INTRODUCTION TO HAM RADIO

What is Amateur Radio?

Amateur radio is an International hobby of Radio Communications and interested individuals communicate with each other using many different types of wireless transmitting modes and devices.

Amateur radio operators are often called "Ham Radio operators" or simply "HAMs". The source of the name ham is not known but it is believed that the first letters are selected from the name of three pioneer scientist namely Hertz, Armstrong, Marconi. The beginning of amateur radio is believed from early 1900s. The name amateur has nothing to do with skill or knowledge but rather implies that ham radio cannot be used for commercial or revenue generating purposes. It is truly a hobby but often one that makes a difference especially in emergency or disaster situations. The WPC at the Ministry of Communications licenses Ham radio operators in India. Specifically, there are a few things that hams are *not* allowed to do:

- ☒ Hams are not allowed to do anything with their radios that earns them money in any way. Ham radio is a hobby, but that doesn't mean it's completely frivolous.
- ☒ Ham radio operators cannot 'broadcast' to the public. This means that ham radio transmissions are meant for other ham radio operators only. What you will hear is hams talking to other hams and not music or other radio programs of 'general' interest.

Modes of Communication

Amateur radio operators generally use voice radio transmitters and receivers to communicate with each other. Some of the other forms of transmission are Radio teletype (Rtty), Morse code (CW), SSTV and Packet modes.

Getting Licensed

To become a radio amateur one needs to get a license. Licensing requirements are different in every country with different rules, privileges, and classes of license. In India anybody can try for getting license after the age of 12 years but there is no educational qualification required. Different levels of license give different privileges. More challenging the license requirements, more are the privileges and more interesting and enjoyable ham radio becomes.

What Hams Do?

Whether one would like to chat with friends to discuss topics of a mutual interest, or volunteer for emergency services, amateur radio is first and foremost about radio communications. Radio amateurs have a wide range of activities they can pursue. Some of these are:

- Talking with friends within the local community using a hand-held transceiver on VHF (2 meters) or UHF (70 cm.). Or talk Internationally using HF radio transmitters.

- Assisting emergency and disaster communication.
- Technical experimenting. Hams have hobby is to build their own equipment whether it is just a simple antenna, something as complex as a transmitter, or an interface between their radio and a computer.
- Use digital communication. By connecting a computer to their radio and with the use of special software one can communicate digitally. Some of these digital modes can be very effective.
- Use one or more of the several Satellites exclusively available to Radio Amateurs. Or communicate with duly licensed astronauts stationed in manned Space Stations (like the ISS).
- Use the SSTV (Slow Scan Television) mode to exchange colours pictures with other Hams around the world.
- Using some of the latest technologies hams can connect a modest radio station to the Internet.

Call Signs

Each Amateur Radio Station is given a unique callsign alloted by the authorities. A callsign consists of combination of letters and numbers. Prefix in the callsign indicates the country of the licence holder. For instance, callsign of an Indian Station Starts with VU; those from United States W, K or N ; United Kingdom with G, Sri Lanka with 4S7 Pakistan with AP, Germany with D and so on. A callsign holder can only operate his station no other person who does not hold a licence is not authorized to operate a ham radio station.

Amateur Radio Bands

Hams are able to use many frequency bands across the radio spectrum. These frequencies are allocated by the WPC in India and by the ITU internationally. Hams may operate from just above the AM broadcast band to the microwave region, in the gigahertz range. During daylight, 14 to 30 MHz is a good band for long-distance communications. At night, the band from 1.6 to 15 MHz is good for long-distance communications. These bands are often referred to historically as short-wave bands (as in “short-wave radio”). HF communication is depended and changes with ionosphere from season to season and with solar activities. Unlike frequencies used by FM radio stations and TV stations, which are line-of-sight and therefore limited to 40 or 50 Kms, short-waves “bounce” off the Earth’s ionosphere from the transmitter to the receiver’s antenna, thereby covering very large distances.

Some ham radio operators use the very reliable ‘Morse code’ while others use voice. Due to their easy readability and immunity to noise, Morse code signals (beeps) often get through when voice transmissions cannot. There are also many digital modes as well, and hams use radio modems to communicate in various networks.

Amateur Service - Definition

Amateur service means a service of self training, intercommunication and technical investigations carried on by amateurs that is by persons duly authorized under these rules interested in radio technique if radio technique solely with a personal aim and without pecuniary interest.

Valid Messages on Amateur Radio

Following messages can be exchanged by radio amateurs,

- Radio communications can be made with similar stations.
- Transmission should be made in plain language and limited to message of a technical nature relating to tests and to remark of personal character for which use of normal communication facility is not justified.

Forbidden Messages on Amateur Radio

00ollowing messages are forbidden to transmit by radio amateur,

- ☒ Messages like the reproduction of broadcast program or tape of recordings.
- ☒ False or misleading calls, or signals, news, advertisement, communications, of business, statement on topics of political or industrial controversy.
- ☒ Indecent language, messages for momentary benefit and third party messages are forbidden which may cause revenue loss to public telecommunication service.

AMATEUR LICENSE CATEGORIES

1. Categories of licence

There shall be five categories of licences, namely :

(i) Advanced Amateur Wireless Telegraph Station Licence;

(ii) Amateur Wireless Telegraph Station Licence, Grade-I;

(iii) Amateur Wireless Telegraph Station Licence, Grade-II;

(iv) Restricted Amateur Wireless Telegraph Station Licence;

(v) Short Wave Listeners' Amateur Wireless Telegraph Station Licence.

2. Eligibility for licence

(1) A licence may be granted subject to such conditions contained in Annexure I to these rules -

(i) to a person,-

(a) who is a citizen of India;

(b) who is not less than 14 years of age;

(c) who qualifies the Amateur Station Operators' Examination for the award of licence or holds either of the following certificate of proficiency, namely:

(i) Radio-communication Operators' General Certificates;

(ii) First or Second Class Radio-telegraph Operators' Certificate; Provided that the holder of a Special Radio Telegraph Operator's Certificate may also be considered eligible for the award of Amateur Wireless Telegraph Station Licence Grade II.

(iii) to a bonafide amateur radio society, club or a school, college, or an institution or a university in India, which has the aim of investigations in the field of radio or the training of persons in radio communication techniques.

Provided that the licence shall be issued in the name of an authorized official of the society, club, school, college, institute or a University in India holding a category of licence appropriate to the transmissions to be conducted by the station including amateur radio beacon transmission.

(2) Notwithstanding anything contained in sub-clause (b) of clause (i) of sub-rule (1), the Central Government may grant, to bonafide experimenters between the ages of 14 and 18 years, Amateur Wireless Telegraph Station Licence, Grade I and to those between the ages of 12 and 18 years, Amateur Wireless Telegraph Station Licence, Grade II or Restricted Amateur Wireless Telegraph Station Licence or Short Wave Listeners' Amateur Wireless Telegraph Station Licence :

(3) Notwithstanding anything contained in sub-clause (c) of clause (i) of sub-rule (1), the Central Government may recognize, subject to any conditions it may prescribe from time to time, such other radiotelegraph operators' certificates or Amateur Station Operators' Certificates as are issued by a competent authority in any other country as equivalent to qualifications referred to in aforesaid sub-rule for the purpose of grant of licence under these rules.

3. An application for licence

An application for the grant of licence from:

(a) an individual, or

(b) an Amateur Radio Society or club or a school, college or an institute or a University in India-

shall be made to the Central Government in Annexure II or Annexure III respectively to these rules, shall be made to the Central Government in Annexure II or Annexure III respectively to these rules, together with all the subsidiary forms and documents duly filled in and completed in all respects.

4. Eligibility for admission to amateur station Operators Examination

No person shall be eligible for admission to an examination for the grant of licence unless :-

(a) such a person fulfils the provisions contained in sub-clauses (a), (b) and (c) of clause (i) of sub-rule (1) of rule 5;

(b) such person pays the fees on the following scale, namely :-

I.	Advanced Amateur Station Operators' Examination	Rs. 25.00
II.	Amateur Station Operators' Grade I Examination	Rs. 20.00
III.	Amateur Station Operators' Grade II Examination	Rs. 10.00
IV.	Amateur Station Operators restricted examination	Rs. 10.00 and

(c) a period of at least one month has elapsed since he last appeared in an examination and failed

5. Examinations

(1) The examinations for the grant of a licence shall be held at a place and on a date as may be notified by the Central Government from time to time.

(2) An application for licence in Annexure II or, as the case may be, in Annexure III to the rules shall be submitted not later than the 15th of the month preceding that in which it is desired to take the examination.

(3) Any person admitted to the examination and found guilty of impersonation or of submitting fabricated documents or documents which have been tampered with or of making statements which are incorrect or false or of suppressing material information or of using or attempting to use unfair means in the examination hall or otherwise resorting to any other irregular or improper means for obtaining admission to the examination may, in addition to rendering himself liable to criminal prosecution, be debarred either permanently or for a specified period from appearing in any of the examinations held for the award of licence under these rules:

Provided that no order under this sub-rule shall be made unless the person concerned has been given a reasonable opportunity or making a representation against the action proposed to be taken.

(4) If any person is found guilty of any malpractice referred to in sub-rule (3) after the grant of a licence to such person, the Central Government may, in addition to prosecuting him cancell the licence so given :

Provided that the Central Government may, pending the cancellation of the licence, suspend or endorse such licence :

Provided further that no order under this sub-rule shall be made unless the person concerned has been given a reasonable opportunity of making a representation against the action proposed to be taken.

6. Observance of conditions of licence, Convention and rules under the Act :

(1) Every licensed amateur wireless telegraph station shall be established, maintained and worked in accordance with -

(a) the conditions contained in Annexure I to these rules;

(b) the provisions of the Convention;

(c) the rules made by the Central Government under section 7 of the Act for the conduct of wireless telegraphs in so far as they are applicable.

(2) Notwithstanding sub-rule (1) the Central Government may modify, vary, cancel or revoke any of the conditions of licence contained in the said Annexure I at any time either by specific notice in writing to the licensee, or by means of a general notice published in the Official Gazette or in a newspaper published in New Delhi.

(3) The licensee shall at his own expense, give effect to any variations in the conditions of licence,

7. Period of validity

A licence granted under these rules shall be issued for a period of 2 years or 5 years, as the case may be, commencing on the date of issue of the licence and expiring on the last day of the month preceding the month of issue.

8. Fee for licence

A licence fee on the following scale shall be payable to the Central Government on receipt of instructions from that Government and in the manner directed bv it:-

Category of licence	Fees for 2 Years (Rs.)	Fees for 5 Years(Rs.)
(i) Advanced Amateur Wireless Telegraph Station Licence	50	125
(ii) Amateur Wireless Telegraph Station Licence, Grade I	40	100
(iii) Amateur Wireless Telegraph Station Licence, Grade II, Restricted Amateur Wireless Telegraph Station Licence & Short wave Listeners' Amateur Wireless Telegraph Station Licence	25	60

(2) The licence fee shall not be refundable on ground of licenscee's inability to establish or make use of the licenced Amateur Wireless Telegraph Station or for adjustment towards higher category of licence.

9. Authorised frequency bands, power and emission

A holder of licence shall use, as appropriate to the licence, such frequency bands, power and classes of emission as are set out in Annexure V of these rules : Provided that the Central Government may by special or general order make changes in the usage of frequency bands, power and types of emission where that Government is satisfied, that it is expedient to do so, keeping in view, among others, the provisions of the Convention, need for enforcement of better technical standards in respect of equipment and national and international radio interference pattern.

10. Renewal of licence

(1) On the expiry of the validity of a licence, it may be renewed for a period of two years if the licensee,-**

(a) makes an application for renewal at least two months before the date of expiry of the licence.

(b) has actively operated his station during the past two years prior to the date of expiry of his licence and provides a certificate to the effect that he has made contacts with other amateur stations on atleast 40 occasions per year; and in the case of short Wave Listener has intercepted amateur station on at least 40 occasions per year.

(c) pays fees on the following scale, namely :-

Category of licence	Fees for 2 Years (Rs.)	Fees for 5 Years(Rs.)
(i) Advanced Amateur Wireless Telegraph Station Licence	50	125
(ii) Amateur Wireless Telegraph Station Licence, Grade I	40	100
(iii) Amateur Wireless Telegraph Station Licence, Grade II, Restricted Amateur Wireless Telegraph Station Licence & Short wave Listeners' Amateur Wireless Telegraph Station Licence	25	60

(2) The licence fee shall not be refundable on ground of licencee's inability to establish or make use of the licenced Amateur Wireless Telegraph Station or for adjustment towards higher category of licence.

(3) The document showing the renewal of licence issued by the Central Government shall be kept along with the licence to which it refers.

(4) It shall not be obligatory for the Central Government to issue a notice that the licence is due for renewal.

11. Surcharge for late renewal

In case the holder of a licence does not apply for its renewal prior to the date of expiry of the licence referred to in sub-rule (1) of rule 14, he may apply for the renewal of licence subsequently also but within a period of two years** after the date of expiry of the licence on payment of a surcharge at the rate of Rs.10/- for every half-year or part thereof. The licence in such a case, shall be renewed from the date of expiry of the licence.

12. Register for wireless telegraphy apparatus

Every licensee shall maintain a register in respect of all wireless telegraphy apparatus established, maintained and worked by him at the amateur station in the form set out in Annexure VI of these rules.

13. Location of Amateur Station

The location of the amateur station shall be specified in the licence along with the usual residence of the licensee endorsed therein and it shall be operated only from the place so fixed. Provided that the Central Government may, permit the change of location if the licensee applies for it in writing giving particulars of the change and submits the license for endorsement, and pays a fee of rupees five.

** Under deserving cases and for exceptionally genuine reasons, the ASOC licence can also be renewed upto a period of 10 years with charging late fee and for the period beyond 10 years, the licence can be renewed after getting fresh inter-ministerial consultations. This in no way, however confers any right to the candidates seeking ASOC renewal under this category and the right of decision of renewal in such cases will solely remain with the Ministry of Communications & Information Technology.

14. Portable and mobile amateur Station

Without prejudice to rule 17, the Central Government may in addition to an amateur station licensed for a.-

(1) Specified location issue a special authorisation to establish, maintain and work an amateur station as a portable station or a mobile station fixed on board a motor vehicle for a specific period in special occasions like exhibitions and jamborees or for specific technical investigations in radio if-

(i) application for such authorisation is made well in advance indicating, among others, the specific period for which the authorisation is required, nature of investigations or details in regard to occasion as the case may be, and area of operation ;

(ii) the applicant holds an Advanced Amateur Wireless Telegraph Station Licence or an Amateur Wireless Telegraph Station Licence Grade I;

(iii) the applicant pays an additional fee of Rs.10/-.

(2) The special authorisation shall, in addition to the conditions specified in rule 10, be subject to following, namely:-

(i) The special authorisation shall not be issued for a period more than 90 days.

(ii) The licensee's amateur station at the fixed location and the mobile station shall not communicate with each others;

(iii) the suffix 'MO' shall be added to the callsign already authorised to the licensee's amateur station at the fixed location for use by the portable or mobile station. Such callsign shall be followed by the location of the station.

(iv) Such other conditions as the Central Government may determine from time to time.

(3) The special authorization may be withdrawn or the conditions contained therein varied at any time by the Government.

15. Amateur Station on board ship

(1) Without prejudice to rule 17, the Central Government may on receipt of an application authorise establishment, maintenance and working of an amateur station on board a ship registered in India. Applications for such authorisation shall be accompanied by a written approval of the master or owners of the ship concerned.

(2) The establishment, maintenance and working of amateur stations on board ships shall, in addition to the conditions specified under rule 10, be subject to such other conditions as the Central Government may determine from time to time and such conditions, among others, shall include the following, namely:-

(i) The amateur station on board ship shall be operated only while the ship is in International waters or Indian territorial waters. Its operation within the territorial waters of another country shall be in conformity with laws and regulations of the country concerned.

(ii) It shall not be operated whilst the ship is in any harbour in India.

(iii) The callsign allotted to such stations shall have suffix 'MS' followed by the callsign of the ship in case of radiotelegraphy or the official name of the ship in case of radiotelephony.

(iv) The amateur station on board a ship shall be independent of ship radio communication, radio navigation and other safety services radio equipment and shall be operated in such manner as not to cause harmful interference to these services of the ship. The amateur station shall have source of electrical energy independent of the ship station and shall also be discontinue electrically independent of it.

(v) The amateur station on board a ship shall discontinue operation at any time on request of an officer of the Central Government, the Master or Radio Officer of the ship or any land station.

16. Loss and Issue of Duplicate of Licence and Document showing the Renewal of Licence :

(1) A person whose Licence or the document showing the renewal of licence has been lost, mutilated or distroyed shall notify the same to the Central Government. An application in Annexure VII of these rules for the duplicate shall be made to the Central Government embodying a statement of the circumstances involved in the loss, mutilation or destruction of the licence or the document showing the renewal of licence for which a duplicate is required. If the licence or the document showing the renewal of licence has been lost, the applicant must state the circumstance in which it was lost and the reasonable search has been made for it, and further that in the event it be found, either the original or the duplicate shall be returned for cancellation. The mutilated licence or the document showing the renewal of licence for which the duplicate is required should be forwarded alongwith the application for cancellation.

(2) The Central Government may issue duplicate copy of any licence or the document showing the renewal of the licence and the following charges shall be levied for such issue-

(i) For duplicate of licence .... Rs. 10

(ii) For duplicate of the document showing the renewal of licence .... Rs. 5

17. Revocation of licence

(1) The Central Government may, at any time, revoke the licence

(i) On the breach of any of the conditions of licence contained in Annexure I; or

(ii) In default of payment of any fees payable under these rules :

Provided that, before revoking a licence, the licencsee shall be given a reasonable opportunity of making a representation against the action proposed to be taken.

(2) The licensee shall not be entitled to any compensation arising out of revocation of his licence nor will any part of the fees paid for the licence shall be refunded for the period a licence stands revoked.

18. Transfer of licence

A licence shall not be transferable:

Provided that the Central Government may permit the transfer of a licence granted to an authorised official of an amateur radio society or club or a school, college or an institute or a University in India in favour of his successor if such successor holds a category of licence appropriate to the transmissions to be conducted by the amateur station.

19. Operation of licensed amateur station

No person other than the licensee shall be permitted to operate the licensed amateur station :

Provided that -

(a) in the presence of the licensee himself, the station may be operated by an other person holding a valid licence of comparable or higher category. The licensee, however, shall be personally responsible for the observance of these rules as if the station is operated by him.

(b) in case of a licence issued to an authorised official of an amateur radio society or club or a school, college, or an institution or a University in India, the station may also be operated by a person who holds a licence of equivalent or higher category with the prior permission of the Central Government in writing; if the licensee keeps personal surveillance over the operation of the station. The licensee shall be responsible for the observance of these rules.

20. Surrender of licence

A licence which is revoked or which has become invalid and licensee does not desire to renew it shall be surrendered to the Central Government for cancellation and record.

21. Dual holding of licence

No person shall be granted more than one licence at the same time :

Provided that the Central Government may exempt a person, holding a licence in his name for amateur radio society or a school, college or an institute or a university in India, from the operation of this rule.

22. Admission of foreign national to examination and grant of licence

(1) Notwithstanding anything contained in these rules, the Central Government may, subject to such terms and conditions as it may impose from time to time, admit a person, who is not a citizen of India, to an examination for the grant of a licence or grant him a licence if otherwise qualified.

(2) The conditions under sub-section (1) shall, among others, include the following, namely :-

(i) the country of which the applicant is citizen, grants reciprocal facilities to Indian nationals :

Provided that it shall not apply where the Central Government considers that reciprocal facilities are not necessary ;

(ii) the applicant is above the age of 18 years;

(iii) the applicant's stay in India is not likely to be less than one year from the date of application.

(iv) the applicant is a holder of an appropriate category of amateur station operator's certificate or licence issued by a competent authority in any other country and recognised by the Central Government.

(v) the licence under this rule shall be initially granted for a period of one year or for the period of validity of visa, for which the applicant's passport is endorsed, whichever is less.

23. Penalty for breach of these rules

Any breach of these rules, other than a breach, which is an offence under section 20 or 21 of the Act, shall be punishable with fine which may extend -

(i) when the person is licensed under the Act, to one thousand rupees and in the case of continuing breach a further fine of two hundred rupees for every day after the first during the whole of any part of which the breach continues;

(ii) when a servent of the person so licensed or another person is punishable for the breach one fourth of the amounts specified in clause (i).

24. Repeal and saving

(1) On the commencement of these rules, the Indian Wireless Telegraphy (Amateur Service) Rules, 1958, shall cease to be in force.

(2) Notwithstanding such cesser,-

(a) Where before such commencement any person has passed the Amateur Station Operators' Certificate Grade I or Grade II Examination, such person shall not be required to pass any such examination under these rules;

(b) Where, before such commencement any person was granted Amateur Wireless Telegraph Station Licence Grade I, or any such Licence was renewed and the period for which such Licence was granted or renewed extends beyond the commencement of these rules, then, such Licence shall continue to be in force for the period specified in the Licence.

Syllabus

Syllabus And The Details Of Examinations For The Award Of Amateur Station Operator's Licence.

1. The examination shall consist of the following two parts :

PART I - Written Test

It shall comprise of one paper containing two sections as under :

Section A : Radio Theory and Practice

Note: Applicants holding degree in telecommunication, or electronics and electrical communications, or a degree recognised by the Central Government as equivalent to the above degree shall be exempted from appearing in Section I of the test.

Section B: National and International Regulations applicable to the operation of amateur station and those relating to the working of station generally.

PART II - Morse

(i) Receiving, and (ii) Sending.

Detailed syllabus :

2.1 Amateur Station Operator's Grade II Examination

Part I – Written Test

(a) Section I : Radio Theory and Practice :

Elementary Electricity and Magnetism :

Elementary theory of electricity, conductors and insulators, units, Ohm's Law, resistance in series and parallel conductance, power and energy, permanent magnets and electromagnets and their use in radio work; self and mutual inductance; types of inductors used in receiving and transmitting circuits, capacitance; construction of various types of capacitors and their arrangements in series and/or parallel.

Elementary Theory of Alternating Currents :

Sinusoidal alternating quantities - peak, instantaneous, R.M.S. average values, phase; reactance, impedance; series and parallel circuits containing resistance, inductance, capacitance; power factor, resonance in series and parallel circuits; coupled circuits; transformers for audio and radio frequencies;

Thermonic Valves :

Construction of valves; thermonic emission, characteristic curves, diodes, triodes and multi-electrode valves; use of valves as rectifier, oscillators, amplifiers, detectors and frequency changers, power packs, stabilisation and smoothing, elementary theory and construction of semiconductor devices - diodes and transistors.

Radio Receivers :

Principles and operation of T.R.F. and superhetrodyne receivers, CW reception; receiver characteristics-sensitivity, selectivity, fidelity; adjacent channel and image interference; A.V.C. and squelch/circuits; signal to noise ratio.

Transmitter :

Principles and operation of low power transmitter; crystal oscillators, stability of oscillators.

Radio propagation :

Wave length, frequency, nature and propagations of radio waves; ground and sky waves; skip distance; fading.

Aerials :

Common types of transmitting and receiving aerials.

Frequency Measurement :

Measurement of frequency and use of simple frequency meters.

(b) Section 2 : Regulations :

(a) Knowldege of

(i) the Indian Wireless Telegraph Rules, 1973.

(ii) the Indian Wireless Telegraphs (Amateur Service) Rules, 1978.

(b) Knowledge of International Radio Regulations as relating to the operation of amateur stations with particular emphasis on the following :

Item	Provision of Radio Regulation
Designation of Emission ...	104-110
Nomenclature of the Frequency & Wavelength ...	112
Frequency Allocation of Amateur Services ...	Article 5
Measures against interference ...	667-677
Interference and Tests ...	693-703
Identification of Stations ...	735-737 743, 772-773
Distress and Urgency Transmissions ...	1389-1396, 1477-1478, 1481, 1483
Amateur Station ...	1560-1567
Phonetic Alphabets and figure code ...	Appendix 16

(c) Standard Frequency and Time Signals Services in the World.

(d) The following ‘Q’ codes and abbreviations will shall have the same meaning as assigned to them in the Convention.: QRA, QRG, QRH, QRI, QRK, QRL, QRM, QRN, QRQ, QRS, QRT, QRU, QRV, QRW, QRX, QRZ, QSA, QSB, QSL, QSO, QSU, QSV, QSW, QSX, QSY, QSZ, QTC, QTH, QTR, and QUM.

Abbreviations : AA, AB, AR, AS, C, CFM, CL, CQ, DE, K, NIL, OK, R, TU, VA, WA, WB.

The above written test is of one hour duration. the maximum number of marks is 100 and candidate must secure at least 40 % in each section and 50% in aggregate for a pass.

Part II - Morse

(a) Section 1 : Morse Receiving : (Speed : 5 words per minute)

The test piece will consist of a plain language passage of 125 letters, five letters counting as one word. Candidates are required to receive for five consecutive minutes at the speed of 5 words per minute from a double head-gear headphone receiver, international morse signals from an audio oscillator keyed either manually or automatically. A short practice piece may be sent at the prescribed speed before the start of the actual test. Candidates will not be allowed more than one attempt in each test. The test may be written in ink or pencil but must be legible. Bad handwriting and over-writing will render a candidate liable to disqualification. More than 5 errors will disqualify a candidate.

(b) Secton 2 : Morse Sending (Speed : 5 words per minute)

The test piece will consist of a plain language passage of 125 letters, 5 letters counting as one word. Candidates are required to send on an ordinary key for five consecutive minutes at the minimum speed of five words per minute. A short practice piece may be allowed before the actual test. Candidates will not be allowed more than one attempt in the test. Efforts should be made to correct all errors. However, more than 5 uncorrected errors will disqualify a candidate. The accuracy of signaling, correct formation of characters and the correctness of spacing shall be taken into account.

Note- A candidate is required to pass both in Part I and Part II. In the case of candidates qualifying in Part I only, the licence shall be restricted to radiophone operations only.

2.2. Amateur Station Operators’ Grade I Examination

Part I - Written Test

Same syllabus as for the Amateur Station Operators Grade II examination. The test is of 2 hours duration. The maximum number of marks is 100 and candidates must secure at least 50% in each section and 55% in aggregate for a pass.

Part II – Morse

(a) Section 1 : Morse Receiving (Speed 8 words per minute)

The test piece will consist of a plain language passage of 300 characters which may comprise of letters, figures and punctuations (Punctuations are indicated below). The average words shall contain five characters and each figure and punctuation will be counted as two characters. Candidates are required to receive for five consecutive minutes at a speed of 12 words per minute. Other conditions are the same as applicable to Amateur Station Operator's Grade II examination.

Note- Test piece may contain only the following punctuations :

Full stop; Comma; Semi-colon; Break Sign; Hypen and question mark.

(b)Section 2 : Morse Sending (Speed 8 words per minute)

The test piece will be similar to Morse Receiving test. Candidates are required to send for five consecutive minutes at a speed not less than 8 words per minute. Other conditions are the same as applicable to Amateur Station Operators' Grade II examination.

Note- A candidate is required to pass both in Part I and Part II simultaneously.

2.3 Advanced Amateur Station / Operators' Examination

Part I - Written Test

(a) Section 1 : Radio Theory and Practice :

In addition to the syllabus prescribed for Amateur Station Operator's Grade II examination, following items shall be included in the syllabus of Advanced Amateur Station Operators' examinations:-

(i) Motors and Generators : Elementary principle and construction of alternators, motors and Generators.

(ii) Alternating current : Constructing of transformers, transformer losses, transformer as a matching device.

(iii) Measuring Instruments : Moving coil and moving iron meters, frequency meters.

(iv) Semi Conductor devices and Transistors : Elementary principles of conduction and construction, symbols biasing methods.

(v) Power Supplies : Half wave and full wave rectifiers, smoothing and regulating, bridge rectifier.

(vi) Modulation: Principles of frequency modulation.

(vii) Transmitters and Receivers : Elementary principles of transmission and reception of Facsimile and Television signals, elementary principles of transmitters and receivers employing single side band.

(viii) Propagation : Characteristics of ionosphere and troposphere. Properties of different reflecting layers, optimum working frequency, day and night frequencies.

(ix) Aerials : Principles of radiation, aerials for different frequency bands including aerials for microwave.

(x) Space Communications : Elementary principles of communication via satellite.

(b) Section 2 : Regulations : Same syllabus as for the Amateur Station Operators Grade I examination.

Part II - Morse Code

Syllabus is same as perscribed in Grade I examination.

Radio Telegraphy

Morse Code

International Morse Code consisting of dot (.) and dashes (-). In Morse Code a dot (.) is made by pressing the telegraph key down and allowing it to spring back up again rapidly; and for making a dash (-) the key is held down for a bit longer period. It is said that a dash (-) unit is three time longer than a dot (.) unit. The Morse Code in fact consists of combinations of aurally distinguishable tones. A tone produced for shot duration is a dot tone and a tone three times longer than this tone is a dash tone.

Introduction to the Morse (CW) Code

To practice Morse Code sending, a novice can use a small device called the 'Code Practice Oscillator' (CPO). This is a small electronic circuit capable of generating a sinusoidal audio tone when a key (or switch) is made 'on' or 'off' manually. The circuit of a CPO shown below can be easily assembled by a novice.

It is advisable not to start practice sending the Morse code until the novice is proficient in receiving Morse code. For receiving practice, you have to rely on a ham radio operator who can send / generate Morse code using a CPO or you can try to find out Morse Code transmissions over your radio receiver. Morse code practice cassettes and multimedia computer software are nowadays available. More gaining confidence in sending does not qualify you to be an expert receiver! In fact you may not be able to receive a single letter in Morse code even if you gained a sending proficiency of 12 words Per Minute (WPM)! Remembering the Morse codes is an art by itself. It involves a rhythmic response in your mind. Try to remember the combination of dot (•) and dashes (–) by their sound and not as a group of printed symbols. For this purpose, a dot (•) is referred to as a 'di' and a dash (–) as a 'dash'. A 'di' coming at the end of the combination is pronounced as 'dit'.

Morse Code Table

THE INTERNATIONAL MORSE CODE

A	• –	J	• – – –	S	• • •	1	• – – – –
B	– • • •	K	– • –	T	–	2	• • – – –
C	– • – •	L	• – • •	U	• • –	3	• • • – –
D	– • •	M	– –	V	• • • –	4	• • • • –
E	•	N	– •	W	• – –	5	• • • • •
F	• • – •	O	– – –	X	– • • –	6	– • • • •
G	– – •	P	• – – •	Y	– • – –	7	– – • • •
H	• • • •	Q	– – • –	Z	– – • •	8	– – – • •
I	• •	R	• – •			9	– – – – •
						0	– – – – –

PUNCTUATIONS

.	(Period)	• – • – • –	($\overline{\text{AAA}}$)
,	(Comma)	– – • • – –	($\overline{\text{MIM}}$)
?	(Question mark)	• • – – • •	($\overline{\text{IMI}}$)
;	(Semicolon)	– • – • – •	($\overline{\text{NNN}}$)
-	(Hyphen)	– • • • • –	($\overline{\text{BA}}$)
Error sign		• • • • • • • •	(8 dots)
Sentence separation indicator		– • • • –	($\overline{\text{BT}}$)
End of transmission of a message		• – • – •	($\overline{\text{AR}}$)
Invitation to transmit		– • –	(K)
Wait		• – • • •	($\overline{\text{AS}}$)
End of work		• • • – • –	($\overline{\text{VA}}$)

Almost all the letters/characters and punctuation marks can be arranged in certain groups which can used to show the resemblance between/among the combination of dot and dashes. For example the letter 'A'(• –) is the opposite of 'N' (– •). Similarly, the letters A, U, V and the character 4 can be made into a group which shows a definite sequence. Given below is a table of such combinations.

Groups of letters / characters, which show definite sequence / resemblance

E	•	**T**	–	**N**	– •	**A**	• –
I	• •	**M**	– –	**D**	– • •	**W**	• • –
S	• • •	**O**	– – –	**B**	– • • •	**V**	• • • –
H	• • • •	∅	– – – – –	**6**	– • • • •	**4**	• • • • –
5	• • • • •						
A	• –	**R**	• – •	**G**	– – •	**F**	• • – •
W	• – –	**K**	– • –	**Z**	– – • •	**L**	• – • •
J	• – – –	**P**	• – – •	**Y**	– • – –	**C**	– • – •
1	• – – – –	**X**	– • • –	**Q**	– – • –		

Learning Morse code

The letter 'R' is represented by '• – • ' (di dah dit) in Morse code. The time taken to produce the sound equivalent to one 'di' or 'dit' (dot) is taken as unit time and called a dot unit. A 'dah' is approximately of three dot units length and the space between two sound elements of a letter is one dot unit, i.e. silence period is one dot unit. The space between two letters or characters is equal to three dot units. The space between two words is equal to five dot units. The word 'cat' can be represented as – • – • • – – (dah di dah dit di dah dah)

Morse Code speed

The minimum speed to qualify for a Grade II licence is 5 words per minute (5 wpm). 5 letters/characters constitute a word. A message containing 125 letters when sent in 5 minutes or when received in 5 minutes makes your speed 5 wpm.

125/5 = 25 words in 5 minute; i.e. 5 words per minute.

In fact Morse code devised by **Samuel F.B. Morse** (1791-1872) is a primitive type of digital communication which still works efficiently in this era of microprocessors and computers.

Morse code is also called CW, i.e. **Continuous Wave**,in the sense that constant amplitude interrupted radio frequency wave is transmitted; interruption being made in conformity with the code.

Analog and Digital methods

The electrical telephone and telegraph are very simple examples which illustrates the difference between the analog and digital methods. In the telephone, the information is transmitted from one end to the other via a current which varies continuously as direct equivalent of sound waves striking the microphone-the analog approach. In the telegraph, the information is encoded (cyphered) and sent as a sequence of current/ no current pulses illustrating the digital approach.

How to learn Morse Code ?

Many newcomers seek exemption from ‘tiresome’ Morse test for Short wave operation. This is unfortunate as the Morse code is the key to enter into the world of ham radio with a very little monetary investment. A novice can assemble a simple Morse code transmitter with lesser technical hurdles than that of a SSB voice transmitter. Morse code can be learnt easily if we use certain techniques to remember the codes. Learning the Morse code can also be considered as an entirely personal venture embarked upon by alone. Following points should be kept in mind while learning the Morse code -

(1) Try to remember the codes from their sound.

(2) Don’t begin with a practice to send. Sending is much easier compared to receiving.

(3) During receiving of a message, don’t write down the ‘dot’ and ‘dash’ combinations. Directly write down the letters in running hand. Don’t bother to know the content of the message. Just continue writing the letters one by one and leave a space when you are not sure about the letter. If you wait wondering about what the letter was, you would get stuck and in the process many letters would pass by you, which you would not be able to jot down.

Why Morse Code is Essential

It was deemed important that ham radio operators prove an ability to transmit and receive in Morse Code signals. In the last 50 years, however, the **International Telecommunication Union (ITU)** has reviewed and modified the amateur Morse Code requirement at every international conference capable of changing it. In 1947 (Atlantic City) the ITU agreed that Morse proficiency should only be required when the operation took place on frequencies below **1000 MHz** (1 GHz.) At WARC-59 (The 1959 World Administrative Radio Conference) this level was dropped to **144 MHz**. A further reduction was made at WARC-79 to its presents **30 MHz.**

Despite the capability of voice communication, Morse code is still in use. One important reason is that a vast group of the radio amateurs still adore Morse code. **A ham radio operator employing digital communication techniques (like Packet Radio, Radio Tele Typing-RTTY or Amateur Tele-printing Over radio-AMTOR) in his ham radio operation treats Morse code with much the same affection he has for those modern innovations!**

A ham radio operator wearing his headphone and the Morse Key in hand can send messages silently without disturbing his family members who might be sleeping comfortably!

Another reason is that short wave radio telephone (voice) signals often suffer very rapid and deep fading; two frequencies separated by only a few hertz, fade at different times. To overcome this, modulated code tones are transmitted. The situation is now that under severe conditions of fading, the carrier frequency may fade out completely but one or the other side band may remain strong as a result a continuously readable signal is received. This is the reason that we hear a band full of exotic sounding CW call-signs at any time of day or night. When the a band appears to be dead, and we can barely copy phone signals the band remains alive with many CW signals.

Call Sign

Formation of Call signs

Call-sign of radio station formed in following ways

Call-sign is an identification of a station issued by a competent authority. The first part of the call-sign is known as prefix which indicates the country of the license and last part is called suffix which normally consists of up-to three alphabets which refer to the individual operator information. The country name of the station is immediately known on hearing call-sign.

Call-sign is formed using 26 letters of alphabet as well as digits o to 9. Prefix may be made of one or two letter or one letter and one digit. Suffix should not be more than three letters. Prefix and suffix are separated by one digit.

In India, license is issued by WPC (Wireless Planning Co-ordinator) Ministry of Communication, New Delhi.

Forbidden combinations for Formation of Call signs

Following combinations are forbidden to be used as call-sign

- Combination which might be confused with distress signal or such other signals of a similar nature.
- Combinations reserved for the abbreviations to be used in radio communication services
- Q codes and the geographical international code.

When the seprator digit is ϕ or 1, the first letter of suffix should not be 0 or I.

