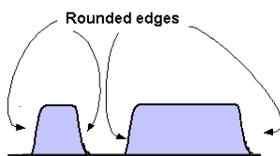

Transmitted Carrier Waveform

E8D06
What is the advantage of including parity bits in ASCII characters? **Some types of errors can be detected**
A parity bit is an extra bit added to a digital word to make the total number of bits odd or even and is not part of the data being sent. It is used to detect errors in the transmission.

E8D07

What is a common cause of overmodulation of AFSK signals?   **Excessive transmit audio levels**

AFSK is Audio Frequency Shift Keying:
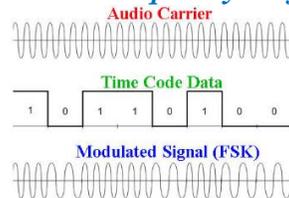
E8D08

What parameter evaluates distortion of an AFSK signal caused by excessive input audio levels?
Intermodulation Distortion (IMD)

Intermodulation (IM) or intermodulation distortion (IMD) is the Amplitude Modulation of signals containing two or more different frequencies, caused by nonlinearities or time or time variance in a system. The intermodulation between frequency components will form additional components at frequencies that are not just at harmonic frequencies (integer multiples) of either, like harmonic distortion, but also at the sum and difference frequencies of the original frequencies and at sums and differences of multiples of those frequencies.

E8D09

What is considered an acceptable maximum IMD level for an idling PSK signal? **-30 dB**

E8D10

What are some of the differences between the Baudot digital code and ASCII? **Baudot uses 5 data bits per character, ASCII uses 7 or 8; Baudot uses 2 characters as letters/figures shift codes, ASCII has no letters/figures shift code**

E8D11

What is one advantage of using ASCII code for data communications**? It is possible to transmit both upper and lower case text**

SUBELEMENT E9 - ANTENNAS AND TRANSMISSION LINES [8 Exam Questions - 8 Groups]

E9A Basic Antenna parameters: radiation resistance, gain, beamwidth, efficiency; effective radiated power

E9A01
What is an isotropic antenna? **A theoretical, omnidirectional antenna used as a reference for antenna gain**
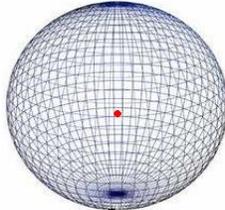
An isotropic source can be thought of a theoretical single point source with equal power being radiated in all directions. A dipole has + 2.15 dB gain over a theoretical isotropic source.

E9A02
What is the effective radiated power relative to a dipole of a repeater station with 150 watts transmitter power output, 2 dB feed line loss, 2.2 dB duplexer loss, and 7 dBd antenna gain?
286 watts
The ERP is equal to the transmitter output plus the sum of the gains and losses.
ERP = 150 watts – (2dB + 2.2 dB) + 7 DB or 150 watts -4.2 dB + 7 dB or 150 watts +2.8 dB
A + 2.8 dB power ratio =(10^) (dB ÷ 10) or (10^ (2.8÷10)) or 10^0.27 or 1.905.
ERP = (power out) (+ 2.8 dB power ratio) or (150) (1.905) or 285.8 watts

150 watts with 3 dB gain would be 300 watts. A 2.8 dB gain would be a little less than 300 watts. Therefore 286 watts is a reasonable value without all the math.

E9A03
What is the radiation resistance of an antenna? **The value of a resistance that would dissipate the same amount of power as that radiated from an antenna**

E9A04
Which of the following factors affect the feed point impedance of an antenna?   **Antenna height**
At the lower HF Bands proximity to the ground will significantly affect the antenna feed point impedance.

E9A05
What is included in the total resistance of an antenna system?   **Radiation resistance plus loss resistance**

E9A06
What is the effective radiated power relative to a dipole of a repeater station with 200 watts transmitter power output, 4 dB feed line loss, 3.2 dB duplexer loss, 0.8 dB circulator loss, and 10 dBd antenna gain? **317 watts**
The ERP is equal to the transmitter output and the sum of the gains and losses.
ERP = 200 watts +((-4 dB) + (-3.2 dB) + (-0.8) + (+10 DB)) or 200 watts -8 dB +10 dB or 200 watts +2.0 dB

ERP = (transmit power) (2 dB power ratio) or ERP = (200) ((=10^ (dB ÷ 10)) or
ERP (200) ((10^(2÷10)) or 10^0.20 or 1.585.
The power out = transmitter power (power ratio) or (200) (1.585 watts) or 316.9 watts

E9A07
What is the effective isotropic radiated power of a repeater station with 200 watts transmitter power output, 2 dB feed line loss, 2.8 dB duplexer loss, 1.2 dB circulator loss, and 7 dBi antenna gain? **252 watts**
The ERP is equal to the transmitter output and the sum of the gains and losses.
ERP = 200 watts -2 dB - 2.8 dB -1.2 dB + 7 DB or 200 watts +1 dB
ERP= (200) (1 dB power ratio) or ERP =200 ((10^ (1 ÷ 10)) or ERP = (200) (10^0.1) or
ERP = (200) (1.259) or power out = transmitter power (power ratio) or (200 watts) (1.259) or 251.7 watts

E9A08
What is antenna bandwidth? **The frequency range over which an antenna satisfies a performance requirement**
The performance requirement is usually VSWR typically called the VSWR bandwidth of the antenna.

E9A09
What is antenna efficiency? **Radiation resistance divided by total resistance**
Total resistance is the radiation resistance plus the ohmic resistance

E9A10
Which of the following improves the efficiency of a ground-mounted quarter-wave vertical antenna? **Installing a radial system**

E9A11
Which of the following factors determines ground losses for a ground-mounted vertical antenna operating in the 3 MHz to 30 MHz range?   **Soil conductivity**

E9A12
How much gain does an antenna have compared to a 1/2-wavelength dipole when it has 6 dB gain over an isotropic antenna? **3.85 dB**
Since a dipole has 2.15 dB gain over an Isotropic source the gain of a dipole compard to an isotropic antenna would be 6 dB – 2.15 dB or 3.85 dB
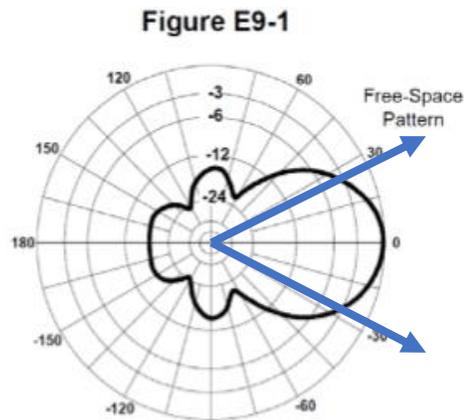
E9A13
What term describes station output, taking into account all gains and losses? **Effective radiated power**

E9B Antenna patterns and designs: E and H plane patterns; gain as a function of pattern; antenna modeling

E9B01
In the antenna radiation pattern shown in Figure E9-1, what is the beamwidth?   **50 degrees**

Figure E9-1

E9B02
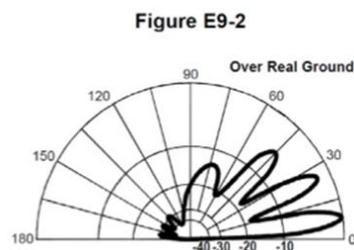In the antenna radiation pattern shown in Figure E9-1, what is the front-to-back ratio? **18 dB**

E9B03
In the antenna radiation pattern shown in Figure E9-1, what is the front-to-side ratio? **14 dB**

E9B04
What is the front-to-back ratio of the radiation pattern shown in Figure E9-2? **28 dB**

E9B05
What type of antenna pattern is shown in Figure E9-2?   **Elevation**

Figure E9-2

E9B06
What is the elevation angle of peak response in the antenna radiation pattern shown in Figure E9-2?   **7.5 degrees**

E9B07
How does the total amount of radiation emitted by a directional gain antenna compare with the total amount of radiation emitted from a theoretical isotropic antenna, assuming each is driven by the same amount of power?   **They are the same**
The directional antenna is simply directing the total energy of the isotropic omnidirectional antenna into a focused narrower beam of radiation.

E9B08
What is the far field of an antenna?   **The region where the shape of the antenna pattern is independent of distance**

E9B09 (B)
What type of computer program technique is commonly used for modeling antennas?
Method of Moments
The Method of Moments involves breaking the antenna structure of the conductors into "segments" so the current on each segment can be determined. The moment is numerically the size of the current and the vector describing the segment.

E9B10
What is the principle of a Method of Moments analysis? **A wire is modeled as a series of segments, each having a uniform value of current**

E9B11
What is a disadvantage of decreasing the number of wire segments in an antenna model below 10 segments per half-wavelength? **The computed feed point impedance may be incorrect**

E9C Practical wire antennas; folded dipoles; phased arrays; effects of ground near antennas
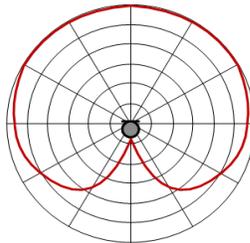
E9C01
What is the radiation pattern of two 1/4-wavelength vertical antennas spaced 1/2-wavelength apart and fed 180 degrees out of phase?   **A figure-8 oriented along the axis of the array**
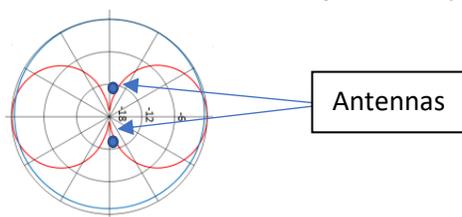*The radiation pattern of two 1/4-wavelength vertical antennas spaced 1/2-wavelength apart and fed 180 degrees out of phase is a figure-8 oriented along the axis of the array.*
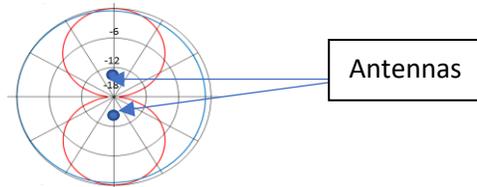
E9C02
What is the radiation pattern of two 1/4 wavelength vertical antennas spaced 1/4 wavelength apart and fed 90 degrees out of phase?   **Cardioid**
The radiation pattern of two 1/4-wavelength vertical antennas spaced 1/4-wavelength apart and fed 90 degrees out of phase is a cardioid.

E9C03
What is the radiation pattern of two 1/4-wavelength vertical antennas spaced 1/2 wavelength apart and fed in phase?   **A Figure-8 broadside to the axis of the array**
The radiation pattern of two 1/4-wavelength vertical antennas spaced 1/2-wavelength apart and fed in phase is a Figure-8 broadside to the axis of the array.
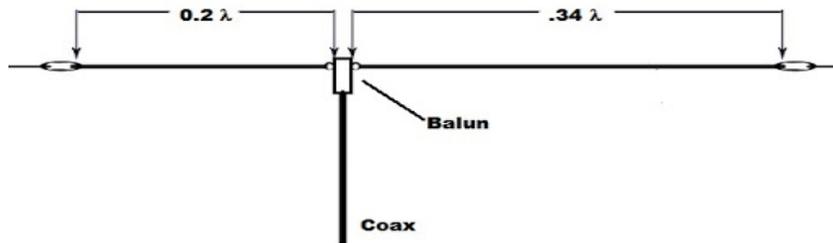

E9C04
What happens to the radiation pattern of an unterminated long wire antenna as the wire length is increased?   **The lobes align more in the direction of the wire**

E9C05

Which of the following is a type of OCFD antenna?   **A dipole fed approximately 1/3 the way from one end with a 4:1 balun to provide multiband operation**
OCFD Antenna is an Off Center Fed Dipole

E9C06

What is the effect of adding a terminating resistor to a rhombic antenna?   **It changes the radiation pattern from bidirectional to unidirectional**