Some important country's call-sign

Canada	VE	**Japan**	JA-JS
Sri Lanka	4S	**Germany**	DA-DR
India	VU	**Italy**	I
Pakistan	AP	**Russia**	UA-UZ
England	G	**Australia**	VK
America	K, W, N	**South Africa**	ZS

Communication

Procedure for Making General Call

Before establishing contact with another station on radio telegraphy/telephony, the following procedure should be followed:

A) if the other station is already on the air giving, say CQ call, you should immediately tune your transmitter to the frequency and answer when the calling station gives invitation to transmit.

B) If the other station is having communication with another station, you should give a breaking call i.e. when one station is at the end of its transmission you should announce your call sign indicating you are on the frequency. You should transmit only when you are invited by a member of the net to go ahead.

C) If you want to give general call, cal CQ which is used as a call sign to address all station within range. This may be repeated throughout a period of not more than one minute after which you should transmit DE if you are on telegraphy or say THIS IS on telephony and give your call sing. The procedure may be repeated but the time taken in calling shall not exceed three minute after which one should listen in the band of frequencies in which the call has been made.

D) In answering a call, letters of the calling station should be sent and then DE or THIS IS followed by your call letters.

In telephony, letters of the call signals may be confirmed by the pronouncement of well-known words of which the initial letters are the same as those in the call signs.

Procedure for Answering a Call

When you want to establish a contact by giving general call to all, CQ call should be given. Before giving CQ call, one should listen to the frequency for sometime to make sure that frequency is not in used by other stations.

The CQ call consist of –

- 'CQ' 3 times in radio telegraphy or 'Hallo all stations' 3 times in radio Telephony
- The word DE (Radio telegraphy) or This is (Radio telephony)
- Call-sign of station giving general call 3 times

The reply to CQ call consist of -

- The call-sign of the calling station 3 times
- The world DE (Radio telegraphy) Or This is (Radio Telephony)
- The call-sign of replying station 3 times

The call may be sent three time sat the interval of two minutes, thereafter, it shall not be repeated until an interval of 10 minutes before starting another call.

Question and Answer Section

Q. What do you mean by 'Amateur Radio Service'?

A. 'Amateur Radio Service' is a two-way radio communication service available to persons who are licensed by the communication authority to carry out experimentation in the field of radio communication techniques. The Indian Wireless Telegraphs (Amateur Service) Rules 1978 defines 'Amateur Service' as "***a service of self training, inter-communication and technical investigations carried on by amateurs that is, by persons duly authorised under these rules interested in radio technique solely with a personal aim and without pecuniary interest".***

Q. What types of messages are forbidden to be transmitted from an amateur radio station?

A. A ham radio operator is allowed to transmit in plain language (Morse Code, RTTY, Packet radio etc. included) and his message shall be of a technical nature related to tests, remarks of personal character, which are not related to business affairs or transactions. He is forbidden to transmit:

(i) Messages like the reproduction of broadcast programs or tape recordings or transmissions of entertainment value or music.

(ii) False or misleading calls, or signals, news, advertisements, communications of business, statements on topics of political or industrial controversy.

(iii) Superfluous signals or any matter which is indecent or of obscene character or of a seditious tendency or which is grossly offensive or such as is likely to arouse racial, religious, or communal animosity; and

(iv) Messages for pecuniary reward or any messages for, or on behalf of third parties.

Q. Is third party communication allowed in India in "Amateur Radio Service'?

A. Third party messages originating from a non-amateur or meant for a non-amateur are not allowed in India, except in case of failure of normal telecommunication facilities during earthquake, flood, cyclones, wide spread fires or during any other disasters. Under such circumstances, a ham radio operator can handle third party messages pertaining to disasters. Such messages should originate from or addressed to a competent civil authority namely, (a) district magistrates or deputy commissioners or collectors of the district and (b) any other officer authorized by the authorities mentioned at (a) above.

Q. What is 'Secrecy of Correspondence'?

A. If any message which the ham radio operator is not entitled to receive is, nevertheless received, the ham radio operator shall not make known or allow to be known its contents, its origin or destination, its existence or the fact of its receipt to any person (other than duly authorized officer of the central government or a competent legal tribunal) and shall not reproduce in writing, copy or make any use of such message or allow the same to be reproduced in writing, copied or made use of.

Q. What is a 'Ham Radio Net'?

A. A ham radio net is a voluntary radio communication network formed under the initiative of a few hams, which is maintained at scheduled time/times of the day (everyday or at scheduled days). The heart of the net is the 'net controller', who takes messages from the hams joining the net and pass it on to its respective destination. Different nets may have different objectives. For example **'Air Net India**' is the National Emergency Traffic (NET) net run by the **Amateur Radio Society of India** (ARSI). This net is conducted everyday from 7:00 PM or 7:30 PM on **14.150 MHz ±** QRM to handle any emergency medical traffic, other emergency traffic and to check the radio wave propagation condition. But one of the main objectives of this net is to provide the facility to the Indian hams to establish contact between two hams. A ham 'X' can pass on the request to the 'net controller' regarding his willingness to contact a ham 'Y'. The 'net controller' then helps both the station to make the contact on a mutually decided frequency. So every active hams should have the habit of checking into this kind of net regularly.

Q. What is a distress Call?

A. A distress call is a call given from a ship, aircraft or vehicle indicating that the caller is threatened by grave and imminent danger, which requires immediate assistance. In **radiotelephony** transmission, the distress signal consists of the word ***MAYDAY*** (pronounced as the French expression '***m'aider'***) spoken three times followed by the words THIS IS and the identification of the station seeking assistance. A distress message should be followed by the distress call.

It contains name of the ship, aircraft or vehicle, position, type of distress and the type of assistance asked for including any other relevant information to facilitate rescue operation.

In **radiotelegraphy,** the distress signal consists of the letters ***SOS*** sent in Morse Code characters • • • – – – • • • (***SOS***). All these characters should be transmitted three times as a single signal where ***dashers*** are to be emphasized to enable distinguish them clearly from the ***dots.*** A typical distress message may look like: **SOS SOS SOS CQ CQ CQ DE** followed by the call-sign. When the distress traffic is over, the distress station should end its transmission with the Q-Code. It looks like: **SOS CQ CQ CQ DE 'call-sign' QUM SK.**

International distress frequency for radio **telegraphy is 500 KHz** and radio **telephony** it is **2182 KHz**.

Q. What action should you take if you receive a distress call?

A. The distress call has **absolute priority** over all other transmissions. Hence it would be your utmost duty to

- Listen to the distress call and stop you transmissions if you were previously occupying that frequency;
- acknowledge receipt of the distress message if the station in distress can copy your signal.
- At the same time, it would be your duty to ensure that your transmission does not interfere with transmissions of other stations, which may be better situated render assistance.
- Even if you cannot render assistance, you should direct the attention of other stations in the nearby frequencies, because they might be in a position to render immediate assistance.
- You shall also try to inform the appropriate authorities, who might be able to conduct a rescue operation.

Q. What is an 'Urgency Signal'?

A. Urgency signal is a wireless message which indicates that the calling station has a vary urgent message to transmit concerning the safety of a ship/vehicle or that of a person but the message cannot be ranked as distress message. **Obviously, the urgency signal should be given priority over all other transmissions except distress call.**

In radio telephony, the word **PAN** is repeated three times (PAN PAN PAN) pronouncing it as the French word '***panne***' . Other procedure to be followed in this type of traffic is same as that in distress traffic.

In radio telegraphy, the urgency signal consists of the group $\overline{\textbf{XXX}}$ (– • • – – • • – – • • –) sent slowly three times. Letters of each group should be clearly separated from each other. The urgency signal transmitted by a ship can be addressed to a specific station. However, a coast station can transmit its urgency signal to all the ship stations after the approval of a responsible authority.

Q. What is a 'Safety Signal'?

A. A safety signal is a message concerned with the safety of ships / vehicles indicating a meteorological warning (e.g. storm), danger to navigation warning or other navigational-aid message. Safety Signal is an important message because a delay in its transmission or reception can bring a disaster.

In radiotelephony, safety signal consists of the word '**SECURITY'** pronounced as '***Say-cure-ity'***.

In radio telegraphy, it consists of the three repetitions of the group $\overline{\textbf{T T T}}$ **(**– – – **)** sent slowly followed by the station call-sign. Letters of each successive group should be clearly separated from each other.

Q. What is test Signal ?

A. When it is necessary for the purpose of adjustment of a transmitter or receiver or for any experiment, the signals which are not intended for communication but testing is called test signal. It shall not be continued for more than 30 seconds and shall be composed of series of VVV in Morse followed by call sing. In case of radio telephony the figure 1,2,3,4,5 .... spoken in figure code followed by callsign. If it is required to send test signal for more than 30 second an artificial antenna should be used.

Q. What do you understand by the word 'phonetics' in amateur radio communication?

A. If we listen to a two-way amateur wireless conversation for the first time in our life, we would come across certain words, which perhaps we never heard before! There is every possibility that we mistake these words for some kind of secret codes! These words in fact are internationally used for pain language **(conversation in secret code language is not allowed in amateur radio communication)** conversation and are known as phonetics.

A ham radio operator has to face different types of hurdles during an ongoing communication. There may be static noise, signal fading, interference from other station operating at close frequencies, local noises in the radio room, unusual voice accents of the other operator, improper pronunciation of words etc. During these and many other difficulties, it has been found that use of phonetics improves the intelligibility in communication. For example, the letter '**D**' is represented by the word '**Delta**' in phonetics while the letter '**B**' is represented by '**Bravo**'. To distinguish '**M**' from '**N**', hams use the words '**Mike**' and '**November**' respectively.

Phonetic alphabet is useful when calling distant station or when the band is crowded, or when for any reason the station called is expected to have difficulty in copying voice signals. For example, the words 'Solstice' can be spelt using phonetic alphabet as ***Sierra Oscar Lima Sierra Tango India Charlie Echo.*** A person conversant in listening to such phonetics gets habituated in spontaneously writing down the exact word out of these phonetics! He feels more comfortable at writing down a message spelt out in phonetics rather than simple mentioning of each letters.

Phonetics are to avoid confusion and not to create confusion! Many letters of the alphabet sound similar unless very clearly heard. B may be heard as G or D or V. The word 'bed' may be heard as 'bet' or 'pet'. So, if we spell it out with phonetics like **B**ravo **E**cho **D**elta, the confusion easily gets eliminated! Good operating procedures include using the standard phonetic alphabet to help communicate more clearly. The recommended phonetics are those prescribed by the International Radio Regulations. The numbers are spelled differently to suggest a particular pronunciation. Also, nine was changed to *"niner"* to avoid confusion with the German word "*nein*" for "no".

When first making contact with another Ham, it is a good idea to say call signs in phonetics to give the other side a better chance of understanding them correctly.

Phonetics used by amateur radio operators.

Letter	World used as phonetics	Spoken as
A	Alpha	AL FAH
B	Bravo	BRAH VOH
C	Charlie	CHAR LEE
D	Delta	DELL TAH
E	Echo	ECK OH
F	Foxtrot	FOKS TROT
G	Golf	GOLF
H	Hotel	HOH TELL
I	India	IN DEE AH
J	Juliet	JEW LEE ETT
K	Kilo	KEY LOH
L	Lime	LEE MAH
M	Mike	MIKE
N	November	NO VEM BER
O	Oscar	OSS CAH
P	Papa	PAH PAH
Q	Quebec	KEH BECK
R	Romeo	ROW ME OH
S	Sierra	SEE AIR RAH
T	Tango	TAN GO
U	Uniform	YOU NEE FORM
V	Victor	VIK TAH
W	Whiskey	WISS KEY
X	X-ray	ECKS RAY
Y	Yankee	YANK KEY
Z	Zulu	ZOO LOO

Phonetics used against figures or marks

Figure or mark	World used as phonetics	Spoken as
0	NADAZERO	NAH-DAH-ZAY-ROH
1	UNAONE	OO-NAH-WUN
2	BESSOTWO	BESS-SOH-TOO
3	TERRATHREE	TAY-RAH-TREE
4	KARTEFOUR	KAY-TAY-FOWER
5	PANTAFIVE	PAN-TAH-FIVE
6	SOXISIX	SOK-SEE-SIX
7	SETTENSEVEN	SAY-TAY-SEVEN
8	OKTOEIGHT	OK-TOH-AIT
9	NOVENINE	NO-VAY-NINER
Decimal point	DECIMAL	DAY-SEE-MAL
Full stop	STOP	STOP

Q. What are the designations of emissions allotted to amateur radio service?

A. The most common designations of emissions, which are allotted to hams, are:

A1A: Continuous Wave (CW) Double side-band telegraphy for aural reception which contains quantized digital information without the use of modulating sub-carrier. (allotted to Grade II, Grade I and Advanced Grade Licence holders). **This is the most commonly used mode for Morse Code Communication in the ham radio bands.**

A2A: Continuous Wave (CW) Double side-band telegraphy for aural reception, which contains quantized digital information with the use of modulating sub carrier.

A3E: Double side-band single channel analog transmission containing telephony (including sound broadcasting). **Commonly known as AM** (Amplitude Modulation).

H3E: Single side band, full carrier single channel analog transmission containing telephony (including sound broadcasting).

J3E: Single side band, suppressed carrier single channel analog transmission containing telephony (including sound broadcasting). **This is the most common mode of voice communication in the ham radio bands.**

R3E: Single side band, reduced or variable-level carrier single channel analog transmission containing telephony (including sound broadcasting).

F3E: Frequency modulated single channel analog transmission containing telephony (including sound broadcasting). **Commonly known as FM.**

F1B: Frequency modulated single channel telegraphy transmission containing quantized digital information for automatic reception.

F2A: Frequency modulated single channel telegraphy transmission containing quantized digital information for aural reception.

F2B: Frequency modulated single channel telegraphy transmission containing quantized digital information with modulating sub-carrier for automatic reception.

F3C: Frequency modulated single channel analog facsimile transmission.

A3C: Amplitude modulated double side-band single channel analog facsimile transmission.

A3F: Amplitude modulated double side-band single channel analog video transmission.

Each letter/digit of the designation of emission represents independent meaning as assigned to them.

Q. What are the frequencies allotted to a Grade-I licence holder in India? How much power is allowed to a Grade-I licence holder? Can a Grade-II licence holder use radiotelephony for communication?

A. The radio frequencies allotted to a Grade-I licence holder in India are:

Short wave / High frequencies (HF)	**VHF / UHF / SHF**
1820 - 1860 kHz	144 - 146 MHz
3500 - 3700 kHz	434 - 438 MHz
3890 - 3900 kHz	1260 - 1300 MHz
7000 - 7100 kHz	3300 - 3400 MHz
14000 - 14350 kHz	5725 - 5840 MHz
18068 - 18168 kHz	
21000 - 21450 kHz	
24890 - 24990 kHz	
28000 - 29700 kHz	

In India, a Grade-I licence holder is allowed to use 150 watts in the HF bands and 25 watts in the VHF/UHF bands.

A Grade-II licence holder is not authorized to use radiotelephony. However, the holder of Grade II Licence shall be entitled for authorisation of radio telephony emission on his providing proof of having made 100 contacts with other amateur stations using CW (Morse Code).

Radio Telephony Operating Procedure.

Once you get your ham radio licence and the call-sign, it is time for you to start transmission. Radio waves are now-a-days a precious commodity and so the ham should not misuse them for his/her own ends. It is the duty of the ham to know the correct operating procedure. If a newly licensed ham radio operator is ignorant about the correct operating procedures, he may create nuisance in the band. A ham should also be aware about the International Operating Code devised by Paul M. Segal.

Code for a ham radio operator

1. The ham is **Considerate.** He/she never knowingly uses the air (radio waves) in such a way as to lessen the pleasure of others.
2. The ham is **loyal.** He/she offers his/her loyalty, encouragement and support to his/her fellow hams, his/her local clubs.
3. The ham is **progressive.** He/she keeps his/her station (radio equipment) abreast of science. It is well-built and efficient. His/her operating practice is above reproach.
4. The ham is **friendly.** Slow and patient sending when requested, friendly advice and council to the beginner, kindly assistance, co-operation and consideration for the interests of other; these are the mark of the ham spirit.
5. The ham is **balanced.** Radio is his/her hobby. He/she never allows it to interfere with any of his/her duties he/she owes to his/her home, his/her job, his/her school or community-and lastly his/her knowledge and his/her radio station are always ready for the service of his/her country and his/her community.
6. A ham is **patriotic**. His/her amateur radio station and skill is always ready for service to his/her country and community.

Calling another station

A call may be given to another station either in voice or using the Morse code. But before giving a call, it is the duty of the ham to check whether the frequency he/she is going to use is already in use by other ham/s or not. Even though a particular frequency seems to be idle, it may not be so. Because, there may still be a ham sending his message whose signals are in skip with us (see questions & answers related to radio wave propagation) and another ham at a different location is listening to him. Giving a transmission in the same frequency in such a situation may interfere with the ongoing communication. So, prior to transmission, it should be ascertained by sending the message- "is the frequency in use?". This should be repeated two more times and if no reply is received, we can occupy the frequency. After occupying a frequency, we can give a '**General Call**' or a '**Directional Call**'. A 'General Call' is a call given to all the stations. This means that you will reply to anybody from any part of the world. The message sounds like - "**CQ CQ CQ this is Victor Uniform Two ..... (your call-sign suffix in phonetics) calling CQ on 20 metre and standing by**". The 'CQ' message may be repeated for three times before giving the **'standing by'** message. As you 'stand by', listen carefully for any possible reply. If no reply is received, you can continue giving your CQ call. There is also a '**Directional Call**' which is **directed to a particular country** or **a particular station.** A call directed to a particular country is like - "**CQ Japan CQ Japan CQ Japan this is Victor Uniform Two......".** This means that you will reply to stations from Japan only. A call may be directed to a particular station also. In this case, the country name is to be replaced with the intended station 'call-sign'. **A person with the true ham spirit does not adhere strictly to his directional call, and as such should not deny reply to a ham from another country replying to his directional call (in the above example) until and unless he is in real emergency. Also there is nothing official about a ham radio operation.** Ham radio operators also form net. When a net is going on, you can also join the net once somebody in the net 'pulls you' into the net. To indicate that you want to join the net, a short **'BREAK"** call may be given.

After establishing contact and offering the initial greetings, **a signal report** should be given to the other station. Your name (**Handle**) and location (**QTH)** should then be spelled out clearly in internationally accepted phonetics. If the other ham finds difficulty in copying your voice signal due to poor propagation condition or due to the difference in pronunciation, you should not loose patience and the message should be repeated if requested. You can also give the weather report (**WX report**) by mentioning the temperature in degrees Celsius. After this, discussion regarding the antenna system and equipment (called **-"working condition"**) begins. Before closing the conversation with a particular station, **73** message (meaning **'Best of Regards'**) should be conveyed to the ham and his family and indication should be given whether you are closing down (**going QRT**) your station, you are changing your frequency (**QSYing**) or you are still occupying the frequency. This will help other stations to follow you in case they want to make a contact with you. If the conversation takes long time, both the stations should repeat their call-sign at least at ten minutes interval.

While in telegraphy (morese), Readibility --

Signal Report RST

When on-the-air contact between amateur radio stations is established, both the stations exchange signal reports. This gives the idea about how strongly the ham radio stations are receiving each other. For telephony (voice), Readability and Signal strength scale is devised, while in telegraphy (morse), Readability, Signal strength and quality of tone is devised.

Readability	Signal Strength	Tone
R1 - Unreadable	S1 - Faint, signals barely	T1 - Extremely rough hissing note
R2 - Barely readable, occasional words distinguishable	S2 - Very weak signals	T2 - Very rough AC note, no trace of musicality
R3 - Readable with considerable difficulty	S3 - Weak signals	T3 - Rough, Low-pitched AC note, slightly musical
R4 - Readable with practically no difficulty	S4 - Fair signals	T4 - Rather rough AC note, moderately musical
R5 - Perfectly readable	S5 - Fairly good signals	T5 - Musically modulated note
	S6 - Good signals	T6 - Modulated note, slight trace of whistle
	S7 - Moderately strong signals	T7 - Near DC note, smooth ripple
	S8 - Strong signals	T8 - Good DC note, just trace of ripple
	S9 - Extremely strong signals	T9 - Purest DC note

A 59 (5 and 9) report is the best report in radiotelephony. You should be honest in giving a signal report. Don’t give a good report just to please your friend! There may be some problem in the antenna system of your friend’s station due to which you are receiving him poorly. Or there may be some problem in the audio quality of your friend’s transmission. Under such a situation, giving a false report will just misguide your friend and your friend may not be able to detect/rectify the fault in his/her system.

Radio Telegraphy Operating Procedure

In radio telegraphy contact using Morse Code, the RST (Readability, Signal Strength and Quality of Tone) system of reporting is followed by the ham radio operators. Throughout the world, Morse code is still used very affectionately by thousands of ham radio operators. They make conversation as fluently as they do in voice using Morse code. In the early days of radio, communication by radiotelegraphy was the primary means to exchange messages between radio operators at all radio stations, including amateur radio stations. In fact Morse Code has many advantages over voice communication in certain situations, as well as for the sheer joy involved in this art of communication, which we have discussed in the chapter on Morse code learning. In Morse code also, either general CQ call or directional call can be given. The calling format is as follows:

General Call:

CQ CQ CQ DE VU2XYZ VU2XYZ VU2XYZ AR PSE K

Specific / Directional Call :

CQ / VU2ABC CQ / VU2ABC CQ / VU2ABC DE VU2XYZ VU2XYZ VU2XYZ AR KN

In Morse code, long words are usually avoided and hence only the abbreviated form of the words is sent. There are certain internationally accepted Morse Code abbreviations which you should remember and use during communication. **'AR'** is synonymous to saying '**over**' in voice (A voice message should be ended with the word over to ....'). '**K**' is the invitations to transmit which is synonymous to saying '**go ahead**' in voice communication. A message ended with **KN** indicates that the message was directed to a particular station only. During an ongoing communication also, the message should be ended with **'KN'** which provides the information to the other stations that communication was already in progress between two stations. Each sentence of the message should be separated by '**BT**'. Given below is a typical Morse code message.

VU2XYZ DE VU2ABC BT TNX FER CALL BT UR RST IS 579 BT MY NAME IS ....ES QTH IS ....BT OK? AR VU2XYZ DE VU2ABC KN

When you finally close your conversation with a particular station, indication should be given, i.e. the message should be ended with **'VA'** (meaning **'over and out with ....**) A typical closing message may look like - .... **VU2ABC DE VU2XYZ VA.** This means that VU2XYZ is now free to communicate with other stations.

Ham terminology

RUNNING BAREFOOT:	A RF transmitter running without an external linear RF amplifier.
CHARLIE WISHKY	Morse Code
CRYSTAL CONTROL CEREMONY:	Marriage ceremony of a ham radio operator
EYE BALL QSO:	When a ham meets another ham in person
HANDLE:	Name of the ham radio operator
	Daughter or Son of the ham radio operator (just as the harmonic frequency generated out of the fundamental frequency!)
HOMEBREWED EQUIPMENT:	A home made apparatus
JUNK MARKET:	The market where old/used/defective component or devices are found
LIMA LIMA:	A Telephone call (Landline!)
RIG:	Wireless apparatus of the ham radio operator
SHACK:	Radio room
SILENT KEY:	Death of a ham radio operator
TICKET:	The amateur Wireless Telegraph Licence

Abbreviations used in Radio Telegraphy (Morse Code)

AA	Artificial antenna or All after	**HRD**	Heard
AB	All before	**HV**	Have
ABT	About	**K**	Go ahead (general request)
AGN	Again	**KN**	Go ahead (directional request)
ANI	Any	**KCS**	Kilocycles
ANT	Antenna	**LID**	Bad operator
AR	Over	**MNI**	Many
AS	Wait	**MO**	Master Oscillator
BK	Break	**MCS**	Megacycles
BC	Broadcast	**ND**	Nothing doing
BCL	Broadcast band Listener	**NW**	Now
BCNU	Be seeing you	**NIL**	Nothing
BT	Separation	**OB**	Old Boy (Young male operator: a novice)
C	Yes	**OM**	Old Man (a male operator)
CFM	Confirm	**OK**	All correct
CL	Closed	**OP**	Operator
CO	Crystal Oscillator	**PSE**	Please
CQ	General Call	**PX**	Press
CONDX	Conditions	**QRP**	Very low power
CU	See you	**QSL**	Received
CUL	See you later	**R**	Roger (Copied OK)
CK	Check	**RCVD**	Received
CANS	Headphone	**RCVR**	Receiver
DE	This is	**RPRT**	Report
DF	Direction Finding	**RPT**	Repeat the message
DX	Long distance	**RX**	Receiver
ECO	Electron Coupled Oscillator	**SA**	Say
ERE/HR	Here	**SED**	Said
ES	And	**SIGS**	Signals
FER	For	**SWL**	Short Wave Listener
FB	Fine Business	**TKS**	Thanks
FONE	Telephony (voice)	**TX**	Transmitter
CKT	Circuit	**TU**	Thank you
GA	Go ahead / Good afternoon	**U**	You
CLG	Calling	**UR**	Your / You are
GE	Good evening	**VA**	End of work
GM	Good morning	**VY**	very
CPSE	Counterpoise	**WA**	Word after
GLD	Glad	**WB**	Word before
GND	Ground	**WX**	Weather
GUD	Good	**WID**	With
HI	Laughter	**WKD**	Worked
HPE	Hope	**WL**	Will
HR	Here	**WUD**	Would
XMTR	Transmitter	**YF**	Wife
XTAL	Crystal	**YL**	Young Lady
XYL	Wife	**73**	Best of regards
88	Love & Kisses	(The abbreviations with bold typeface are according to syllabus for licencing examination)	

Q CODES

Q-codes :

A ‘Q-code’ consists of three letters starting with the letter ‘Q’. Q-codes are devised to facilitate faster communication in Morse code. Instead of sending a long sentence, the amateur radio operator can just send a combination of three letters to represent a long sentence. If the amateur radio operator asks something to his fellow operator, then the Q-code is followed by a question mark. If the Q-code is used to represent a statement (not a question), then it is not ended with a question mark. For example, if you want to ask your friend on the air whether he is busy (Are you busy?); the Q-code will be ‘QRL?’. If you want to say that you are busy, send ‘QRL’. There are nearly 100 Q-Codes used by the marine radio operators. We have mentioned below the Q-codes required to be learnt by an amateur radio operator. Q-codes are very often used during the voice communication also.

QRA? What is the name of your station?

QRA The name of my station is.........

QRG? Will you tell me my exact frequency (or, that of ....)?

QRG Your exact frequency (or, that of.....) is.....kHz (or Mhz)

QRH? Does my frequency vary?

QRH Your frequency varies.

QRI? How is the tone of my transmission?

QRI The tone of your transmission is: (1) Good. (2) Variable. (3) Bad.

QRK? What is the readability of my signals (or, those of.....)?

QRK Readability is: (1) Unreadable. (2) Readable now and then. (3) Readable with difficulty. (4) Readable. (5) Perfectly readable.

QRL? Are you busy?

QRL I am busy (or, busy with ....). Please do not interfere,

QRM? Are you being interfered with?

QRM I am being interfered with.

QRN? Are you troubled by static noise?

QRN I am troubled by static noise.

QRQ? Shall I send faster?

QRQ Send faster (.........wpm)

QRS? Shall I send more slowly?

QRS Send more slowly.

QRT? Shall I stop sending?

QRT Stop sending

QRU? Have you anything for me?

QRU I have nothing for you.

QRV? Are you ready?

QRV I am ready.

QRW? Shall I inform ...... that you are calling him on .... kHz?

QRW Please inform .... That I am calling him on .... kHz.

QRX? When will you call me again?

QRX I will call you again at .... hours.

QRZ? Who is calling me?

QRZ You are being called by.

QSA? What is the strength of my signals (or those of ......)?

QSA Your signals are (1) Scarcely perceptible. (2) Weak. (3) Fairly good. (4) Good. (5) Very good.

QSB? Are my signals fading?

QSB Your signals are fading.

QSL? Can you acknowledge receipt?

QSL I am acknowledging receipt.

QSO? Can you communicate with .... direct or by relay?

QSO I can communicate with .... Direct or by relay through ....

QSU? Shall I sent or reply on this frequency (or, on ....kHz) (with emissions of class......)?

QSU Send or reply on this frequency (or, on........ kHz) (with emissions of class......).

QSV? Shall I send a series of 'V's on this frequency (or .... kHz)

QSV Send a series of 'V's on this frequency (or, ... kHz)

QSW? Will you send on this frequency (or, ...kHz)(with emissions of class ....)?

QSW I am going to send on this frequency (or, ...kHz) (with emissions of class......)

QSX? Will you listen to .... (call-sign) on ....kHz?

QSX I am listening to ......(call-sign) on ....kHz?

QSY? Shall I change my transmission to another frequency?

QSY Change your transmission to another frequency.

QSZ? Shall I send each word or group more than once?

QSZ Send each word or group twice (or, ...times)

QTC? How many telegrams have you to send?

QTC I have .... telegrams for your (or, for ....)

QTH? What is your position in latitude and longitude (or, according to any other indication)

QTH My position is .....latitude ....longitude (or, according to any other indication.)

QTR? What is the correct time?

QTR The correct time is ....hours.

QUM? Is the distress traffic ended?

QUM The distress traffic is ended.

Running a Amateur Radio Station

Functions of an Amateur Station

Equipments in a well installed station

A well equipped station should possess the following,

a) A communication receiver **(RIG)** with very good selectivity with facility for micro tuning.

b) Main Power supply. Batteries.

c) A transmitter with the authorized power output equipped for transmission of CW, AM and SSB signals. For short range communication, there should be a power reduction switch so that during local contacts excessive power is not radiated.

d) A very good directional antenna and preferably with antenna tuner Clock.

Equipment Register

Sr. No	Particulars of the apparatus Make / Mode / Chassis & Type	Name & address of the person form whom received (in case assembled by licensee write self made)	Date of receipt or assembly	In case of purchase give receipt no. & indicate the license no. of he seller	Name & address of the person to whom sold or transferred	Date of Sale or Transfer	Particulars of the license issued in the name of purchaser	Remark
1	ICOM 706 HF / VHF transceiver	Icom Inc. 20577, Taiwan.	06 / Jul / 2004	Sal / Oct-26678				

QSL Card

Radio amateurs used send QSL card as written confirmation of a first contact. QSL card be designed by our choice but it must contain at least following information

1 Name of the station worked
2 Date of Contact
3 Time
4 Frequency
5 Mode emission
6 Signal report exchange
7 Input power
8 Type of equipment
9 Type of Antenna
10 Name & Address of operator
11 Remarks

QSL cards can be sent directly or via QSL bureau. QSL bureau are run by hams in every country which collect and dispatch QSL cards which is very economic way of exchange cards.

Maintaining LOG

Draw the format of a log & Equipment use Amateur with 2 entries & explain briefly

Date	Time		Freq	Mode	Station Worked (Call Sign)	RST (Readability, Strength, Tone)		QSL		Name & other Details	Remarks
	Started	Ended				Given	Recd	Sent	Recd		
1/Jul/ 2004	1415 hrs	1430 hrs	170 Mhz	FM	VU2PQ R	59	59	✓	-	Shri P Q R	4/Jul/04 1600 hrs
3/Jul/ 2004	1730 hrs	1800 hrs	7050 KHz	CW	VU2STV	599	599	-	-	Shri S T V	9/Jul/04 1530 hrs

Radio Theory

Introduction to basic electronics

What is electronics?

Electronics is the field of manipulating electrical currents and voltages using passive and active components that are connected together to create circuits. Electronics circuits range from a simple load resistor that converts a current to a voltage, to computer central processing units (CPUs) that can contain millions of transistors. Electronic devices operate by the movement of electrons through conductors, e.g. wires, and electronic components.

What are passive components?

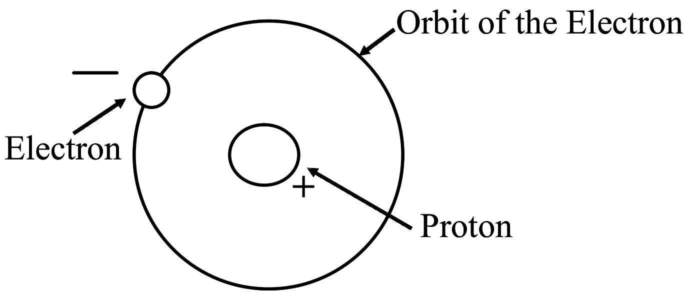
Resistors, inductors, transformers and capacitors are called ***Passive devices.*** They don't alter their resistance, impedance when alternating currents (ac) are applied to them.

What are active components?

Vacuum tubes, diodes, transistors etc. are called active devices. They change their resistance or impedance when varying voltages are applied to them and as a result can amplify, rectify, modify or distort ac waveforms. Passive devices normally don't distort waveforms.

Matter and electricity

All matter consists of atoms. Each atom is primarily composed of three fundamental particles called electrons, protons and neutrons. At the centre of the atom is the nucleus formed by the combination of **Protons,** particles with **positive charge,** and neutrons, particles with no intrinsic charge, Orbiting around the nucleus are the **electrons,** particles that have a **negative charge.** All these three particles are responsible for the chemical and electrical properties of atoms. **The size of the whole atom is of the order o 10^{-8} cm.** Atoms of all element except hydrogen contain one or more than one neutron in their nucleus. **Hydrogen is the simplest atom with one positively charged proton and one negatively charged electron orbiting it.**



A Hydrogen Atom

One or more atoms constitute a molecule, which is the tiniest representative of a particular substance showing all the characteristics of that substance. For example, it is possible to divide a drop of water again and again unit it cannot be divided further but still be water, this tiniest particle will be the molecule of water. A molecule of water contains two atoms of hydrogen (H) and one atom of oxygen (O).

What is an electron?

Electrons are the negatively charged stable elementary particles, which revolve around the nucleus of an atom in several possible and 'allowed' orbits. The mass of an electron is 9×10^{-28} grams. Proton is about 1840 times heavier than electron. There is always attraction between unlike charges. Because electron is much lighter than proton, hence it is pulled towards the proton and is primarily responsible for electrical conduction.

What is charge?

It is the property possessed by some elementary particles causing them to exert forces of attraction or repulsion on each other. The types of forces exerted by charged particles are differentiated by the terms negative and positive, the natural unit of negative charge being possessed by the electron. The proton has an equal amount of positive charge. A body is said to be charged when it contains an excess or lack of electrons with respect to its proton content. The unit of charge is coulomb (C) and symbol is 'q'. One coulomb is equivalent to 6.28×10^{18} electrons.

What is current?

Electrons moving in one direction under the influence of an electric field constitute an electric current. Atoms of a metal form a crystal lattice, and in the spaces between the lattices are the free electrons moving chaotically, wandering aimlessly here and three. These electrons can be made to acquire an aim by connecting the metal plate to the two poles of a voltage source (e.g. a battery). They will move towards the positive two poles of a voltage source (e.g. a battery). They will move towards the positive pole of the battery, and an electric current will begin to flow in the metal. An electric current can also flow in a gas. A voltage applied across a gas-filled tube causes ionization of the gas; free electrons stream towards the plate with the positive potential, colliding with the atoms in their way and detaching electrons from their orbits. The positive ions move towards the opposite end of the tube.

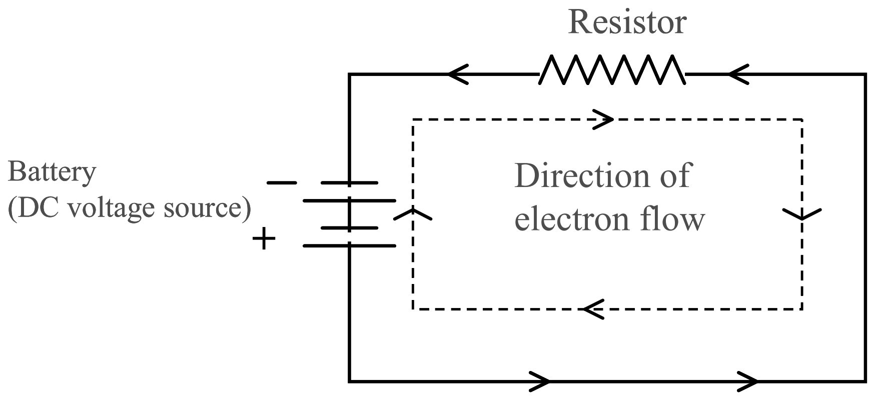
What is voltage?

Voltage is also called potential difference or electromotive force-EMF. Potential difference is defined as the work required from some energy source in moving a unit positive charge between two points in an electric field. It is the electronic potential energy between two points, and is the driving force that causes charge to flow. Its unit is volt (V). One volt is defined as the potential difference that requires one joule of energy to move one coulomb of charge. **Voltage is always measured relative to some other point in a circuit, e.g. the potential across a resistor.** Voltage measurement made at a single point in a circuit is made relative to the earth (ground), which is assigned an "absolute" voltage of zero.

Types of Electricity

Direct Current (DC)

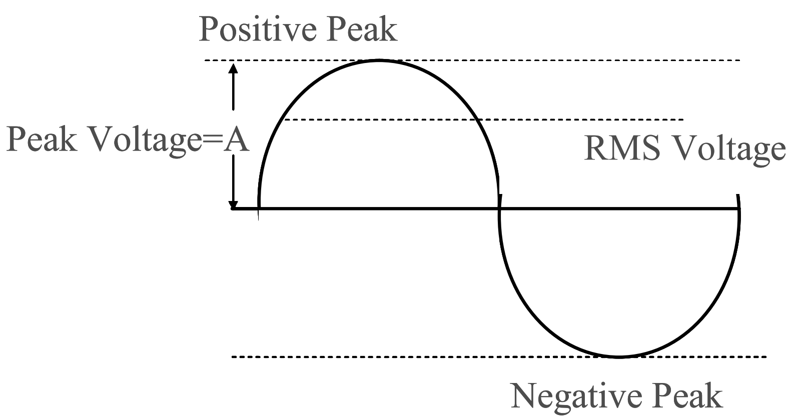
The direct current flows in one direction in a circuit. DC voltage has a fixed polarity (e.g. a battery or an electrical cell) and magnitude of the voltage remains constant. In an electrical circuit, the flow of electric current is indicated buy an arrow mark originating from the positive terminal of the battery towards the negative terminal of the battery. This is the conventional method of showing the direction of current flow. But the real direction of electron flow is from the negative terminal of the battery to the positive terminal.



Conventional direction of current flow

Alternating Current (AC)

Alternating current flows first in one direction for one-half cycle and then in the opposite direction during the other half cycle. The same definitions apply to alternating voltage. AC voltage switches polarity back and forth. AC voltage /. current has a wave-from which represents the frequency of the source. The wave-form of the household ac is known as the 'sine' wave. The magnitude of the A.C. voltage changes with time. AC is obtained from A.C. generators.



A sine wave cycle. The upper half denotes the positive cycle and the lower half denotes the negative cycle

Advantage of AC

Heat is developed in all type of electrical circuits due to the flow of electric current. The magnitude of the D.C. being constant produces more heat produced by an A.C. In long distance transmission lines, large amount of power will be dissipated in the form of heat if D.C. is used which can be reduced by the use of A.C.

A.C. Voltage can be measured in four different ways.

Peak Voltage

The value or amplitude of an A.C. voltage never remains constant. With an initial voltage of zero, the amplitude rises to a peak value, after which it again falls back to zero. After reaching zero, the direction of the current changes and the voltage rises to its negative peak. Peak voltage measurement is necessary to ensure or know that the amplitude of the A.C. voltage does not exceed a limit.

Instantaneous Voltage

It is also called the **average voltage.** The voltages, if measured, at different points of the half cycle of the sine wave will be the instantaneous voltages. But parctically it is not possible. So one way to denote instantaneous voltage is to take the average voltage. In a sine wave A.C. voltage. In a sine wave A.C. voltage, the average voltage can be found out by multiplying the ‘peak voltage’ by a constant (value of the constant can be worked out to be equal to 0.367).

Root-Mean-Square Voltage

Measuring an A.C. voltage involves the use of a meter which measures AC Voltage in terms of how much DC voltage it would take to have the same effect in a circuit. Since during most of the cycle the AC has a value less than the value at its peak, or for that matter, than of a constant DC voltage, it will not be able to produce as much heat (in a heating element) as produced by the same amount of DC voltage. Power being proportional to either E^2 or I^2 ($P=E^2/R=I^2R$), if all the instantaneous values of a half cycle of sine-wave current (or voltage) are squared and then the average, or mean, of all the squared values is found, the square root of this mean value will be 0.707 of the peak value. This root-mean-square, or rms, value represents how effective a sinusoidal AC will be in comparison with its peak value.

The RMS value is the value of voltage of an AC source, the power consumed by whom is the same as by a d.c. voltage. That is, it is the effective value (Veff) of a sine-wage voltage found from the formula: $V_{eft} = V_{max}$ X 0.707.

Effective Voltage

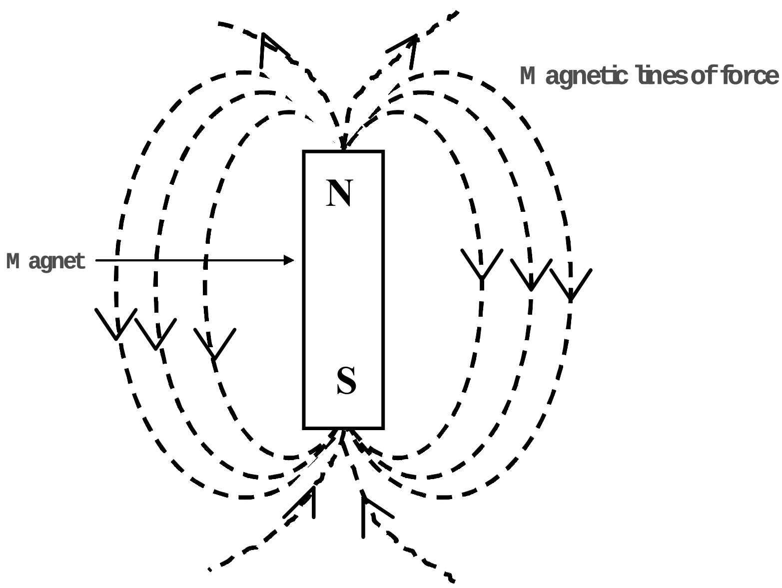
In a domestic AC supply, 230 volts is actually the effective voltage (V_{eff}). The actual voltage or the peak voltage (V_{max}) of the supply is : $V_{max} = V_{eff} / 0.707 = 325$ volts. Or, to determine a peak value of AC that will be as effective as a given DC, it is necessary to multiply the effective value given by the reciprocal of 0.707 (1/0.707), which is 1.414.

Magnetism

What is a magnet ?

A piece of iron, nickel, cobalt, steel, alloy (e.g. alloy made from non-magnetic copper, manganese and aluminium) etc. usually in the form of a bar having properties of attracting or repelling iron and other materials which contain iron is called a magnet. But what gives it its force is not completely known. One of the theories to describe magnetism is the theory of domains. It says that materials that can be made into magnets have many tiny crystal like structures called domains. Each domain is made up of many atoms. Each domain has a small magnetic force of its own. When the material is not magnetized, the domains are haphazardly arranged pointing in all directions so that their tiny forces cancel each other. To make the material into a magnet, the domains need to be lined up so that their individual magnetic forces all help each other pull the same way. When most of the domains line up, the magnet becomes strong. When all of the domains line up in one direction, the magnet is saturated. It cannot be made any stronger regardless of how much you try to magnetise it.

In a magnetic bar, there are two poles; North and South. They are marked as 'North' and 'South' poles because, when the magnetic bar is suspended horizontally, one of the ends will always point towards the Earth's geographical north and the other pole towards the Earth's geographical south. This is because of the fact that the Earth itself behaves like a huge magnet. In a magnet, the like poles repel and the unlike poles attract-a reason for the specific alignment of the magnetic bar. The magnetic bar is surrounded by the invisible lines of forces which originate from the 'North' pole and terminate in the 'South' pole.



A bar magnet

Ferro-magnet

Iron, nickel and cobalt (including the alloy mentioned above) are considered ferromagnetic. Ferro-magnetic materials are difficult to be converted to magnet but once magnetized under the influence of another magnetic field, they cannot be completely demagnetized. Ferromagnetic materials are used to make permanent magnets. **One of the strongest permanent magnetic materials is a combination of iron, aluminium, nickel and cobalt called "Alnico".**

Paramagnetic material

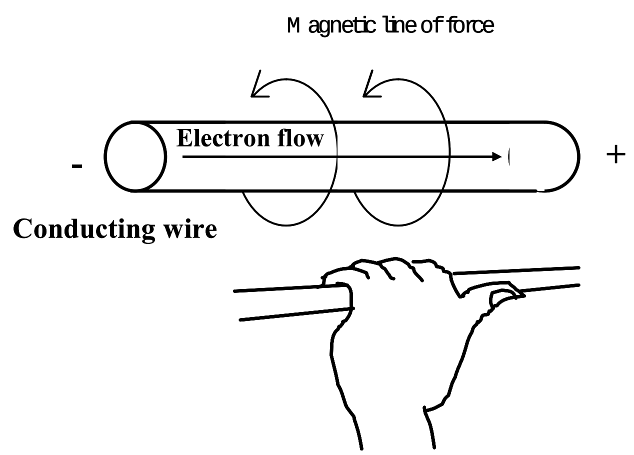
A material within which an applied magnetic field in increased by the alignment of electron orbits is called paramagnetic material. They are made up of non-ferromagnetic atoms. When placed in a magnetic field, they may weakly attempt to line up in the direction of the magnetic field. Paramagnetic materials always become completely nonmagnetic when an external magnetizing force is removed from them.

Use of Permanent magnets in Electronics

Electricity and electronics cannot be discussed by leaving apart 'magnetism' separately. Permanent magnets are used in electronics to make electric meters, headphones, loudspeakers, radar transmitting tubes etc. Temporary ferromagnetic materials (known as soft ferromagnetic material) are also equally important in electricity and electronics to make devices, which may be quickly magnetized and demagnetized. Soft ferromagnetic, such as silicon steel and soft iron are used to make electromagnets, generators and electric motors etc.

Electromagnets

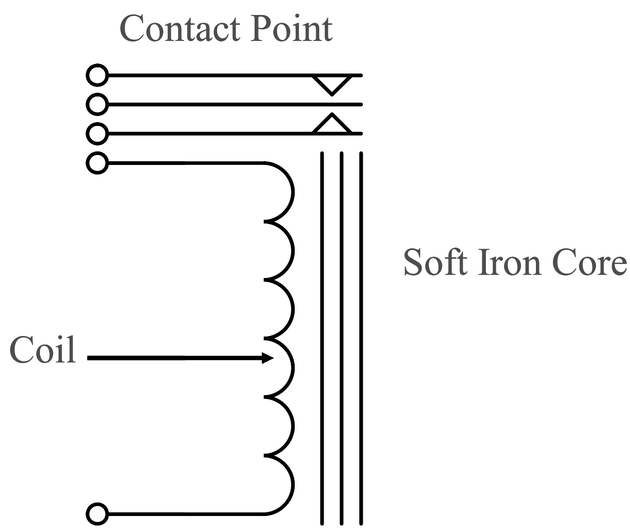
The flow of an electric current through a wire creates a circular magnetic field around the wire. This magnetic field has the highest intensity near the conducting wire and the intensity gradually decreases as the distance from the wire increases. The direction of these magnetic flux lines can be found by the 'left hand rule'. If the conducing wire shown below is grasped by the left hand, the curled fingers point to the direction of magnetic flux lines and the thumb shows the direction of electron flow.



The left hand rule

If a straight conducting wire is made into a loop giving it a 'coil' shape, the small magnetic loops around the wire overlap each other resulting in a stronger magnetic field around the whole coil. The strength of the magnetic field depends on the number of turns in the coil, amount of current in the coil and the permeability of is capable of transferring the magnetic flux line more efficiently. Based on this principle, electromagnets can be made. An electromagnet consists of a coil surrounding a soft iron core. The core remains magnetized so long as there is flow of current in the coil. The direction of the magnetic field in a coil can also be found by the 'left hand rule'. If a coil is grasped in left hand, the curled fingers point to the direction of electron flow, the thumb shows the direction of magnetic flux and N pole of the coil.

Electromagnets have many applications in electronics. TWO OF THE most important uses of electromagnetism are in **transformers** and **motors.** Electromagnetic relays, electric bells, buzzers are commonly used electromagnets. Electromagnetic relays are used as switching devices in electrical and electronic circuits.



Symbol of an Electromagnetic Relay

Transformers

Transformer is a device which consists of two coils arranged in a way so as to generate magnetic coupling effect (the coupling effect is enhanced by winding the two coils on a common iron core) and thereby transfer electrical energy (AC voltage) from one coil (called the *Primary coil*) to the another coil (called the secondary coil). A transformer works on the principle of 'mutual inductance'. One of the most useful characteristics of a transformed is its ability to step-up or step-down of AC voltages. The step-up or step-down ratio will be proportional to the turns in each coil, i.e.

$$V_s = N_s / N_p \times V_p$$

Where, V_s = Secondary voltage

N_s = Number of turns on secondary

N_p = Number of turns on primary

V_p = Primary voltage.

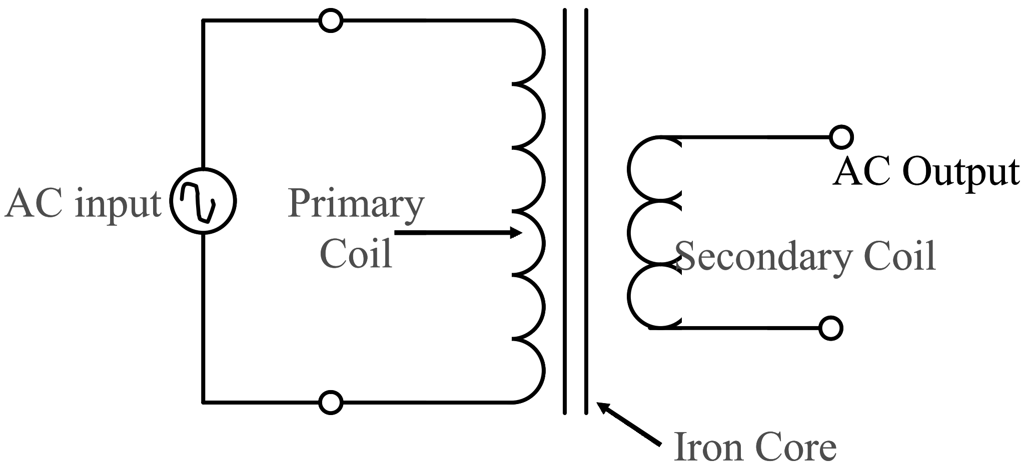
The current flowing in the primary and secondary, follows a similar relationship but in opposite ratio. i.e.

$$I_s = N_p / N_s \times I_p$$

Where I_s = Secondary current

I_p = Primary current.

In other words, a step-up in voltage produces a step-down in current and vice versa.



Symbolic form of a Step-down Transformer

Transformers as Coupling Device

Transformers are very useful to use in radio or audio frequency circuits as coupling devices. As well as providing coupling, they can act as 'amplifiers' to step up an audio or radio frequency voltage (but not as *power* amplifiers); and even more important for impedance (see page 72) matching. By choosing the proper turns ratio the impedance of a fixed load can be transformed to any desired higher or lower i impedance, within practical limits. This can be a particularly important requirement when coupling transistor radio stages.

For impedance matching, the following relationship applies:

$$\frac{N_P}{N_S} = \sqrt{\frac{Z_P}{Z_S}}$$

Where,

Z_p = Impedance of the transformer looking into the primary terminals

Z_s = Impedance of the load connected to the secondary of the transformer

Electrical Circuit Components

What are resistors?

A resistor is a device designed to have a definite amount of resistance-used in circuit to limit current flow or to provide a voltage drop. Resistance (R) is the retarding force in a material that impedes the flow of current. The potential (E) needed to achieve a current (I) through a material that behaves linearly, e.g. conductors and resistors, is given by Ohm's law:

$$E = IR$$

Where, E	=	emf (in volts, V)
I	=	intensity of current (in amperes, A)
R	=	Resistance (in ohms, W)

So, if we know any two values, we can find out the other value. The above formula can rearranged as shown below:

I = E/R or Current in amperes = volts / ohms.

From this formula, it is evident that - **"Current varies directly as the voltage and inversely as the resistance."**

The formula can also be arranged to find out the resistance in a circuit if the voltage and current are known.

R = E/I or Resistance in ohms = volts / amperes.

Practical Resistors

The resistance of a material depends on four physical factors:

(1) The **type of material** from which it is made, For example copper and silver are very good conductors of electric current, but iron is six times lesser in its conductivity than them.

(2) The **length** (greater the length greater is the resistance).

(3) **Cross-sectional area** (greater the cross-sectional area larger the amount of free electron implying lesser resistance).

(4) **Temperature** (except for carbon and other semiconductor materials).

So each material has a specific resistance inherent in them. **The specific resistance of a material is the number of ohms in a 1 foot long 0.001 inch diameter** round wire of the material at room temperature. Silver has the latest specific resistance, i.e. 9.75 W and nichrome is an alloy, which has specific resistance as high as 660 W.

Wire-wound resistor

Nicrome or German silver wires are wound on a tubular ceramic form to make wire-wound resistor. Wire-wound resistors are generally available in values from **1 ohm to 300 kilo ohms.** Power ratings of this type of resistors vary from **1 to 50 watts.**

Carbon resistor

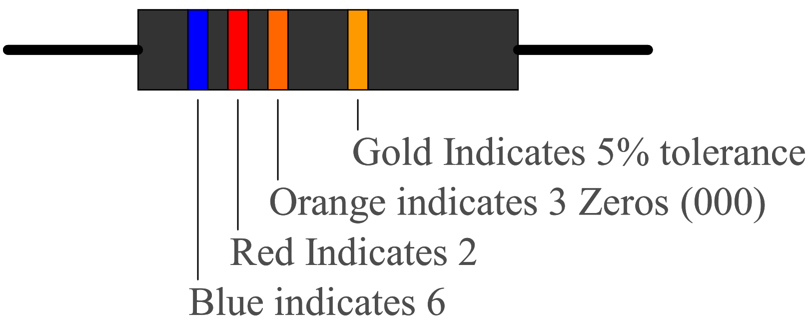
Powdered carbon is mixed with a binding material and baked into small, hard tubes with wire attached to each end to make carbon resistors. The percentage of carbon in the mixture determines the resistance value in ohms. Carbon resistors are generally available in values from **10 ohms to 22 mega ohms.** Power ratings of this type of resistors vary from **1/8 watt to 2 watts.**

Colour codes of resistors

Carbon resistors are colour coded to indicate their values. Each resistor has four colour bands on its body. The first band (the band which is nearest to the end of the resistor) is the first number. The second band is the second number. The third band is the multiplier, i.e. number of zeros following the second number.

Colour	Band 1	Band 2	Band 3
Black	0	0	-
Brown	1	1	0
Red	2	2	00
Orange	3	3	000
Yellow	4	4	0000
Green	5	5	00000
Blue	6	6	000000
Violet	7	7	0000000
Gray	8	8	00000000
White	9	9	000000000

Resistors having values lower than 10 W have three colour bands. The third band is either golden or silver in colour. A golden band indicates that the first two numbers are to be multiplied by 0.1, A silver band indicates multiplication by 0.01. The tolerance of three band resistors is 20%. If the golden or silver band is the fourth band respectively,



The Value of this resistor is 62000 Ω or 62 K Ω

Questions:

1. A circuit has a resistance of 100 ohms and voltage applied across the circuit is 20 volts. What is the amount of current flowing through it?

   We have, I = E/R or I = 20/100 = 0.2 A (ampere) or 200 mA (milliampere)

2. Find out the voltage required to produce 3 A of current through a 50 W (ohms) resistor.

   We have, IR = E or 3 x 50 = 150 V (volts)

Power and Energy

As mentioned above, heat is developed in the load resistor as a result of current flowing through it. In absence of the load, a battery despite having the electromotive force (EMF), cannot produce movement of electrons and no electrical work is accomplished. When there is a load across the battery, movement of electrons take place. The product of the EMF (in volts) and movement of electrons (in amperes) gives us the amount of electrical work accomplished whose unit is watt (W).

P = EI

Where p = power (in watts, W)
E = emf (in volts, V)
I = current (in amperes, A)

So, 1 V causing 1 A to flow through a 1 W resistor produces 1 W of power.

The above formula can also be expressed as

$P = EI = (IR) = I^2R$ (because the ohm's law states : E = IR)
Or
$P = EI = E\,(^E/_R) = E^2/_R$ (because the ohm's law states: $I = {^E/_R}$)

Question :-

1. Find out the heat dissipated by a 50 W resistor when 0.25 A of current flow passes through it.

   We have, $P = I^2R$ or $P = 0.25^2 \times 50 = 0.0625 \times 50 = 3.125$ W.

2. Find out the power dissipated by a 10,000 W resistor connected across a voltage source of 250 v.

   We have $P = E^2/_R = 250^2/_{10,000} = 6.25$ W.

3. Find out the maximum voltage that may be connected across a 20 W, 2000 W resistor.

We have, $P = E^2/_R$

Or, $E^2 = PR$

Or, $E = \sqrt{PR}$

Or $E = \sqrt{20 \times 2000} = 200$ V.

4. Find out the maximum current that can flow through a 100 Ω 1 Ω resistor.

We have, $I = \sqrt{\frac{P}{R}}$

Or $I = \sqrt{\frac{1}{100}}$ = = 0.1 A or 100 mA.

What are conductors?

Materials which allow the flow of electric current through them are called conductors. Metals are known to be good conductors, with copper and silver among the best. The conductivity of a particular material depends on the number of free electrons present in it. A conductor may be a very good conductor, a fairly good conductor or a poor conductor. So, a greater conductivity or conductance implies lesser resistance and a lesser conductivity implies greater resistance. So, conductance (conductance is expressed in **siemens, S**) and resistance (R) are the same thing but from opposite viewpoints. They are said to be reciprocal of each other, i.e.

R = 1 / S or S = 1 / R

So the Ohm's law can be expressed in terms of conductance by using 1/S in place of R in the three formulas:

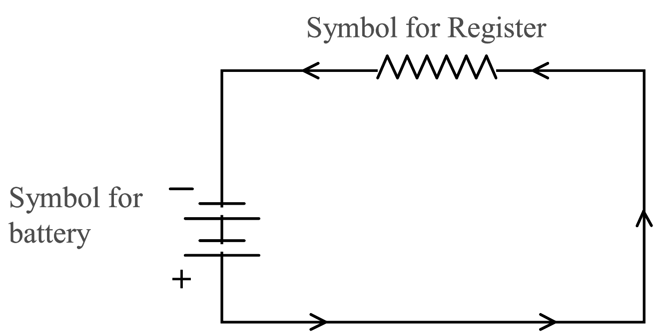
E = IR = I (1/S) or E = I/S

$I = \frac{E}{R} = \frac{E}{1/S}$ OR I = ES

$R = \frac{E}{I}$ Or $\frac{1}{S} = \frac{E}{I}$ Or SE = I Or $S = \frac{I}{E}$

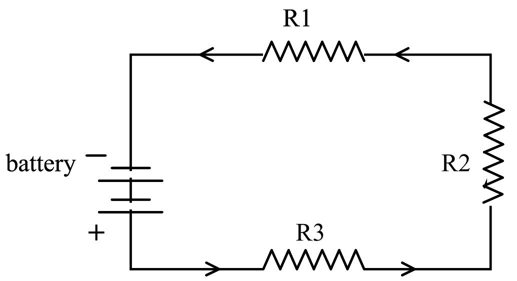
Resistance in series and parallel

The circuit shown here is a simple circuit with one load or resistor across a voltage source (e.g. a battery).



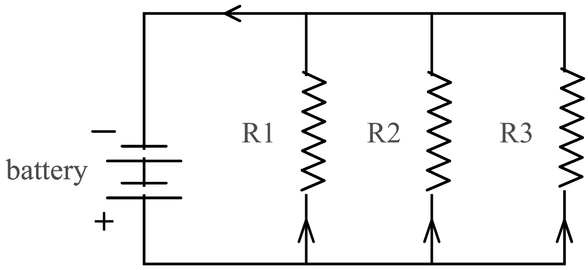
A Simple circuit with one resistor and a battery

The circuit shown below is a series circuit where three resistors are connected one after another. It is evident from the diagram that there is only one path through which



A Series circuit with three resistors and a battery

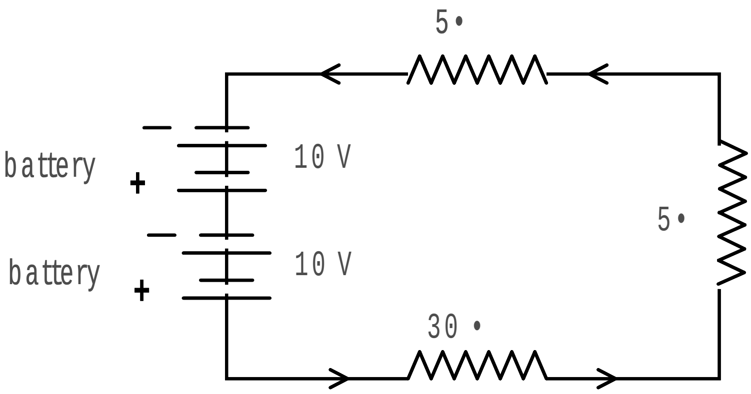
The circuit shown below is a **parallel Circuit** where each resistor has its independent path for the flow of current from the same source of voltage.



A Parallel circuit with three resistors in parallel

The circuit shown below consists of two batteries and three resistors in series. In a series circuit the same amount of current flows through all parts of each circuit. The resistors are connected in series to obtain a greater resistance and it is equal to the sum of the values of each resistor, i.e. 40 W. Two batteries are connected in series in this circuit to obtain the highest possible voltage which is the sum of the values of each battery, i.e. 20 v.

$I = E/_R$ or $I = 20/40 = 0.5A$.



A Circuit With Three resistors in series (total=40 Ohms) and two batteries in series(total=20 V).

Precaution

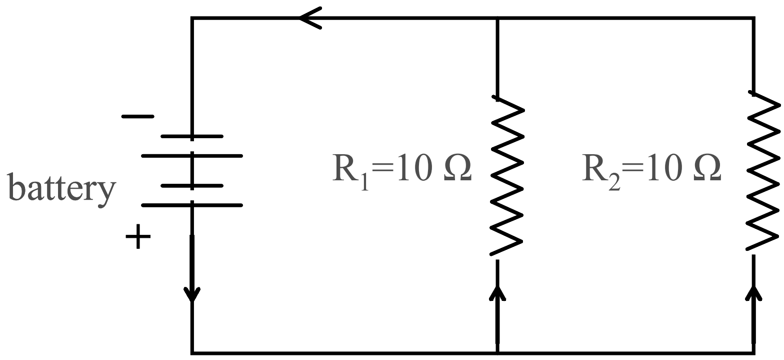
We should be careful while connecting batteries in series, because, the maximum current possible through the circuit is no greater than the greatest current that the weakest battery can deliver. If one of the batteries in the above example is weaker than the other and capable of passing only, say, 0.2 A, it will be overworked, may overheat and the voltage across the terminal will drop.

In this type of circuit, the voltage that can be obtained across each resistor is called the **'Voltage drop'.** From the Ohm's law, the voltage across each resistor can be calculated. The voltage drop across the 30 Wl resistor is 15 V (0.5 x 30) and the voltage drop across the 5 W resistor (each) is 2.5 V. Thus the sum of the voltage-drops is equal to the source voltage (2.5 + 2.5 + 15 = 20V).

Internal Resistance of batteries

The battery might possess an internal resistance which is to be considered while calculating the various quantities in a circuit. If a 10 V battery has 1 Winternal resistance and connected across a 9 Wload resistor, the amount of current flowing through the circuit would be 1 A. A voltage drop of 1 V will take place inside the battery and hence the 10 V battery will produce only 9 V across its terminals when connected to the 9 W load. When the circuit is open (no currents flowing through it), the voltage across the battery would be 10 V.

Resistors in parallel circuit.



A Parallel Circuit with two resistors in parallel

The circuit shown above is a circuit where two resistors are connected in parallel across the voltage source. Obviously, there are two paths for the flow of current. One part of the current flows through R_1 and the other part flow through R_2. Since total conductance S_1 of a circuit is equal to the sum of all the conductance connected in parallel, the formula can be expressed as:

$$S_t = S_1 + S_2$$

Or $S_t = I/R_1 + I/R_2$

Or $1/R_t = 1/R_1 + 1/R_2$

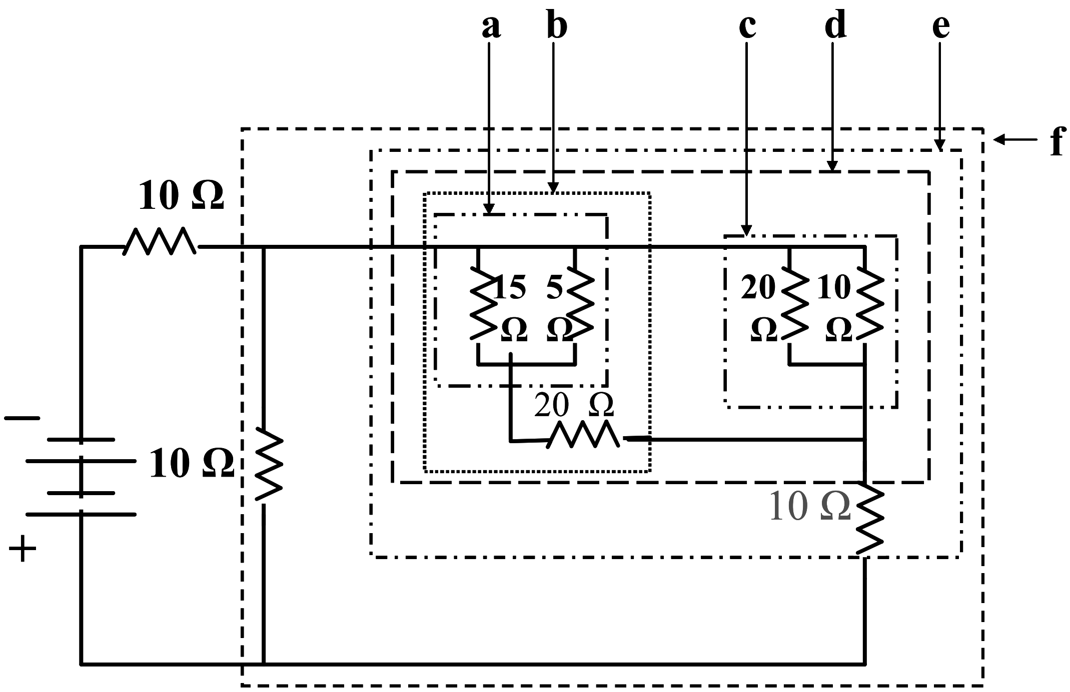
The above equation can also be expressed as shown below :

$$\frac{1}{1/R_t} = \frac{1}{1/R_1 + 1/R_2}$$

Or $$R_t = \frac{1}{\frac{R_1 + R_2}{R_1.R_2}}$$

in the above circuit, $R_t = \frac{10x10}{10+10} = 5\Omega$

Caclculation in a complex circuit.



A Complex circuit

The circuit shown above seems to be a complex circuit. By looking at the arrangement of the resistors, their values can be computed in simple steps. As indicated above, calculate as per the steps shown (e.g. step (a), step (b) .....]

Step (a) : 15 W & 5W resistors are arranged in parallel imparting a value equivalent to 3.75 W

Step (b) : 3.75 W + 20 W = 23.75 W (arranged in series)

Step (c) : 6.67 W (arranged in parallel)

Step (d) : 23.75 W & 6.67 W are arranged in parallel. The equivalent value is 5.20 W

Step (e) : 5.20 W + 10 W in series, i.e. 15.20 W

Step (f) : 10 W and 15.20 Ware in parallel, i.e. 6.03 W and

finally, 10 W + 6.03 W are in series. The equivalent value is 16.03 W

What are insulators?

The materials, which do not allow the flow of electric current through them are called insulators, Glass, porcelain, dry air and dry wood are well known insulators.

Inductors

Physically an inductor is a coil of wire. The coil may be a single turn or part of a turn or it may have thousands of turns. The interior (core) may be air or it may have thousands of turns. The interior (core) may be air or it may contain iron or iron compounds.

Approximate formula for calculating inductance from physical characteristics:

$$L \text{ (microhenry)} = a^2n^2 / (9a + 10b).$$

Where :

L is inductance in micro henrys.
a is coil radius in inches.
b is coil length in inches
n is number of turns.

This formula assumes one layer and a core of air. Adding a ferrous core increases the inductance.

Self-Inductance

Self-inductance is the property of a circuit whereby a change in current causes a change in voltage. Self-inductance is also more simply known as inductance. If ‘L’ is the inductance, then increasing the value of ‘L’ increases the amount of voltage that is induced in response to a change in current. Decreasing the value of ‘L’ decreases the amount of voltage that is induced in response to a change in current.

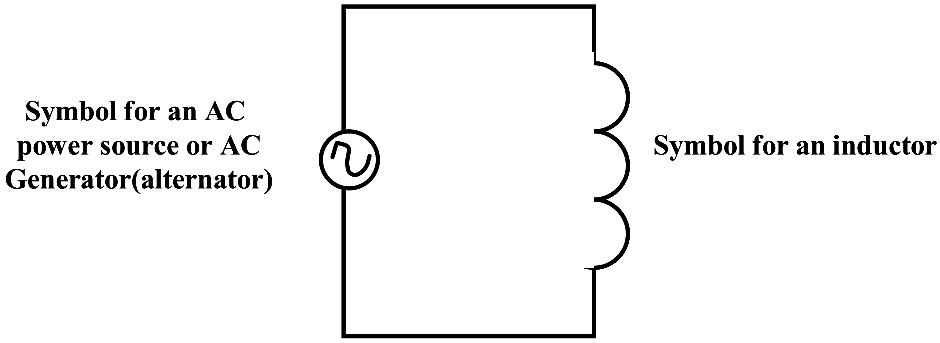
Inductance is measured in units of henries (h). Commonly used engineering units for indtance are- henry (1 h), millihenry (1 mh = 1 x 10^{-3} h) and microhenry (1 mh = 1 x 10^{-6} h).

One henry is the amount of inductance that is required for generating one volt of induced voltage when the current is changing at the rate of one ampere per second.

Inductance is the property of a coil when it is subjected to AC voltage. It results from the fluctuation of the current flowing through the circuit. When the current through the coil builds up, an expanding magnetic field also builds up cutting the turns of the coil resulting in the formation of a counter voltage in the coil which opposes the flow of the original current. This property of the coil is known as inductance. Since DC voltage remains constant (except for the instant when the circuit is closed, i.e. the instant when the switch is made on), there is no fluctuation in the magnetic lines of force produced across the turns of the coil and counter voltage is not generated. So a coil offers very negligible resistance (that due to the physical resistance) to the flow of DC current.

Inductive reactance

Inductive reactance is the opposition to AC current flow that is caused by the presence of an inductor in the circuit. The symbol for inductive reactance is X_L. The unit of measure for inductive reactance is ohms (W). The amount of inductive reactance in a circuit is proportional to the ***applied frequency (****f)* and the ***value of the inductor* (L).**



The equation for calculating the amount of inductive reactance in an ac circuit is given by.

x_L = 2p*f*L

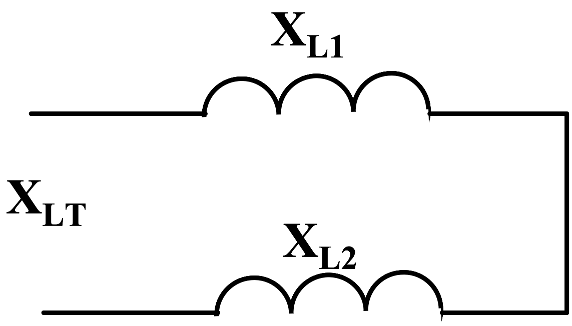
Where,

f is the frequency of AC voltage and L is the inductance

The total inductive reactance of a series X_L circuit is equal to the sum of the individual reactance.

Inductive reactance in series.

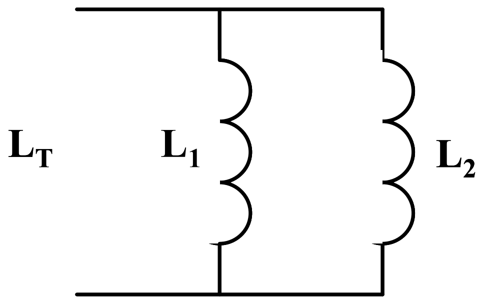
$X_{LT} = X_{L1} + X_{L2} + X_{L3} + \ldots + X_{Ln}$



Where X_{LT} is the total inductive reactance and $X_{L1,}$ X_{L2}, ... X_{Ln} etc. are the values of individual reactance.

Inductive reactance in parallel

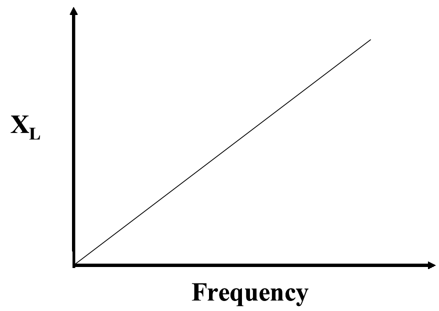
$X_{LT} = 1 / (1/X_{L1} + 1/X_{L2} + 1/X_{L3} + 1/x_{Ln})$



$$L_T = \frac{L_1.L_2}{L_1 + L_2}$$

Inductive reactance is an AC version of resistance. In fact, you can use Ohm's Law by substituting X_L for R :

$$V_L = I_L X_L$$



Where :

V_L is the voltage across the inductor in volts

I_L is the current through the inductor in amperes.