A rhombic antenna consists of one to several parallel wires suspended above the ground in a "rhombus" (diamond) shape. Long versions are typically supported by a pole or tower at each vertex to which the wires are attached by insulators. Each of the four sides is the same length. If the sections are joined by a resistor the antenna will receive from and transmit to only the direction the end with the resistor points at. This antenna has high forward gain and wide frequency bandwidth.
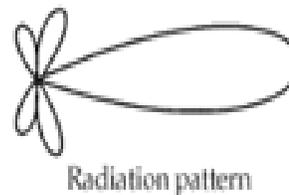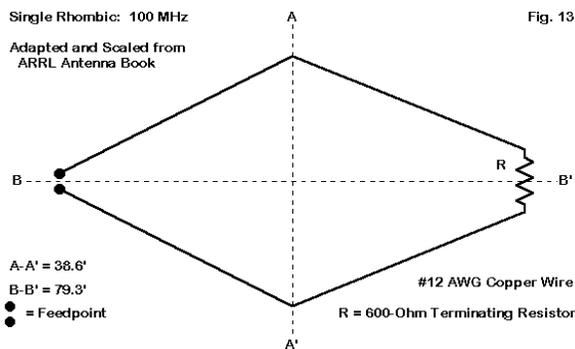
E9C07

What is the approximate feed point impedance at the center of a two-wire folded dipole antenna? **300 ohms**
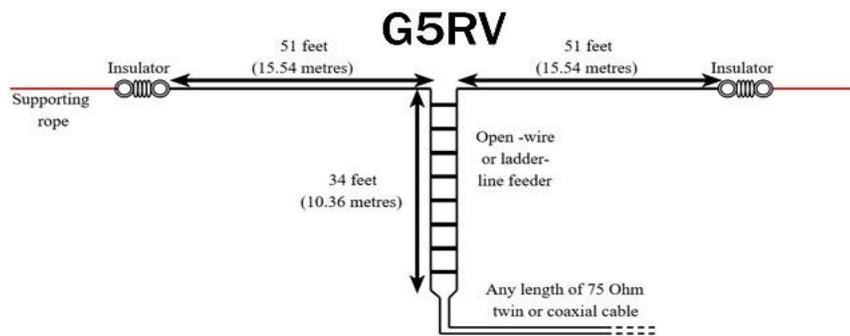
E9C08

What is a folded dipole antenna?   **A half-wave dipole with an additional parallel wire connecting its two ends**
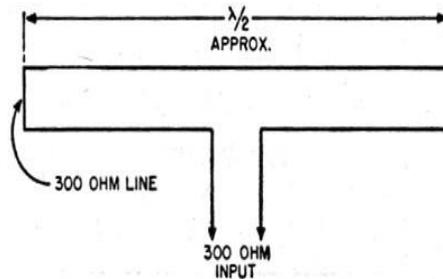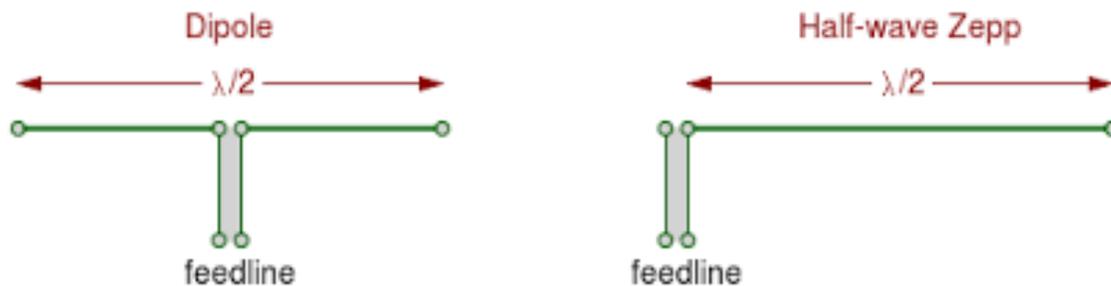

E9C09

Which of the following describes a G5RV antenna?   **A multi-band dipole antenna fed with coax and a balun through a selected length of open wire transmission line**

E9C10

Which of the following describes a Zepp antenna?   **An end-fed dipole antenna**

E9C11

How is the far-field elevation pattern of a vertically polarized antenna affected by being mounted over seawater versus soil?   **The low-angle radiation increases**
Better for long distance DX

E9C12
Which of the following describes an Extended Double Zepp antenna?   **A center-fed 1.25-wavelength antenna (two 5/8-wave elements in phase)**
This antenna is constructed much like an ordinary Dipole antenna but with 5/8 Wavelength Elements matched with an added Impedance Matching Section of balanced feed line. The Matching Section is 450 Ohm Open Wire Feedline and is a compromise impedance between the 5/8 Wave antenna elements and the feed point, a 4:1 Current Balun is used to match the feedline.

E9C13
How does the radiation pattern of a horizontally polarized 3-element beam antenna vary with increasing height above ground?   **The takeoff angle of the lowest elevation lobe decreases**

E9C14
How does the performance of a horizontally polarized antenna mounted on the side of a hill compare with the same antenna mounted on flat ground?   **The main lobe takeoff angle decreases in the downhill direction**

E9D Yagi antennas; parabolic reflectors; circular polarization; loading coils; top loading; feedpoint impedance of electrically short antennas; antenna Q; RF grounding
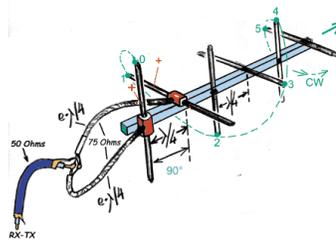
E9D01
How much does the gain of an ideal parabolic dish antenna change when the operating frequency is doubled?   **6 dB**

E9D02
How can linearly polarized Yagi antennas be used to produce circular polarization? **Arrange two Yagi's perpendicular to each other with the driven elements at the same point on the boom fed 90 degrees out of phase**

E9D03
Where should a high Q loading coil be placed to minimize losses in a shortened vertical antenna? **Near the center of the vertical radiator**

E9D04
Why should an HF mobile antenna loading coil have a high ratio of reactance to resistance? **To minimize losses**

E9D05
What usually occurs if a Yagi antenna is designed solely for maximum forward gain? **The front-to-back ratio decreases**

E9D06
What happens to the SWR bandwidth when one or more loading coils are used to resonate an electrically short antenna?   **It is decreased**

E9D07

What is an advantage of using top loading in a shortened HF vertical antenna?   **Improved radiation efficiency**
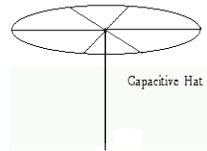
E9D08

What happens as the Q of an antenna increases?   **SWR bandwidth decreases**
The antenna has a narrower optimal frequency range or decreased operating bandwidth.

E9D09

What is the function of a loading coil used as part of an HF mobile antenna?   **To cancel capacitive reactance**

E9D10

What happens to feed-point impedance at the base of a fixed length HF mobile antenna when operated below its resonant frequency?   **The radiation resistance decreases and the capacitive reactance increases**

E9D11

Which of the following conductors would be best for minimizing losses in a station's RF ground system?   **Wide flat copper strap**


E9D12

Which of the following would provide the best RF ground for your station?   **An electrically short connection to 3 or 4 interconnected ground rods driven into the Earth**
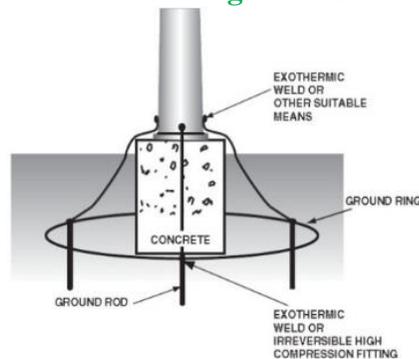
E9E Matching: matching antennas to feed lines; phasing lines; power dividers

E9E01
What system matches a higher-impedance transmission line to a lower-impedance antenna by connecting the line to the driven element in two places spaced a fraction of a wavelength each side of element center? **The delta matching system**

$$A = 142/F_{MHz}$$
$$B = 54/F_{MHz}$$
$$C = 45/F_{MHz}$$
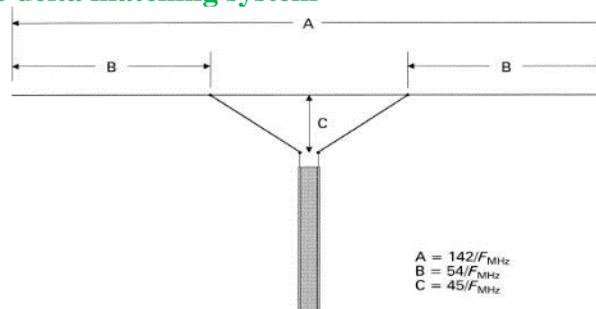
E9E02
What is the name of an antenna matching system that matches an unbalanced feed line to an antenna by feeding the driven element both at the center of the element and at a fraction of a wavelength to one side of center? **The gamma match**
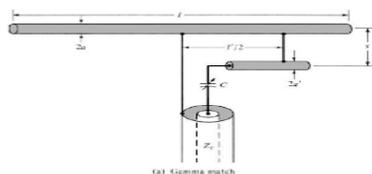
E9E03
What is the name of the matching system that uses a section of transmission line connected in parallel with the feed line at or near the feed point? **The stub match**
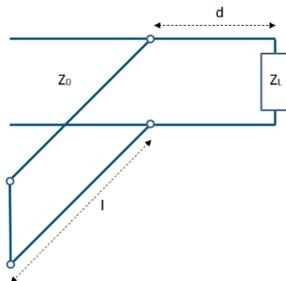
Stub matches are widely used to match any complex load to a transmission line. They consist of shorted or opened segments of the line, connected in parallel to a line at appropriate distances from the load. The single stub match is a widely used matching circuit.
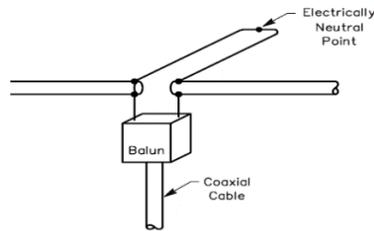
E9E04
What is the purpose of the series capacitor in a gamma-type antenna matching network? **To cancel the inductive reactance of the matching network**

E9E05

How must an antenna's driven element be tuned to use a hairpin matching system?
The driven element reactance must be capacitive

E9E06

Which of these feed line impedances would be suitable for constructing a quarter-wave Q-section for matching a 100-ohm loop to 50-ohm feed line?   **75 ohms**

E9E07

What parameter describes the interactions at the load end of a mismatched transmission line?
**Reflection coefficient**
Reflection coefficient is a parameter that describes how much of an electromagnetic wave is reflected by an impedance discontinuity in the transmission medium. It is equal to the ratio of the amplitude of the reflected wave to the incident wave. It is another way of expressing the match between the source and the load.

E9E08

What is a use for a Wilkinson divider?   **It is used to divide power equally between two 50-ohm loads while maintaining 50-ohm input impedance**
The Wilkinson Power Divider is a specific class of power divider circuit that can achieve isolation between the output ports while maintaining a matched condition on all ports.
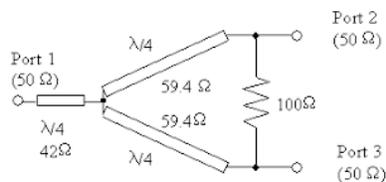
E9E09

Which of the following is used to shunt-feed a grounded tower at its base?   **Gamma match**

E9E10

Which of these choices is an effective way to match an antenna with a 100-ohm feed point impedance to a 50-ohm coaxial cable feed line?   **Insert a 1/4-wavelength piece of 75-ohm coaxial cable transmission line in series between the antenna terminals and the 50-ohm feed cable**

E9E11
What is the primary purpose of phasing lines when used with an antenna having multiple driven elements? **It ensures that each driven element operates in concert with the others to create the desired antenna pattern**

E9F Transmission lines: characteristics of open and shorted feed lines; coax versus open-wire; velocity factor; electrical length; coaxial cable dielectrics

E9F01
What is the velocity factor of a transmission line? **The velocity of the wave in the transmission line divided by the velocity of light in a vacuum**
Velocity factor is a measure of how much the radio waves are slowed from their free space velocity, the speed of light.

E9F02
Which of the following has the biggest effect on the velocity factor of a transmission line?
Dielectric materials used in the line

E9F03
Why is the physical length of a coaxial cable transmission line shorter than its electrical length?
Electrical signals move more slowly in a coaxial cable than in air
If the wavelength in free space for a frequency is approximately 2 meters, then the wavelength in a coaxial cable with a velocity factor of 0.66 would be (2 meters) (0.66) **or 1.32 Meters.**

E9F04
What impedance does a 1/2-wavelength transmission line present to a generator when the line is shorted at the far end? **Very low impedance**
Every ¼ λ (wavelength) the stub looks like the opposite of the previous ¼ λ.   For example, this is what Stubs look like at different wavelengths.