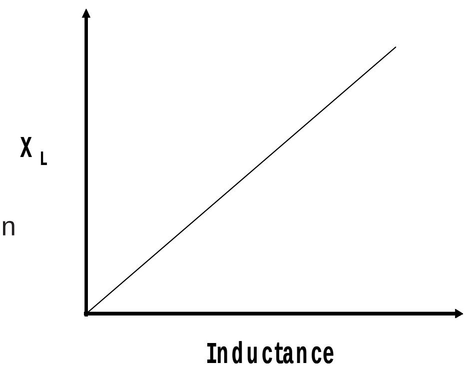
X_L is the amount of inductive reactance in ohms.

The amount of inductive reactance (X_L) changes proportionally with the applied

- Increasing the value of *f* causes X_L to increase.

- Decreasing the value of *f* causes X_L to decrease.

The amount of inductive reactance (X_L) changes proportionally with the value of inductance (L).:



- Increasing the value of L causes X_L to increase.

- Decreasing the value of L causes X_L to decrease.

Questions :

1. What is the value of inductive reactance for an 0.1 H coil that is operating at 1 kH_z?

Ans : 628 W
Use the basic equation : $X_L = 2p/L$

2. What value inductor is required for producing an inductive reactance of 10 W at 1.8 kHz?

Ans : 88.5 · H.

Use this form of the basic equation : $L = \frac{X_L}{2\pi f}$

3. At what frequency will a 150 mH inductor have an inductive reactance of 150 W ?

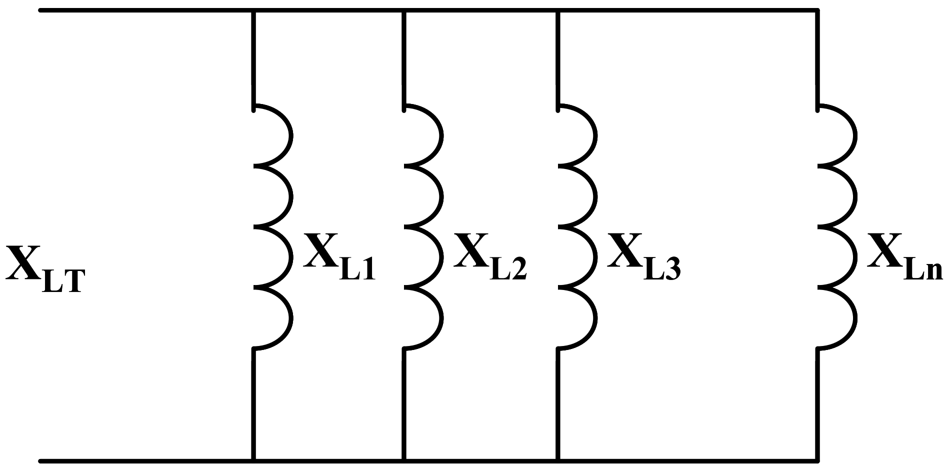
Ans : 159 Hz

Use this form of the basic equation: $f = \frac{X_L}{2\pi L}$

4. What is the total inductive reactance of a circuit when X_{L1} = 150 W and X_{L2} = 75 W are in series?

Ans : 225 Ω.

Equation to find out inductive reactance in a circuit with a number of inductors in parallel.



Use one of these inverse equations to determine the total inductive reactance of a parallel inductor circuit

$$X_{LT} = \frac{1}{\frac{1}{X_{L1}} + \frac{1}{X_{L2}} + \frac{1}{X_{L3}} + \ldots\ldots \frac{1}{X_{Ln}}}$$

$$\frac{1}{X_{LT}} = \frac{1}{X_{L1}} + \frac{1}{X_{L2}} + \frac{1}{X_{L3}} + \ldots\ldots \frac{1}{X_{Ln}}$$

Where :

X_{LT} = total inductive reactance

$X_{L1,}$ X_{L2}, X_{L3}, X_{Ln} = values of the individual; reactance.

The procedure for finding the total inductive reactance of a parallel inductor circuit is identical to finding the total resistance of a parallel resistor circuit.

The total reactance of two inductors in parallel can be found by applying the product-over-sum formula :

$$X_{LT} = \frac{X_{L1} . X_{L2}}{X_{L1} + X_{L2}}$$

Capacitor

Capacitor is a device used to store electrical energy and then release it as current into the circuit. Its property is just the reverse of an inductor. The capacitance of a capacitor is measured in Farad.

A capacitor has a capacitance of 1 farad if a 1 Volt difference in potential results in the storage of 1 coulomb of charge.

1 Coulomb = 6.28×10^{18} electrons.

Where,C is capacitance in farads,

Q is the charge in coulombs,

E is the voltage in volts.

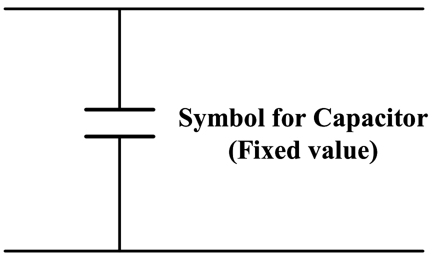
Partically farad is a large unit. The smaller units ae micro farads (mf) and pico farads (pf).

$$1\text{Micro farad}(1\mu f) = \frac{1}{1{,}000{,}000}\text{farad}$$

$$1\text{picofarad}(pf) = \frac{1}{1{,}000{,}000{,}000{,}000}\text{farad}$$

When two metallic plates or conductors are separated by an insulator, also known as a dielectric, they behave like a capacitor. The conductors can be long or short piece of metal plate or any other conducting material. The insulator between the two conductors which is known as dielectric can be air, mica, wax-impregnated paper ceramic etc. the properties of a capacitor.:

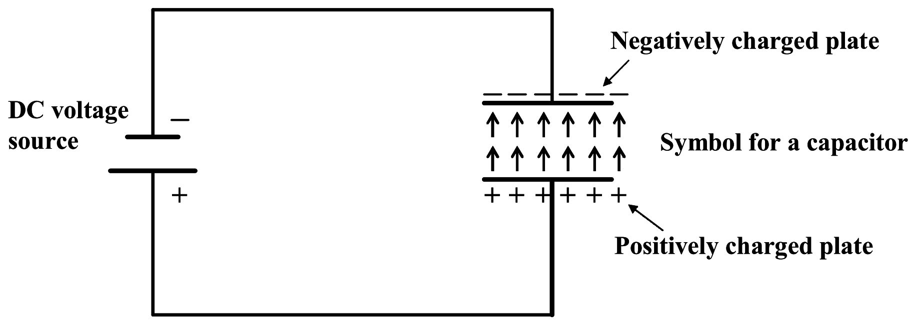
1. It stores energy in the form of electrical field
2. Capacitance is the property of an electric circuit that tends to oppose a change in voltage.
3. It passes A.C. and blocks D.C.



Symbol for Capacitor (Fixed value)

Functioning of a capacitor

A capacitor when connected across a voltage source, an electrostatic field builds up between the metallic plates. The field builds up due to the accumulation of electrons on the negative plate and release of electrons from the positive plate until the capacitor voltage reaches its maximum. The capacitor will be in this charged state as long as it is connected to the voltage source. After removal of the voltage source, the capacitor can not loose its charge (theoretically, a perfect capacitor would hold the charge forever, but in practice, some of the charge leaks out), unless both the plates are connected with the help of a conducting path. When there is a conducting path, electrons from the negatively charged plate flow to the positive plate until both the plates ae neutralized.



Capacitor in a DC circuit

Capacitor in a DC circuit

In DC circuits, the capacitor will allow current to flow till it becomes fully charged, however since no current can flow through the dielectric material of the capacitor, no current flows after the capacitor gets fully charged.

Capacitor in an AC circuit.

The AC voltage or current is fluctuating in nature. It is not only fluctuating but also changing the direction of flow, i.e. the polarity of the AC voltage source keeps on changing resulting in charging and discharging of the capacitor. Unlike a DC circuit, here, current will continue to flow in the circuit (though the electrons don't cross the dielectric material of the capacitor).

Capacitor in a varying DC circuit

If the voltage source is a varying DC, then also there is continual charging and partial discharging of the capacitor resulting in an AC current flowing through the circuit. In fact, the capacitor blocks the DC, but passes the AC component.

Factors the affect capacitance

1. **Area of plates :** The larger the plates, the higher its capacity to store charges, i.e. **capacitance is directly proportional to the plate areas.**

2. **Space between the plates :** The closer the plates, higher is the capacity to hold charges, because, the electrostatic pull on the electrons collected at the negative side of the voltage source will be more. **Capacitance is inversely proportional to the spacing between plates.**

3. **Type of dielectric used :** Some materials are more dielectric than the others. Vacuum is the basic dielectric with which other materials are compared. It is said to be having a dielectric constant of 1. The dielectric constant of air is slightly more than this (1,0006). Dielectric constant is the ability of a material to permit the establishment of electric lines of force between oppositely charged plates. A dielectric (other than air) makes the positively charged surface of a capacitor repel more free electrons and negatively charged surface accept more electrons than when air is dielectric , thus increasing the capacitance. The dielectric constant of mica ranges from 5 to 9. Dielectric constant of glass is 4.2 **Capacitance is directly proportional to the dielectric constant.**

A formula to determine the capacitance of a two-plate capacitor is :

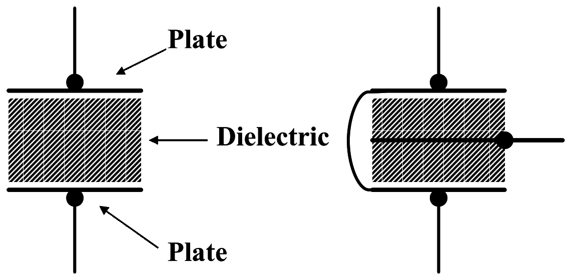
$$C_{pf} = \frac{0.225KA}{S}$$

Where, C = Capacitance in pF
K = dielectric constant
A = area of one of the plates, in inch^2
S = spacing between plates, in inches.

The above formula is valid for a two plate capacitor. For a multiplate capacitor, the formula is:

$$C_{pf} = \frac{0.225KA(N-1)}{S}$$

Where N = number of plates in the capacitor.



2 Plate capacitor **3 Plate Capacitor**

It is seen that a 3-plate capacitor has twice the plate area exposed and thus twice the capacitance.

Quantity of charge in a capacitor.

The quantity of charge in a capacitor can be found from the formula : **Q = CE**

Where,

Q = charge, in coulombs (C)

C = capacitance, in F

E = voltage, in V

If a 0.1 mF capacitor is charged by a 10 V source, the electron difference will be:

Q = 0.0000001 x 10 = 0.000001 C or 10^{-6} C

10^{-6} C = 6.25 x 10^{18} x 10^{-6} = 6.25 x 10^{12} electrons

If the charged capacitor is disconnected from the voltage source, it will still retain the electron difference on its plates (assuming that there is no leakage). Now, if a similar uncharged capacitor is connected across the charged capacitor, electrons flow from the charged to the uncharged capacitor and it will get charged to 5 V as a result of distribution of half amount of electrons into it. Since the other capacitor lost half of its electrons, its voltage will be reduced to 5 V (now, both the capacitors will be having a voltage of 5 V each) from 10 V. If both the capacitors are reconnected in series, the total voltage-drop across them would become 10 V.

Capacitive Reactance

Capacitive reactance is the resistance offered by a capacitor to the flow of AC through it. It is measured in ohms (m). The formula to calculate capacitive reactance in a circuit is:

$$X_C = \frac{1}{2\pi fC}$$

Where X_c = reactance, in m

f = frequencey, in Hz

C = capacitance, in F.

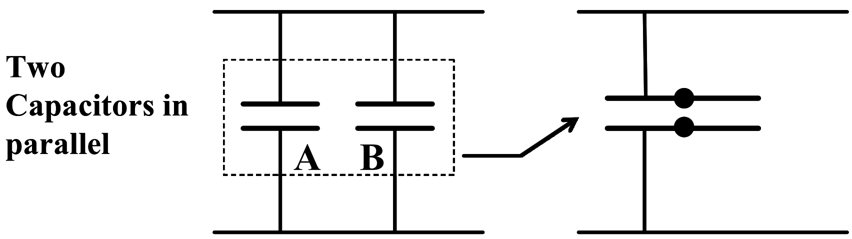
Questions:

1. Find out the reactance of a 0.002 mF capacitor to a frequency of 2,000 kHz.

Solution :

$$X_C = \frac{1}{2\pi fC} = \frac{1}{6.28(2{,}000{,}000)0.0000000002} = \frac{1}{0.2512} = 39.81\Omega$$

Capacitor in parallel :



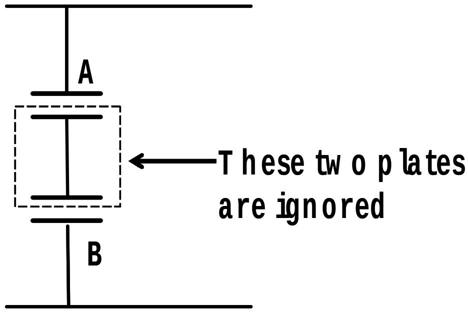
Two Similar Capacitor have twice the capacitance of one alone

Capacitors can be connected in parallel to obtain a greater value. The formula is:

Total capacitance of capacitors in parallel, $C_t = C_1 + C_2 + C_3 + ... + C_n$

While connecting the capacitors in parallel, it should be noticed that the voltage applied on them does not exceed the voltage rating of the capacitor with the minimum voltage rating.

Capacitors in series.



Two Capacitors in series

As shown above, when two capacitors are connected in series, the bottom & top plates of the respective capacitors are ignored and consequently combined effect of two capacitors of equal value is to simulate a single capacitor with half the value of a single capacitor, i.e. if two 10 m F capacitors are connected in series as shown above, we will get an effective capacitance of 5 mF. This is because the circuit sees only two plates (plate a & b) with a dielectric distance of twice that of a single capacitor (capacitance decreases when distance between plate increases). It is to be noted that when capacitors of different voltage ratings are connected in series, the voltage that can be applied to them can be equal or less than the total voltage obtained by adding voltages of each capacitor, alternatively, we can say that when capacitors in series are connected across voltage source, the sum of the voltage-drops across each of them will always equal the source voltage.

The formula to calculate the total capacitance of a number of capacitors connected in series is:

$$C_1 = \frac{C_1 x C_2 x C_3 x C_n}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_n}}$$

Types of capacitors

There are fixed value capacitor as well as variable value capacitors available for electronics work. Paper, mica, ceramic and polyester capacitors have fixed values.

Paper capacitor

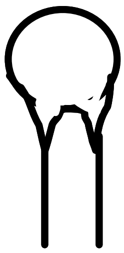
Paper capacitors are made by rolling two metal foils with a strop of paper and then impregnating with a dielectric between them. For high voltage applications, several layers of papers are used to separate the metallic foils. They are not suitable for use at frequencies above 1 MHz, which virtually restricts their application to audio frequency (AF) circuits. They are available in capacities from **0.05 µF up to 1 or 2 µF** with working voltages from 200 to 1000 volts.

Mica capacitor

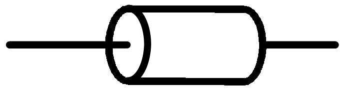
Mica is used as a dielectric between the metallic plates in this type of capacitors. These capacitors have excellent high frequency response.

Ceramic capacitor

In this type of capacitor, ceramic is used as a dielectric which has a high dielectric constant. Ceramic capacitors have good stability with regards to temperature and voltage changes. They are widely used in miniaturize audio frequency (AF) and radio frequency (RF) circuits. Their capacities ranges from 1 PF to 1µ F with high working voltage.



A Disk ceramic capacitor



A tabular ceramic capacitor

Polyester film capacitor

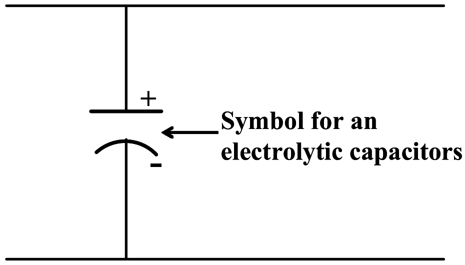
In this type of capacitors polyester is used as a dielectric to impart a high breakdown voltage. Their capacities ranges from **0.01 µF** up to **2.2µ F**. Their low inherent inductance makes them suitable for coupling and decoupling applications.

Polystyrene capacitor

These capacitors are made from metallic foil interleaved with polystyrene film, usually with fused polystyrene enclosure to provide high insulation resistance. They provide good stability and reliability at high radio frequencies because of their low inherent inductance and low series resistance. Their values range from **10 pF** to **100,000 pF,** but working voltage generally falls substantially with increasing capacity (as low as 60 volts for a 100,000 pF polystyrene capacitor).

Electrolytic capacitor

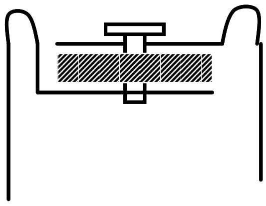
An electrolytic capacitor consists of an aluminum-foil positive plate immersed in a solution called an electrolyte (ionizable solution capable of carrying current). The aluminum foil is the positive plate, and the electrolyte is the negative plate, if a liquid can be called a plate. To make an electrical connection to the liquid, another aluminum foil is placed in the solution. To prevent the two foils from touching each other, a piece of gauze is placed between them. The +ve foil is surrounded by a thin oxidized film formed due to application of a particular voltage which acts as the dielectric. Electrolytic capacitors can not be used in AC circuits. Their values range from **1 µF to 4700 µ F** or more with working voltage ranging from 10 volts dc up to 500 volts.



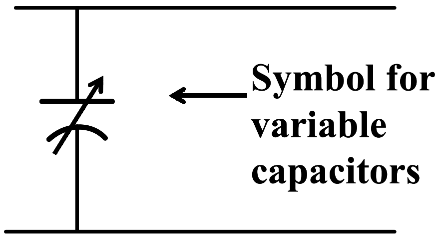
Symbol for an Electrolytic Capacitor

Variable capacitors

Variable capacitors are widely used in radio frequency work where it is required to change the value of the capacitor in order to tune the circuit to a particular frequency. Usually, air is used as a dielectric in this type of capacitor. The capacitance is made to vary either by changing the distance between the plates or by changing the plate area exposed. This type of capacitor may consist of two plate or more than two plates. Metallic gang capacitors and button trimmers are the most common example of variable capacitors. In a trimmer the two metallic plates are made to vary in their distance with the use of a screw.



A Trimmer



Electrical Impendance

Electrical impendance is the total opposition to current flow in an AC circuit. It takes into account all sources of opposition. Since it is the total opposition, impedance is measured in ohms, just as resistance and reactances are. If an inductor and resistance are connected in series with a source of A.C., the impendance of the circuit is:

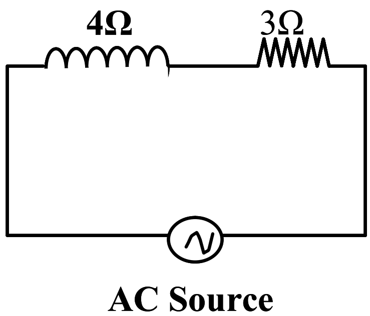
$$Z = \sqrt{X_2^2 + R^2}$$

If, X_L = 4 W and R = 3 W

Therefore,

$$Z = \sqrt{16 + 9}$$

$$= 5 \ \Omega$$



AC Source

The impedance of a series R - L circuit can never be equal to or greater than the sum of X_L and R, nor can it be equal to or less than either X_L or R.

Inductance and Capacitance in Series.

When an inductor and a capacitor are connected end to end, a series L-C circuit is formed. If the inductor is a pure inductor and capacitor, a pure capacitor, then the circuit has no D.C. resistance which is practically impossible. There is always some resistance present in the circuit. Inductor has inductive reactance, X_L and capacitor has the capacitive reactance, X_C. The net resistance present in the circuit is negligible.

If the circuit has an inductance L of 1 henry in series with a capacitor C of 10 µF and the applied voltage E is 100 volts and frequency is 50 Hertz.

Then,

Inductive reactance X_L = 2pfL = 6.28 x 50 x 1 = 314 W

Capacitive reactance,

The impedance of such circuit is the difference of inductive reactance and capacitive reactance.

$Z = X_C - X_L = 318.5 - 314 = 4.5\ \Omega$

If X_L is greater than X_C then the impedance is $X_L - X_C$

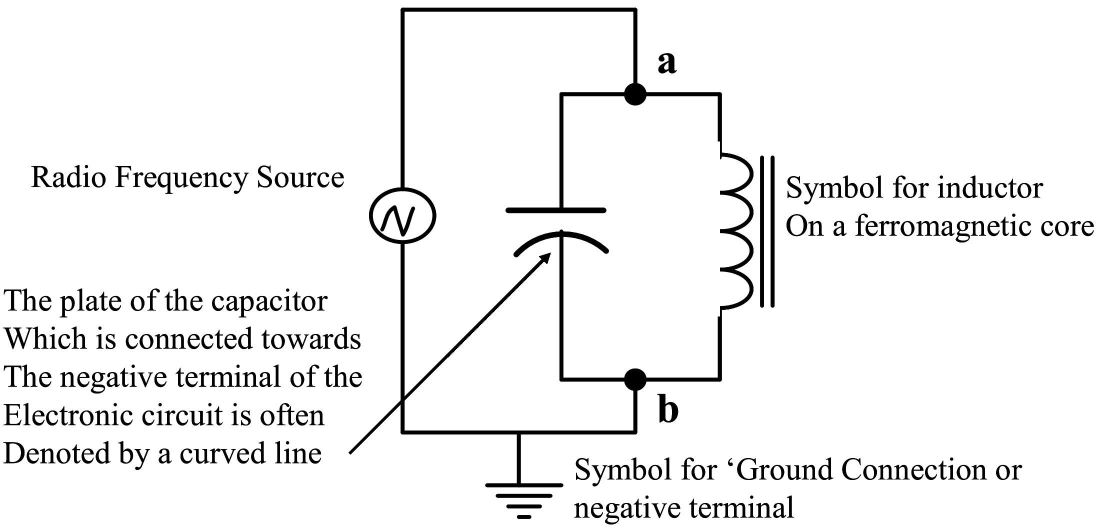
Resonant frequency

Resonant circuits make it possible to select one frequency from all others. For example, there are hundreds of radio stations that broadcast signals strong enough to be received by your radio receiver. The tuning circuit of the radio receiver accomplishes the task of discarding all other signals but to allow only the desired signal to be processed. **The single frequency at which the circuit responds best is called the resonant frequency of the circuit.** Resonance occurs when the inductive reactance becomes equal to capacitive reactance of $X_L = X_C$.

It can be achieved by either varying capacitance or inductance. In a radio receiver, it is achieved by varying the value of the variable capacitor. A series resonant circuit offers very little resistance when the circuit operates at the resonant frequency. High current is permitted to flow through the circuit.

Parallel Resonant Circuit

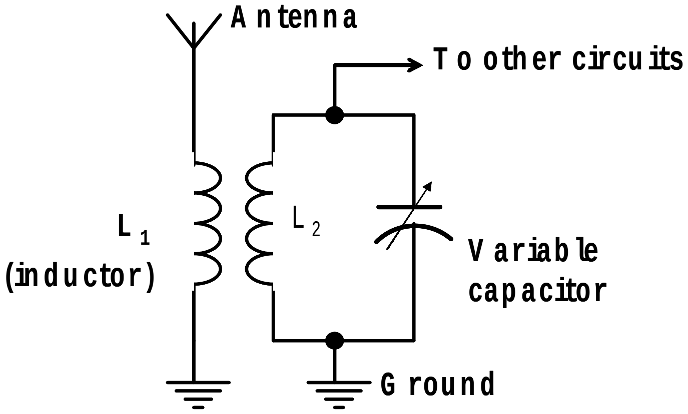
In the circuit diagram shown below, the part of the circuit between the points ‘a’ and ‘b’ is called a ‘tank’ because the resonant frequency will be captured and held there while all other frequencies are allowed to flow through it. So if the AC source is producing AC current at the resonant frequency, that current is blocked by the tank. The current is not permitted to travel from ‘a’ to ‘b’ through the tank. But when the AC source is producing current at any other frequency, the current can flow from ‘a’ to ‘b’ with little opposition.



A Parallel resonant tank Circuit

Tuning Circuit

In a radio receiver, the selection of the desired frequency out of hundreds of other frequencies is achieved by the use of resonant circuit. The resonant circuit basically consists of an inductor and a capacitor. The frequency of resonance is usually achieved by changing capacitance of the variable capacitor.

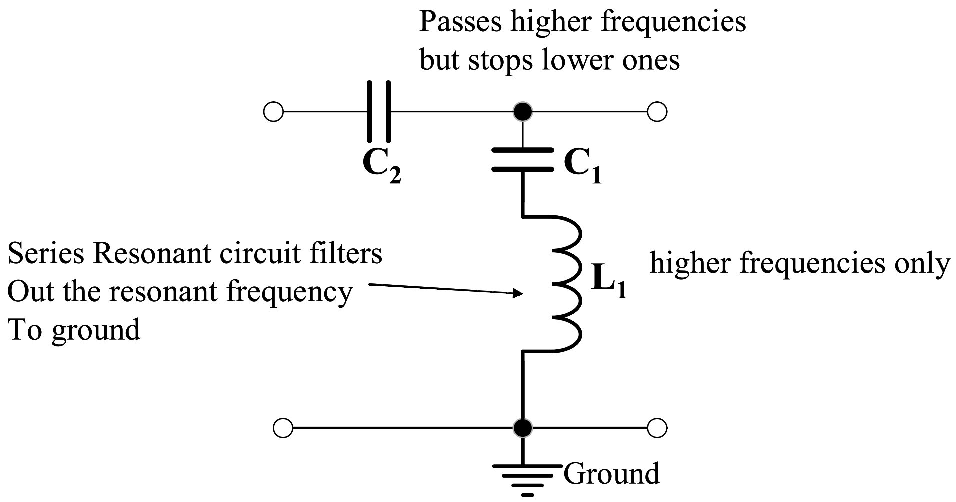


In the tuning circuit shown above, all the frequencies captured by the antenna are passed to ground through the primary coil L_1. They will try to cause current flow in the tank circuit, but only the resonant frequency will be successful in creating a current flow. The information it carries will be sent to the other radio circuits while the non-resonant frequencies are practically ignored.

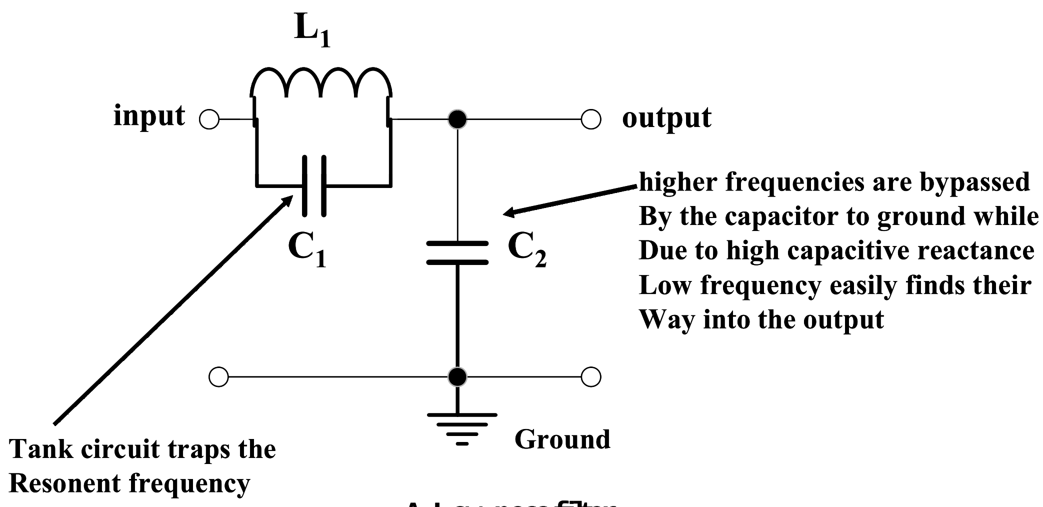
In the circuit shown above, the condition of series resonance is present but is not apparent. In this circuit the transformer secondary coil has a capacitor across it with a reactance of the secondary, forming a resonant circuit. At first glance it appears to be a parallel-resonant circuit. The primary coil, however, is inducing an AC voltage into each turn of the secondary coil. Theoretically, the secondary may be considered to have a source of AC inserted in series with its turns.

Filtering

Resonant circuit are used to filter out the desired frequency. A series resonant circuit allows to pass its resonant frequency while the parallel resonant circuit (called the tank circuit) blocks the flow of its resonant frequency



A high pass filter



A Low pass filter

'Q' of a circuit

The term 'Q' is applied to AC circuits in which inductance and capacitance are involved. It in fact express the 'quality' of the inductor or capacitor and since lesser the ohmic resistance of the coil (inductor), more perfect inductor the coil is, with little loss. 'Q' can be found from the formula :

$Q = X_i / R$ (in case of coil); where X_i = inductive reactance, R = Ohmic resistance.

Again,

$$\mathbf{X_i = 2\pi fL}$$

Where,
f = frequency
L = inductance

Therefore, $Q = 2\pi f L / R$; this shows that the same coil or inductor possesses hig ‘Q’ at higher frequency.

Skin effect

A phenomenon called ‘Skin effect’ also causes loss of efficiency of a coil or inductor. It is observed that at higher frequencies, electrons flow nearer to the surface of the conducting wire; since the usable cross-sectional area lessens, the ohmic resistance increases resulting in a lower ‘Q’.

Prevention of ‘Skin effect’

(i) By using large diameter wire .

(ii) By silver-plating of the wire used.

(iii) Using fewer turns while making the coil, but increasing the core permeability; e.g. using powdered iron core.

(iv) By using ‘ Litzendraht wire’, an insulated multistrand wire, several thin strands have more surface for a given wire diameter than does a solid wire (Litz wire is effective only up to about 1 MHz)

Thermionic Emission & Valves

An electric current can also flow in a gas. A voltage applied across a gas-filled tube causes ionization of the gas; free electrons stream towards the plate with the positive potential, colliding with the atoms in their way and detaching electrons from their orbits. The positive ions move toward the opposite end of the tube.

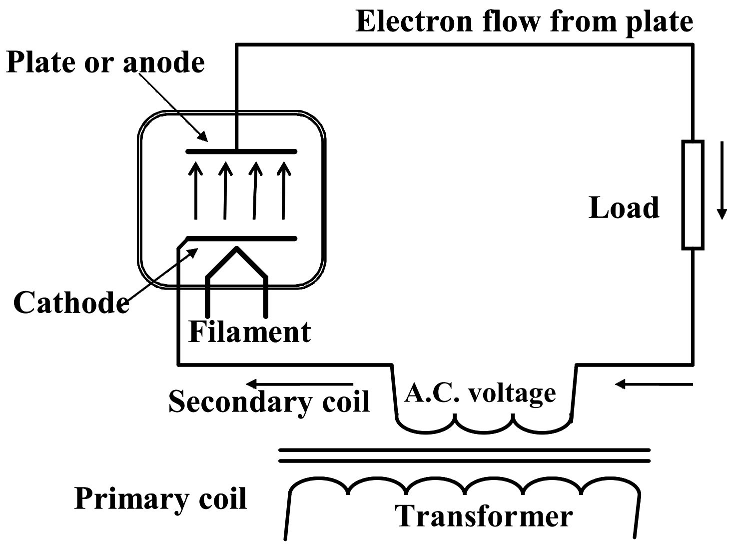
The most common material used in the construction of a vacuum tube envelope is glass. The electrode leads pass through a glass bead sealed into an eyelet. The electrodes in a vacuum tube are supported by insulators such as mica and a variety of ceramics. The electrodes themselves are commonly made from metals such as nickel, copper, aluminum, molybdenum, and tungsten.

In thermionic valves the electrons move in a vacuum. An example of such a device is the diode. The envelope of a diode houses two main parts which are also called the anode (or plate) and the cathode. Near the cathode there is a filament or miniature electric heater which heats the cathode. Most tubes employ heater-cathodes. A heater-cathode consists of a metal cylinder coated with special oxides that liberate great quantities of electrons when heated to a relatively low temperature. In this case an “electron liquid”, consisting of electrons that move chaotically in the very body of the cathode, between its atoms, begin to “boil”. This phenomenon is known as ‘electronic emission’. As a result of this emission, a cloud of “electron gas” is formed round the cathode. If the cathode is now connected to the negative terminal of a voltage source and the anode, to the positive terminal, the anode will begin attracting electrons from the cloud, “drawing” them away from the cathode, and a current will flow inside the diode. Freedom for the electron proves very short-lived; no sooner does it escape from the cathode it is immediately attracted by the anode.

A diode is in fact a one-way valve. When the negative terminal of the voltage source is connected to the anode and the positive terminal to the cathode, the electrons will not be able to escape the cathode, because it attracts them. But even those that do escape have nowhere to fly in particular: previously the anode attracted them, now it forces them back to the cathode. With such a connection no current flows through the diode. This property of the diode is employed for converting the alternating current to direct current, which is called rectification. The current flowing through a diode is called the plate current. The flow of plate current can be controlled by two ways: by varying cathode temperature; and by changing the applied voltage (called the plate voltage). But cathodes are designed to operate most efficiently at one particular temperature. An increase in plate voltage results in an increase in plate current. But after a certain point, further increase in plate voltage will not cause any corresponding increase in the plate current. This point is called the saturation point.

Diode valve as a rectified

As shown in the circuit given below, the source of plate voltage in the plate circuit is a transformer providing an alternating voltage to the plate. During one half cycle, the plate end of the transformer-secondary winding may be positive and the cathode end negative. On the next half cycle the plate end will be negative and the cathode end positive. As described above, the diode allows only one half cycle of the emf to produce current in the circuit. With ac plate voltage the plate current is pulsating dc. This one-way-gate effect is a main use of diodes. A diode is also called a rectifier.



A diode Valve as a rectifier

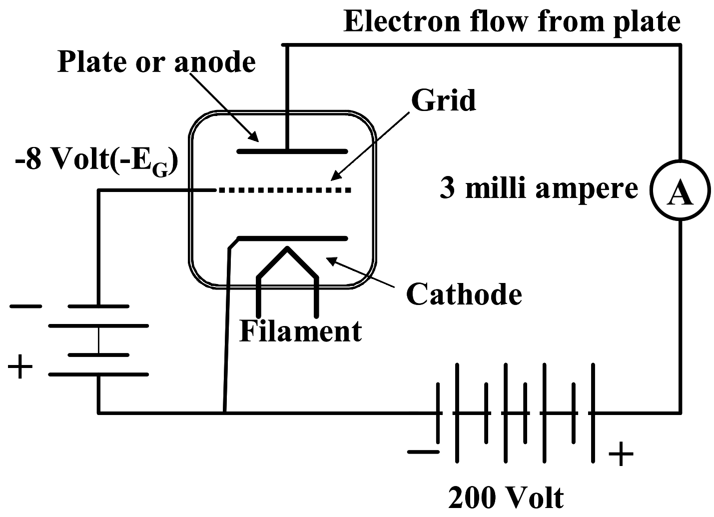
Triode Valve

The introduction of a third electrode (control grid) between the cathode and the anode of a diode makes it a triode. In the triode, current is controlled by means of a voltage applied between the cathode and the grid. With a high negative grid potential (with respect to the cathode), the grid becomes a barrier for the electrons. They will “crowd” in the space between the cathode and the grid; the valve will be cut off, since no current will flow from the cathode to the anode. With a positive grid potential, the grid will help the anode, since its positive potential will be added to that of the anode. A heavy current will flow through the valve. However, with too high a positive grid potential the grid may turn from a helper of the anode into its competitor: some electrons will be drawn to it and will not reach the anode. In this case a harmful grid current appears in the valve. That is why in normal operation the grid is made to vary only more or less negatively.

Amplification factor of a triode valve

In the circuit shown below, the voltage (-Eg) in the grid circuit is -8 V. Plate voltage (+Ep) is 200 V. Plate current is 3 mA. By increasing +Ep by 40 V it is found that plate current increases from 3 to 7 mA. Returning to the original values, Grid voltage (-Eg) is -8 V, +Ep = 200 V, and Ip = 3 mA, it is found that if the -Eg value is reduced by 2 V, from -8 to -6 V, the Ip will again rise from 3 to 7 mA. This indicates that the same

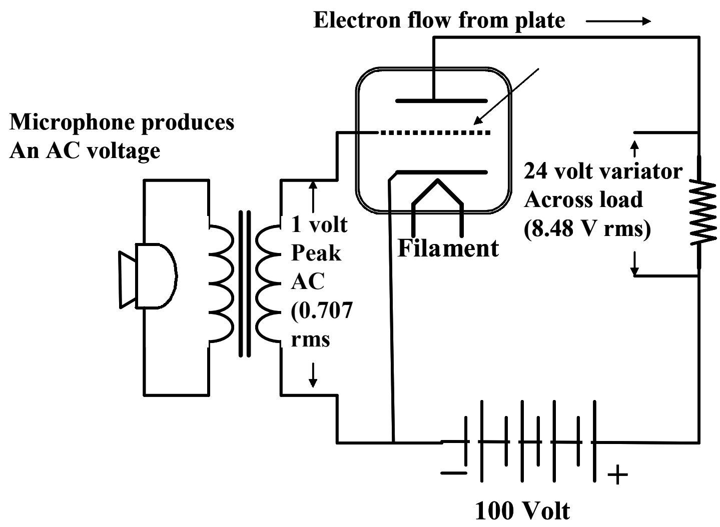
Ip change can be produced either by changing the Ep by 40 V or by changing the -Eg by 2 V. This controlling ratio of 40:2 is equal to 20. The tube is said to have a m (mu) or amplification factor of 20. Thus the grid is found to be 20 times more effective in changing plate current than the plate voltage.



A triode amplifier circuit

Triode as an amplifier

In a theoretical circuit comprising a microphone, a transformer, a triode valve with a load resistance, the microphone induces a small ac voltage increase, until there is a voltage drop of perhaps 87 V across the load resistor. As grid voltage varies from -1 V to +1 V (a 2 V peak to peak variation), the voltage across the load resistor varies between 87 and 63, i.e. 24 V. The voltage ratio of 2:24 indicates that across the plate load resistor, the voltage variation is 12 times more than the variation between the grid and the cathode.



A simple audio amplifier circuit

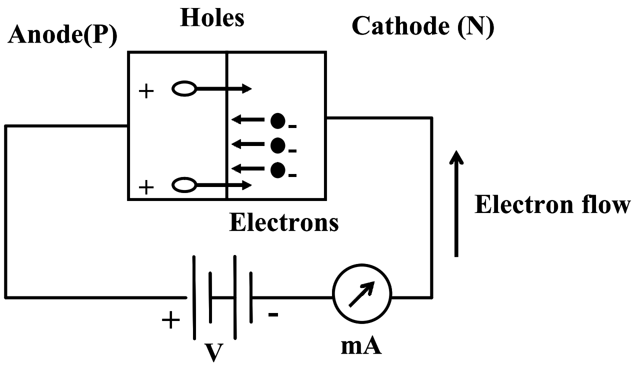
Bias Voltage

In the circuit described above, the grid was driven negative and positive alternately. But this creates distortion. To avoid the distortion, in a practical circuit, the grid may never by allowed to become positive and thus there is no grid current (Ig) from the cathode. This is accomplished by adding a dc voltage source in series with the grid-cathode circuit. The negative potential is applied to the grid through the transformer, and the positive potential to the cathode. The negative dc voltage added in series with the grid circuit is known as the bias voltage. If a negative 10 V bias is enough to produce plate-current cutoff with a given plate voltage, then a possible bias voltage would be half of this, i.e. 5 V for a class A amplifier. It can accommodate a peak ac emf of 5 V from the secondary of the grid-circuit transformer and neither cutoff the plate current not drive the grid into positive region.

Semiconductors: Diodes & Transistors

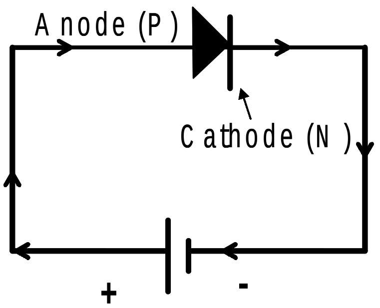
In the early days of electricity there were only two groups of material: insulators and conductors. Insulators are materials which do not allow the flow of electric current through them. Glass, porcelain, dry air and dry wood are well-known insulators. Metals are known to be good conductors, with copper and silver among the best. The conductivity of a particular material depends on the number of free electrons present in it.

There is another group of material known as semiconductors. Semiconductors like germanium and silicon are bad conductors of electricity in their purest form. But when certain impurities (iridium or arsenic, which have a slightly different atomic structure from that of germanium or silicon) are added in the form of carefully controlled quantities, either an increase of free electrons or deficiency of electrons results. A semiconductor is called in **n-type semiconductor** where conduction takes place by reason of excess free electrons. A semiconductor is called a **p-type semiconductor** where conduction takes place due to freely moving 'holes' (positively charged) which replace electrons displaced by random electron movement in the material.



P-N junction diode with 'forward Bias'

When pieces of p-type and n-type semiconductors are joined together, a p-n junction results. Flow of electric current through such a junction is possible only when the positive pole of the battery (voltage source) is connected to the p-type semiconductor and the negative pole to the n-type semiconductor. This is called the **"forward biased"** condition.



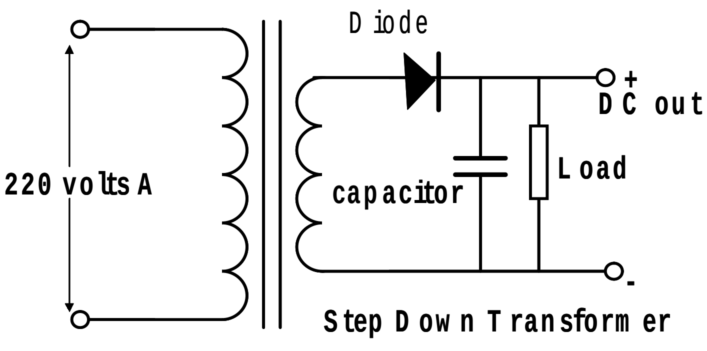
A forward biased semiconductor diode

In this condition, positively charged holes are repelled by the battery voltage towards the junction between p and n type material. Simultaneously, the electrons in the n-type material are repelled by the negative battery voltage toward the p-n junction.

Despite the presence of a potential barrier at the p-n junction, which prevents electrons and holes from moving across and combining, under the influence of the electric field of the battery the holes move to the right across the junction and the electrons move to the left. As a result, electrons and holes combine and for each combination of the takes place near the junction, a covalent bond near the positive battery terminal breaks down, an electron is liberated and enters the positive terminal. This action creates a new hole which moves to the right toward the p-n junction. At the opposite end, in the N-region near the negative terminal, more electrons arrive from the negative battery terminal and enter the n-region to replace the electrons lost by combination with holes near the junction. These electrons move toward the junction at the left, where they again combine with new holes arriving there. As a consequence, a relatively large current flows through the junction. The current through the external connecting wires and battery is due to that of the flow of electrons. If, however, the polarity of the battery is reversed, i.e., the positive terminal is connected to n-type semiconductor and the negative terminal of the battery to the p-type semiconductor, the p-n junction will block the electron flow by building up a voltage barrier at the junction. The holes are now attracted to the negative battery terminal and move away from the junction because of the attraction of the positive terminal. Since there are effectively no hole and electron carriers in the vicinity of the junction, Current flow stops almost completely. The diode is now in reverse biased condition. This type of device is called a **"solid state diode"** or a semiconductor diode.

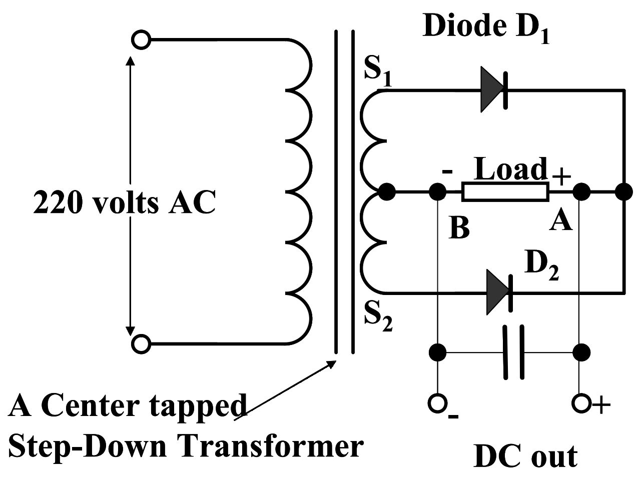
Use of Semiconductor diode

By exploiting their property of one way flow of electric current, they can be utilized to convert alternating current to direct current (known as rectification). Without adequate filtering, the resultant d.c. is pulsating in nature. However, it will be appreciated that a diode will work in both a dc and an ac circuit. An example of the use of a diode in a dc circuit (say output side of a dc power supply) to eliminate any possibility of reverse polarity voltage surges occurring which could damage transistors in the same circuit.



A basic half-wave rectifier circuit

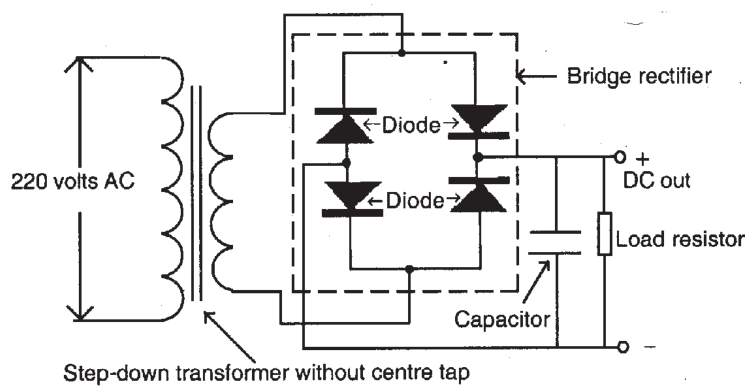
The circuit shown above is a basic half-wave rectifier circuit passing one half of each AC cycle as DC and suppressing the other half cycle. The purpose of the capacitor is to maintain the DC voltage output as far as possible by discharge on each 'suppressed' half cycle. The DC output in this type of circuit is not smooth having a 'ripple' at the AC frequency.



A basic full-wave rectifier circuit

The circuit shown above is that of a simple full wave rectifier whose secondary voltage is halved (because of the center tapping), but the current that can be drawn is doubled. During the first half cycle S_1 is positive and S_2 in negative with respect to G. Current flows through the diode D_1 and not through D_2. During the second half cycle, S_1 is negative and S_2 is positive with respect to G. Current flows through the diode D_2 and not through D_1. Thus, during both the half cycles, 'A' remains positive and 'B' remains negative. The process is repeated and across the load a full wave rectified DC is obtained. The capacitor charges and discharges alternately to produce a smoother DC supply. The 'ripple' will still be there which will be equal to twice the AC frequency.

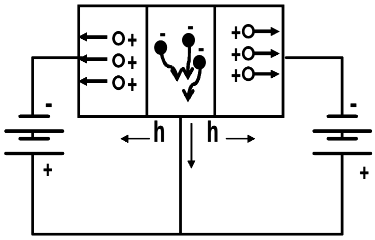
The usual form of full-wave rectified circuit is the bridge rectifier shown below. This gives approximately the same no-load voltage as a half-wave rectifier with the advantage of full-wave rectification and better smoothing. A single high value electrolytic capacitor is used for smoothing.



A practical full wave power supply

Transistors

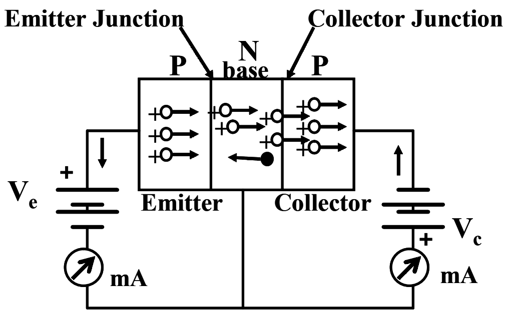
The simplest of the transistors are of two types-either **p-n-p** or **n-p-n** Two p-n junction diodes can be sandwiched back to back to form a p-n-p or n-p-n junction transistor. But in a practical transistor, the center or n-type portion of the sandwhich is extremely thin in comparison to the p-regions. In the 1st illustration, **both the p-n junctions are reverse biased.**



Non-conducting P-N-P junction

In this type of connection, boles in the each of p-region are attracted towards the negative battery terminal and the mobile electrons in the n-region are initially moved away from both junctions in the direction of the positive battery terminal. Due to the displacement of holes and electrons, **there will be no current flow in the external circuit.**

In the **2nd illustration,** one of the **p-n junctions is forward biased,** while the **other is reversed biased.** In a transistor, the middle layer (here n-region) is called the **base,** the forward biased p-n junction is called the emitter junction and the reverse biased p-n junction is called **collector** junction. Due to positive potential at the emitter junction, the holes in the p-region cross into the n-region (**the base).** But this region is very thin and there are very few electrons with which holes can combine. So, majority of the holes drift across the base into the collector junction. About 5 per cent of them are lost in the base region as they combine with electrons. For each hole that is lost by combination with an electron in the base and collector areas, a covalent bond near the emitter electrode breaks down and a liberated electron leaves the emitter electrode and enters the positive battery terminal. The new hole that is formed then moves immediately toward the emitter junction, and the process is repeated. Thus, a continuous supply of holes are injected into the emitter junction, which flow across the base region and collector junction, where they are gathered up by the negative collector voltage. The flow of current within the p-n-p transistor thus takes place by hole conduction from emitter to collector, while conduction in the external circuit is due to the flow of electrons.



Basic connection of P-N-P junction Transistor

Because of the reverse bias no current can flow in the collector circuit, unless current is introduced into the emitter. Since a small emitter voltage of about 0.1 to 0.5 volt permits the flow of an appreciable emitter current, the input power to the emitter circuit is quite small. As we have seen, the collector current due to the diffusion of holes is almost as large as the emitter current. Moreover, the collector voltage can be as high as 45 volts, thus permitting relatively large output powers. **A large amount of power in the collector circuit may be controlled by a small amount of power in the emitter circuit.** The power gain in a transistor (power out/power in) thus may be quite high, reaching values in the order of 1000.

Current gain of transistor (α)

The ratio of **collector current** to **emitter current** is known as **alpha** (α), i.e.

$$\alpha = \frac{I_C}{I_E} = \frac{\text{Collectorcurrent}}{\text{EmitterCurrent}}$$

It cannot be higher than 1. It is the measure of possible current amplification in a transistor.

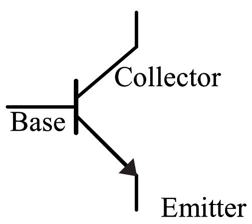
Beta (β) is another constant defined as ratio of collector current to base current. If I_E is the emitter current, and I_C/I_E = a, then I_B = base current = 1 - α , i.e.

$$\beta = \frac{I_C}{1 - \alpha}$$

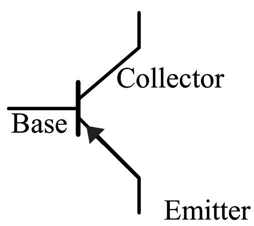
Transistor Symbols and Connection

When transistors are operated as amplifier, **three different basic circuit connections** are possible: (a) Common-base, emitter input; (b) common-emitter, base input; and (c) common-collector, base-input.

Regardless of the circuit connection **the emitter is always forward biased** and **collector is always reverse biased.**

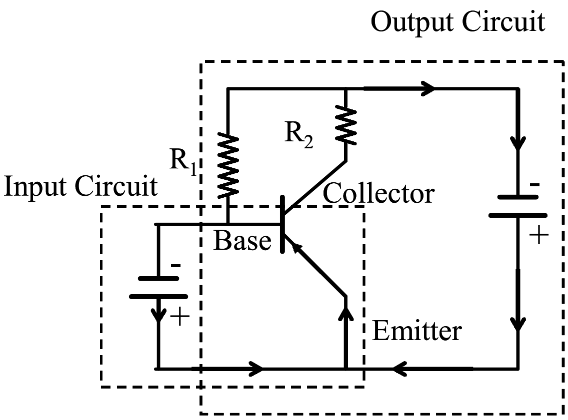


Circuit symbol of NPN transistor

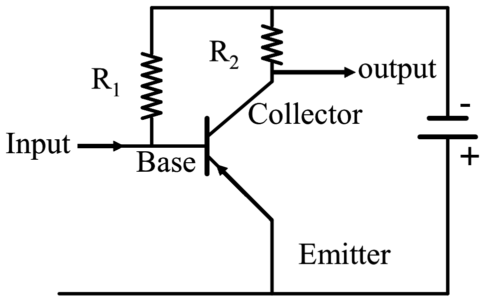


Circuit symbol for PNP transistor

Described below is a **'common emitter, base-input'** basic transistor amplifier circuit using a PNP transistor. The transistor is in **common-emitter configuration.** It needs two separate supply voltages—**one for base bias** and the **other for the collector.** In the first diagram, two separate batteries are used. But the voltages can also be provided by a single supply (**as shown in the second diagram)** taken to the common connection (the emitter) and the collector; and tapping the collector side to apply the necessary forward bias voltage to the base dropped a bias resistor.

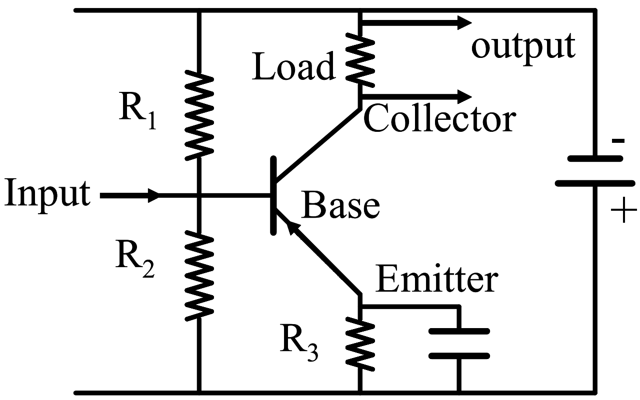


A common emitter amp circuit using a PNP transistor with two power supplies



A common emitter amp circuit using a PNP transistor with single power supplies

In this type of amplifier circuit, the collector current is fed through an output load (R_2). The biasing voltage to the base is provided through the resistor R_1 is of the order of 0.1 to 0.2 volts for germanium transistors; and about 0.6 to 0.7 volts for silicon transistors. This type of biasing is called as *current biasing.* A relatively small base current can instigate a very much larger collector current (or, more correctly, a **small input power** is capable of producing a much **larger output power**). In other words. the transistor works as an amplifier. However, this type of circuit is not very stable. To provide stability, another type of base biasing is used, which is called voltage biasing. In the amplifier circuit shown below, with voltage bias, two resistors (R_1 & R_2) are used as a potential divider. A resistor R_3 is also added in the emitter line to provide emitter feedback automatically to control the bias voltage under varying working conditions. This resistor is usually paralleled with a capacitor to provide further stabilization.



Voltage bias transistor amplifier circuit

Radio Receiver

A radio receiver is a device, which is used to receive **radio frequency transmission from a radio transmitter.** A radio transmitter transmits ***radio frequency*** (RF) signal generated at a particular frequency , on which the intelligence (e.g. any type of audio) is superimposed. Transmission of this audio information or ***audio frequency*** (AF) is possible only through the use of radio frequency. However, in reality the audio frequency (AF) does not get transmitted; instead, the sound content is literally carried on the back of the RF signal, the two together forming what is called a ***modulated signal.***

Modulated radio frequency can be produced in two different ways-**amplitude** or 'up-and-down' modulation, known as **AM;** and **frequency modulation** (FM). In FM broadcast, actually a very small variation in the RF signal frequency takes place about the station frequency. FM technique is usually followed in very high frequency (VHF) transmissions.

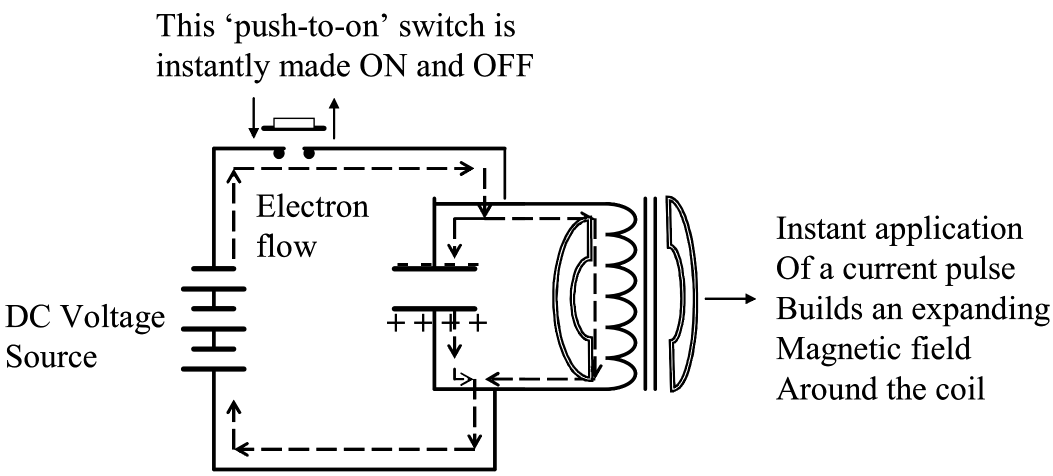
Amplitude modulation technique is easier and hence widely used for medium wave and short wave broadcasts. There are hundreds and thousand of broadcasts that take place in different radio frequencies or wavelengths. The relationship between wavelength and frequency is :

$$\text{Wavelength} = \frac{300000000\text{meters}}{\text{Frequency(inHertz,Hz)}}$$

$$\text{Frequency(inMegaHertz,MHz)} = \frac{300}{\text{Wavelength(inmeters)}}$$

Radio Frequency (RF) generation

A basic oscillator which can produce oscillations at a particular frequency consists of a capacitor, a coil (inductor) and a DC voltage source along with a switch as shown below.



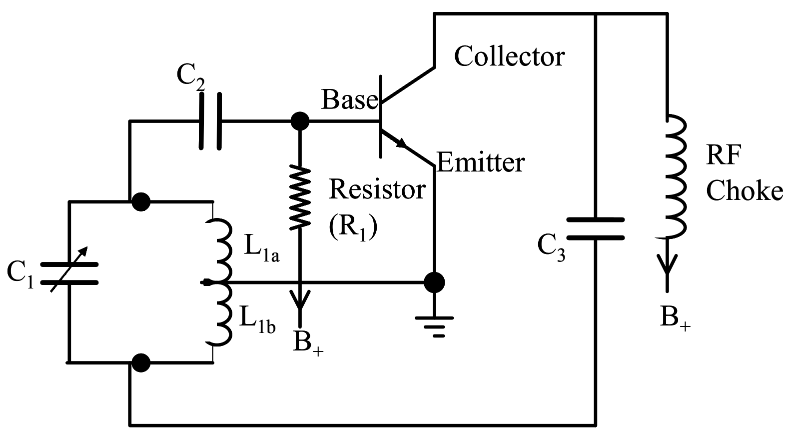
A basic inductive capacitive (LC) oscillator Circuit to produce damped oscillation

By making the switch 'ON' instantly and then releasing it to make 'OFF', a pulse of current finds it path to the capacitor as well through the inductor resulting in an expanding magnetic filed across the inductor while charging the capacitor simultaneously. The instant when the switch is made 'OFF', the capacitor discharges releasing the extra electrons on the top plate through the inductor to reach the other plate. The current thus produced is in the same direction as when the switch was made 'ON'. Thus it aids to maintain the expanding magnetic field produced during the instant when the switch was made 'ON'. The capacitor will reach a neutral state after the electron from the top plate neutralizes the bottom plate (the positively charged plate), i.e. the capacitor will be getting discharged in the process. As there is no supply of electrons from the DC voltage source (because the 'switch' is 'OFF'), and the capacitor is also fully discharged, so, the magnetic field around the inductor will now collapse resulting in a self-induced voltage. This self-induced voltage will make enough current to flow through the inductor to charge the capacitor in opposite direction. A similar process described above will now start and repeat over and over again producing damped oscillating currents until all of the energy is wasted by circuit resistance and other losses. This is called the **'flywheel effect'.** It is similar to what happens when a pendulum is started in motion. It tries to continue swinging at the same frequency until all of the starting energy is used up. The unique thing to notice here is that oscillations will maintain a particular frequency despite loosing their amplitude. This frequency is called the resonant frequency and the circuit described above is called a tank circuit. The frequency of resonance can be found from the formula:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

In the electronic circuitry, a damped oscillation is not at all desirable from the practical utility point of view. So, the objective is to use a transistor or triode valve to provide the necessary gain (and not loss!) and feedback (the energy) to sustain the oscillations or to produce perfect since wave frequency. Described below are two practical oscillator.

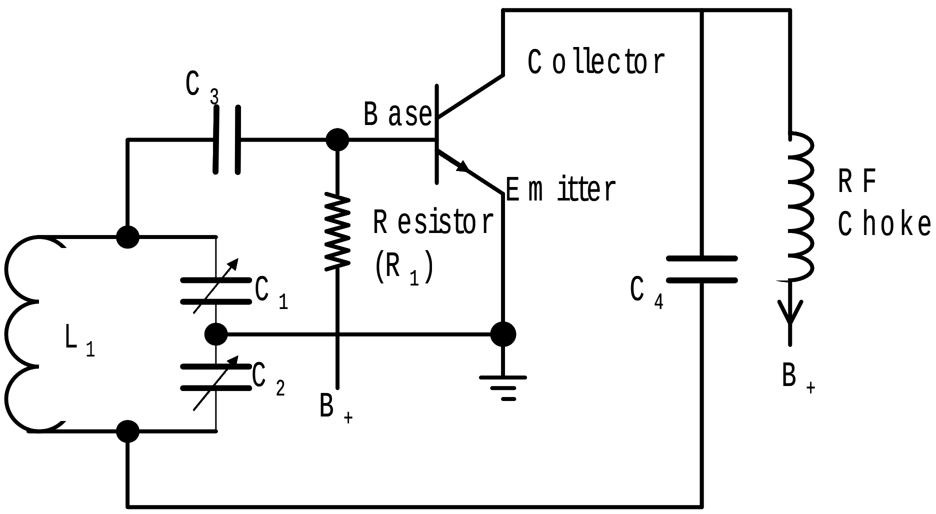
Hartley Oscillator



A Hartley oscillator circuit

In the Hartley oscillator circuit shown above, the frequency of oscillation is determined by the resonant frequency of the tank circuit consisting of C_1 and L_1. L_1 is tapped at its center to form two inductors : L_{1a} and L_{1b}. L_{1a} is effective in the base circuit of the PNP transistor and L_{1b} is in the collector circuit of the transistor. When B+ is applied to the collector through a RF choke, collector begins to flow. The resulting drop in collector voltage is coupled through C_3 and developed across L_{1b}. This serves as the initial excitation for the tank and causes circulating current to begin to flow in the tank. The circulating current produces a voltage across L_{1a}, which is coupled by capacitor C_2 to the base of the transistor. The amplified signal at the collector is coupled back to the tank circuit by capacitor C_3, and developed across L_{1b}. The feedback voltage developed across L_{1b} is in phase with the input voltage across $L_{1a,}$ and so maintains the tank circuit oscillations.

Colpitt's Oscillator

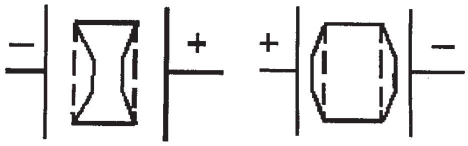


A Colpitts oscillator circuit

The Colpitts oscillator is similar to the Hartley oscillator, **except that two capacitors are used in the tank circuit instead of a tapped coil.** The output frequency of a Colpitts oscillator is determined by the value of the tank inductance and the total capacitance of the two series capacitors. Capacitor C_1 is in the base circuit and C_2 is in the collector circuit. The AC tank voltage produced by the circulating current divides between the two capacitors. The voltage across C_1 is applied to the base of the transistor by coupling capacitor C_3 and base resistor R_1. The resulting collector signal is coupled back to the tank circuit by capacitor C_4 and developed across tank capacitor C_2. The feedback is in phase with the base voltage as a result of the 180-degrees phase shift introduced by the transistor, and the 180-degree shift caused by the ground tap between C_1 and C_2.

Crystal oscillators

Crystal oscillators are used in most modern commercial radio transmitters, either telegraph or telephone. Quartz crystal oscillators are used because they do not drift more than a few hertz from the frequency for which they are ground. A variable Frequency Oscillator (VFO) tends to drift considerably more.



Expansion and contraction of a crystal

Crystals made from quartz are used in radio frequency oscillator circuits in order to impart stability to the frequency of oscillation. The function of the quartz crystals are based on the piezoelectric effect, i.e. generation of electricity by compressing or stretching the quartz. Conversely the quartz crystal can be made to expand or contract physically by applying a voltage across it (e.g. by placing it between two metallic plates where the voltage is applied).

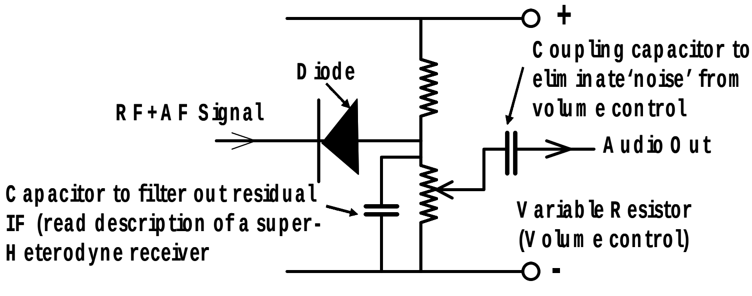
At its resonant frequency a crystal behaves exactly like a tuned circuit. If a crystal between metal plates is shock-excited by either a physical stress or an electric charge, it will vibrate mechanically at its natural frequency for a short while and at the same time produce an ac emf between the plates. This is somewhat similar to the damped electron oscillation of a shock excited LC circuit.

Tuning circuit of radio receiver

The job of a radio receiver is to receive only a particular radio frequency at a single time. For this, a sorting device known as the ***'tuning circuit'*** is used at the *'front end'* of a radio receiver.

Detection

After sorting out the desired frequency, a diode is used at the **'detector'** or '**demodulator'** stage of the receiver, where it rectifies out one half of the RF signal containing the audio information. This half cycle of the RF is still imposed with the AF content. So the next step is to filter out the RF to receive or detect an undulating AF signal. These undulations follow exactly the same variations as the AF signal originally imposed on the transmitter RF signal at the transmitting station by a microphone.



A diode detector circuit

A resistor and a capacitor acts as a filter for a specified frequency. So, a diode detector is to match a load (resistor) with the capacitor so as to form the required filter circuit, so that only the varying dc (undulating AF portion of the signal) is passed at the output from the detector stage. A basic diode detector circuit is shown here.

AF Amplification

The audio signal thus obtained is then amplified in the audio amplifier stage of the receiver. There may be more than one stages of amplification but with the limitation of using only a certain number of stages of amplification after which distortion in the audio takes place.

The radio receiver described above is a very simple radio receiver which has a limitation in its detector stage. This type of receiver is called **Tuned Radio Frequency** receiver (TRF). The detector works most effectively with an RF input voltage of 1 volt or more. Signal obtained directly from an aerial circuit are most of the time more than a few millivolts in strength, and weaker the signal the less effectively they will be detected. So, the range of stations that can be picked up is limited, and no amount of amplification after detection can make up for this limitation.

This limitation or lack of sensitivity can be overcome by amplifying the incoming signal before detection, so that the detector is always working with good signal strength. This is accomplished by the use of an amplifier stage right at the beginning of the circuit or by **Super-heterodyne circuitry.** By **comparing and contrasting** a **'Tuned Radio Frequency (TRF) receiver'** with a **'Super-heterodyne receiver',** we can better understand the advantages as well as functioning of a super-heterodyne receiver.

Difference between a Tuned Radio Frequency (TRF) receiver and a Super-heterodyne receiver.

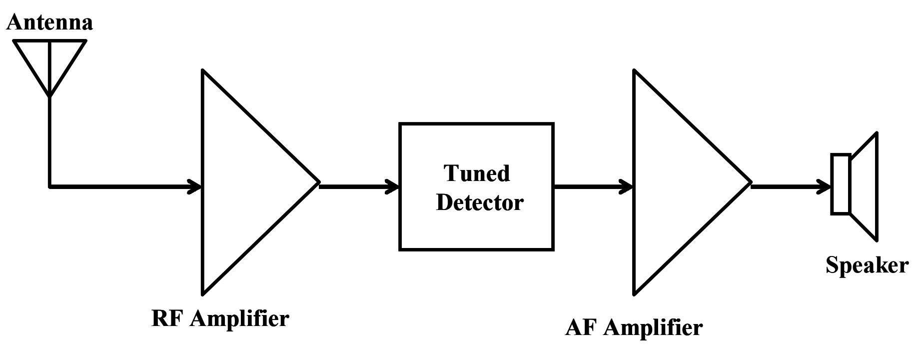
A **TRF receiver** consists of the following stages:

(i) Antenna input stage

(ii) A few stages for RF-amplification

(iii) A detector stage for demodulation

(iv) One or more stages of AF amplifier.



Simple Tuned Radio Frequency (TRF) Receiver

On the contrary, a **super-heterodyne receiver** consists of:

(i) RF Amplifier
(ii) Mixer or Converter
(iii) Local Oscillator
(iv) IF Amplifier
(v) Detector
(vi) Automatic Gain Control (AGC) Circuit.
(vii) AF Amplifiers

1. In a TRF receiver a series of loosely coupled tuned circuits are used to increase selectivity and each circuit are ganged (interconnected) so that they resonate at the same frequency. But in a super-heterodyne receiver, this principle is not followed, instead, the RF amplifier, mixer and local oscillator are ganged to produce an intermediate frequency (IF).

2. In a TRF receiver the high amplitude original frequency is demodulated at the detector stage. But in Super-heterodyne sets, the IF is demodulated.

3. In a TRF Receiver, no image frequency is produced. But image frequency is produced in super-heterodyne receiver.

4. In a TRF receiver, selectivity is not constant; the receiver is more selective at the low frequency bands, while less selective at the high frequency end. Because the detector and amplifiers of a super-heterodyne receiver can be designed to amplify only intermediate frequency (IF), this type of receiver is more selective and offer high fidelity (exact reproduction quality of the transmitted signal).

5. In TRF receiver, amplification is not constant over the tuning range. In super-heterodyne receiver amplification is constant since all the time it amplifies a constant frequency at the IF stages.

Functioning of a Super-heterodyne Receiver

The main objective of the super-heterodyne receiver is to produce an intermediate frequency (IF) by the process of heterodyning or beating. This can be accomplished when two frequencies are mixed to produce the beat frequency. In super-heterodyne receivers, the IF is usually **455 kHz which is selected because the broadcast band begins above that frequency.** So, if we imagine a situation when the RF amplifier is tuned to receive a 800 kHz broadcast signal, the local oscillator must be tuned to 1255 kHz, which will result in an IF of 455 kHz (1255-800 kHz=455 kHz).

Since we have to tune the RF amplifier section throughout the entire broadcast band, the frequency of the local oscillator must also vary in a manner that it always maintains a gap of 455 kHz. To achieve this condition, the Local Oscillator and RF Amplifier section are ‘**ganged’,** i.e. their tuning condensers are connected/ganged mechanically in such a way that when we tune the variable capacitor in the local oscillator also changes its value, it ‘tracks’ the frequency to which the ‘Aerial Circuit’ is tuned and remain separated from the tuned frequency by 455 kHz up.

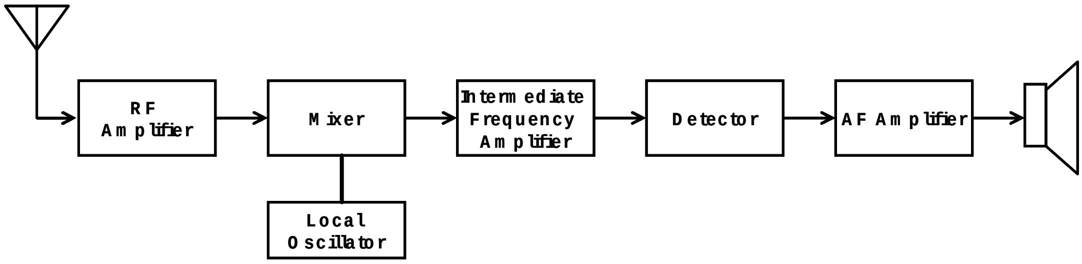
The Intermediate Frequency (IF), which is a considerably low frequency is being used, because-

(i) it is a suitable frequency to achieve amplifying efficiency.

(ii) It provides better selectivity.

(iii) It provides better sensitivity throughout the broadcast band.

(iv) It provides uniform sensitivity as well as uniform selectivity.



Block Diagram of Super Heterodyne Receiver

Radio Frequency (RF) Amplifier section

This section performs two major tasks:

(i) it couples the antenna voltage to the converter of the receiver.

(ii) By selectivity, it accepts only the desired frequency and all others are rejected.

(iii) By amplifying the desired signal, the Signal-to-Noise ratio is increased in the converter stage for efficient operation.

Converter or Mixer Section.

The main objective of the super-heterodyne receiver is to produce a constant. Intermediate Frequency (most commonly used frequency being 455 kHz in commercial broadcast band radio sets). In the mixer stage, the local oscillator frequency and the selected station frequency is or combined, where, by the process of 'heterodyning', i.e. 'beating', the 'Intermediate Frequency (IF)' is obtained. If the RF amplifier section selects and amplify a signal of 800 kHz, then the local oscillator produces a frequency of 1255 kHz. By mixing both the frequency at the mixer stage, a difference of frequency of the value 455 kHz is obtained (1255 - 800 = 455 kHz).

Intermediate Frequency (IF) Amplifier

The 455 kHz IF is fed to the IF amplifier through an IF transformer. The circuitry of the IF section is so designed and tuned so that it gives the optimum gain at that particular IF frequency.

Detector / Demodulator and 1st Audio Frequency Amplifier stage

The Amplitude Modulated (AM) IF is demodulated and detected. A diode working as rectifier solves this purpose. The triode/transistor amplifies the audio signal and the volume control potentiometer system controls the intensity of sound.