	¼ λ	½ λ	¾ λ	1 λ	1-¼ λ
Shorted Stub	open	short	open	short	open
Open Stub	short	open	short	open	Short

E9F05
What is the approximate physical length of a solid polyethylene dielectric coaxial transmission line that is electrically 1/4 wavelength long at 14.1 MHz? **3.5 meters**
Solid polyethylene dielectric coaxial transmission line has a velocity factor of 0.66. A quarter wavelength at 14.1 MHz in free space would be (300 ÷ 14.1) ÷ (4) **or (21.277) ÷ (4) or 5.319 Meters.** *If our coaxial cable has a velocity factor for polyethylene dielectric of 0.66 the cable length would be (5.319 meters) (0.66)* **or 3.510 meters.**

E9F06
What is the approximate physical length of an air-insulated, parallel conductor transmission line that is electrically 1/2 wavelength long at 14.10 MHz?   **10.6 meters**
A Half wavelength at 14.1 MHz in free space would be (300 ÷ 14.1) ÷ (2) **or (21.277) ÷ (2) or 10.613 Meters**

E9F07
How does ladder line compare to small-diameter coaxial cable such as RG-58 at 50 MHz?
Lower loss

E9F08
Which of the following is a significant difference between foam dielectric coaxial cable and solid
dielectric cable, assuming all other parameters are the same?
A. Foam dielectric has lower safe operating voltage limits
B. Foam dielectric has lower loss per unit of length
C. Foam dielectric has higher velocity factor
D. All these choices are correct

E9F09
What is the approximate physical length of a foam polyethylene dielectric coaxial transmission
line that is electrically 1/4 wavelength long at 7.2 MHz? **6.8 meters**

*¼ wavelangth = (300 ÷ 7.2) ÷ 4   or 41.666) ÷ 4 or 10.416. This the fee space length, for a
cable with a 0.66 velocity factor it would be (10.416) (0.66) or 6.875 Meters*

E9F10
What impedance does a 1/8-wavelength transmission line present to a generator when the line is
shorted at the far end?   **An inductive reactance**

E9F11
What impedance does a 1/8-wavelength transmission line present to a generator when the line is
open at the far end?   **A capacitive reactance**

E9F12
What impedance does a 1/4-wavelength transmission line present to a generator when the line is
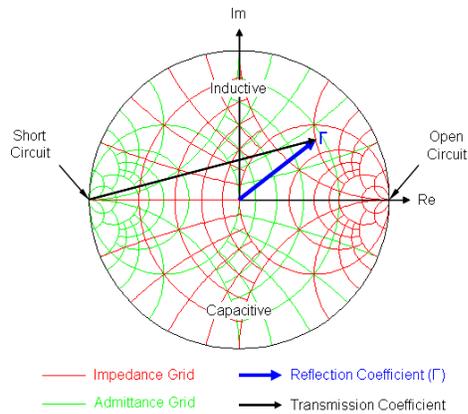open at the far end?   **Very low impedance**

E9F13
What impedance does a 1/4-wavelength transmission line present to a generator when the line is
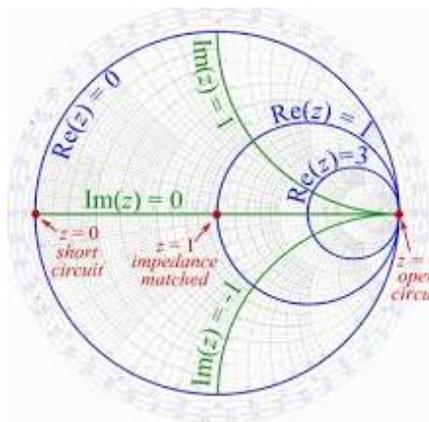shorted at the far end?   **Very high impedance**

E9G The Smith chart

E9G01
Which of the following can be calculated using a Smith chart? **Impedance along transmission lines**

E9G02
What type of coordinate system is used in a Smith chart? **Resistance circles and reactance arcs**

E9G03
Which of the following is often determined using a Smith chart? **Impedance and SWR values in transmission lines**

E9G04
What are the two families of circles and arcs that make up a Smith chart? **Resistance and reactance**
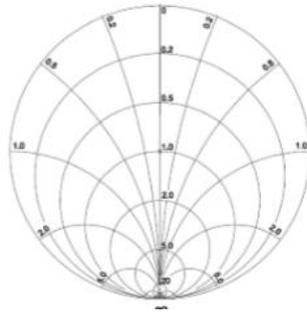
E9G05
Which of the following is a common use for a Smith chart? **Determine the length and position of an impedance matching stub**

E9G06
On the Smith chart shown in Figure E9-3, what is the name for the large outer circle on which the reactance arcs terminate?   **Reactance axis**

Figure E9-3

E9G07
On the Smith chart shown in Figure E9-3, what is the only straight line shown?
The resistance axis

E9G08
What is the process of normalization with regard to a Smith chart?   **Reassigning impedance values with regard to the prime center**

E9G09
What third family of circles is often added to a Smith chart during the process of solving problems? **Standing wave ratio circles**

E9G10
What do the arcs on a Smith chart represent?   **Points with constant reactance**

E9G11
How are the wavelength scales on a Smith chart calibrated? **In fractions of transmission line electrical wavelength**

E9H Receiving Antennas: radio direction finding antennas; Beverage antennas; specialized receiving antennas; long-wire receiving antennas

E9H01
When constructing a Beverage antenna, which of the following factors should be included in the design to achieve good performance at the desired frequency? **It should be one or more wavelengths long**
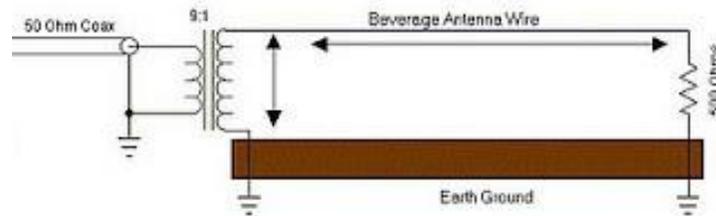

E9H02
Which is generally true for low band (160 meter and 80 meter) receiving antennas? **Atmospheric noise is so high that gain over a dipole is not important**

E9H03
What is Receiving Directivity Factor (RDF)? **Forward gain compared to average gain over the entire hemisphere**
Receiving Directivity Factor (RDF) is a figure of merit for radio receiving antennas. It is the antenna gain in the forward direction divided by the gain in all other directions.
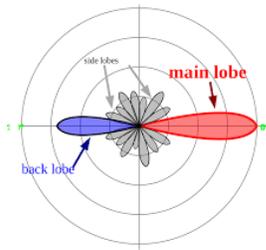
E9H04
What is an advantage of placing a grounded electrostatic shield around a small loop direction-finding antenna? **It eliminates unbalanced capacitive coupling to the surroundings, improving the nulls**
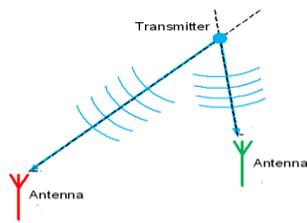
E9H05
What is the main drawback of a small wire-loop antenna for direction finding? **It has a bidirectional pattern**
An ideal antenna for direction finding would be omni directional such as a Yagi or Quad

E9H06
What is the triangulation method of direction finding?   **Antenna headings from several different receiving locations are used to locate the signal source**

E9H07
Why is RF attenuation used when direction-finding?   **To prevent receiver overload which reduces pattern nulls**
It is best to use the least sensitive setting on a receiver to find signal direction because they provide better nulls away form the station and are easier to detect using the receivers s-meter,

E9H08
What is the function of a sense antenna?   **It modifies the pattern of a DF antenna array to provide a null in one direction**

E9H09
What is a Pennant antenna?   **A small, vertically oriented receiving antenna consisting of a triangular loop terminated in approximately 900 ohms**
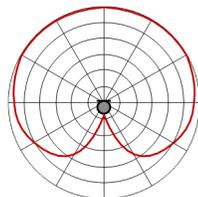*This is a small low noise receiving antenna for those without adequate room for large beverage type antennas.*
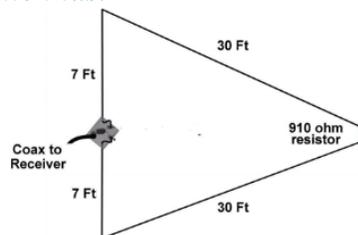
E9H10
How can the output voltage of a multiple-turn receiving loop antenna be increased?
By increasing the number of turns and/or the area

E9H11
What feature of a cardioid pattern antenna makes it useful for direction finding?   **A very sharp single null**

SUBELEMENT E0 – SAFETY - [1 exam question -– 1 group]

E0A Safety: RF radiation hazards; hazardous materials; grounding

E0A01
What is the primary function of an external earth connection or ground rod? **Lightning protection**

E0A02
When evaluating RF exposure levels from your station at a neighbor's home, what must you do?
Ensure signals from your station are less than the uncontrolled Maximum Permitted Exposure (MPE) limits
These are the MPE limits (Effective Radiated Power), above which a station MPE evaluation is required

Band	Power (W) into Antenna
160-meters	500
80-meters	500
40-meters	500
30-meters	425
20-meters	225
17-meters	125
15-meters	100
12-meters	75
10-meters	50
6-meters	50
2-meters	50
1.25-meters	50
70-centimeters	70

A Radio Frequency power density calculator can be found at
http://hintlink.com/power_density.htm

E0A03
Over what range of frequencies are the FCC human body RF exposure limits most restrictive?
 30 to 300 MHz
That would be the 10 meter through the 1.25 meter bands from the chart in the previous question

E0A04
When evaluating a site with multiple transmitters operating at the same time, the operators and licensees of which transmitters are responsible for mitigating over-exposure situations?
Each transmitter that produces 5 percent or more of its MPE limit in areas where the total MPE limit is exceeded.

E0A05
What is one of the potential hazards of operating in the amateur radio microwave bands?
The high gain antennas commonly used can result in high exposure levels
A transmitter with 50 watts into an antenna with 10 dB 0f gain would have a power level of 500 watts in the direction is aimed

E0A06
Why are there separate electric (E) and magnetic (H) field MPE limits?
A. The body reacts to electromagnetic radiation from both the E and H fields
B. Ground reflections and scattering make the field strength vary with location
C. E field and H field radiation intensity peaks can occur at different locations
D. All these choices are correct

E0A07
How may dangerous levels of carbon monoxide from an emergency generator be detected?
 Only with a carbon monoxide detector
Carbon monoxide, or "CO," is an odorless, colorless gas that can kill you.

E0A08
What does SAR measure? **The rate at which RF energy is absorbed by the body**
SAR stands for Specific Absorption Rate and is defined as the power absorbed per mass of tissue. It has units of measure in watts per kilogram (W/kg).

E0A09
Which insulating material commonly used as a thermal conductor for some types of electronic devices is extremely toxic if broken or crushed and the particles are accidentally inhaled?
Beryllium Oxide

E0A10
What toxic material may be present in some electronic components such as high voltage capacitors and transformers? **Polychlorinated biphenyls**
A polychlorinated biphenyl (PCB) is an organic chlorine compound. Polychlorinated biphenyls were once widely deployed as dielectric and coolant fluids in electrical apparatus like transformers and High Voltage capacitors.

E0A11
Which of the following injuries can result from using high-power UHF or microwave transmitters? **Localized heating of the body from RF exposure in excess of the MPE limits**

Reference Materials

For Amateur Extra Class License Syllabus

Greek alphabet comonly used in electronics

ß	Beta	θ	Theta
α	Alpha	τ	Tau
γ	Gama	Ω	Omega
Δ	Delta	π	PI
λ	Lamda		

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Scientific Notation commonly used in electronics

giga	G	1,000,000,000	1x 10^9
mega	M	1,000,000	1x 10^6
kilo	k	1,000	1x 10^3
Milli	m	0.001	1x 10^-3
Micro	μ	0.000,001	1x 10^-6
Nano	n	0.000,000,001	1 x 10^-9
Pico	p	0.000,000,000,001	1 x 10^-12

Note: The ^ symbol is used to denote an exponent. For example: 2 cubed would be 2^3 which is 2 x 2 x 2 or 8. If we want to represent a small or large quantity, we will express it as a number multiplied by 10 raised to a negative or positive power.