AF Power Amplifier

This section further amplifies the audio signals which is finally fed to an output transformer which matches the impedance of output stage with the speaker (in modern transistor receivers, the necessity of output transformer is eliminated).

AGC or AVC in a super-heterodyne radio set

Automatic Gain Control is a most needed part of super-heterodyne circuitry. A disadvantage of manual gain control (volume control) with a receiver is that it can't provide constant output under all conditions. If a receiver is tuned from a weak signal to strong signal, its output must increase intolerably. This would then require readjustment of the volume control. Similarly, when a receiver is tuned to particular signal the output level can vary widely if the input signal strength fluctuates as a result of fading and adjustments of the volume control has to be done. Since such signal fluctuat9ions are rapid, constant readjustment of volume control would be necessary which is impractical. This is where AGC or AVC comes into picture and is used in addition to the manual control.

All AGC or AVC (Automatic Volume Control) circuits perform two basic functions;

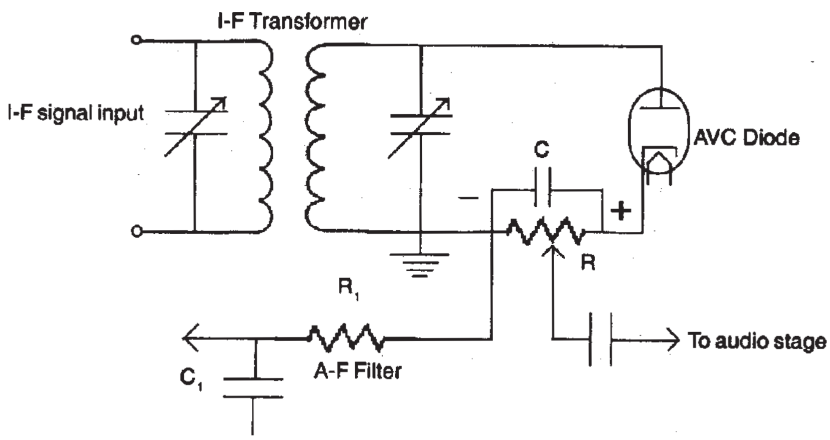
(i) The first of these is to develop a DC (Direct Current) which is proportional to the receiver input signal all the time.

(ii) The AGC voltage is applied to the RF and IF stage of the receiver where it serves as a Bias voltage.

In this way the AGC voltage controls the gain of RF and IF stages, and therefore the overall gain of the receiver. When the signal level at the receiver input increases, the AGC voltage increases proportionately. Consequently, a larger bias is applied to the IF and RF stages and their gain is applied to the IF and RF stages and their gain is reduced.

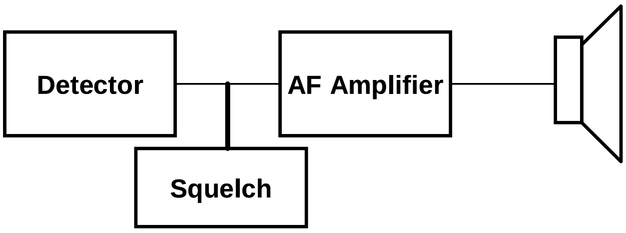
The receiver output thus remains relatively constant instead of increasing in accordance with the input signal strength and vice-versa.

In valve type RX (receiver), the grids of RF and IF portions valves are biases by negative voltage. While in a transistor it depends on transistor type.



Squelch circuit

The squelch circuit or Q (**Quieting**) circuit is a circuit which is controlled by AGC or AVC voltage. The modern high gain receivers shows a disadvantage without it, that is, without a squelch circuit, annoying buzzing and cracking sounds are heard over the loudspeaker in absence of input signal. So a circuitry is arranged in such a way that AF gain is kept reduced in absence of input signal from the antenna.



Block Diagram of Squelch circuit

With no signal there is no Negative AGC voltage, and the squelch tube allows current to flow through it then passing through R_3 to the +250 V point. Thus R3 produces a DC voltage drop across it which is more negative at midpoint than at the bottom being in series with the amplifier grid circuit, tube past cutoff, preventing it from functioning.

When a signal is received, AGC or AVC voltage biases the squelch tube to 'cutoff', stopping plate current flow. Consequently, the voltage drop across R3 ceases, allowing the AF amplifier tube to act in a normal manner.

Image Frequency in a super-heterodyne receiver set.

The intermediate stage (mixer + local oscillator) of a super-heterodyne radio set produces an Intermediate Frequency (IF) due to the beating of RF input frequency and Local Oscillator Frequency. This frequency is obtained by deducting the **RF input from the tuned circuit** from that of **Local Oscillator Frequency.** So, while receiving a 800 kHz RF signal, the Local Oscillator is made to oscillate at a frequency of 1255 kHz which results in an Intermediate Frequency (IF) of 455 kHz (which is accepted as a standard in almost all the Broadcast band receiver circuits); **but it is found that in cae of comparatively less selective receiver, if a broadcast frequency 455 kHz up, from the 1255 kHz local oscillator frequency manages to intrude the RF tuned circuit even to a little extent, then another difference of frequency equal to intermediate frequency results;** viz. 1710-1255=455 kHz. But this '455 kHz' being generated from **a signal frequency having different audio information causes adverse effect at the audio end of the receiver.** The intelligence of both would be present in the speaker at the same time making the sound reproduction is unintelligible.

Prevention of Image Frequency

(i) By highly selective RF tuned amplifier.

(ii) By using an IF which is convenient to use and at the same time separation between desired and image signals is made large. Possibility of image frequency generation is greater in a receiver designed for an IF of 175 kHz than a receiver using an IF of 455 kHz.

Characteristics of receiver

Selectivity :

Selectivity is the measure of the ability of a radio receiver to select a particular frequency or particular band of frequencies and rejecting all other unwanted frequencies. But higher selectivity does not necessarily make a better receiver. For instance, a 'broadcast signal' consists of the carrier frequency and its two side bands. In a situation where a carrier frequency of 800 kHz is modulated with a 5 kHz (5000 Hz. tone, the sum of the carrier and the audio frequency results in the Upper Side Band (USB) of 805 kHz. The difference of carrier and audio frequency results in a Lower Side Band (LSB) of 795 kHz. So, for proper reproduction of the broadcast signal at a particular carrier frequency, the receiver must receive (select frequencies from 795 to 805 kHz. A receiver more selective than this would reject a part of the frequencies thus proper reproduction would be hindered.

Sensitivity of a receiver

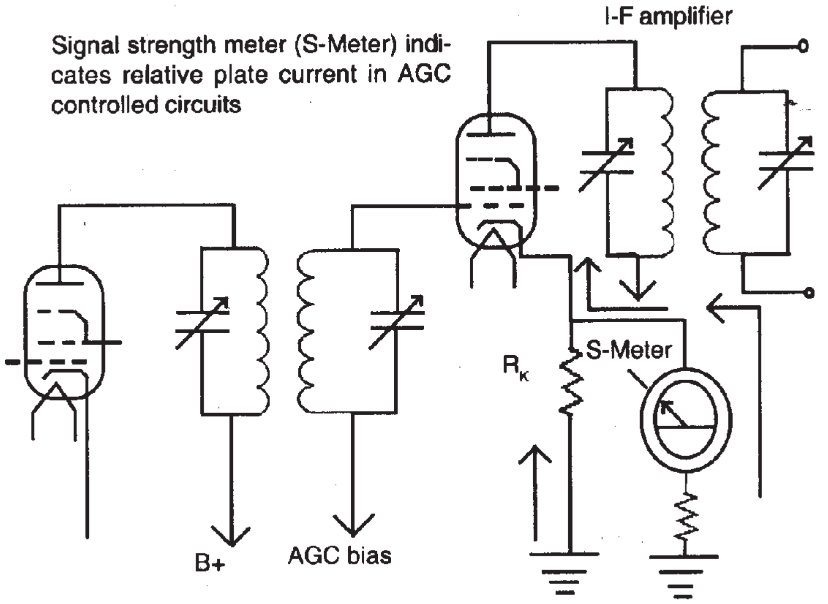
It is the ability of a radio receiver to respond to the desired radio frequency signal effectively. Higher the ability of the receiver to respond to a weak signal, greater is its sensitivity.

Fidelity :

The Fidelity of a receiver is its ability to accurately reproduce the same signal without any change in quality. That is all the frequencies in the entire original transmitted signal should be reproduced. Good design of detector and AF amplifier circuits can give better fidelity to the receiver.

What is a S-meter?

A S-meter is a visual indicator of signal strength. A simple S meter consists of a milliammeter in series with an RF or IF amplifier plate/collector circuit. With no signal, there is no AGC bias voltage and maximum plate current flows. With a signal, the AGC biases the tube, reducing the plate current and the indication on the meter. The stronger the signal, the lower the meter indication, signifying a strong strength.



A typical S-meter circuit

What is a Beat Frequency Oscillator?

To change the second detector from a rectifying or envelope detector to a heterodyne detector to receive A1A (Continuous Wave Morse Code). A2A (Modulated CW Morse Code), J3E (Single Side Band), the Beat Frequency Oscillator is turned on. It is a variable frequency oscillator using a Hartley, Colpitts or Armstrong circuit. It is tunable to the Intermediate Frequency and one or two kilohertz higher and lower. It heterodynes with any signal coming through the IF strip, producing an audible beat frequency in the detector. Both the BFO and LO (Local Oscillator) must have good frequency stability.

Why ham radio transmissions are not heard in ordinary radio receiver sets?

The radio sets available in the market for general public are designed to receive Amplitude Modulated (AM) of Frequency Modulated (FM) broadcasts only. But the ham radio operators use a very efficient mode of transmission called Single Side Band (SSB) transmission. The power of a ham radio station is also very low (usually not more than 100 watts) in comparison to the broadcast station (which use power in the kilowats range). In fact many of the broadcast band radio receivers available in the market also covers some of the frequencies, which are allotted to the ham radio stations. A 4 band radio set (inclusive of the Medium Wave band) can be expected to cover some popular ham radio frequencies like 7 to 7.1 MHz (i.e. 7000 to 7100 kHz), 14 to 14.35 MHz (i.e. 14,000 to 14,350 kHz) and 21 to 21.450 MHz (i.e. 21,000 to 21,450 kHz). This kind of receiver can be improvised to receive ham radio transmissions with very little effort.

First, we will need an outdoor aerial. Because, these radio sets are not sensitive to receive low power transmissions. Majority of the hams use power below 100 watts (a broadcast station may use 4000 or 5000 watts of power or even more than that!). A novice ham radio operator may be found to be operating with a power as low as 0.5 watt!

Ham radio conversation if heard on an ordinary radio set sounds like the 'Duck quacking'. There is no intelligibility in the audio. As already mentioned, our ordinary radio sets are meant to receive AM signals only and not to receive SSB signals-a separate unit is required at the '**Detector**' stage of the AM receiver, which is nothing but a stable '**Frequency Generator**' (RF Oscillator), called the '**Beat Frequency Oscillator**' **(BFO)**. The BFO is used to introduce a '**Local Carrier Frequency**' (frequency of the carrier is 10 to 20 Hertz within that of the transmitter carrier frequency which is suppressed at the transmitter of the ham radio station willingly in order to save power). A BFO can also be used to make the un-modulated Continuous Carrier Wave (CW) transmissions (e.g. in Morse Code transmission) intelligible.

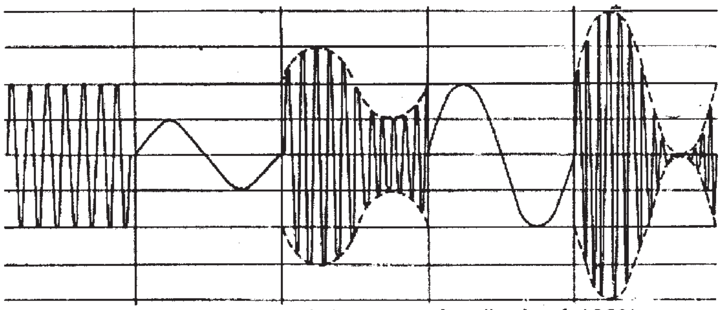
Radio Transmitters

Amplitude Modulation and %ge of modulation

Amplitude Modulation (AM) is a process in which the amplitude of a radio frequency current is made to vary and modify by impressing an audio frequency current on it.

A radio frequency current has a constant amplitude in absence of modulation and this constant amplitude RF carries no information. i.e. no audio intelligence and is of no use to radio telephone (voice communication), but has application in morse code communication.

So, to give intelligence to the RF current, audio signal is impressed / superimposed on the RF current in a non-linear modulator circuit; as a result of which carrier current amplitude begins to rise to a maximum value above and below its original amplitude during the positive cycle of the audio signal and during the negative cycle of the audio signal, it falls to a minimum value.



This results in the carrier having two outlines of the audio signal, this is because the variation at instant in the amplitude of the carrier wave is directly proportional to the value of the modulating signal.

During amplitude modulation, two side band frequencies are also produced. Upper sideband frequencies equal to the carrier frequency plus audio frequency and lower side band frequency is equal to carrier frequency minus audio frequency. So the amplitude modulated carrier occupies a space in frequency spectrum, the width of which is equal to twice the highest modulating frequency.

Percentage of modulation

The degree of modulation in an AM wave is expressed by %ge of maximum deviation from the normal amplitude of the carrier RF wave.

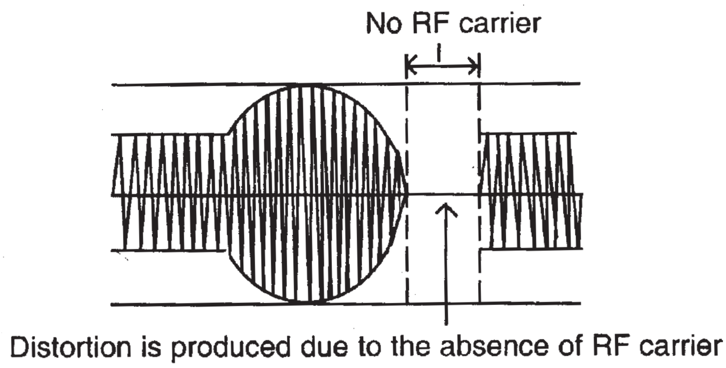
The effect of such modulated wave is measured by a receiver's ability to reproduce the signal in distorted or undistorted manner.

Percentage of modulation = $(Voltage_{Max} - Voltage_{Min}) / (Voltage_{Max} + Voltage_{Min}) \times 100$

Where $Voltage_{Max}$ is the maximum instantaneous value of the modulation and $Voltage_{Min}$ is the minimum value of the RF carrier.

Why over modulation is not desirable?

Over modulation is not desirable, i.e. modulation should not exceed 100%, because if modulation exceeds 100% there is an interval during the audio cycle when the RF carrier is removed completely from the air thus producing distortion in the transmission.



Over modulation

What are the Side-bands of an AM Signal?

Side bands are the sum and difference frequencies produced at the transmitter by the modulating frequencies. For instance a 5 kHz (5,000 Hz) Audio tone might be used to modulate an 800 kHz carrier frequency. This would produce frequencies of 800 kHz, 805 kHz and 795 kHz. 800 kHz is the carrier and 795 and 805 kHz are the two side band frequencies.

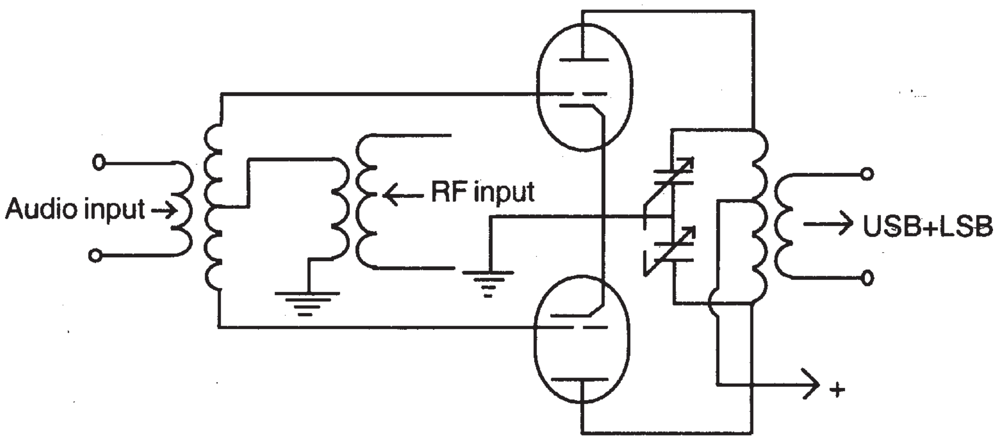
What is Single Side Band (SSB) transmission?

At full modulation the carrier in an AM signal requires two thirds of the power but conveys no information. The second side band can be viewed as redundant (overlooking frequency-selective fading in an ionospheric transmission path, that may distort one side band at times). Interference between several carrier frequencies, resulting in steady audio whistles or 'beats' is another disadvantage of AM.

Power may be saved and the band occupied by an AM signal in the frequency spectrum can be halved if only one side band is transmitted without carrier. The result is single side band suppressed carrier signal, called simply single side band signal (SSB) transmission.

The carrier must be reintroduced at the receiver in such systems and closely adjusted to the original carrier frequency to avoid signal distortion. The introduced carrier carrier must be within 10 or 20 Hertz of the original carrier frequency for adequate intelligibility of voice signals, and stable oscillators are needed for generation of the local carrier.

For SSB the transmitter does not need to generate carrier power, and ratings are in terms of peak-envelope-power (PEP), the power capability at the peak of the modulating signal with linearity of the amplifier is maintained. For equal information content, and 100% modulation, the SSB signal requires only $^1/_6$ th power of the double side band signal. However, the situation is even more favourable to SSB when speech is transmitted. Speech is not a continuous sine wave, and its average power is low with respect to its peak requirements. A peak-to-average power ratio of 10:1 is often assumed for speech, and under that condition, a Double Side Band (DSB) AM signal would require 1.05 times carrier power, whereas for equal intelligibility the SSB signal would require only 0.05 units of power or $^{1}/_{21}$ as much.



A balanced modulator circuit using valve

Because of the lower power rating, circuit components designed for SSB equipment can be smaller and lower in cost.

For generation of a modulated signal without carrier, a **balanced modulator** is used. A filter then discards one side band.

Why 100% modulation should be aimed in voice transmission?

The power of a modulated wave is found from the formula.

$\mathbf{P_{mod} = (1 + m^2/_2) \times P_{carr}}$

Where P_{mod} = Power of the modulated wave,

M = degree of modulation,

P_{can} = power in the carrier frequency.

The power in an amplitude modulated wave is divided between the carrier and the two side bands. The carrier power is constant, and so, the side band power is the difference between the carrier power and the total power in the modulated wave. The above formula is to find the power of the modulated wave when carrier is modulated by single sinusoidal tone.

If the carrier power = 50 watts

%ge of modulation = 100 or 1

degree of modulation = 1

Then the power of the modulated wave,

$P_{mod} = (1 + m^2/_2) \times 50 = {}^3/_2 \times 50 = 75$ watts.

Since the carrier power = 50 watts; the two side bands have 25 watts in them. i.e.

${}^{25}/_{75}$ x **100% = 33.3 %** of the total power with 100% modulation.

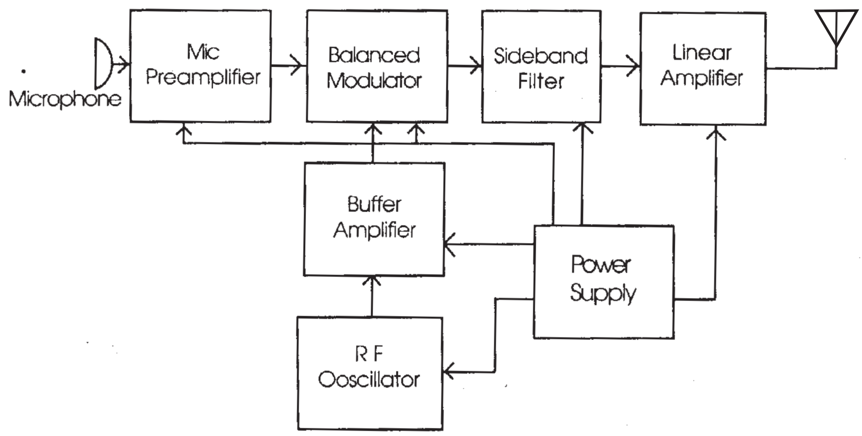
In case of 50% modulation with same carrier power we have,

$\mathbf{P_{mod} = (1 + 0.50^2/_2) \times 50 = {}^{2.25}/_2 \times 50 = 56.25}$ **watts.**

Now the side bands have only 6.25 watts (since 56.25 = 6.25)

Since all the intelligence being transmitted is contained in the side bands, the desirability of a high percentage of modulation is crystal clear. A comparatively low powered, but well modulated transmitter often produces a stronger signal at a given point than does a much higher powered, but poorly modulated, transmitted the same distance from the receiver.

Schematic diagram of our intended transmitter and its function in brief



Block diagram of a Single Side Band Transmitter

RF Oscillator

This is the stage where the carrier frequency intended to be used is generated by means of Crystal Oscillator Circuitry or capacitance-inductance based Variable Frequency Oscillator (VFO). The RF oscillator is designed to have frequency stability and power delivered from it is of little importance, hence can be operated with low voltage power supply with little dissipation of heat.

Buffer Amplifier

The low power RF carrier output from the RF oscillator is amplified in this portion and it also keeps the RF oscillator and power amplifier circuits separate electrically imparting frequency as desired by the amateur can be done in this stage, when the carrier frequency multiplication technique is applied here. In it the Morse key for keying out carrier continuous wave can be accommodated.

Modulator

Audio information is impressed upon the carrier frequency at this stage.

Balanced Modulator

In this type of modulator, while the audio information (voice) is impressed upon the carrier frequency, at the same time its output gives a signal without carrier frequency but yet with the two side band frequencies carrying the voice / audio information.

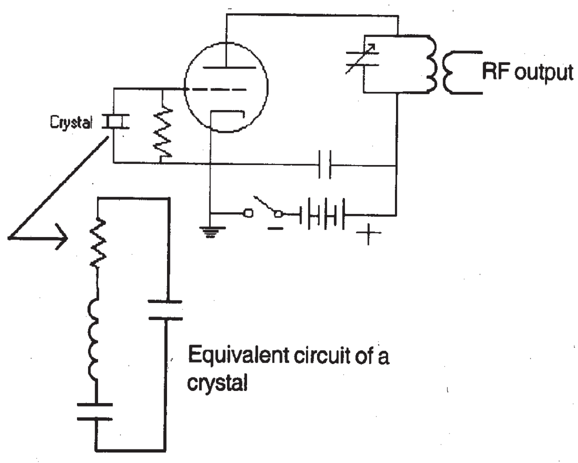
Side-band filter

It discards out any one of the side band.

RF linear Amplifier

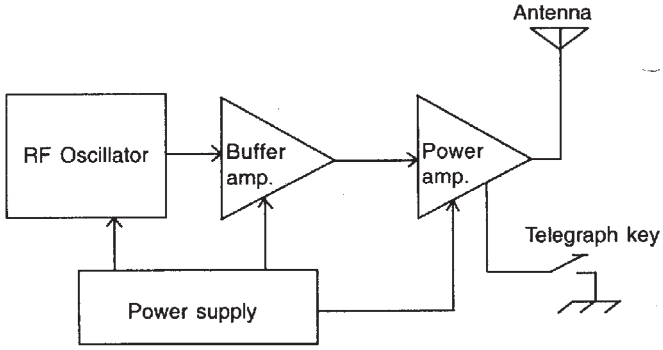
RF power amplification is done here and this stage is coupled to the antenna system through antenna impedance matching circuitry. Care is taken at this stage so that no harmonic frequency is generated which will cause interference in adjacent band (splatter) on other bands.

The circuit shown below is a TPTG (Tuned Plate Tuned Grid) circuit. When the switch is closed, the LC (Inductance-Capacitance) tank in the plate circuit is shock-excited into oscillation by the sudden surge of plate current. The ac developed across this LC circuit is fed back to the top crystal plate through inter-electrode capacitance, and to the bottom plate of the crystal through the bypass capacitor from the LC circuit. The crystal starts vibrating and working as an ac generator on its own. The emf generated by the crystal, applied to the grid and cathode, produces plate current (Ip) variations in the plate LC circuit.



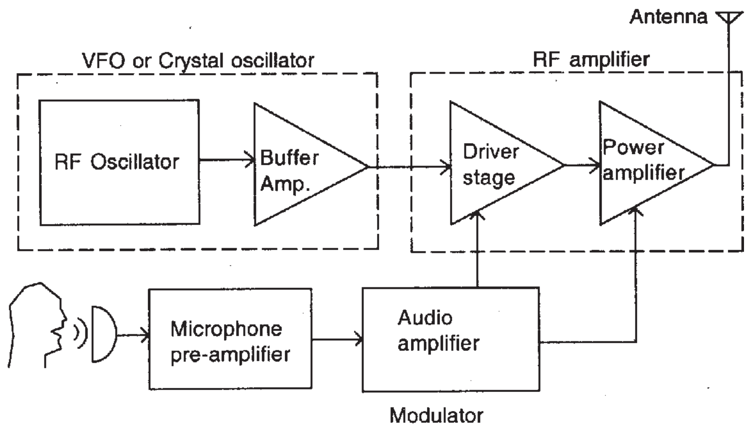
A Tuned Plate Tuned Grid (TPTG) circuit

With both crystal and LC circuit oscillating and feeding each other in proper phase, the whole circuit oscillates as a very stable ac source. The plate LC circuit must be tuned slightly higher in frequency than the crystal to produce the required phase relationship between the two circuits to sustain oscillations.



Block diagram of a simple radiotelegraph transmitter

Block diagram of a simple Amplitude Modulated (AM) transmitter



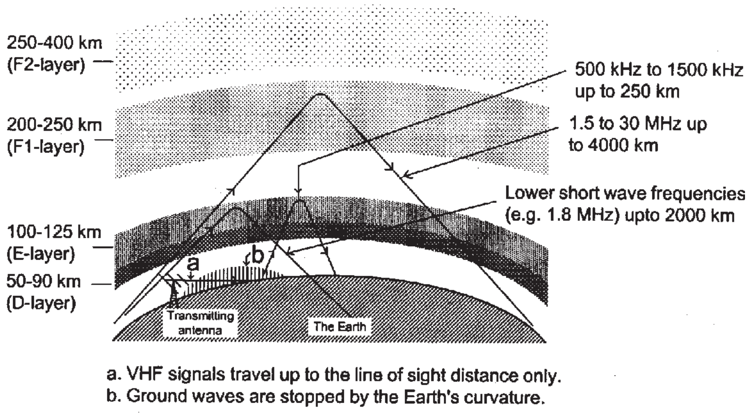
Radio Wave Propagation

The Role of Ionosphere in Radio Wave Propagation

Long distance propagation of radio waves depends on an invisible layer of charged particles, which envelops the Earth. This layer of charged particles known as the ionosphere has been in existence for millions of years. For those, who pioneered the long distance radio communication during the early part of the twentieth century, the ionosphere came as a boon. During the formative days of radio communication, radio scientists could not come to a definite conclusion about how radio waves propagated round the world. The father of radio, Guglielmo Marconi himself was at a loss to explain how, on 12th December, 1901, he established the first real long distance wireless communication between St. Johns, New Foundland, USA (now in Canada) and Poldhu in the Southern Tip of England, a distance of more than 3,000 kms across the Atlantic Ocean. At that time, it was known the except for very short distances, the radio waves did not follow the natural curvature of the earth. Earth's curvature is a direct block to line-of-sight communication. When enough distance separates **two** radio stations so that their antennas fall behind the curvature, the Earth itself blocks the transmitted signals from the receiver, because electromagnetic waves travel in straight lines until they are deflected by something.

Oliver Heaviside in England and **A.E. Kennally** in America, in 1902, suggested that there must be some kind of reflecting medium in the upper atmosphere that caused the radio waves to be returned to Earth at considerable distances from the transmitter.

Under the action of solar radiation and the hail of meteorites, an ionized layer is formed in the upper part of the Earth's atmosphere. In this layer, the neutral air molecules are decomposed into irons and electrons and the whole layer presents a



Different layers of the ionosphere and propagation radio waves

chaos of charged particles. Short wave radio signals (radio signals which fall in the range of 1.5 MHz to 30 MHz) are reflected from this layer just as light rays are reflected from the surface of a mirror, or sound wave from a barrier. Likewise, this layer can be compared to the edge of a billiard table. Communication specialists use this layer like the dege of a biliard table : if the ball does not go straight into the pocket, it can be directed on the rebound! In the same way, the short wave signals radiated by distant radio stations get to our receiver on the rebound. They can continue traveling to several places round the world, for the Earth is also like the edge of a billiard-table.

The ionosphere is located above the troposphere, starting at an altitude of 50 kms above the surface of the earth and extending up to an altitude of 400 kms or more. The troposphere is the region of the earth's atmosphere immediately adjacent to the earth's surface and extending upward for some tens of kilometers. Radio waves are refracted or bent slightly, when traveling from one medium to another. **Refraction is caused by a change in the velocity of a wave when it crosses the boundary between one propagating medium and another.** If this transition is made at an angle, one portion of the wave-front slows down or speeds up before the other, thus bending the wave slightly. Radio waves are commonly refracted when they travel through different layers of the atmosphere, whether it is highly charged ionospheric layers 100 km and higher, or weather-sensitive area near the Earth surface. When the ratio of the refractive indices of two media is great enough, radio waver can be reflected, just like light waves striking a mirror.

The role of ionosphere in radio wave propagation can be discussed only in terms of the different radio frequencies available for communication and in the light of the existence of different ionospheric layers. Although the various methods used confirmed the theories of Heaviside and Kennally, there were differences between the results obtained by Professor Appleton and other investigators. It was discovered that there was not one, but more than one reflecting layers in the ionosphere. **The first trials with pulse waves in 1925 by Breit and Tuve in America** were successful in that the method proved to be much more practicable. Since **radio waves take 1 millisecond to travel 300 km.** the height of the layer established from the first echo in this case was found to be 300 km. The ionised layers were designated with letters of the alphabet by E. V. Appleton.

The lowest layer known at a height of about **50 to 90 km** being called the **D region** because this is not strictly a layer **but a relatively dense part of the atmosphere where atoms are broken up into ions by sunlight that recombine very quickly.** The amount of ionisation therefore depends on the amount of sunlight and the region has the effect of absorbing the energy from a radio wave, particularly at frequencies in the band of 3 to 4 MHz and frequently as high as 7 MHz. **High frequencies** (1-5.30 MHz) penetrate this layer, while low frequency (LF: 30-300 kHz) and medium waves are absorbed by this layer. To some extent LF and Very Low Frequency (VLF: 3 to 30 kHz) are reflected during daytime.

The **E-layer** extends from an altitude of 100 km. Though sunlight is an important factor for its existence, after sunset also it exists for some time. This layer is responsible for evening and early night time propagation of medium waves (500 kHz to 1500 kHz) up to a distance of about 250 km. Propagation of lower short wave frequencies, e.g. 2 MHz, up to distance of 2000 km at daylight time is due to this layer. It has little effect at night.

F_1 layer exists at an altitude of 200 km during daytime and its characteristics are very similar to E-layer which merges into F_2 layer at night. HF frequencies in the range of 100 kHz to 30 MHz (i.e. 30,000 kHz) propagates through this layer during daytime.

F_2 layer is the most important layer, which exists at altitudes ranging from 250 to 400 km and HF long distance propagation round the clock is due to this layer. The behaviour of this layer is influenced by the time of the day, by season and by sunspot activity. **F_2 layer was formerly known as Appleton layer.** This layer has a high ionization gradient. This layer exists both in the daytime and nighttime. Since at such an altitude air density is extremely low, the free ions and electrons (due to the action of ultraviolet radiation from the Sun) cannot recombine readily and so can store energy received from the sun for many hours; that is the reason **the refractive property of this layer changes only to a negligible extent during day and night.** The path which the short wave signal follows through the F_2 layer is in reality a curved one. Degree of the curve depends on the angle of incidence of the wave, ionization gradient of the layer and frequency of the signal. Maximum distance for F_2 layer reflection is about 4000 km.

Radio wave propagation by multiple reflection

A strong enough radio signal can propagate by multiple reflections. Having returned to Earth from the ionosphere, the Earth's surface acts as a reflector and returns the signal back to the ionosphere, where it is reflected back to Earth yet again. In this way radio signals can travel around the globe almost instantly! Because, radio wave travels at a velocity of 3,00000 km per second in vacuum. Its velocity gets changed very negligibly in a different medium, which is insignificant, because the earth is a very small place with a radius of only 6000-km. Communication between any two points on the earth is thus almost instantaneous.

Propagation characteristics of different ham radio bands

The problem of variable propagation conditions can be partially overcome by using frequency diversity, in which an allotted wireless communication network is provided with several frequency assignments spanning the high frequency (short wave) band of frequencies. The radio operator can thus choose the channel that gives the best results at any given time. The 1800 kHz (1.8 MHz or 160 metre band) band suffers from extreme daytime D-layer absorption. Even at high radiation angles, virtually no signal can pass through the F layer and daytime communication is limited to ground-wave coverage. **At night, the D layer quickly disappears and world-wide 160 m communication becomes possible via F_2-layer skip. Atmospheric and man-made noise limit propagation of this band. Tropical and mid-latitude thunderstorms cause high levels of static in summer, making winter evenings the best time to work long distance at 1.8 MHz.**

The **3500 kHz** (3.5 MHz or 80 metre band) is the lowest HF ham band, which is similar to 160 m in many respects. Daytime absorption is significant, but not quite as extreme as at 1.8 MHz. High-angle signals may penetrate to the E and F layers. **Daytime communication range is typically limited to 400 km, primarily via**

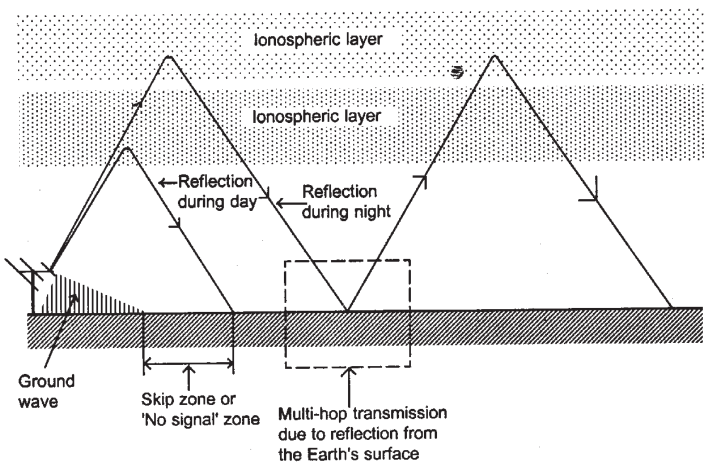
ground-wave propagation. A night, signals are often propagated halfway around the world. As at 1.8 MHz, atmospheric noise is a nuisance, making winter the most attractive season for the 80 m. The **7000 kHz** (7 MHz or 40 metre) band is useful for daytime communication up to a distance of **800 km** via **E and F layers.** Long distance world-wide communication takes place in this band through F_2 layer. The **10 MHz** or 30 metre band is unique because it shares characteristics of both daytime and night-time bands. Communication up to **3000 km is typical during daytime,** and this extends halfway around the world. The band is generally open via F_2 on a 24-hour basis. The 10 MHz band is recently released to the Indian ham radio operators.

Skip distance, skip zone and dead zone

Skip distance, skip zone and **dead zone** are importantly associated with ionospheric propagation. If we take a simple case, where a radio receiver located at a distance of 200 kilometres away from the wireless transmitting station is unable to receive the radio signal, but another receiving station (the **intended station**) at a greater distance (say 1000 km) is able to receive the radio signal perfectly, **then distance of the intended receiver from the transmitter is termed as 'skip distance'.**

Despite being located closer to the radio transmitter, one of the receiving stations is not able to receive the radio signal. This is because of the fact that this receiving station is located in a **skip zone** or **dead zone. The ground waves transmitted from the transmitter are unable to reach this receiving station because of signal attenuation by the earth or are stopped by the Earth's curvature and the sky wave will not reach the receiver, because it bounces again more than 200 kilometers way.** So some '**blind zones**' are formed and if the receiver is located in that blind zone it will receive no signal or very weak signal.

The above situations are particularly pronounced in high frequency (HF) signals where ground waves fade away and skip distances may be a thousand kilometers or more. In such a situation, another station (who is not in skip with the station in blind zone) can relay the message to the receiving station located in the blind zone.



Skip zone and multi-hop transmission

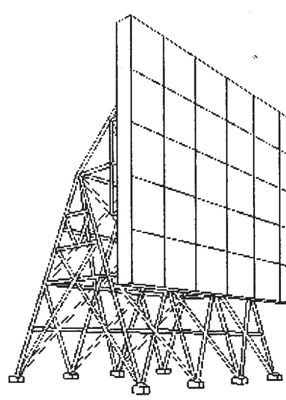
How do the hams overcome the variable propagation conditions of the ionosphere and the problem of skip?

The problem of variable propagation conditions can be partially overcome by using frequency diversity, in which an allotted communication network is provided with several frequency assignments spanning the High Frequency (HF) band or frequencies. The ham can choose the frequency that gives the best results at any given time. Similarly if a station is in skip at a particular frequency, another workable frequency can be found out.