Example1:
2,200 could be shown a (2.2) (10^3) which means 2.2 multiplied by 1,000 because 10^3 is 10 x 10 x10 or 1,000

Example 2:
0.000336 could be shown as 336 (10^ -6)

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Series connected Resistors

Total resistance for Resistors in series is simply the sum of each of the resistors.
$R_{(total)} = R1 + R2 + R3 + \ldots\ldots Rx$

Example 1:
A 12 ohm, 18 ohm and 53 ohm resistors connected in series would be the equivalent of a single resistor of: *R(total) = 12 +18 + 53 or 83 Ohms*

Example2:   **2:**
An 8,000 ohm, 14,000 ohm 1,300 ohm and 5,300 ohm resistors connected in series would be the equivalent of a single resistor of: *R(total) = 8,000 +14,000 + 1,300 + 5,300 or 28,600 Ohms*

Example 3:
A 1 megohm, 150 kilohm and 25 kilohm resistors connected in series would be the equivalent of a single resistor of: *R(total) = 1,000,000 +150,000 + 25,000 or 1,175,000 Ohms or 1.75 megohms*

Parallel connected Resistors

Total resistance for Resistors in Parallel is one over the sum of one over each resistor
$R_{(equivalent)} = 1 \div((1 \div R1) + (1 \div R2) + (1 \div R3) +……. (1 \div Rx))$

Example 1:
A 23 ohm, 30 ohm and 47 ohm resistor at connected in parallel. The equivalent resistance would be:
R(equivalent) = 1 ÷ ((1 ÷ 23) + (1 ÷ 30) + (1 ÷ 47)) or R = 1 ÷ (0.0438 + 0.0333 + 0.02128) or 1 ÷ 0.0983 or 10.19 ohms

Example 2:
A 100 ohm, 38 ohm and 800 ohm resistor at connected in parallel. The equivalent resistance would be:
R(equivalent) = 1 ÷ ((1 ÷ 100) + (1 ÷ 38) + (1 ÷ 800)) or R = 1 ÷ (0.01 + 0.0263 + 0.00125) or 1 ÷ 0.0378 or 26.62 ohms

Example 3:
A 5 ohm, 3 ohm and 11 ohm resistor at connected in parallel. The equivalent resistance would be:
R(equivalent) = 1 ÷ ((1 ÷ 5) + (1 ÷ 3) + (1 ÷ 11)) or R = 1 ÷ 0.200 + 0.333 + 0.090 or 1 ÷ 0.0375 or 1.60 ohms

Series connected Inductors

Series Inductors simply add. The total Inductance's of series is the sum of the individual Inductors:
Ltotal = L1 + L2 + L3 ………..+ Lx

Example 1:
The equivalent vale for a 10 mH, 20 and 30 mH inductors in series would be:
Ltotal =10 +20 + 30 or 60 mH

Example 2:
The equivalent vale for a 2 H, 7H and 500 mH inductors in series would be:
Ltotal =2 +7 + 0.50 or 9.5 H

Example 3:
The equivalent vale for a 10 µH, 7µH and 100µH inductors in series would be:
Ltotal = 10 +7 + 100 or 117µH

Parallel connected Inductors
The total for Inductors in Parallel is one over the sum of one over each inductance
$L_{total} = 1 \div ((1 \div L1) + (1 \div L2) + (1 \div L3) + \ldots.. (1 \div Lx))$

Example 1:
A 1 H, 5 H and 8 H in Parallel would be:
$L_{total} = 1 \div ((1 \div L1) + (1 \div L2) + (1 \div L3)) \text{ or }$
$L_{total} = 1 \div ((1) \div 1) + (1 \div 5) + (1 \div 8)) \text{ or }$
$L_{total} = 1 \div ((1 \div 1) + (1 \div 0.5) + (1 \div 0.125)) \text{ or } L_{total} = 1 \div 1.625 \text{ or } 0.755 \text{ Henries}$

Example 2:
For a circuit with a 100 mH, 50 mH and 120 mH in parallel would be:
$L_{total} = 1 \div ((1 \div L1) + (1 \div L2) + (1 \div L3) \text{ or }$
$L_{total} = 1 \div ((1 \div 0.100) + (1 \div 0.050) + (1 \div 0.120)) \text{ or }$
$L_{total} = 1 \div (10 + 20 + 8.33 \text{ or } L_{total} = 1 \div 38.33 \text{ or } L_{total} = 0.026 \text{ Henries or } 26 \text{ mH}$

Example 3:
For a circuit with a 1 mH, 2 mH and 5 mH in parallel would be:
$L_{total} = 1 \div ((1 \div L1) + (1 \div L2) + (1 \div L3) \text{ or }$
$L_{total} = 1 \div ((1 \div (0.001)) + ((1) \div (0.002)) + ((1) \div (0.005))) \text{ or }$
$L_{total} = 1 \div (1,000 + 500 + 200) \text{ or } L_{total} = 1 \div 1,700 \text{ or } 0.00059 \text{ Henries or } 0.59 \text{ mH or } 590\mu H$

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Parallel connected Capacitors

Total capacitance for capacitors in parallel is simply the sum of each of the capacitors:
$C_{total} = C1 + C2 + C3 + \ldots\ldots. Cx$

Example 1:
Four 10µf capacitors in parallel would be: $C_{total} = 10 + 10 + 10 + 10 \text{ or } 40 \mu f$

Example 2:
A 10µf, 15µf, 3µF in parallel would be: $C_{total} = 10 + 5 + 3 \text{ or } 18\mu f$

Example 3:
A 97pf, 35 pf and 27 in parallel would be: $C_{total} = 97 + 35 + 27 \text{ or } 159pf$

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Series connected Capacitors

Series capacitors is the sum of each capacitor divided into one and then that sum divided into one. For equal value capacitors C_{total} = value one capacitor ÷ number of capacitors.

$C_{total} = 1 \div ((1 \div C1) + (1 \div C2) + (1 \div C3) + \ldots.. (1 \div Cx))$

Example 1:
Three 10 µf capacitors in series would be:
Ctotal = 10 µf ÷ 3 or 3.333 µf

Or using the equation:
Ctotal = 1 ÷ ((1 ÷ C1) + (1 ÷ C2) + (1 ÷ C3) or Ctotal = 1 ÷ ((1 ÷ 10) + (1 ÷ 10) + (1 ÷ 10)) or
Ctotal = 1 ÷ ((1 ÷ 0.1) + (1 ÷ 0.1) + (1 ÷ 0.1)) or Ctotal = 1 ÷ 0.3 or Ctotal = 3.333 µf

Example 2:
Two 220µf capacitors in series would be: *Ctotal = 220 µf ÷ 2 or 110 µf*

Or using the equation:
Ctotal = 1 ÷ ((1 ÷ C1) + (1 ÷ C2))X   or Ctotal = ((1 ÷ 220) + (1 ÷ 220)) or
Ctotal = ((1 ÷ 0.004545) + (1 ÷ 0.004545)) or Ctotal = 1 ÷ .00909 or 110 µf

Example 3:
A 10 µf, 1.5µf and 18 µf capacitors in series would be:
Ctotal = 1 ÷ ((1 ÷ C1) + (1 ÷ C2)+ (1 ÷ C3)) or
Ctotal = 1 ÷ ((1 ÷ 10) + (1 ÷ 1.5) + (1 ÷ 18)) or
Ctotal = 1 ÷ (0.1 + 0.667 + 0.055) or 1 ÷ 0.822 or 1.216 µf

Example 4:
A 20 µf, 35µf and 50 µf capacitors in series would be:
Ctotal = 1 ÷ ((1 ÷ C1) + (1 ÷ C2)+ (1 ÷ C3)) or
Ctotal = 1 ÷ ((1 ÷ 20) + (1 ÷ 35) + (1 ÷ 50)) or
Ctotal = 1 ÷ (0.05 + 0.029 + 0.020) or Ctotal = 1 ÷ 0.99 or 10.1 µf

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Ohms Law

Ohms law describes the relationship between Voltage, Current and Resistance in a circuit. The triangles show below will allow you to easily determine the unknown when the other two quantities are known:

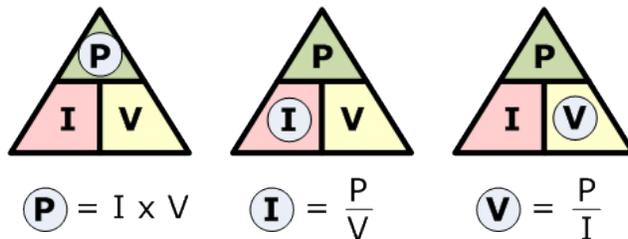$$V = I \times R \qquad I = \frac{V}{R} \qquad R = \frac{V}{I}$$

Example 1:
If you want to know the voltage in a circuit when the current is 1 ampere and the resistance is 10 ohms, simply cover the V with your thumb and you will see that it is equal to the resistance times the current **or**
Voltage = 1 ampere times 10 ohms or 10 volts.

Example 2:
If you want to know the current in the in a circuit with 20 volts and 500 ohms cover the I and you will see that it is equal to the voltage divided by the resistance **or**   *Current = 20 ÷ 500 or 0.04 amperes or 40 ma*

Example 3:
If you want to know the resistance in a circuit with a voltage of 120 volts and a current of 0.04 amperes cover the R and you will see that it is equal to the voltage divided by the current **or**
Resistance = 120 volts ÷ 0.04 amperes or 3,000ohms

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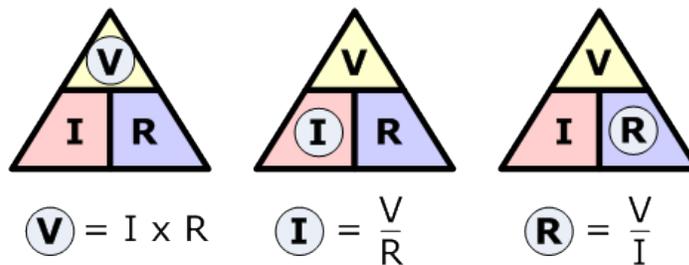
Power Law

$$P = I \times V \qquad I = \frac{P}{V} \qquad V = \frac{P}{I}$$

The power law describes the relationship between Voltage in Volts, Current in Amperes and Power in watts in a circuit. The triangles shown above allow you to easily determine the unknown when the other two quantities are known,

Example 1:

If you want to know the Power in a circuit when the current is 1 ampere and the voltage is 10 volts, simply cover the P with your thumb and you will see that it is equal to the Voltage times the current **or** *Power = 1 ampere times 10 volts or 10 watts.*

Example 2:

If you want to know the current in the in a circuit with 20 of power dissipated and a voltage of 36 volts cover the I and you will see that it is equal to the voltage divided by the resistance **or** *Current = 20 ÷ 36 or 0.556 amperes or 556 ma.*

Example 3:

If you want to know the voltage in a circuit with a power dissipated of 1,000 watts volts and a current of 0.400 amperes cover the V and you will see that it is equal to the Power divided by the current **or**
Voltage = 1,000 watts ÷ 0.400 amperes or 2,500 volts

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AC Voltage Peak vs RMS

AC Peak Voltage vs. RMS:
For a pure sine wave the equivalent RMS value is 0.707 times the peak value. Conversely the peak voltage can be calculated as 1.414 times the RMS Value.

Examples: The peak voltage at a standard 120V RMS AC line voltage outlet is 1.414 x 120V or approx. 170 volts peak. The peak to peak (maximum negative to maximum positive peaks) would be two times the peak voltage or approx. 340 V Peak to Peak.

Peak = RMS Voltage x 1.414 or Peak = 120 x 1.414 or Peak =169.7 Volts

PP = 2x Peak   or   PP = 2 x (120 x 1.414) o PP = 2 x 169.7 or PP = 339.4 Volts

An AC voltage that reads 65 volts on an RMS meter will have a peak to peak voltage of 184 Volts.