What is line-of-sight propagation?

The radio frequencies above 30 MHz has the tendency to penetrate the ionosphere making them unsuitable for long distance propagation. So, the range of frequencies from **30 to 300 MHz** (also 300 MHz and above), which are placed under the **Very High Frequency** (VHF) category are mainly used for line-of-sight communication. The most common example of line-of-sight communication is the TV Telecast. Ham radio operators use VHF frequencies in the range of 144-148 MHz (as well as 50 MHz in some countries) for line of sight communication.

A TV transmission tower is made as tall as possible so that its signals can have a wide area of coverage. To receive a TV telecast, we have to turn our TV antenna (known as a Yogi antenna) towards the TV transmission tower. In areas where the TV transmission tower is located at a far away place from a viewer, the viewer has to increase the height of this TV receiving antenna. This means that both the transmitting and receiving antenna should literally see each other to make the communication effective. Otherwise there should be some means to redirect the signal back to the receiver. Artificial Satellites in space (which houses active electronic relaying device). terrestrial relay station and passive reflectors,, (the metallic plates we see above the hills) are employed to extend the VHF coverage. Line-of-sight communication is considered reliable within a short distance (or even for long distance communication if artificial communication satellites are employed), because instead of relaying on the ionosphere (whose propagation conditions are not under human control), relay stations (known as repeater station) can be set up on tall towers. The relay station can cover a certain area most reliably round the clock. Different services employing VHF for communication also have their own repeater station.



A passive reflector

Another advantage of VHF is that the size of the VHF equipment is very small (because of its low power as well as miniaturization in the circuit design). A VHF communication set is also popularly known as a Walkie-Talkie. We are certain that the above description is sufficient to clear any doubt about the range of a Walkie-Talkie !

What are the two phenomena significant in line-of-sight reception?

In case of line-of-sight reception, sometimes there may be **two components** of the signal. One is the **direct signal** and other may be **the signal reflected from the ionosphere** (e.g. in case of a 50 MHz signal, which rarely gets reflected by the ionosphere). Both the signals leave the antenna with the same signal phase, but travel different paths to the receiving antenna. These paths may be of different length. Because the reflected signal **suffers 180 degree phase reversal** at the point of reflection, the two signals may **aid or oppose** each other in the receiving antenna. The resultant signal may be stronger or weaker than the direct path signal alone, which is not desirable.

The problem arising out of the undesirable phase reversal phenomenon can be overcome by varying the height of the antenna.

What is the temperature inversion phenomenon as applicable to the line-of-sight communication?

The line-of-sight propagation is limited to the optical horizon and it is only about 75 km for frequencies above 30 MHz; but it is found that in the spring, or sometimes in summer, this line-of-sight propagation extends to about 500 kms. This is due to the presence of layer of hot, dry air above a layer of cool, moist air. The direct waves are bend back which otherwise pass over the receiving antenna.

What is 'Grey line' propagation as applicable to line-of-sight communication?

It has been observed that around sunspot maximum years at about 11-years intervals, the daytime F_2 layer, roughly 250-400 kms above the surface of the Earth, can often open long distance paths of frequencies up to and beyond **50 MHz.** In periods of low sunspot activity very few long-distance paths are open above 25 MHz. Radio amateurs, whose transmitters are so much less powerful than those used for broadcasting, have come to recognise the importance of what is called '**grey line**' propagation. This takes the form of reliable but brief long-distance paths that open between places where the times of dawn and dusk, dawn and dawn or dusk and dusk roughly coincide, giving rise to the possibility of extended 'one-hop' propagation due to layer entrapment brought about by tilts in the F-layer, as the lower F_1 and higher F_2 layers combine or separate.

What is a critical frequency?

The whole spectrum of radio frequencies suffer various degrees of refraction by the ionosphere. Waves which are very slightly refracted can not return back to the Earth and if not having adequate power, get absorbed into the ionosphere. Those having sufficient power can penetrate the ionosphere depending upon the degree of refraction.

The amount of refraction is inversely proportional to the frequency of the wave. Obviously, **lower the frequency, greater is the refraction and higher the frequency, lower is the refraction.** Though a greater refraction should cause the frequency to be returned back to Earth, it does not happen always. During day time, the D layer (It is the lowest region of the ionosphere at a height of about 50 to 90 km. It is not strictly a layer but a relatively dense part of the atmosphere were atoms are broken up into ions by sunlight that recombine very quickly) absorbs most of these waves prohibiting their entry into the E and F layers and hence does not get reflected. **If the frequency of a wave transmitted directly upward is steadily increased, a point would be reached where the wave would pass right through the ionosphere. The frequency at which this occurs is called the *critical frequency.*** All frequencies higher than this will not be returned to Earth.

What is a beacon?

The beacon is nothing but a radio signal, usually in coded form transmitted from a particular station to identify itself. The usefulness of the beacons is that they provide indication of propagation conditions between any two locations worldwide. They also act as in-band frequency reference for wireless experiments experimenting with transmitters. They also provide reliable checking facility for beam antennae.

What are differences between fade-out and fading?

Fade-out

It is the gradual phenomenon, that take place with the change of time of the day. Fadeout of radio signal is related to the ionization gradient of the ionosphere, which decreases in absence of sunlight. Since ionization is intense during day light hours, higher frequencies of the short wave spectrum can be used during daylight hours. As the night approaches, signal strength at that higher frequency decreases. Using a frequency at the lower edge of the HF spectrum will yield satisfactory result against this fadeout.

Fading

As district from fade-out, fading is the constant variation of the received strength of radio wave. To the listener it appears as gradual rising and falling of the volume. The signal waxes and wanes and at times even drops below usable values. This phenomenon is manifested chiefly in long-distance transmission. It is caused by multiple reflections from the ionosphere which cause two or more waves from the same transmitter travel over different paths of different lengths and hence differ in phase and amplitude when they arrive at the receiving aerial.

Aerials

A General Note on Aerials

Aerial or antenna is a device, which acts as the mouth and ear of a radio transmitter or receiver respectively. Though we don't notice any external aerial in many of the commercial radio sets, they in fact, have aerials in built within the cabinets holding their electronic circuitry. But a ham radio operator is mainly concerned with an external outdoor antenna without which he can't expect to radiate radio energy into space from his radio transmitter. Similarly, without an external outdoor antenna, his radio receiver will not be able to pick up the radio waves speeding across the sky. A radio receiver might not need an external outdoor aerial to receive high power radio transmissions. But most of the ham radio transmitters use considerably low power (compared to the broadcast radio stations) which necessitates the use of outdoor aerials. A low power transmitter with an efficient antennae system or a less sensitive receiver with efficient antennae system can be made to work beyond imagination!

The aerials are usually made out of metallic rods or wires which are cut into specific lengths. The aerial should not be placed behind any obstruction, conducting materials such as tin-roof, ferro-concrete and to lesser extent foliage when wet. The aerial should be as high as practical above the ground and grounded objects such as metal roofs, power or telephone wires etc.

Different types of antenna system use by ham radio operators :

(1) Horizontal Dipole,

(2) Inverted - V dipole,

(3) Yagi beam,

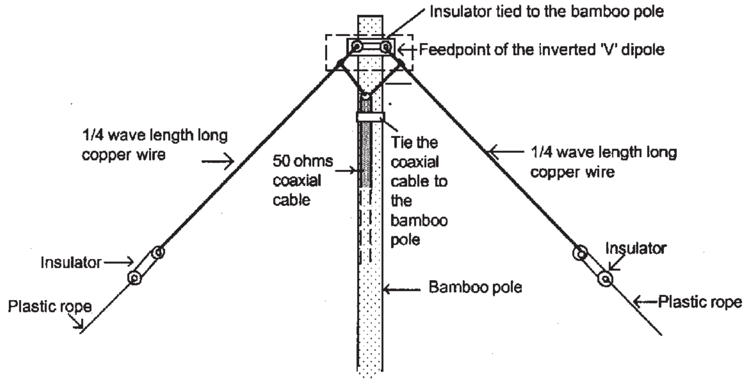
(4) Ground plan vertical,

(5) Cubical quad.

Horizontal dipole is a very popular antenna, which is also easier to construct and erect. Two supporting structures (e.g. two bamboo poles) are required to erect a simple horizontal dipole antenna, whereas an inverted 'V' dipole antenna requires only a single pole further simplifying the erection method. This single pole at the same time supports the feed-point of the dipole. A horizontal dipole antenna is directional in nature, but given an inverted shape (e.g. an inverted 'V' antenna), it becomes omni-directional. However, the ends of the inverted 'V' dipole should not come too close to lossy ground. The input impedance of this antenna with apex height of half wavelength long and apex angle of 127º is 50 Ohms (RG11 coaxial cable).

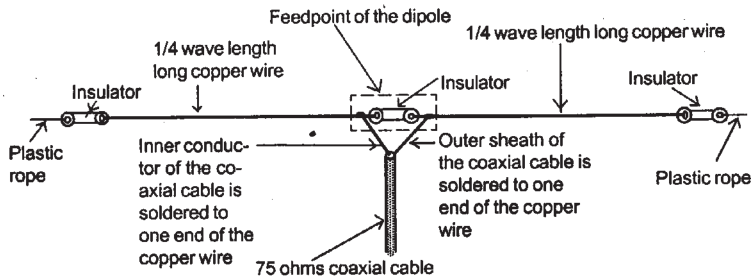
Working function of a horizontal dipole antenna

A horizontal dipole antenna is a resonant antenna, which is half-wavelength long. Resonant circuits are well-known in radio engineering as combination of coils and capacitors, which cause a signal gain at certain frequencies. The same is applied to a half-wave dipole antenna.



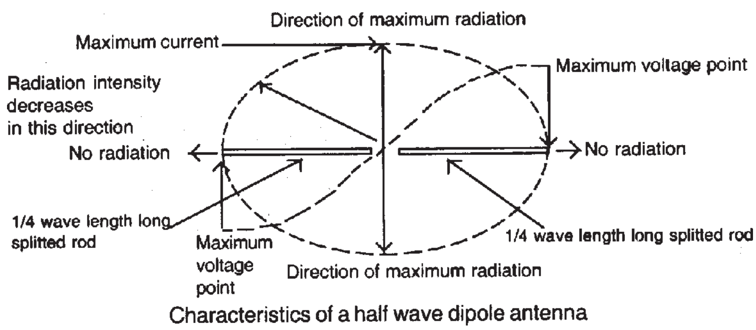
An inverted 'V' dipole antenna

It consists of two straight wire or rod sections, each $^1/_4$ wave long and positioned in one line (collinear). The antenna is fed in the centre by a coaxial cable having a characteristics impedance of 50 Ohms or 75 Ohms.



A practical dipole antenna

The maximum radiation direction is perpendicular to the axis from the middle point. The cause of directional radiation by a resonant ½ wave dipole antenna is that the radiation intensity is proportional to the square of the current in the antenna, and in the dipole current is maximum at the middle; hence the maximum radiation line passes through the middle of the antenna perpendicularly.



Characteristics of a half wave dipole antenna

Why half-wave dipoles are fed at the centre?

Most half-wave dipoles are fed at the centre, because in a half-wave resonant dipole, maximum current point is at the centre of the antenna and this is the minimum voltage point. It is easier to construct transmission lines for low voltage than for high voltage.

The other reason is that in a ½ wave dipole, the capacitive reactance and inductive reactance cancel each other (the antenna being resonant), leaving resistance only as net impedance. Under this condition, the antenna impedance is the resistance between any two points equidistant from the centre along the antenna length making it easier to match the transmission line impedance with the antenna impedance.

What is VSWR (Voltage Standing Wave Ratio)?

When the transmission line does not match the load impedance (antenna impedance), maximum transference of energy to the antenna is not possible. The energy fed down the line is transferred to the antenna only partially; in fact, some is reflected back, forming standing waves on the line. Every half-wave along the line, high-E (Voltage) and Low-I (Current) points appear. Halfway between these two points will be Low-E and High-I points.

The ratio of voltage across the transmission line at the high-E point to that at Low-E points is called the VSWR.

$VSWR = E_{max} / E_{min}$

Or,

$SWR = I_{max} / I_{min}$

The SWR is also equal to the ratio of the characteristic impedance of the transmission line to the impedance of the antenna (load), or vice versa. For example, if the line has a characteristic impedance of 300 ohms and antenna impedance is 50 ohms, the SWR is 300/50, or 6. A higher SWR indicates a greater mismatch between the transmission line and the antenna.

When the load (antenna) impedance matches the transmission line impedance, there will be no standing waves.

SWR = 1:1 or 1

VSWR is greater than one for a mismatched system and equal to one for a perfectly matched system.

VSWR on a transmission line is caused by power being reflected back to the transmitter from the antenna. If P_F is the forward power and P_R is the reflected power measured in watts by a directional wattmeter, then VSWR can also be calculated by the formula:

$$VSWR = \frac{1 + \sqrt{P_F / P_R}}{1 - \sqrt{P_F / P_R}}$$

What is 'radiation resistance'?

When an antenna is excited into oscillation by a RF source, it radiates energy into space acting as a source of power. The antenna, which is the source of power must have an internal resistance or impedance.

We have; Power, **$P = I^2R$,**

Where I = current, R = resistance

Or, **$R = {}^{P}/_{I^2}$**

So in case of the antenna, radiation resistance is the **ratio of the radiated power to the square of the centre current in the antenna.**

Radiation resistance is also defined as a **fictitious resistance,** which when substituted for the antenna would consume as much power as the antenna radiates.

Radiation resistance is also called '**Feed-point**' **impedance;** in case of a dipole antenna feed point impedance is nearly 73 Ohms.

Why impedance matching is necessary in an antenna and transmission line system?

Impedance matching is of utmost importance so far as energy transference from the transmitter to the antenna through the transmission line is concerned; because, mismatching will prevent maximum output being radiated. I.e. if the transmission line impedance doesn't match the antenna feed-point impedance, a part of the energy fed down the line will be reflected back from the antenna causing standing waves on the line; it makes the system inefficient.

Mismatching a transmission line to an antenna results in the line at the transmitter end appearing to have either inductive reactance (X_i) or capacitive reactance (X_c), which will detune the inductance-capacitance (LC) circuit to which it is coupled; mismatching should be avoided so that final stage of the RF amplifier is not detuned.

In many of the commercial wireless equipment, mismatching should be strictly avoided to prevent damage of the circuitry.

What is a current fed antenna?

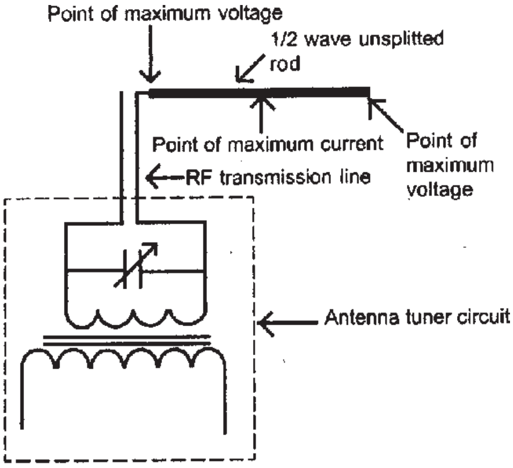
There are many methods of feeding energy to an antenna. The antenna is said to be current fed when excitation energy from the RF-generator is introduced to the antenna at the point of high circulating currents. The example **a ½ wave dipole antenna.** In this case, the ½ wave antenna is cut in two parts at the midpoint and energy is fed by co-axial transmission line.

In a dipole antenna maximum current flows through the middle point, hence it is current fed antenna with a characteristic feed point impedance of about 73 ohms, which is considerably small as compared to end point impedance of the antenna. Midpoint is the low-voltage point.

What is a voltage fed antenna?

When the excitation energy from the RF source is introduced at the point of maximum voltage, the antenna is said to be voltage fed antenna. The example is the ½ wave unsplitted antenna excited by a resonant R-F line. Voltage changes at this point excite the antenna into oscillation. The impedance at the end of the antenna is high or it is the high impedance point.

Any multiple of a ½ wave resonant antenna may be end-fed by using a tuned feeder system leaving one end of the feed-line unconnected. This antenna is also called Zepp (used earlier on Zeppelins) antenna.



Voltage fed dipole antenna

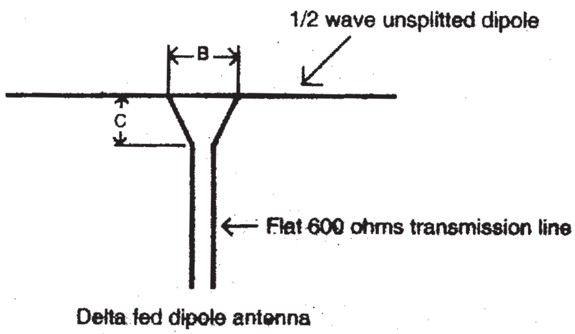
Different types of antenna system impedance matching procedure

(a) Using the **proper transmission line** for each particular antenna is a way of achieving impedance matching. For example, a ½ wave horizontal dipole has a midpoint impedance of 73 ohms, so coaxial cable transmission line which has a characteristic impedance of 75 ohms (e.g. RG8) is used to feed the R-F energy into the antenna.

(b) **Delta match :** This type of matching procedure is used with an unsplitted ½ wave dipole antenna; the dipole being resonant, its capacitive reactance (X_c) and inductive reactance (X_L) cancel each other, leaving resistance only as net impedance. Under this condition, the antenna impedance is the resistance between any two points equidistant from the centre and thus transmission lines having characteristic impedance of 300 to 600 ohms be used by getting two points of the antenna to feed where it offers a feed point impedance equal to transmission line impedance.

To do so, it is essential to spread out the feeders at the antenna end.

The formula used to make this type of matching are:

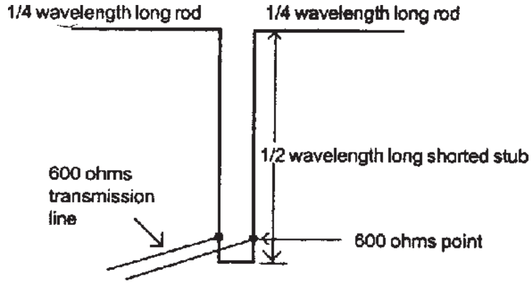


Delta fed dipole antenna

B = (0.25 x Wavelength)/2 ; where B is the distance between the two feed point which will offer 600 ohms impedance.

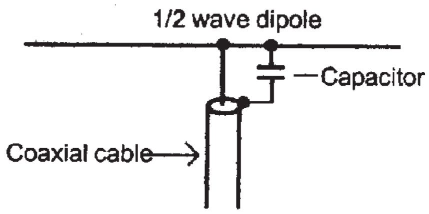
And C = (0.32 x wavelength)/2, where C is the vertical distance upto which spreader should be spread (the inclination).

(c) **Stub Match :** A shorted stub of ½ wave length or open stub of ¼ wave can be connected to the splitted dipole. Here the low midpoint impedance of 73 ohms of the dipole is repeated at the close end of the stub; but there are certain points on the stub which would offer as high as 600 ohms impedance yet matching with 73 ohms feed point.



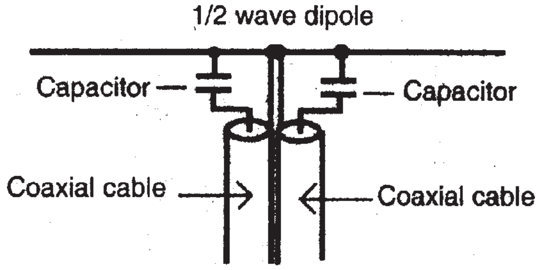
Half wave shorted stub

(d) **Gamma Match :** Here outer sheath of the 75 ohms coaxial cable is connected to the middle point of the unsplitted dipole, while the inner conductor is connected to a point through a capacitor to cancel inductive reactance, so that antenna impedance at feed point is 75 ohms. Gamma match is slightly unbalanced.



Gamma match

(e) **T-Match :** In this type of impedance matching, two coaxial cables are held side by side and both their outer sheaths are connected to the midpoint of the unsplitted dipole, while two points are chosen on the dipole where inner conductors going parallel to each other (of the coaxial) are connected.



T match

(f) **¼ wave transmission line impedance matching device :** A ¼ wave line can act as an impedance matching device between high and low impedance circuits if it has the proper intermediate impedance found from the formula : $Z = \sqrt{Z_1 \cdot Z_2}$

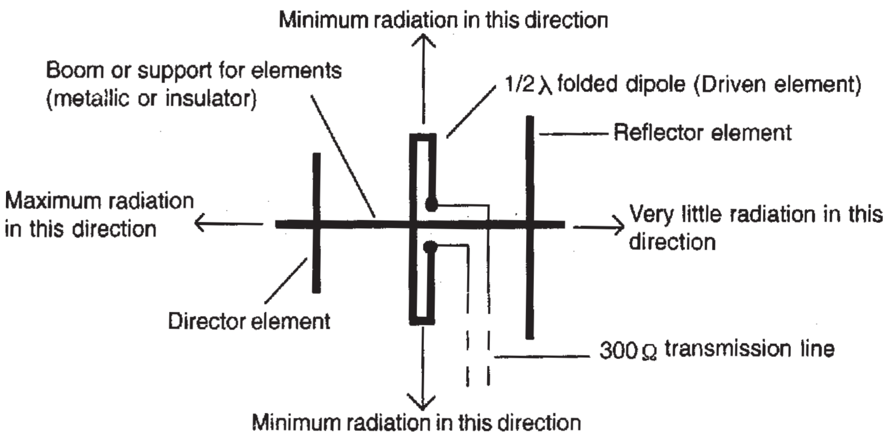
Where Z_1 = antenna feedpoint impedance; Z_2 main transmission line impedance. When we want to match a 300 ohms transmission line to a 70 ohms feed point impedance dipole antenna, then the ¼ wave transmission line connected between both the system should have

$Z = \sqrt{300 \times 70} = 145$ ohms.

What is a Yagi antenna?

When a half wave dipole antenna consists of one or more parasitic arrays, the antenna becomes parasitic beam antenna, named as "Yagi" after its designer Proff. Yagi, Japan.

The antenna consists of mainly three elements, the **½ wave splitted dipole driven element (either folded or straight),** in front of this driven element is the 5% shorter **director element,** back of the driven element is the 5% longer **reflector.** All the elements can be assembled on a **Single conducting boom.** This antenna beams radio signals in the direction of the director and theoretically no signals to the backward direction. Yagi antenna is most commonly used for very high frequency (VHF) work. Because of shorter wavelengths, it is easier to construct a Yagi antenna for VHF work than the HF work, Instead of using a folded dipole (the driven element), as shown below in the diagram, the driven element can be kept unfolded (straight). In that case, the feed-point impedance of the antenna would be around 75 Ω .



A 3 element Yagi beam antenna

AMPLIFIERS

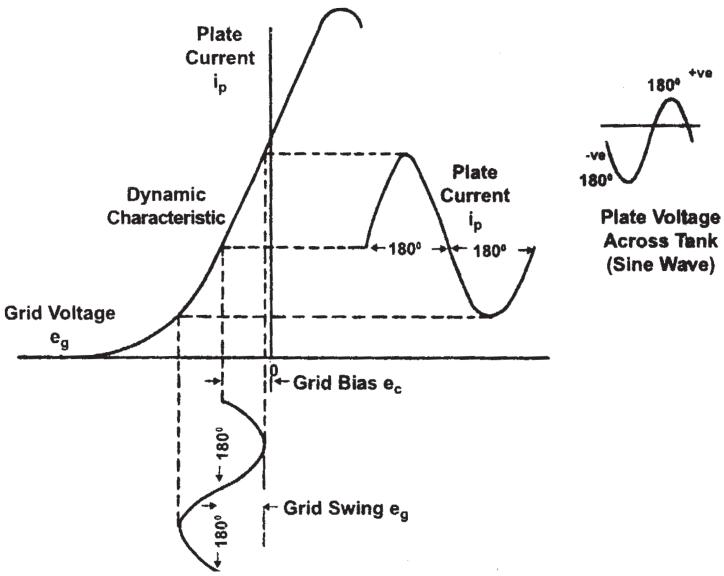
A device which amplifies weak signals to strong signals is called an amplifier

Classification of amplifiers

Power amplifiers use special valves or transistors capable of large output current values and able to dissipate power at anode through special arrangement.

Class 'A' Amplifier :

Class 'A' amplifiers are those in which the grid bas and plate voltage are so chosen that the tube operates over the linear portion of dynamic curve or it is an amplifier in which plate current flows over the entire cycle.



Characteristics :

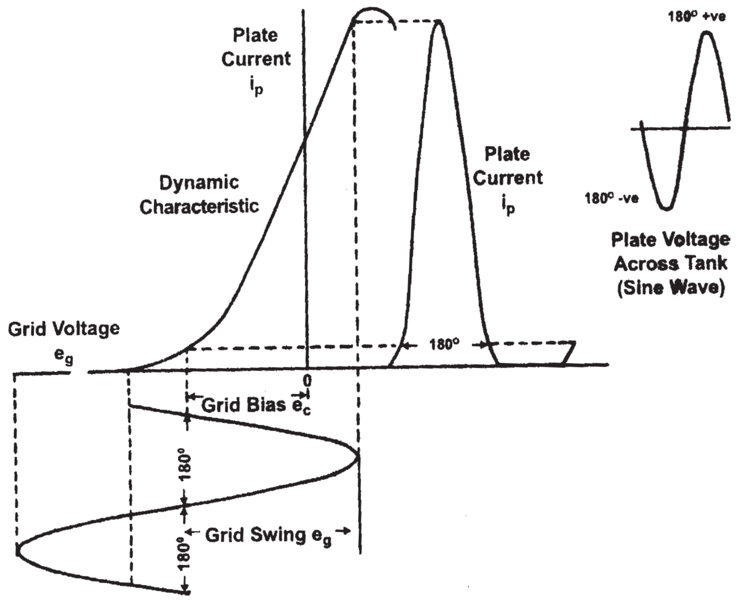
1. Since the tube operates over the linear portion of the dynamic curve, hence the waveform at the output is exactly similar to that of input. Therefore they are used where freedom from distortion is the main factor.
2. It has high voltage amplification and very small distortion.
3. In practice the power output is small because both current and voltage are restricted to comparatively small variations.

Class 'B' Amplifier :

These amplifiers are biased to cut-off or approximately so, hence plate current flows during positive half cycle of the input voltage.

Characteristics :

1. Since negative half cycles are totally absent in the output, the distortion is high as compared to that in class 'A' amplifiers.
2. Since voltage required in the input is large, voltage amplification is reduced.
3. The plate efficiency is 50% This is due to the reason that plate current flows only when signal is applied.
4. For a given tube rating, the power output is relatively high.

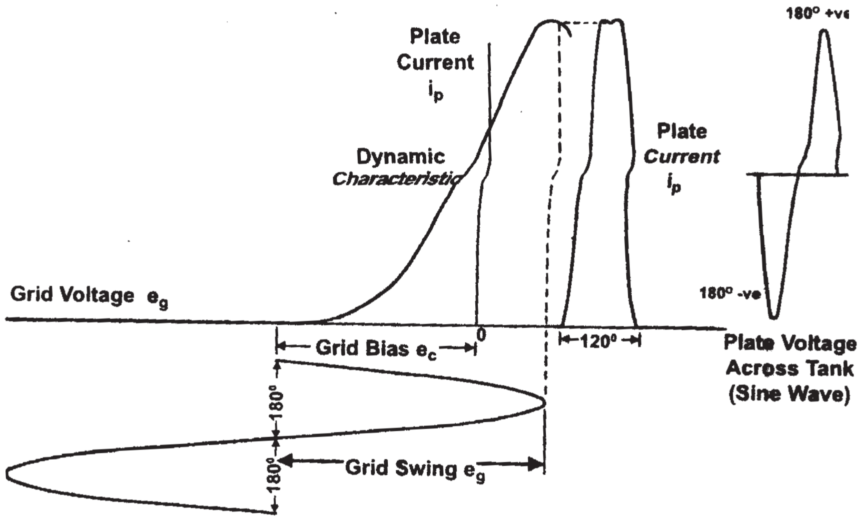


Class 'AB' Amplifier :

The grid bias and signal voltages are so adjusted that the plate current flows for more that half and less than entire cycle. The characteristic of this amplifier lie in between those of class 'A' and class 'B' amplifiers.

Class 'C' Amplifier :

In these type of amplifiers the tube is biased beyond cut off point, the grid bias is as much as twice the cut off value. Hence the plate current flows in pulses of less than one half cycle.



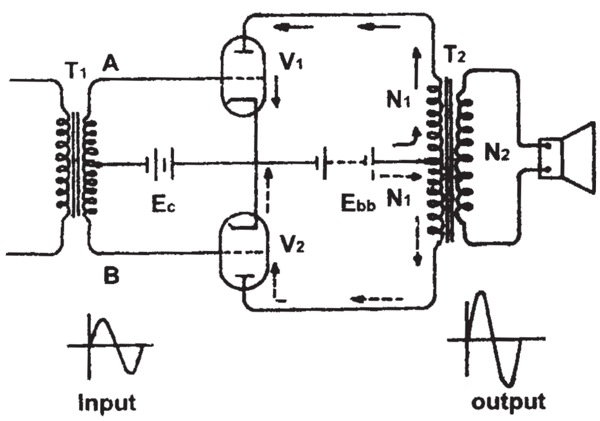
Charateristics:

1. Since the grid may be driven to the plate saturation value of grid voltage, so plate pulses beat no resemblance to the input waveform. Hence distortion is exceedingly high.
2. Since input signal used is vary large, the voltage amplification is very law.
3. Power output per tube is higher as compared to class 'B' Amplifier.
4. Plate efficiency is as high as 85% to 90%. This is due to the fact that the plate current flows only when the grid is driven positive.

   These amplifiers are not used as audio frequency amplifiers because of high distortion. But they are used as radio frequency amplifiers for high power output.

Push Pull Amplifier :

In order to increase te deficiency in power amplification two triode tubes are used in push pull arrangements in the output stage. One tube amplifies the +ve half ccle of the signal while the other tube amplifies –ve half cycle of the signal.



Push pull arrangement :

When one tube is pushing (conduction.), the other is pulling (stoping conduction.)

Circuit details :

Below figure shows the circuit where two tubes V1 and V2 are used in push pull. Both the tubes are operated in class B operation i.e. plate current is nearly zero in the absence of the signal. The centre tapped secondary of the input transformer T1 supplies equal and opposite voltage to the grid circuit of the two tubes. The output transformer T2 has centre tapped primary. The output is taken across the secondary of output of transformer T2.

Operation :

During the +ve half cycle f the signal, the end A of the input transformer is +ve and end B is –ve. This will make the grid of valve V1 more +ve and that of valve V2 more

–ve. This does not means that grid will actually become +ve. It cannot happen becase the DC grid bas keeps both grids at a –ve potential. Thus valve V1 conducts and valve V2 cut off. Therefore, this half cycle of the signal is amplifies by valve V1 and appears in upper half of the output transformer primary. In the next half cycle of the signal, valve V2 conducts and valve V1 is cut off. Therefore this half cycle of the signal is amplifies by valve V2 and appears in the lower half of the output transformer primary. The plate current flow on alternate half cycle of the signal through the center tapped primary of the output transformer and since they are in opposite direction, the effect is the same as a normal sine wave AC. This induces voltage in the secondary of the output transformer.

Advantages :

(i) Its efficiency is high (About 80%)

(ii) For the same plate dissipation, the output power is nearly 5 times of a single tube amplifier. Ex : Public address system.

Distortion in Amplifiers :

The output of an amplifier is said to be distorted. If the output waveforms of the output voltage and currents etc different from that of input.

(i) Non linear Harmonic Distortion :

Due to the nonlinerarity of the dynamic characteristics, the output current and voltage waves, in addition to the fundamental wave of input signal frequency, contain harmonic components, the number and magnitude of which depends on the amplitude of input signal.

(ii) Frequency Distortion :

It is produced due to the unequal amplification of the different component frequencies present in the given signal. In the case of audio signals, frequency distortion leads toa change in quality of sound.

(iii) Phase Distortion :

It is said to take place when the phase angles between the component waves of the output are not the same as the corresponding angles of the input. The changes in phase angles are due to the presence of reactive elements in the tube (grid – cathode capacitance)

The hyman ear is unable to distinguish the phase difference and is thus not sensitive to the distortion. Hence phase distortion is of no practical significance in audio amplifiers.

Annexure-1

Monitoring Stations in INDIA

Correspondence to be addressed to
Officer-in-charge, Wireless Monitoring Station,
Ministry of Communication & Information Technology, Government of India

1. Opp. Jagatpark Society, Ghatlodia,
   Ahmedabad-380052
   Tel :2760 3444 FAX: 26923890
2. Kotra, Pushkar Road,
   Ajmer-305001.
   Tel : 600641 FAX: 600593
3. 18, Padmanabha Nagar,
   Bangalore-560 070
   Tel : 2669 0102 FAX: 26790300
4. Gorai Road, Borivli(West),
   Mumbai-400 092
   Tel :28671626 FAX: 28650244
5. 66-A, Sec-B, Shahpura
   Bhopal-462003
   Tel : 2464653 FAX: 433930
6. Village-Gopalpur ,
   PO Sarkarpool, 24-Parganas,
   Kollkota-743352
   Tel.24012960 FAX: 2401 9407
7. Lasha Villa, Near Shiv Mandir,
   515/3/1, III rd Floor, Hill Cart Road,
   Darjeeling-734 111
   Tel 252383 FAX: 257100
8. Girdharilal Sardarmalls Bldg,
   Mancotta Road, **Dibrugarh**-786 001
   Tel. 2325238, 232 6887.
9. Sylvia Road, Chogm Sangolda Rd.,
   PO Alto Porvorim, **GOA**-403 112
   Tel. 2417245 FAX: 2410280
10. Gurauli Bujurg
    P.O. Chappia ,**Gorakhpu**r-273 016
    Tel. 2321709 FAX: 2323481
11. IIIrd Floor Room No. 302,
    Telecom Engineering Centre ,
    Cherlapally, **Hyderabad**-500380
    Tel 27794504 FAX: 27794530
12. Main Garhi Road, Hardyal Nagar
    (Nr. Brahma Kumari Ashram)
    Jalandhar City -144022.
    Tel 225210 FAX: 232544
13. Perungudi, Kandanchavadi,
    Near FACIT ASIA LTD.,
    Chennai-600096
    Tel 24960275 FAX: 24963083
14. Fathima Mansion, III rd Floor ,
    P.O. Pijai, **Mangalore**-575004
    Tel 2493960 FAX: 2494249
15. Chindwara Road, PO Koradi T.P.S.,
    Nagpur-441111
    Tel.2612114 FAX: 2612040
16. Ghitorni, PO Mehrauli,
    New Delhi-110 030
    Tel: 26502658 FAX: 26502380
17. P.O.Harmoo Housing Colony,
    Ranchi-834012
    Tel.2243023 FAX: 2241433
18. Lapalang Rynjah, **Shillong**-793006
    Tel 537613 FAX:233727
19. Palora Top, Behind BSF Camp,
    Jammu-181124
    Tel: 2597167 fax: 2433557
20. Kachani Post Office, Nettayam,
    Trivandrum-695013
    Tel: 273202 FAX: 2374533
21. Door No. 39-27-41, Madhavadhara,
    VUDA Colony, Marribalem P.O.
    Visakhapatnam-530018
    Tel: 2539365 FAX: 2542402

Schedule of Examinations Of The Ministry Of Communications Located.

SR. No.	Place	Month of examination
1	Delhi,Mumbai,Calcutta and Chennai	Every month
2	Ahmedabad, Hyderabad and Nagpur	January, March, June, August, October & December
3	Ajmer, Bangalore, Darjeeling, Gorakhpur,	January, April, July and October
4	Jalandhar, Goa, Mangalore, Shillong, Ranchi, Srinagar and such other places where a	monitoring station of the Monitoring Organizations

Annexure-2

Frequency bands–emission–power table

Authorised Frequency Bands, Power and Emission

(rule 13 Indian Wireless Telegraphs (Amateur Service)Amendment rules, 2003.)