Peak to Peak voltage = 2 x RMS x 1.414 or PP= 2 x 65 x 1.414 or PP= 183.8 Volts

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Wavelength

Wavelength is the distance a wave will travel during one cycle usually expressed in meters. Radio waves travel at the speed of light at approximately 300 million meters per second (actual speed is 299 792 458 meters every second) Wavelength is important in amateur radio when designing and building antennas, building Tuning Stubs, and cutting phase shifting cables.

Wavelength can be calculated using the following equation:

Wavelength (in Meters) = (speed of light in meters/second) ÷ (frequency in Hz) or for typical amateur radio calculations Wavelength in meters = 300 ÷ frequency in MHz

This is an important relationship to remember since there are several questions in the exam relating to wavelength for a specific frequency or the frequency for a given wavelength. The Triangle below may help you use this equation. Cover the value you do not know, and you will see what you need to do with the known values to find the unknown value.
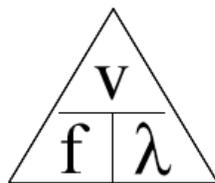
We frequently refer to the frequency bands in amateur radio by their wavelength in meters. For instance, 146 Megahertz (MHz) would be the 2 meter band.   Wavelength is easily calculated as using the triangle. Cover the λ in the triangle and you will see it is equal to (300) ÷ (frequency in MHz). To find the wavelength for 146 MHz we would proceed as follows:

WL (in Meters) = (300) ÷ (146) or WL = 2.055 meters or rounded off to 2 meters

Example 1:
For a frequency of 446 MHz: *WL (in Meters) = (300) ÷ (446) or WL = 0.67 meters or 67 Centimeters (rounded up to 70 cm)*

Example 2:
For a frequency of 7.34 MHz:
WL (in Meters) = (300) ÷ (7.34) **or WL = 40.872 meters (rounded down to 40 meters)**

Example 3:
For a frequency of 51 MHz:
WL (in Meters) = (300) ÷ (51) **or WL = 5.882 meters (rounded up to 6 meters)**

Electrical vs physical wavelength in Coaxial Cable

Passing an RF signal though a coaxial cable slows its speed or the cable appears to be longer than the measured wavelength in free space. The amount of difference is the Velocity Factor of the cable. For normal solid polyethylene dielectric coaxial transmission line is 0.66. This means tat one wavelength of cable will be 0.66 of that in free space as calculated using the wavelength triangle.

Example #1
The approximate physical length of a solid polyethylene dielectric coaxial transmission line with a velocity factor of 0.066 that is electrically one-quarter wavelength long at 14.1 MHz is 3.5 meters

¼ wavelength = (0.25 (300÷14.1))(0.66) **or .(25 x 21.28)(0.66)** *or* **5.319 x 0.66** *or 3.51 meters*

Example #1
The approximate physical length of 450 ohm Ladder line transmission line with a velocity factor of 0.91 that is electrically one-quarter wavelength long at 14.1 MHz is 4.84 meters

¼ wavelength = (0.25 (300÷14.1))(0.91) **or .(25 x 21.28)(0.91)** *or* **5.319 x 0.91** *or 4.84 meters*

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Capacitive reactance

Capacitive reactance is the equivalent resistance of a capacitor in an AC circuit at a given frequency. Capacitive reactance goes from a very high value at low frequencies and is a very low value at high frequencies. Capacitive reactance can be determined by the expression Xc (capacitive reactance in ohms) is equal to 1 over 2 x π x F x C with the frequency (F) in Herts and the capacity in Farads. In easier to use form for most RF problems enter the frequency in MHz and the Capacity in microfarads.

Example 1:
To determine the capacitive reactance of a .001 microfarad capacitor at 7.35 MHz use the following expression:
Xc = 1 ÷ ((2) (π) (7.35) (0.001)) **or 1 ÷ (2 (3.1415) (7.35) (0.001))** *or 21.654 ohms*

Example 2:
Determine the capacitive reactance of a 100 pF capacitor at 28 MHz:
Xc = 1 ÷ ((2) (π) (28) (0.0001)) **or 1 ÷ ((2) (3.1415) (28) (0.000,1))** *or 56.84 ohms*

Example 3:
Determine the capacitive reactance of a .1 microfarad capacitor at 100 KHz;
Xc = 1 ÷ ((2) (π) (0.1) (0.1)) or 1 ÷ ((2) (3.1415) (1.8) (0.1)) or 15.915ohms

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Inductive Reactance

Inductive reactance is the equivalent resistance of an inductor in an AC circuit at a given frequency. Inductive reactance goes from a very low value at low frequencies and is a very high value at high frequencies. Inductive reactance can be determined by the expression XL (inductive reactance in ohms) is equal to   2 $_x$ π $_x$ F $_x$ L with the frequency (F) in Hertz and the Inductance in Henries.   In easier to use form for most RF problem enter the frequency in MHz and the Inductance in microhenries.

Example 1:
To determine the inductive reactance of a 15 microhenry inductor at 14.2 MHz use the following expression: *X_L = (2) (π) (14.2) (15) or (2) (3.1415) (14.2) (15) or 1,338 ohms*

Example 2:
To determine the inductive reactance of a 10 microhenry inductor at 10MHz use the following expression: *X_L = (2) (π) (10) (10) or (2) (3.1415) (10) (10) or 628.3 ohms*

Example 3:
To determine the inductive reactance of a 3 microhenry inductor at 146 MHz use the following expression: *X_L = (2) (π) (146) (3) or (2) ((3.1415) (146) (3)) or 2,752 ohms or 2.752 kilo-ohms*

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Modulation Index
The modulation index indicates by how much the modulated variable varies around its unmodulated level. It relates to variations in the carrier frequency:

Modulation Index = ΔFrequency /Frequency of modulation

For a 5 KHz deviation signal with a 3 KHz modulating frequency the modulation index would be: Mod Index = 5,000 ÷ 3,000 or Mod index = 1.666

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L and S bands

 The terms L band and S bands with regard to satellite communications are the 23 centimeter and 13 centimeter bands

The 23 cm band would be ~ 1,300 MHz and the 13 CM Band would be ~2,300 MHz

L Band	1 - 2 GHz
S Band	2-4 GHz

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Image frequency responses

What transmit frequency might generate an image response signal in a receiver tuned to 14.300 MHz and which uses a 455 kHz IF frequency?

The Local Oscillator signal would be 455 KHz higher than the receive frequency, or 13,755 Mhz. A signal 455 KHz above this LO Frequency would also produce a 455 KHz if output **or**
 13.755MHz +455KHz or 15.210 MHz

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Intermodulation products

What transmitter frequencies would cause an intermodulation-product signal in a receiver tuned to 146.70 MHz when a nearby station transmits on 146.52 MHz?

 The first intermodulation product is: $I_{mod} = 2F_1 - f_2$ or 146.70 = 2(146.52) - f_2 or 146.70 - f_2 or 146.7 -293.04 = - f_2 or -146.34 = - f_2 or f_2 = 146.34 MHz

The Second intermodulation product is: $I_{mod} = F_1 -2f_2$
146.70 = 146.52 -2 f_2 or   146.70 +145.52 = 2 f_2 or   293.22 = 2 f_2 or f_2 =146.61 MHz

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Third order intercept point

What does a third-order intercept level (point) of 40 dBm mean with respect to receiver performance?

A pair of 40 dBm signals will theoretically generate a third-order intermodulation product with the same level as the two input signals . The pair of input signals as they are increased together will produce a third order products. The third order signal increases at faster rate (3:1) than when the two test signals are increased. When the third order signal rises to the level of the test signals this is considered the third order intercept point and is expressed in dBm.

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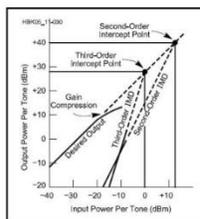
Trigonometry Tutorial

For problems associated with electronics involving circuits with resistance and reactance in the Extra class Exam you will need a basic understanding of trigonometry. Trigonometry centers on a right triangle (that is a triangle   that has one angle that is 90° and the sum of the remaining two angles is equal to 90°). Using trigonometric functions if we   know two sides, or an angle (other than the 90°angle) and one side of the triangle we can calculate the remaining angles and sides.
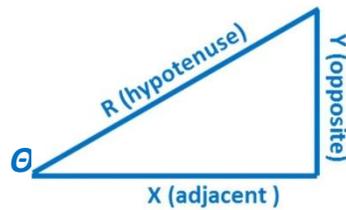
The sides of the triangle are given names from the rectangular coordinate system with the horizontal side called X (also called the Adjacent side) and the vertical side is called Y (also called the opposite side) and the side connecting the X and Y sides is called the Hypotenuse called R in this example If two of the three sides are known then the third side can be found using the following equation:

$$Hypotenuse(R) = \sqrt{(X^2+Y^2)}$$

Example 1:
If X=3 and Y=4 then R=5   then H $= \sqrt{(3^2 + 4^2)}$ or H $= \sqrt{(9+16)}$ or H $= \sqrt{25}$ or H = 5

Example 2:
If X=5 and Y=10 then R=11.18 then H $= \sqrt{(5^2 + 10^2)}$ or H $= \sqrt{(25+100)}$ or H $= \sqrt{125}$ or Hypotenuse or 11.18

Example 3:
If X=50 and Y=100 then R=111.80   H $= \sqrt{(50^2 + 100^2)}$ or H $= \sqrt{(2,500+10,000)}$ or H $= \sqrt{12,500}$ or H = 111.8

There are three trigonometric functions that can be used to calculate the angle, Θ, between X and R and between Y and R. They are Sine, Cosine and Tangent to solve for the angle between the X side and the R side: *Sine of Θ = Y ÷ R*
Cosine of Θ = X ÷ R
Tangent of Θ = Y ÷ X

Example 1:
To find the angle, θ, for a triangle with side X value of 3 and a side Y value of 6:
We use the equation, Tangent of θ = Y ÷ X or Tangent of θ = 6 ÷ 3 or 2.00. To find the angle enter 2 into your calculator and press the <u>arctangent</u> (or (Tan^-1)) key which will show you the angle represented by the tangent value, in this case 2.00. The answer is 63.43°.

Example 2:
To find the angle, Θ, for a triangle with a side X value of 3 and a side Y value of 4:
We use the equation, Tangent of θ = Y / X or Tangent of θ = 4 ÷ 3 or 1.333. To find the angle enter 1.333 into your calculator and press the <u>arctangent</u> (or (Tan^-1)) key on some calculators) key which will show you 53.13°

Example 3:
To find the angle, Θ, for A triangle with a side X value of 12 and a side Y value of 12:
We use the equation Tangent of θ = Y / X or Tangent of θ = 12 ÷ 12 or 1.   To find the angle enter 1 into your calculator and press the <u>arctangent</u> (or (Tan^-1)) key which will show the angle is 45.0°
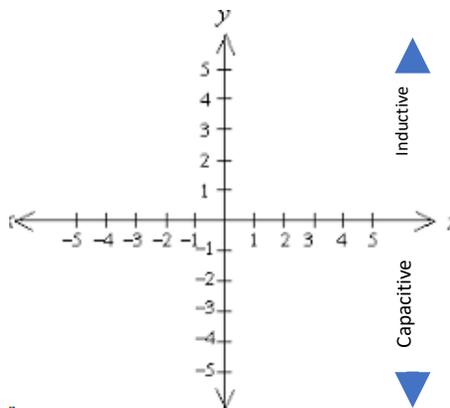
Example 4:
To find the value of Y when the angle is 35° and X is 25
The Tangent of 35° is 0.70 which is Y ÷ X or 0.70 = 25 ÷ X or (0.700) (25) = X or 17.5

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Rectangular coordinate system

In order to plot complex impedance (resistance, + inductance, - capacitance) in rectangular coordinates you will need to solve for the reactance of both the inductive and capacitive reactance's at the frequency of interest. If the sum of the reactance's is 0 (they are the same value) then the circuit impedance is only the resistive component.

This is a rectangular coordinate system. The horizontal line is the resistance axis and the vertical axis is inductive reactance (+) or capacitive reactance (-) also referred to a +j (inductive reactance) or -j (capacitive Reactance). To solve a problem using these coordinates calculate the sum of the inductive reactance and the capacitive reactance. Go out on the a (resistive) axis to the resistance value, then up (inductive reactance) or down (capacitive reactance)to the reactance value. Draw a line from this point to the center where the two axis cross. This line is the impedance and the angle can be determined with simple trigonometry.

Example 1:
What is the phase angle between the voltage across and the current through a series RLC circuit if XC is 500 ohms, R is 1 kilohm, and XL is 250 ohms?
The reactance is the sum of the (Inductive reactance) – (the capacitive reactance) or 250 – 500 or -150
Tangent of θ (the angle of the impedance vector) = Y ÷ X or Tangent of θ = -250 ÷ 1,000 or
Tangent of θ = -0 .25 or arctangent of 0.25 = -14.04°
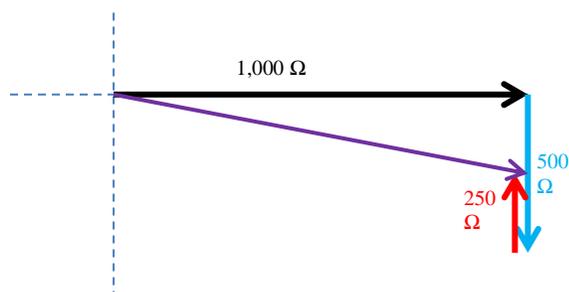
Example 2:
What is the phase angle between the voltage across and the current through a series RLC circuit if XC is 25 ohms, R is 100 ohms, and XL is 50 ohms?

The reactance is the sum of the (Inductive reactance) – (the capacitive reactance) or 50 – 25 or +25
Tangent of θ (the angle of the impedance vector) = Y ÷ X or Tangent of θ = - 25 ÷ 100 or
Tangent of θ = + 0 .25 or arctangent of 0.25 = +14.04°
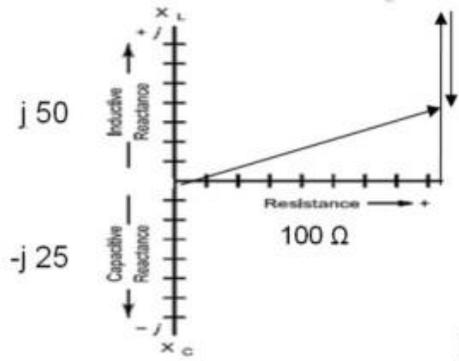
Example 3:
What is the phase angle between the voltage across and the current through a series RLC circuit if XC is 18 ohms, R is 50ohms, and XL is 30 ohms?   *Tangent of θ = Y ÷ X or Tangent of θ = (30-18) ÷100 or*
Tangent θ = (12) ÷ 100 or Tangent of θ =0.12 or arctangent of 0.12= +6.84°

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Amplifier Classes

Analog Amplifiers are categorized by their type or class of operation, and circuit configuration. Classes of operation are A, AB, B & C. There is also a digital form of an analog amplifier.

Comparison between Different
Classes of P.A.

Power amplifiers	Conduction angle	Maximum Efficiency (Theoretical)
Class A	360	50%
Class B	180	78.5%
Class C	<180	90%

The class of operation of an amplifier stage is defined by its **conduction angle**. That is the angular portion of the sine wave drive cycle, in degrees, during which plate current (or collector or drain current in the case of solid state devices) flows. This, in turn, determines the amplifier's efficiency and linearity.

Amplifier Classes

Class A: The conduction angle is 360°. DC bias and drive level are set so that the device is not driven to output current cutoff at any point in the driving- voltage cycle so some device output current flows throughout the complete 360° of the cycle. Output voltage is generated by the variation of output current flowing through the load resistance. Maximum linearity and gain are achieved in a Class A amplifier, but the efficiency of the stage is low. Maximum theoretical efficiency is 50%, but 25 to 30% is more typical.

Class B: Conduction angle = 180°. Bias and RF drive are set so that the device is just cut off with no signal applied and device output current flows during one half of the drive cycle. Efficiency can reach as high as 65%, with fully acceptable linearity.

This is a class B push pull amplifier output stage. Each transistor only conducts on one half of the cycle, but they are summed to produce a full cycle. The advantage over a class A amplifier is that there is little or no current flowing when there is no input signal. There will be some loss of signal at the crossover point which will show up as distortion.

Class AB: The conduction angle is greater than 180° but less than 360°. In other words, dc bias and drive level are adjusted so device output current flows during a little more than half the drive cycle, but less than the whole drive cycle. The class AB amplifier eliminates the crossover signal distortion with a little more than 180° conduction at the expense of a little current flow with no signal input. Efficiency is much better

than Class A, typically reaching 50-60% at peak output power. Class AB linearity and gain are not as good as that achieved in Class A but are acceptable for even the most rigorous   applications.

Class C: The conduction angle is much less than 180°—typically 90°. DC bias is adjusted so that the device is cut off when no drive signal is applied. Output current flows only during positive crests in the drive cycle, so it consists of pulses at the drive frequency. Efficiency is relatively high, up to 80%, but linearity is extremely poor. Thus, Class C amplifiers are not suitable for amplification of amplitude modulated signals such as SSB or AM but are quite satisfactory for use in on off keyed stages or with frequency or phase modulation.

Class D: amplifier or switching amplifier is an amplifier in which the amplifying devices (transistors, MOSFET's) operate as electronic switches, and not as linear gain devices as in other amplifiers. They operate by rapidly switching back and forth between the supply rails, being fed by a modulator using pulse width, pulse density, or related techniques to encode the audio input into a pulse train. The audio is recovered through a simple low-pass filter into the loudspeaker. The high-frequency pulses are blocked. Since the pairs of output transistors are never conducting at the same time, there is no other path for current flow apart from the low-pass filter/loudspeaker. For this reason, efficiency can exceed 90%.

Class D amplifier block diagram

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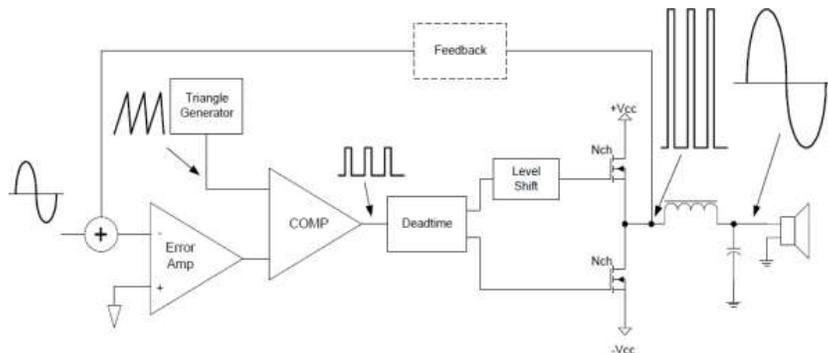
Decibels (dB)

The decibel (dB), is a logarithmic unit that is widely used in electronics audio and communication. The dB is a logarithmic way of describing a ratio between two values. The ratio may be of RF power, sound pressure, voltage or intensity and many other values.

For Power - dB = $10(\log_{10})$ (Power 1) ÷ (Power 2)
for an amplifier with 10 watts input and 125 watts output the gain in dB would be:
dB = $10((\log_{10})$ (Power 1/ Power 2)) or $10((\log_{10})$ (125÷ 10)) or $10((\log_{10})$ (12.5)) or 10(1.09) or 10.96 dB

For voltage - dB = $20(\log_{10})$(voltage 1 ÷ voltage 2)
for an circuit with 75 volts input and 3 volts output the loss in dB would be:
dB = $20((\log_{10})$(voltage 1 ÷ voltage 2)) or $20((\log_{10})$(3 ÷ 75)) or $20((\log_{10})$(0.0400)) or 20(-1.398) or a loss of - 27.96 dB

Simple Power dB relationships:

Loss (-)			Gain (+)
one half		3 dB	2 times
one tenth		10 dB	10 times

Example 1:
For example, for a +3dB value (power gain):
ratio = 10^(3 ÷ 10) or 10^(0.3) or 1.9996 or rounded off to 2

Example 2:
For example, for a -3dB value (power loss):
ratio = 10^(-3 ÷ 10) or 10^(0.3) or 0.509 or rounded off to one half.

Example3:
For example, for a -1.5dB value (power loss):
ratio = 10^(-1.5 ÷ 10) or 10^(0.15) or 0.707

 Example 4:
To answer the question what is power at the antenna if the output of a 50 transmitter and there is -1.3 dB loss in the cable feeding the antenna:

The power at antenna is the ratio of the power lost times the transmitter output power
(50 watts) ((10^ (-1.3 ÷ 10)) or (50 watts) (.7413) or 37.07 watts.

If the question asks how much power was lost:
take the input power subtract the power at the end of the cable calculated above or Loss = (50) – (37.07) or Loss = 12.93 watts

Calculation of ratio from dB:
Given the dB calculating the ratio of the two you need to reverse the process. Take the dB value and divide it by 10 to get back to the log of the input ratio. Then take 10 and raise it to this power (10^ (x) and you will get the ratio of the two original values.

Example 1:
what is the power loss in percentage for a -1.5 dB loss:
Ratio = 10^ ((1.5) ÷ (10)) or 10^ (-0.15) or 0.708
if we have a 1.5 dB loss in our system and we started out with 50 watts we would have:
(50) (.707) or 35.39 watts

Example 2:
what is the power gain in percentage for a +7 dB gain:
Ratio = 10^ ((7) ÷ (10)) or 10^ (+0.7) or 5.012

if we have a 17 dB gain in our system and we started out with 50 watts we would have:
(50) (5.012) or 2506 watts

Example 3:
what is the power loss in percentage for a 4 dB loss:
Ratio = 10^ ((4) ÷ (10)) or 10^ (-0.4) or 0.398 or 39.8%.
if we have a 1.5 dB loss in our system and we started out with 75 watts we would have:
(75) (.398) or 29.85 watts

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Time constant:

When a voltage is applied to a capacitor through a resistance (all circuits have resistance) it takes time for the voltage across a capacitor applied through a resistor to reach the applied voltage. At the instant the voltage is applied the current in the circuit is at a maximum limited only by the circuit resistance. As time passes the voltage across the capacitor rises and the current decreases until the capacitor charge reaches the applied voltage at which point the current goes to zero.

The voltage across the capacitor will rise to 63.2 % of the applied voltage in one time constant. The time constant in seconds is calculated by multiplying the resistance in megohms by the capacitance in microfarads.

For example, 100 volts applied to 1µF capacitor with a series one megohm resistor will charge to 63.2 volts in one second. Remember that TC= R (megohms) x C(microfarads) or TC= (1) (1) or 1 second and the charge after 1 time constant will be 63.2% of the applied 100 volts, or 63.2 volts

$$TC_{(Seconds)} = R_{(Megohms)} \ x \ C_{(Microfarads)}$$

Example 1:
The time constant of a circuit having two 220 microfarad capacitors and two 1 megohm resistors, all in parallel: *TC (Seconds) = R(Megohms) x C(Microfarads) or ((1) ÷(2))((220)(2)) or (0.5) (440) or 220 seconds*

Example 2:
The time constant of a circuit having a 47 microfarad capacitor and a 520 kilohm resistor:
TC (Seconds) = R(Megohms) x C(Microfarads) or (47) (0.520) or 24.44 seconds

Example 4:
Another example: The time constant of a circuit having a 100 microfarad capacitor and a 100 kilohm resistor. *TC (Seconds) = R(Megohms) x C(Microfarads) or (0.100) (100) or 0.01 second or 10 milliseconds*

After 5 time constants the capacitor will be at greater than 99.9% of the applied voltage as shown in the graph bellow (in theory the capacitor takes an infinite time to reach the applied voltage getting to 63.2% of the remaining difference each additional time constant):
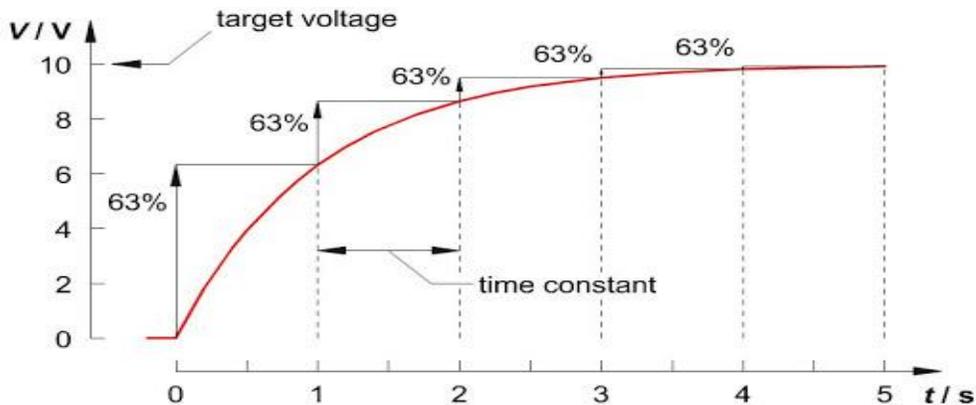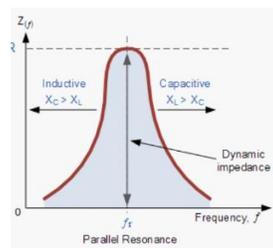

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Resonant Frequency

A resonant frequency occurs in a circuit with and inductor and capacitors in series or parallel exhibit the same reactance in ohms or the inductive reactance is equal to the capacitive reactance. In a perfect circuit current is continuously exchanged rom the inductor to the capacitor and back forever once it is started. Since there is no perfect circuit the current exchange will diminish with time unless refreshed.

The graph below shows the circuit impedance as frequency is tuned through the resonant frequency of a parallel inductor / capacitor circuit

Calculating the resonant frequency of a series or parallel circuit is done using the following equation:

Example 1:
A series resonance network consisting of a capacitor of 2uF and an inductor of 20mH. The resonant frequency of this network can be calculated using the following equation:

$F = 1 \div ((2 \pi) (\sqrt{((L) (C))}$ *or* $1 \div ((6.283) (\sqrt{(20^{\wedge}-3) (2^{\wedge}-6)))$ *or*
$1 \div ((6.283)(\sqrt{4.00^{\wedge}-8}))$ *or* $(1 \div ((6.283) (0.00020))$ *or* $1 \div (0.126)$ *or* $795.7\ Hz$

Example 2:

The resonant frequency for a network with 2 µh and 100 pf is

F = 1 ÷ ((2 π) (√((L) (C))) or 1 ÷ ((6.28) (√ (2^-6) (100^-12)) or 11,259,662 Hz or 11.259 MHz

Example 3:

the resonant frequency for a network with 12 µh and 47 pf is

F = 1 ÷ ((2 π) (√((L) (C)) or 1 ÷ ((6.28) (√ (12^-6) (47^-12)) or 6,705,0321 Hz or 6.702 MHz

Series resonant circuits have their lowest impedance at resonance. . Parallel resonant circuits have at their highest impedance at resonance.

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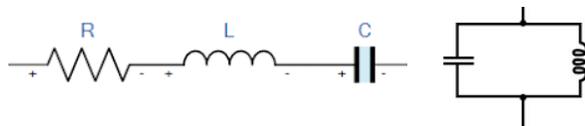
Circuit Q or Quality factor

The Q value is a parameter that indicates the quality of resonant circuit. A higher Q resonant circuit will have a narrower bandwidth (BW). Bandwidth is the difference in frequency where the power is 3dB lower than the power at the center of the pass band.
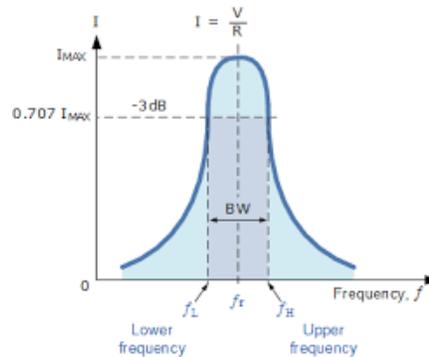
Example 1:

The Q for a circuit with a center frequency of 1.0 MHz and a 3dB bandwidth 10 kilohertz can be determined as follows: *Q = (C$_{frequency}$) ÷ (3 dB BW) or Q = 1,000,000 ÷ 10,000 or Q = 100*

Example 2: The Q for a circuit with a center frequency of 28.0 MHz and a 3dB bandwidth 455 kilohertz can be determined as follows: *Q = (C$_{frequency}$) ÷ (3 dB BW) or Q = (28,000,000) ÷ (455) or Q = 61.5*

Example 3:

The bandwidth for a circuit with a center frequency of 7.1 MHz and a and a Q of 150
BW = Resonant Frequency ÷ Q or 7,100,000 ÷ 150 or 116,666 Hz or 116.6 KHz

Example 4:

The bandwidth for a circuit with a center frequency of 14 MHz and a and a Q of 120
BW = Resonant Frequency ÷ Q or 14,000,000 ÷ 120 or 47,333 Hz or 47.3 KHz

The Q of an RLC circuit can be calculated by one of the two following equations:

For a parallel resonant circuit, the Q is equal to the resistance divided by the reactance of either the inductor or capacitor (at resonance they are the same). For a series resonant circuit Q is equal to the reactance of either the inductor or capacitor (at resonance they are the same) divided by the resistance.

Example 1:

For a parallel resonant circuit with a resistance of 1.5 ohms and a reactance of 100 ohms:

Q= Resistance ÷ Reactance or 1.5 ÷ 100 or 0.015

Example 1:

For a parallel resonant circuit with a resistance of 1.5 ohms and a reactance of 100 ohms:

Q= Resistance ÷ Reactance or 1.5 ÷ 100 or 0.015

Example 2:

For a parallel resonant circuit with a resistance of 5 ohms and a reactance of 400 ohms:

Q= Resistance ÷ Reactance or 5 ÷ 400 or 0.0125

Example 3:

For a series resonant circuit with a reactance of 5,000 ohms and a resistance of 50 ohms

Q= Reactance ÷ Resistance or 5,000 ÷ 50 or 100

Example 4:

For a series resonant circuit with a reactance of 350 ohms and a resistance of 5 ohms

Q= Reactance ÷ Resistance or 350 ÷ 5 or 70

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Power Factor

The power factor of an AC electrical power system is defined as the ratio of the power absorbed by the load to the apparent power flowing in the circuit, and is a dimensionless number. A power factor of less than one indicates the voltage and current are not in phase, thus reducing the average product of the two. Real power is the instantaneous product of voltage and current and represents the capacity of the electricity for performing work. Apparent power is the product of RMS current and voltage. Due to energy stored in the load and returned to the source, or due to a non-linear load that distorts the wave shape of the current drawn from the source, the apparent power may be greater than the real power. A negative power factor occurs when the device (which is normally the load) generates power, which then flows back towards the source.

In an electric power system, a load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred. The higher currents

increase the energy lost in the distribution system and require larger wires and other equipment. Because of the costs of larger equipment and wasted energy, electrical utilities will usually charge a higher cost to industrial or commercial customers where there is a low power factor.

Calculating power factor:

If you know the phase angle between the current and voltage you can calculate the power factor. Power factor is the cosine of the angle between the phase between the current and voltage.

Example 1:
In a circuit where the current leads the voltage (a capacitive load) by 30° the power factor is:
Power Factor= Cosine (30°) or 0.866

For a circuit where the lags leads the voltage (inductive load) the power factor would still be *0.866* because power factor is a dimensionless number.

Example 2:
In a circuit where the current leads the voltage (a capacitive load) by 15° the power factor is:
                    Power Factor= Cosine (15°) or 0.966

Example 3:
In a circuit where the current leads the voltage (a capacitive load) by 70° the power factor is:
                    Power Factor= Cosine (70°) or 0.342

Power factor can also be determined by the True power divided by the Apparent power. For example, a circuit that uses 50 watts of power is supplied by a voltage of 20 v at 3 amperes (60 watts) by dividing 50 watts by 60 watts would have a power factor of 0.833.

                    Power Factor= 50 watts ÷ 60 Watts or 0.833

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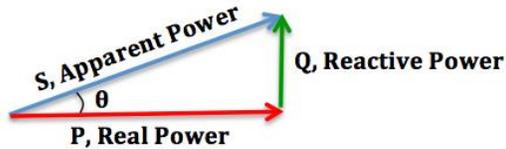
Operational amplifiers

An *Operational Amplifier*, or *op-amp* for short, is fundamentally a voltage amplifying device designed to be used with external feedback components such as resistors and capacitors between its output and input terminals. These feedback components determine the resulting function or "operation" of the amplifier and by virtue of the different feedback configurations whether resistive, capacitive or both, the amplifier can perform a variety of different operations, giving rise to its name of "Operational Amplifier".

An *Operational Amplifier* is basically a three-terminal device which consists of two high impedance inputs. One of the inputs is called the Inverting Input, marked with a negative or "minus" sign, (–). The other input is called the Non-inverting Input, marked with a positive or "plus" sign (+).

A third terminal represents the operational amplifiers output port which can both sink or source a voltage or a current. In a linear operational amplifier, the output signal is the amplification factor, known as the amplifiers gain (**A**) multiplied by the value of the input signal.
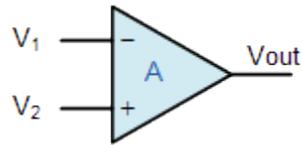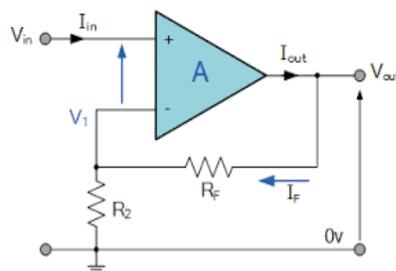

Operational amplifier symbol

The configuration below most common configuration is an OP Amp where the output is the opposite (inverted) polarity of the input. A positive signal on the input will be a negative value of the input signal multiplied by the amplifier gain.   If the input is + 0.25v volts and the gain is 10 the output will be -2.5 volts.
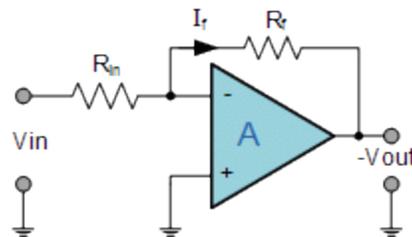
The configuration below is a non-inverting OP Amp where the output is in phase with the input. A positive signal on the input will be a positive value of the input signal multiplied by the amplifier gain. If the input is + 0.25v volts and the gain is 10 the output will be +2.5 volts.

The gain of an operational amplifier is controlled by feedback resistor that can very accurately control the gain of the amplifier in a circuit. In the circuit shown below the gain is determined by the ratio of the input resistor and the feedback resistor.

Example 1:

If the input resistor is 1,000 ohms and the feedback resistor is 10,000 ohm the gain would be 10 the feedback resistor divided by the input resistor or 1,000 ÷ 100 or 10. This is an inverting amplifier configuration so a + 0.1 volt input would give a – 1 volt output.

Gain = (10,000) ÷ (1,000) or 10, therefore the output would be the input voltage times the gain or (10) (0.1) (-1) or – 1 volt (Note the answer is multiplied by -1 is because it is an inverting amplifier).
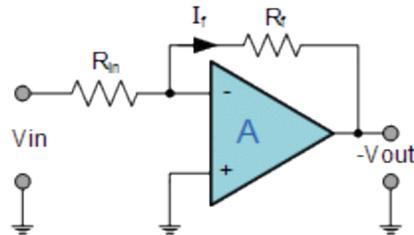
Example 2:

If the input resistor is 400 ohms and the feedback resistor 1s 3,800 the gain would be:

Gain = R(feedback) ÷ R(input) or (3800) ÷ (400) or 9.5.
With a +0.320 volt input, the output would be (9.5) (0.320)(-1) or -3.04 volts (multiply by -1 because this is an inverting configuration)

Example 3:

If the input resistor is 1,200 ohms and the feedback resistor 1s 88,000 the gain would be:

Gain = R(feedback) ÷ R(input) or (88,000) ÷ (1,200) or 73.33. With a -0.0.8 volt input the output would be (73.33) (-0.08) (-1) or +5.86 volts (positive because this is an inverting configuration)

Additional components can be arranged with operational amplifiers to make Summing circuits, filters, oscillators, integrators and other useful circuit functions.

Some of the other configurations or functions for operational amplifiers:

Low Pass Filter   High pass filter
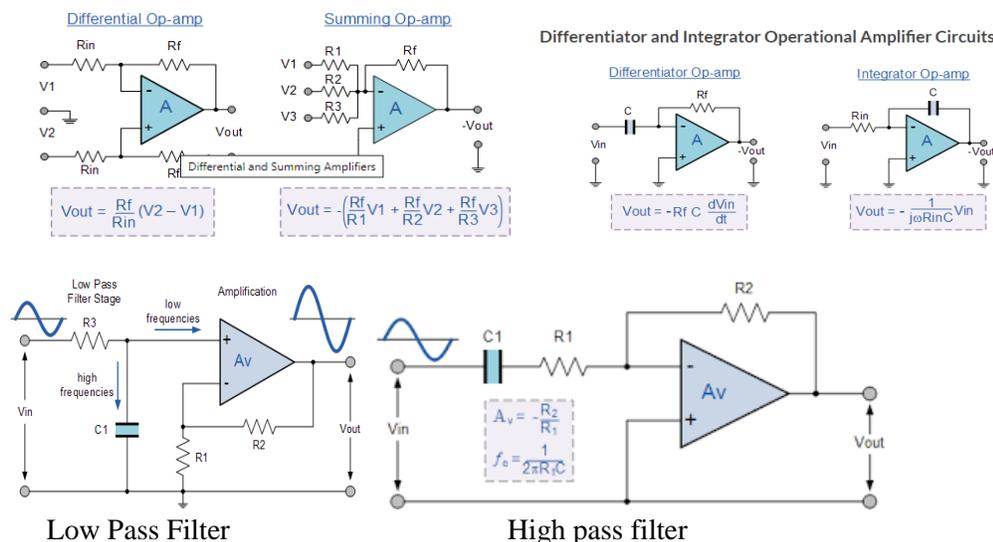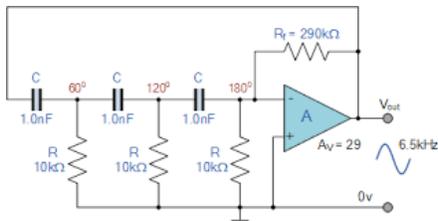
Audio oscillator
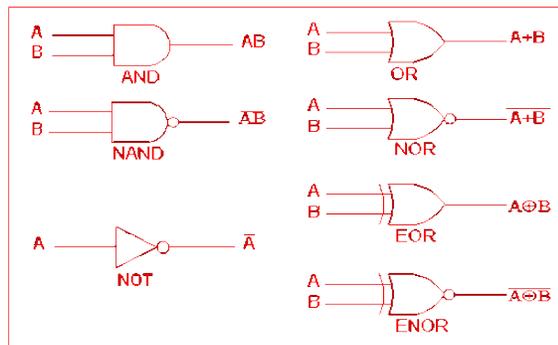
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Digital Logic

Digital logic devices are used to generate a specific output based one or more input(s).   For example:

A **AND** gate will have a true (1 state) output only when both inputs are true (1 state).

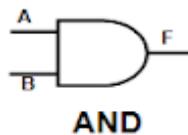A **NAND** gate will have a false (0 state) output only when both inputs are true (1 state).

A **NOR** gate will have a true (1 state) output only when both inputs are false (0 state)

A **OR** gate will have a true (1 state) output only when either or both inputs are true (1 state.

A **NOT** gate will have an output state opposite of the input state. If the input true (1 state) the output will be false (0 state) and If the input state is false (0 state) the output will be true (1 state).

The relationship between input and output states is shown in a truth table for the device.

NOT

Input	Output
I	F
0	1
1	0

AND

Inputs		Output
A	B	F
0	0	0
1	0	0
0	1	0
1	1	1

NAND

Inputs		Output
A	B	F
0	0	1
1	0	1
0	1	1
1	1	0

OR

Inputs		Output
A	B	F
0	0	0
1	0	1
0	1	1
1	1	1

NOR

Inputs		Output
A	B	F
0	0	1
1	0	0
0	1	0
1	1	0

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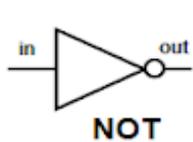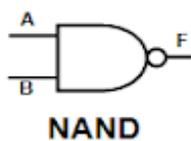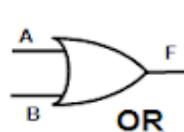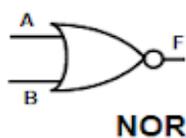
Effective Radiated Power

 Example 1:

Let's take an example with the following characteristics:
 Power output from radio =   50 watts
            Feed line loss =   - 4 dB
            Duplexer loss =   - 2 dB
         Circulator loss =   - 1 dB
          Antenna Gain =   + 4 dB

We calculate the overall ERP as follows:

> *ERP =(Input power) –(Loss/gain in system) or ERP =5- watts - ((-4) + (-2) + (- 1) +(+4)) or*
> *ERP = 50 watts - 3 dB*
> *ERP = (50)((10^(-3÷10)) or ER P= (50) (10^-.3) or ERP = (50)(.0501) or 25 watts*

Example 2:

Let's take another example with the following characteristics:
                 Power output from radio =   12 watts
                     Feed line loss =   - 0.5 dB
                  Antenna Gain =   + 3 dB

ERP =(Input power) – (Loss/gain in system) or ERP = 12 watts – ((+3dB) – (0.5 dB)) or 2.5 dB

12 watts + 2.5 dB = (12) ((10^((2.5)÷(10))) or ERP = (12) ((10^ (.25))   or ERP = (12) (1.778) or 6.75 watts

Transmitter Power Measurements

The PEP power output for a transmitter with an observed 30-volt **_peak_** envelope voltage (as seen on an oscilloscope) would be 9 watts. We are assuming a 50 ohm system.

Example 1:

To find the PEP power we take the peak voltage and multiply it by .707 to get the Peak RMS voltage then using the Peak RMS voltage we calculate power using the equation:

$P(watts) = ((V_{RMS})^2) \div (R_{load})$ **or PEP $_{(watts)}$ = (30) (0.707) ^{2} ÷ (50) or PEP = ((30) (0.707) ^{2}) ÷ (50) or PEP = ((21.2) ^{2}) ÷ (50) or 449.8 ÷ 50 or 8.997 watts**

 Example 2:

The PEP power output for a transmitter with an observed 300 volts **_peak to peak_** envelope voltage (as seen on an oscilloscope) would be:

$P(watts) = ((V_{RMS})^2) \div (R_{load})$ **PEP $_{(watts)}$ = (((300) ÷ (2)) (0 .707)) ^{2}) ÷ (50) or ((150) (0 .707) ^{2}) ÷ (50) or (106) ^{2} ÷ (50) or 11,247 ÷ 50 or 224.9 watts**

Example 3:

The PEP power output for a transmitter with an observed 20 volts **_peak to peak_** envelope voltage (as seen on an oscilloscope) would be:

PEP $_{(watts)}$ = ((20) ÷ (2) (0 .707))^2 ÷ (50) or PEP = ((10) (0 .707)) ^{2} ÷ (50) or (7.07)^2 ÷ 50 or PEP = 49.984 ÷ 50 or 0.999 watts

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Amplifier efficiency

Amplifier efficiency is the ratio of power output divided by power input times 100%.

Efficiency = P(out) / P(input) x 100%

Example 1:
A typical 1500-Watt PEP class B amplifier will require 2500 watts of DC input power (assume 60% efficiency). *A typical class A amplifier will be typically 25 to 35% efficient.*

P(input) = P(output) ÷ Efficiently = (1500 Watts) ÷ (0.60) = 2500Watts

Example 2:

What is the efficiency of an amplifier outputs 600 watts and has a plate voltage of 2,500 volts and draws 400 milliamperes?

Efficiency = output power ÷ input power or E = (600) ÷ ((2,500) (.400)) or E = 600 ÷ 1,000 or 0 .60 or 60%

Example 3:

What is the efficiency of an amplifier outputs 50 wats and has an input voltage of 13.8 volts and draws 9 amperes?

Efficiency = output power ÷ input power or (50) ÷ ((13.8) (9)) or (50) ÷ (138) or 0.403 or 40.3 watts

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Antenna Efficiency:

Antenna efficiency is Radiation Resistance / Total Resistance) x 100 per cent

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Common Q signals

QRB	*How far are you from my station?*
QRK	*What is the readability of my signal?*
QRL	*Are you busy? / Is this frequency in use?*
QRM	*Are you being interfered with?*
QRP	*Shall I decrease power?*
QRV	*Are you ready?*
QTH	*What is your location?*
QTR	*What is the correct time?*
QSK	*Full break in telegraphy*
QRQ	*Send Faster*
QRS	*Send slower*
QRV	*I am ready to receive*
QRZ	*Who is calling me?*
QSL	*Can you acknowledge receipt?*
QSY	*Shall I change to another frequency?*

A complete list of Q signals can be found at:

https://www.hamradioqrp.com/p/cw-abbreviations.html

The Standard Phonetic Alphabet used for amateur radio:

A – Alpha	J – Juliet	S – Sierra
B – Bravo	K – Kilo	T – Tango
C – Charlie	L – Lima	U – Uniform
D – Delta	M – Mike	V – Victor
E – Echo	N – November	W – Whiskey
F – Foxtrot	O – Oscar	X – X-Ray
G – Golf	P – Papa	Y – Yankee
H – Hotel	Q – Quebec	Z – Zulu
I – India	R – Romeo	

The International Telecommunications Union
Standard Phonetic Alphabet

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Return loss VS VSWR and Reflection coefficient table

Return Loss (dB)	VSWR	Reflection Coefficient	Mismatch Loss (dB)	Return Loss (dB)	VSWR	Reflection Coefficient	Mismatch Loss (dB)
1	17.39	0.89	6.87	21	1.20	0.09	0.03
2	8.72	0.79	4.33	22	1.17	0.08	0.03
3	5.85	0.71	3.02	23	1.15	0.07	0.02
4	4.42	0.63	2.20	24	1.13	0.06	0.02
5	3.57	0.56	1.65	25	1.12	0.06	0.01
6	3.01	0.50	1.26	26	1.11	0.05	0.01
7	2.61	0.45	0.97	27	1.09	0.04	0.01
8	2.32	0.40	0.75	28	1.08	0.04	0.01
9	2.10	0.35	0.58	29	1.07	0.04	0.01
10	1.92	0.32	0.46	30	1.07	0.03	0.00
11	1.78	0.28	0.36	31	1.06	0.03	0.00
12	1.67	0.25	0.28	32	1.05	0.03	0.00
13	1.58	0.22	0.22	33	1.05	0.02	0.00
14	1.50	0.20	0.18	34	1.04	0.02	0.00
15	1.43	0.18	0.14	35	1.04	0.02	0.00
16	1.38	0.16	0.11	36	1.03	0.02	0.00
17	1.33	0.14	0.09	37	1.03	0.01	0.00
18	1.29	0.13	0.07	38	1.03	0.01	0.00
19	1.25	0.11	0.06	39	1.02	0.01	0.00
20	1.22	0.10	0.04	40	1.02	0.01	0.00

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The Smith Chart

There are several charts available on which the properties of transmission lines are graphically presented. The most useful graphical presentations are those that give impedance relations that exist along a lossless transmission line for varying load conditions. The Smith Chart is the most widely used for transmission line calculations. The Smith Chart is a special kind of impedance coordinate system that shows the relationship of impedance at any point along a uniform transmission line to the impedance at any other point on the transmission line.

The Smith Chart is based on two sets of orthogonal (90° apart) circles. One set represents the resistive component of the transmission line impedance. The second set of circles represents the ratio of the reactive component of the transmission line impedance to the characteristic impedance of the transmission line.

All possible impedance values can be plotted on the Smith Chart. The horizontal line through the center is the resistance line ang goes from zero on the far left and infinity on the far right. The center is the nominal circuit impedance usually 50 ohms normalized to 1. The arcs are lines of constant reactance (again normalized to 1). Inductive reactance is in the upper half of the circle and capacitive reactance is in the lower half of the circle. The outer circle is calibrated in degrees and wavelength.

Using the Smith Chart, it is easy to determine what complex load impedance will match the complex source impedance.