Category of Licence	Frequency Bands	Emission	Max D.C.input power
Restricted Amateur Wireless Telegraph Station Licence see note (v) below	144-146 Mhz 434-438 Mhz @	A3E, H3E, J3E, R3E , F3E	10 Watts (Terrestrial Service only authorized)
Amateur Wireless Telegraph Station Licence Grade II See Note (vi)	1820-1860 * Khz 3500-3700 * Khz 3890-3900 Khz 7000-7100 Khz 14000-14350 Khz 18068-18168 Khz& 21000-21450 Khz 24890-24990 Khz& 28000-29700 Khz	A1A ,A3E H3E,J3E,R3E	50 Watts
	144-146 Mhz 434-438 Mhz@	A1A ,A2A,A3E H3E,J3E,R3E F1B, F2B, F3E	10 Watts (Terrestrial Service only authorized)
Amateur Wireless Telegraph Station Licence Grade I	1820-1860 * Khz 3500-3700 * Khz 3890-3900 Khz 7000-7100 Khz 14000-14350 Khz 18068-18168 Khz& 21000-21450 Khz 24890-24990 Khz& 28000-29700 Khz	A1A ,A2A,A3E H3E,J3E,R3E F1B, F2A, F3E, F3C, A3C, A3F	150 Watts
	144-146 Mhz 434-438 Mhz@ 1260-1300 Khz @# 3300 – 3400 Khz@ 5725-5840 @	A1A ,A2A,A3E H3E,J3E,R3E F1B, F2B, F3E	25 watts for terrestrial service, Amateur Satellite Service is permitted in the appropriate subbands in accordance with Radio Regulations and in those cases the maximum output RF power (e.i.r.p)is 30 dbw
Amateur Wireless Telegraph Station Advanced Grade See note (i) below	1820-1860 * Khz 3500-3700 * Khz 3890-3900 Khz 7000-7100 Khz 14000-14350 Khz 18068-18168 Khz& 21000-21450 Khz 24890-24990 Khz& 28000-29700 Khz	A1A ,A2A,A3E H3E,J3E,R3E F1B, F2B, F3E, F3C, A3C, A3F	150 Watts
	144-146 Mhz 434-438 Mhz@ 1260-1300 Khz @# 3300 – 3400 Khz@ 5725-5840 @	A1A ,A2A,A3E H3E,J3E,R3E F1B, F2B, F3E	50 Watts for the band 144-146 Mhz and 25 watts for terrestrial service, Amateur Satellite Service is permitted in the appropriate subbands in accordance with Radio Regulations and in those cases the maximum out RF power (e.i.r.p.)is 30 dbw

* On primary shared basis as per the relevant provisions of radio regulations.

& the authorization is on non-interference and non-protection basis.

@ On secondary basis as per the relevant provisions of radio regulations.

\# 1260-1270 Mhz for Earth to Space Satellite service only. The above authorization is subject to site clearance as per the procedure prescribed by the Standing Advisory Committee on Radio Frequency Allocation (SACFA) as applicable.

Note: (i) Following sub-bands of frequencies are authorized with enhanced RF power to holder of Advanced Amateur Telegraph Station Licence.

3520	-	3540	*Khz	All emissions as authorized	400 watts
7050	–	7100	Khz		
14220	-	14320	Khz		
3890	–	3900	Khz		
14050	-	14150	Khz		
21100	–	21400	Khz		

II. For A3F emission, the transmission shall be restricted to call sign of the station, location and other particulars of the amateur station. They shall be limited to point to point test transmission employing a standard interlace and scanning with a bandwidth not more than 4 Khz.

III. DC input power is the total direct current power input to the final stage of the transmitter.

IV. In case of Short Wave Listeners Amateur Licence, the holders are permitted to listen to all the bands authorized to amateur service.

V. The syllabus for the examination of the 'Restricted Amateur Wireless Station Licence' shall be as per Part I of 'Amateur Station Operators II' examination.

VI. The holder of 'Amateur Wireless Telegraph Station Licence, Grade II' shall be entitled for authorization of radio telephony emission below 30 MHz on his providing proof of having made 100 contacts with other amateurs using the morse code.

Frequency and Wavelength Band

The radio spectrum shall be subdivided into nine frequency bands, which shall be designated by progressive whole numbers in accordance with the following table. As the unit of frequency is the hertz (Hz), frequencies shall be expressed :

In kilohertz (kHz), upto and including 3000 kHz;

In megahertz (MHz), above 3MHz, up to and including 3000 Mhz;

In gigahertz (GHz) above 3 GHz, up to and including 3000 Mhz;

For bands above 3000 GHz i.e. centimilimetric waves, micrometric waves and decimicrometric waves, it would be appropriate to use tetrahertz(THz)

Band Number	Symbols	Frequency Range (lower limit exclusive, upper limit inclusive)	Corresponding Metric Subdivision	Metric Abbreviations for the bands)
4	VLF	3 to 30 KHz	Myriametric waves	B.Mam
5	LF	30 to 300 KHz	Kilometric waves	B.Km.
6	MF	300 to 3000 Khz	Hectometric waves	B.hm.
7	HF	3 to 30 MHz	Decametric waves	B.dam
8	VHF	30 to 300 MHz	Metric waves	B.m
9	UHF	300 to 3000 MHz	Decimetric waves	B.dm.
10	SHF	3 to 30 GHz	Centimetric waves	B.cm.
11	EHF	30 to 300 GHz	Millimetric waves	B.mm.
		300 to 3000 GHz	Decimillimetric waves	

Annexure - III

Call-Sign Prefixes of Amateur Radio Stations of different Countries allotted by the Internal Telecommunication Union (ITU)

Prefix	Country	CQ Zone
1AO	Sovereign Military Order of Malta	15
1S	Spartly Is.	36
1X	Chechnya (erstwhile USSR)	
2A-2Z	United Kingdom	14
3A	Monaco	14
3B6, 7	Agalega & St. Brandon	39
3B8	Mauritius	39
3B9	Rodriguez Is.	39
3C	Equatorial Guinea	36
3C0	Annobon	36
3D2	Fiji, Conway Reef, Rotuma IS	32
3DA	Swaziland	38
3DN	Fiji	32
3K3	European Islands between 30 Deg. E-long. To 170 Deg. W. long	
3V	Tunisia	33
3W, XV	Vietnam	26
3X	Guinea	35
3Y	Peter IS.	38
3Y	Bouvet	12
3Z	Poland	15
4F	Philippines	27
4JA-4JZ, 4KA-4KZ	Azerbaidjan	21
4J1, R1MV	Malyj Vysotskij Island	16
4K0	Drifting Ice Station (Russian Polar Stations)	
4K1	Antarctica (Russian Polar Stations)	
4K4	Asian Islands between 65 Deg E long. T 170 Deg. W long	
4K2	Franz Josef Land (Russian Polar Stations)	40
4LA - 4LZ	Georgia	21
4P - 4S	Sri Lanka	22
4U	ITU Geneva	14
4U	United Nations Headquarters	05

Prefix	Country	CQ Zone
4X, 4Z	Isreal	20
5A	Libya	34
5B, P3, H2	Cyprus	20
5H, 5I	Tanzania	37
5N, 5O	Nigeria	35
5R, 5S	Madagascar	39
5T	Mauritania	35
5U	Niger	35
5V	Togo	35
5W	Waestern Sarnova	32
5X	Uganda	37
5Y, 5Z	Kenya	37
6O	Somalia	37
6V, 6W	Senegal	35
6Y	Jamaica	08
7U-7N	Japan	25
7O	Yemen	21, 37
7P	Lesotho	38
7Q	Malawi	37
7S	Sweden	14
7T-7Y	Algeria	33
7Z	Saudi Arabia	21
8J	Japan	25
8P	Barbados	08
8Q	Maldive IS	22
8R	Guyana	09
8S	Sweden	14
8Z	Saudi Arabia	21
9A	Croatia	15
9G	Ghana	35
9H	Malta	15
9I, 9J	Zambia	36
9K	Kuwait	21
9L	Sierra Leone	35
9M2, 4	West Malasiya	28
9M6, 8	East Malaysia	28

Prefix	Country	CQ Zone
9N	Nepal	22
90-9T	Zaire	36
9U	Burundi	36
9V	Singapore	28
9X	Rwanda	36
9Y, 9Z	Trinidad and Tobago	09
A2	Botswana	38
A3	Tonga	32
A4	Oman	21
A5	Bhutan	22
A6	United Arab Emirates	21
A7	Qatar	21
A8	Liberia	35
A9	Bahrain	21
AA-AL	USA	3, 4, 5
AT-AO	Spain	14
AT-AW	India	22
AP-AS	Pakistan	21
BS7	Scarborough Reef	27
BM, BO, BU, BV	Taiwan	24
BA, BD, BG, BT, BY	China	23, 34
C2	Nauru	31
C3	Andorra	14
C5	Gambia	35
C6	Bahamas	08
C8-C9	Mozambique	37
CA-CE	Chile	12
CEO	Easter Island, San Felix and San Ambrosia, Juan Femandez Island	12
CE9	Antarctica	
CF-CK	Canada	1-5
CM, CO	Cuba	08
CN	Morocco	33
CP	Bolivia	10
CT	Portugal	14
CT3	Madeira IS.	141

Prefix	Country	CQ Zone
CU	Azores	33
CV-CX	Uruguay	13
CY9	St. Paul Island	05
CY0‘	Sable Island	05
D2-3	Angola	36
D4	Cape verde	35
D5	Liberia	35
D6	Comoros	39
DA-DM	German	14
DU-DZ	Philippines	27
E2	Thailand	26
E3	Eritrea	37
E4	Palestine	
EA-EH	Spain	14
EA6-EH6	Balearic IS.	14
EAB-EHB	Canary Is.	33
EA9-EH9	Ceuta and Melilla	33
EI-EJ	Ireland	14
EK	Armenia	21
EL	Liberia	35
EP-EQ	Iran	21
ER	Maldova	16
ES	Estonia	15
ET	Ethiopia	37
EU, EV, EW	Byelorussia	16
EX	Kyrgyzstan	17
EY	Tajikistan	17
EZ	Turkmenistan	17
F, TM, TO-TQ	France	14
FG	Guadeloupe	08
FH	Mayotte	39
FJ, FS	Saint Martin	08
FK	New Catedonia	32
FM	Martinique	08
FO	Clipperton IS.	07
FO	French Polynesia	32

Prefix	Country	CQ Zone
FP	St. Pierre * Miquelon IS	05
FR, FG	Glorioso IS	39
FR, FJ, FE	Juan de Nova (Europe)	39
FR, FT	Tromelin IS.	39
FR	Reunion IS.	39
FT8W	Crozet IS.	39
FT8X	Kerguelen IS.	39
FT8Z	Amsterdam & St. Paul IS.	39
FW	Wallis & Futuna IS.	32
FY	French Gulana	09
G, GX	England	14
GD, GT, MD	Isle Of Man	14
GH, GJ	Jersey	14
GI, GN	Northern Ireland (UK)	14
GM, GS	Scotland (UK)	14
GU, GP	Guernsey	14
GW, GC	Wale (UK)	14
H4	Solomon IS.	28
HA, HG	Hungary	15
HB	Switzerland	14
HBD	Liechtenstein	14
HC, HD	Equator	10
HCB, HDB	Galapagos IS.	10
HH	Haiti	08
HI	Dominican Republice	08
HJ, HK	Colombia	09
HK0	Malpelo IS	09
HK0	San Andres & Providencia	07
HL, DS, DT	South Korea	25
HO, HP, 3E, 3F	Panama	07
HQ, HR	Honduras	07
HS	Thailand	26
HV	Vetican	15
HZ	Saudi Arabia	21
IA-IZ	Itlay	15, 33
ISo, IMo	Sardinia	15

Prefix	Country	CQ Zone
J2	Djibouti	37
J3	Grenada	38
J4	Greece	20
J5	Guinea-Bissau	35
J6	St. Lucia	08
J7	Dominica	08
J8	St. Vicent & Grenadlines	08
JA-JS	Japan	25
JD1	Minami-Tori-Shima	27
JD1	Ogasawara IS.	27
JT-JV	Mongolia	23
JW	Svalbard IS.	40
JX	Jan Mayen IS.	40
JY	Jordan	20
K,W,NA-NZ,AA-AK	United States of America	3,4,5
KC6	Belau (Western Caroline IS.)	27
KG4	Guatanamo Bayt	08
KH0	Manana IS.	27
KH1	Baker & Howland IS.	31
KH2	Guam	27
KH3	Johnston IS.	31
KH4	Midway IS.	31
KH5	Palmyra Jarvis IS.	31
KH5K	Kingman Reef	31
KH6	Hawali	31
KH7	Kure IS.	31
KH8	American Samao	32
HK9	Wake IS.	31
KL7	Alaska	1
KP1	Navassa IS.	08
KP2	Virgin IS.	08
KH3, KP4, WO	Puerto Rico	08
KP5	Desecheo IS.	08
LA-LN	Norway	14
LO-LW, AY, AZ	Argentina	13
LX	Luxembourg	14

Prefix	Country	CQ Zone
LY	Lithuania	15
LZ	Bulgaria	20
M1, M0	United Kingdom	14
OA-OC	Peru	10
OD	Lebanon	20
OE	Austria	15
OF-OI	Finland	15
OH0	Aland IS.	15
OJ0	Market Reef	15
OK, OL	Czeck republic	15
OM	Slovak Republic	15
ON-OT	Belgium	14
OX	Greenland	40
OY	Faroes	14
OZ	Denmark	14
P2	Papua New Guinea	28
P4	Aruba	09
P5	North Korea	25
PA-PI	Netherlands	14
PJ2, 4, 9	Bonaire, Curacao (Neth Antilles)	09
PJ5-8	St. Maarten, Saba & St. Eustatius IS	08
PP-PY	Brazil	11
PP0-PY0	Fernando de Noronha, St. Peters & St. Paul Rocks, Trinidad & Martin Vaz	11
PZ	Surinam	09
S0	Western Sahara	33
S2	Bangladesh	22
S4	South Africa	38
S5	Siovenia	15
S7	Seychelles	39
S9	Sao Tome & Principe	36
SA-SM	Sweden	14
SN-SR	Poland	15
ST	Sudan	34
ST0	Southern Sudan	34
SU	Egypt	34

Prefix	Country	CQ Zone
SV-SZ	Greece	20
SV/A	Mount Athos	20
SV5	Dodecanese	20
SV9	Crete	20
T2	Tuvalu	31
T30	W.Kiribati (Gilbert IS.)	31
T31	Central Kiribati (British Phoenix IS.)	31
T32	East Kiribati (Line IS)	31
T33	Banaba Is. (Ocean IS.)	31
T5	Somalia	37
T7	San Marino	15
T9, 4N4, 4O4	Bosnia-Herzegovina	15
TA-TC	Turkey	20
TF	Iceland	40
TG, TD	Guatemala	07
TI, TE	Costa Rica	07
T19	Cocos IS	07
TJ	Cameroon	36
TK	Corsica	15
TL	Central Africa	36
TN	Congo	36
TR	Gabon	36
TT	Chad	36
TU	Ivory Coast	35
TY	Benin	35
TZ	Mali	35
UA-UI1, 3, 6, RA-RZ	European Russia	16
UA2	Kaliningrad	15
UA-UI8, 9, 0, RA-RZ	Asiatic Russia	
UJ-UM	Uzbekistan	17
UN-UQ	Kazakhastan	17
UR-UZ, EM-EO	Ukraine	16
V2	Antigua Barbuda	08
V3	Belize	07
V4	St. Kitts & Nevis	08
V5	Namibia	38

Prefix	Country	CQ Zone
V6	Micronesia (East Caroline IS.)	27
V7	Marshall IS.	31
V8	Brunel	28
VA, VE, VF, VO, VY	Canada	1-5
VK, VI, AX	Australia	29, 30
VK0	Macquarie IS.	39
VK0	Macquarie IS.	30
VK9C	Cocos-Keeling IS.	29
VK9L	Lord Howe IS.	30
VK9M	Mellish Reef	30
VK9N	Norfolk IS.	32
VK9W	Willis IS.	30
VK9X	Christmas IS	29
VP2E	Anguilla	08
VP2M	Montserrat	08
VP2V	British Virgin IS.	08
VP5	Turks & Caicos IS	08
VP8	Falkland IS	13
VP8, LU	South Georgia IS. Sourth Orkney IS., South Sandwich IS.	13
VP8, CE9, HF0, LU, RA1	South Shetland IS	13
VP9	Bermuda IS.	05
VQ9	Chagos IS.	39
VR6	Pitcairn IS.	32
VS6, VR2	Hong Kong	24
VU2, VU3	India	22
VU7	Andaman & Nicobar IS. (India)	26
VU4	Laccadive IS. (India)	22
XA-XI, 4A-4C	Mexico	06
XA4-X14	Revilla Gigedo	06
XJ	Canada	1-5
XT	Burkina Faso	35
XU	Cambodia	26
XW	Laos	26
XX9	Macao	24
XY-XZ	Myanmar	26
YA, T6	Afghanistan	21

Prefix	Country	CQ Zone
YB-YH	Indonesia	28
Y1	Iraq	21
YJ	Vanuatu	32
YK	Syria	20
YL	Latvia	15
YN	Nicaragua	07
YT, YU, YZ, 4N	Yugoslavia	15
YV-YY, 4M	Venezuela	09
YV0	Ares IS.	08
Z2	Zimbabwe	38
Z3, 4N5	Macedonia	15
ZA	Albania	15
ZB2	Gibraltar	14
ZC4	Cyprus (United Kingdom Sovereign Bases)	20
ZD7	St. Helena	36
ZD8	Ascension IS.	36
ZD9	Tristan de Cunha & Gough IS.	38
ZF	Cayman IS.	08
ZK1	North & South Cook IS.	32
ZK2	Niue	32
ZK3	Tokelau IS.	31
ZL, ZM	New Zealand	32
ZL7	Chatham IS.	32
ZL8	Kermadec IS.	32
ZL9	Auckland & Campbell Is.	32
ZP	Paraguay	11
ZR-ZU	Republic of South Africa	38
ZS0-1	Penguin IS	38
ZS8	Prince Edward & Marion IS.	

MODEL QUESTION PAPERS

MODEL PAPER - I

Max Marks : 100 **Time : 1 Hours**

Note : (I) Section A & B are compulsory

SECTION A (TECHNICAL THEORY) **MAX MARKS. 50**

In addition to question no.1, attempt any TWO questions from this section.

Q.No.1: (A) Choose correct answers (any eight),Each question carries 1 mark.

i) A source of 100 V is applied across a 20-W R1 and 30-W R2 in series. V1 is 40 V. The current in R2 is
(a) 5 Amp. (b) 3 1/3 Amp (c) 1 1/3 Amp (d) 2 Amp

ii) With eight 10 – W M resistances connected in parallel across a 10 V source, the main line current equals
(a) 0.1- mA (b) 1/8 - mA (c) 8 - mA (d) 10 - mA

iii) A generator has a 100 V output on open circuit which drops to 50 V with a icao current of 50 mA and an R1. of 1000W. The internal resistance R1 is equals.
(a) 25 - W (b) 50 - W (c) 100 - W (d) 1000 - W

iv) In a parallel circuit with an equal branch resistances.
(a) The lowest R has the highest I (b) The highest R has the Highest
(c) The same as one wire (d) Two thirds the resistance of one wire

v) A voltmeter using a 50-mA meter involvement has a sensitivity of
(a) 1000 m/V (b) 20,000 m/V (c) 50,000 m/V (d) H MW/V

vi) If two wire conductors are tied in parallel, Their total resistance becomes
(a) Double the resistance of one wire (b) One half the resistance of one wire
(c) The same as one wire (d) Two thirds the resistance of one wire

vii) Current changing from 43 mA to 59 mA in 2 millisec induces 40 V in a call. It's inductance equals.
(a) 40mH (b) 5 H (c) 6 H (d) 20 H

viii) A coil has an inductive resistance of 1000-W. If its inductance is doubled and the frequency is doubled, then the inductive reactance will be
(a) 1000 - W (b) 2000 - W (c) 4000 - W (d) 16000 - W

ix) An LC circuit resonam at 1000 kHz has a Q of 100. The bandwidth not been half power points equals
(a) 10 KHz between 995 & 1005 Khz; (b) 10 KNz between 1000 & 1010 KHz;
(c) KHz between 995 & 1000 KHz; (d) 200 KHz between 900 & 1100 KHz;

x) Cells are connected in series to
(a) increase the voltage output (b) decrease the voltage output
(c) decrease the internal resistance (d) increase the current capacity

(B) Give the brief answers of the following questions. Each carries 2 Marks.

i) For 6 meter band used in AMATEUR RADIO; What will be the corresponding frequency ?

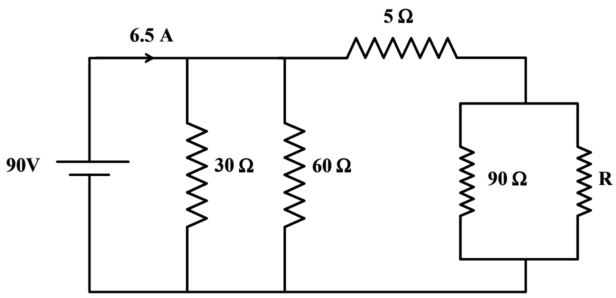
ii) What are the RMS and the Average values of a full smscidal wave of current whose peak value is denoted as Imax ?

iii) What are the four color hands of a resister whose vaide is d.7.W. : with 20% of tolerance ?

iv) Draw a diagram of a High lass filter using Inductors & Capacitors ?

Note : Each question carries 17 marks. Attempt any two.

Q.2 Define kirchoff's Voltage & current Law. Calculate the resistence R in the following circuit.



Q.3 (A) Draw the schematic diagram of a full wave and half wave amplifier and explain its functions and differences.

(B) Explain briefly the Class-B push-Pull amplifiers. What are the advantages of this type of amplifiers ?

Q.4 What do you understand by (explain briefly)
(a) Sensitivity (b) Selectivity (c) Vading
(d) Directivity (e) Imape frequency

Q.5 (A) Draw and explain the block diagram of a Superhetrodyne receiver.

(B) What is the Resonance and why it is occurs ? Briefly explain the series and paral 1 resonance.

SECTION B (RADIO REGULATIONS) MAX MARKS : 50

In addition to question no.1, attempt any TWO other questions from this section.

Q.1(A) Choose correct answers (any Eight) Each question carries 1 Mark.

i) The Q code for Shall change to transmission or another frequency is
(a) QRF ? (b) QSY ? (c) QRG ? (d) QRE ?

ii) The Q code for "-is the distress traffic over ?" is
(a) QRW ? (b) QHV ? (c) QWS ? (d) QUM ?

iii) QRX 1000 IST means that
(a) My Rx is tuned to 1000 KHz (b) The correct time is 1000 hrs IST
(c) Do you call me at 1000 hrs IST (d) I will call you again at 1000 hrs IST

iv) What is the R-S-T system code for a "Fairly good signal readable with practically no difficulty" ?
(a) R-3, S-4 (b) R-4, S-5 (c) R-4, S-3 (d) R-5, S-6

v) QRP ? Means
(a) What your Transmission power ? (b) Shall I charge transmission tone ?
(c) Shall I decrease power ? (d) What is your position ?

vi) The distress frequency in radio telephony is
(a) 535 KHz (b) 2812 KHz (c) 545 KHz (d) 2182 KHz

vii) The frequency 30 to 300 Mitz are expressed in metric subdivision as
(a) Hectometric waves (b) Declmatric waves
(c) Decimillimetric waves (d) Metric waves.

viii) What is meaning of "Rig" in radio amateur technology ?
(a) Register (b) Wireless equipment
(c) Ring tone (e) Best regard

ix) A station will be identified when its calisign is not available.
(a) By Hight identification number in case of airerafts.
(b) Official identification mark or registered mark in case of mobile station.
(c) By characteristic signal.
(d) All of the above

x) During the course of their transmission amateur station shall send their callsign
(a) Every one hour (b) For initial contact only
(c) only on demand (d) At the beginning & at the end of each period of transmission

(B) Give the brief answers of the following questions Each carries 2 Marks

i) How much maximum transmission power is allowed to the Amateur Wireless Telegraph Station under the Licence Grade-II.

ii) What do you understand by F2B300H emission.

iii) Give any two names of the TIMING NET and their STANDARD TIME

iv) Give the phonetic and code words to be used for the folloings.

(a) F ____________________ (b) 2 ____________________

(c) O ____________________ (d) 1 ____________________

Note : Each question in carries 17 marks Attempt any TWO.

Q.2 Write call-sign of the following country / institutions.

(a) India (b) France (c) Union of Soviet Socialist Republic.

(d) World Meteorological Organization (e) Gread Britan North Ireland

Q.3 (a) What are the frequency and of frequencies authorized for grade II ASOC licences ?

(b) Define Amateur Services. What are the messages allowed and forbidden in Amateur Service in India.

Q.4 1) Give Short notes on :

a) Silence period b) QSL card c) time signal

2) Explain Distress Signal and call on radio telephony and radio telegraphy.

Q.5 1) Draw the format of a log and equipment resister used in amateur with two entries and explain briefly

2) What are the urgency and safety signal in radio telephony and radio telegraphy.

MODEL PAPER - II

Max Marks : 100 **Time : 1 Hours**

Note : (I) Section A & B are compulsory

SECTION A (TECHNICAL THEORY) **MAX MARKS. 50**

In addition to question no.1, attempt any TWO questions from this section.

Q.1 (A) Choose correct answers (any eight) Each question carries 1.5 marks.

i) Which of the following is a low-pass filter ?

a) L- type with series C and Shunt L b) π–type with series C and shunt L

c) T-type with series C and shunt L d) L-type with series L and shunt C

ii) A parallel circuit with 20 V applied across two branches has a total line current of 5 A. One branch resistance equals 5 Ω. The other branch resistance equals :

a) 5 Ω b) 20 Ω c) 25 Ω d) 100 Ω

iii) A shunt for a millimeter :

a) Extends the range and reduces the meter resistance

b) Extends the range and increase the meter resistance

c) Decrease the range and the meter resistance

d) Decrease the renge but increase the meter resistance

iii) For a carbon-composition resister color-coded with Yellow, Violet, Orange, and silver stripes from left to right, the resistance and tolerance are :

a) 740 Ω ± 5% b) 4700 Ω ± 10%

c) 7400 Ω ± 1% d) 47000 Ω ± 10%

v) The AC power line voltage of 120 V rms has a peak value of :
a) 100 V b) 170 V c) 240 V d) 338 V

vi) When an alternating voltage reverses in polarity, the current it produces :
a) Reverses in direction b) Has a steady DC value
c) Has a phase angle of 180° d) Has a back emf opposing a steady DC

vii) A 5:1 voltage step-up transformer has 120 V across the primary and a 600 resistance across the secondary. Assuming 100 percent efficiency the primary current equals :
a) 1/5 Ampere b) 600 millianmpere
c) 5 Ampere d) 10 Ampere

viii) Inductive reactance is measured in ohms because it :
a) Reduces the amplitude of AC b) Increases the amplitude of AC
c) Increases the amplitude of DC d) Has a back emf opposing a steady DC

ix) A 100-Ω R is in series with 100 –Ω XL. The total impedance Z equals :
a) 70.7-Ω b) 100-Ω c) 141-Ω d) 200-Ω

x) A 0.01-μF capacitance in series with R is used as a coupling capacitor Co for 1000 HZ. At 10,000 Hz:
a) Co has too much reactance to be good for coupling
b) Co has less reactance which improves t the coupling.
c) Co has the same reactance and coupling
d) The voltage across R is reduced by one-tenth

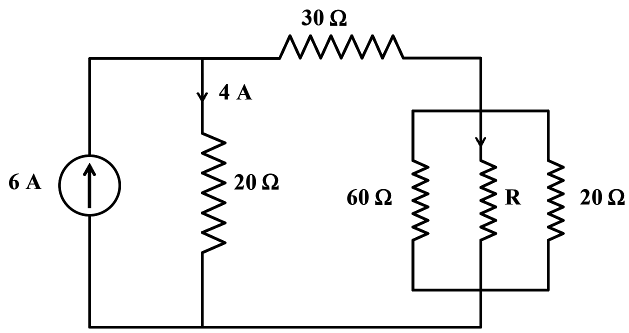
(B) Give the brief answers (any two) of the following questions. Each carries 2 Marks.

i) What is the resonance condition in a series or parallel LC circuit in which R, XL, and Xc are the resistance, inductive reactance and capacitive reactance respectively ?

ii) What is relation between frequency (f) and wave length (λ) of an electromagnetic wave ? Calculate corresponding wave length of 6 MHz frequency ?

iii) What do you mean by J3E and H3E emission ?

Q.2 What is difference between kirchhoff's voltage and current law? Calculate the resistance R and the current I in the following circuit.



Q.3 (I) Explain the construction and working of a ZENER DIODE. How it is used for voltage stabilization ?

II) Explain the working of a full-wave rectifier. Describe the smoothing circuit in a full-wave rectifier.

Q.4 I) Draw the circuit diagram of a complementary symmetry push-pull class B amplifier. Explain its working and mention its advantages.

II) What do you understand by Phase and Phase Difference in an AC circuit ?

Q.5 I) Draw the block diagram of a transmitter. Explain the functions of each stage and clearly indicate the CW and AM sections.

II) Explain how the radio frequency of an oscillator or a transmitter is measured ?

SECTION-B (Radio Regulations) MAX MARKS : 50

Q.1 (A) Choose correct answers (any eight). Each question carries 1 ½ marks.

i) The "Q" code for "Are you ready?" is :
a) QRR? b) QRF? c) QRE? d) QRV?

ii) The "Q" code for "shall I change to transmission on another frequency?" is:
a) QRF? b) QSY? c) QRT? d) QTC?

iii) What is meaning of abbreviation "WX" used by amateurs ?
a) Wax b) Weather
c) Weeping Child d) Wrong Transmission

iv) What is R-S-T system code for a "Strong signal with filtered rectified AC, but strongly ripple modulated"?
a) R-2, S-3 b) S-8, T-6 c) R-4, T-5 d) S-8, T-5

v) "QRZ..." is meant for :
a) Who is calling me? b) When will you call me again?
c) You are being called by.... d) I am ready

vi) What do you mean by "QSB?" in abbreviation Q-code?
a) Your signals are fading b) What is the readability of my signals?
c) Shall I begin my transmission? d) Are my signals fading?

vii) 400 Watt power can be used on some certain frequencies by
a) Advanced Grade b) Grade-I
c) Both Advanced Grade & Grade-I d) None

viii) UTC time corresponding to 1030 IST is
a) 1050 Hrs b) 1200 Hrs c) 1600 Hrs d) 0500 Hrs

ix) Frequency band (in KHz) allotted on HF range to Restricted Grade is :
a) 7000 to 7100 b)14000 to 14350 c) 144 to 146 d) None

x) If 'dit' and 'Dah' in morse code has a length of 1 unit and 3 unit then What should be the gap between two words in a message?

a) 1-Unit b) 3- Unit c) 4- Unit d) 5- Unit

B) Give the brief answers (any two) of the following questions. Each carries 2 Marks.

i) Give the name of the things maintained up-to-date by a HAM license after getting a License from min. of Communication.

ii) Give (any two) authorized frequency bands with the corresponding type of emission and maximum transmitted power allowed to the AMATEURS in HF and VHF band.

iii) What are the phonetic and code words to be used for the followings?

a) Q .... b) H............. c) 3 .... d) 8 ....

Q.2 i) What are the important equipments to be kept in a fully equipped and well installed amateur station?

ii) What is the method of forming call-sign of a radio station? What combinations are forbidden to be used as call-sign?

Q.3 i) What are your duties to prevent excessive mutual interference on the bands being used? Give Q-Code used in situations of mutual interference.

ii) How would you answer a call?

Q.4 i) What is difference between urgency and distress signal? What action will you take if you intercept a distress message?

ii) What are the international distress frequencies in the different frequency bands?

Q.5 i) Draw the format of the following with two entries :

a) LOG of amateur radio station

b) Equipment Register for wireless telegraphy apparatus

ii) Write short notes (any three) on the followings:

a) IMI b) AR c) BT d) OSCAR e) K

MODEL PAPER - III

Max Marks : 100 **Time : 1 Hours**

Note : (I) Section A & B are compulsory

SECTION A (TECHNICAL THEORY) MAX MARKS. 50

In addition to question no.1, attempt any TWO questions from this section.

Q.1 (A) Choose correct answers (any eight) Each question carries 1.5 marks.

i) Which 10 V applied across hundred 10-Ω resistances in parallel; the current through each resistance equals:

a) 2-Ampere b) 1-Ampere c) 0.50-Ampere d) 100-Ampere

ii) If the length & the cross sectional area of a conductor made half; What will be the effective resistance ?

a) Half of the original value b) Double of the original value
c) Quadruple of the original value d) Equal to the original value

iii) The direction of transmission and reception for an OMNI antenna is in :

a) Parallel to the length of antenna
b) Perpendicular to the length of antenna
c) At an angle of 45° to the length of antenna
d) All directions

iv) A constant voltage generator has :

a) Low Internal Resistance b) High Internal Resistance
c) Minimum Efficiency d) Minimum Current Capacity

v) For a carbon-composition resister color-coded with Green, Black, Gold, And silver stripes from left to right, the resistance and tolerance are :

a) 0.5- Ω ± 5% b) 0.5- Ω ± 10% c) 5- Ω ± 10% d) 50- Ω ± 10%

vi) With double the number of turns but the same length and area, the Inactions is

a) The same b) Double c) Quadruple d) One-Quarter

vii) The Capacitance Increases with :

a) Larger plate area and greater distance between plates
b) Smaller plate area and less distance between plates
c) Larger plate area and less distance between plates
d) Higher values of applied voltage

viii) A conductive plate inserted exactly in between the two plates of a capacitor, it's capacity :

(a) Equivalent to its capacitance (b) Zero
(c) Infinite (d) Can't be measured

(B) **Give the brief answers (any two) of the following questions. Each caries 2 marks.**

(i) What is the resonance condition in a series or parallel LC circuit in which R, X_L, and Xc are the resistance, Inductive reactance and capacitive reactance respectively?

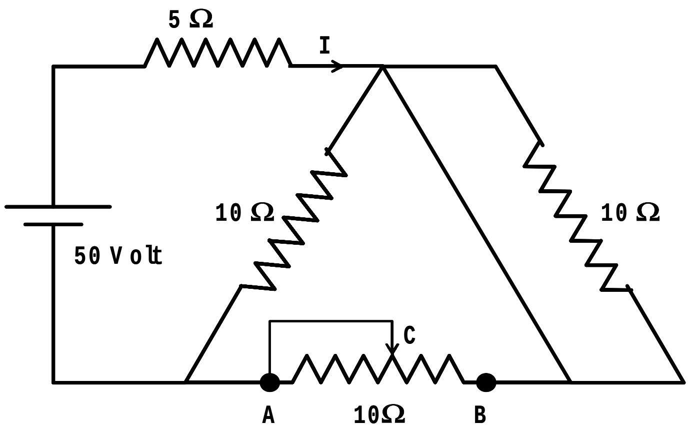
(ii) What is relation between frequency (t) and wave length (λ) of an electromagnetic wave? Calculate corresponding wave length of 1000- MHz frequency?

(iii) What do you mean by F2A and A3C emission?

Q.2. **What are the differences between Kirchhoft's Current & Voltage Law? Calculate the different values of Current I as shown in diagram when the pointer C of the potentiometer resistance 10-Ω will be:**

(a) At positon A

(b) At position B



Q.3(i) Describe the different types of inductance coils used in Transmitters and Receivers What are their uses ?

(ii) What is use of a low frequency choke ?

Q.4 (i) Draw the block daigram of AM transmitter and Explain the functions of each stage.

ii) Define the term Fading and Diversity reception.

Q.5 **Write short notes on following (Any Four):**

(a) Q-Factor of a circuit

(b) Signal-to-Noise Ratio

(c) Eddy Current

(d) Detector Circuit

(e) Squelch System

(f) VSWR

SECTION-B (Radio Regulations) MAX MARKS : 50

Q.1 (A) Choose correct answers (any eight). Each question carries 1 ½ marks.

i) The "Q" code for "Shall I inform-that you are calling him on Kes/mes?" is :
(a) QSW ? (b) QRI? (c) QRW? (d) QTR?

ii) The "Q" code for "Does my frequency vary?" is:
(a) QRV? (b) QRH? (c) QRF? (d) QTR?

iii) What is meaning of abbreviation "DX" used by amaterrs?
(a) Department (b) Dir & Dash
(c) Dear (d) Foreign Countries

iv) What is R-S-T system code for a "Unreadable Very week signals having very rough and broad AC"?
(a) R-2, S-2, T-1 (b) R-1, S-1, T-2
(c) R-1, S-2, T-1 (d) R-2, S-1, T-3

v) "QSP?" is meant for :
(a) What is your position? (b) Will you relay to.....?
(c) Shall I Decrease power? (d) Who is calling me?

vi) What do you mean by "QRQ?" in abbreviation Q-code?
(a) Will you send on.....KHz?
(b) What is the readablity of my signals?
(c) Shall I Send faster? (d) Shall I send more slowly?

vii) The Distess frequency allocated in radio telephony is :
(a) 500-KHz (b) 2812-KHz (c) 2182-MHz (d) 2182-KHz

viii) During the course of their transmission amateur station shall send their call sign:
(a) Every one hou
(b) For initial contact only
(c) Only on demand
(d) At the beginning and at the end of each period of transmission

ix) The Restricted Amateur station license empower to use the emissions of transmission:
(a) A2A (b) F3E (c) F3C (d) None

x) If dit and Dah in morse code has a length of I unit and 3 units respectively then what should be the gap between a Dit and Dah in a message?
(a) 1-Unit (b) 3-Unit (c) 2-Unit (d) 1.5-Unit

(B) Give the brief answer (any two) of the following questions, Each carries 2 marks.

i) Write the Call-Sign blocks alloted to the INDIA, United Nations, Nepal and International Civil Aviation Organisation (One for each)

ii) Give the Frequency & corresponding IST Time and name of any NET's from the VHF daily Nets.

iii) What are the phonetic and code words to be used for the followings?

(a) T............... (b) 0............. (c) X.............. (d) 9 ....

Q.2 (i) What is the method of forming call-sign of a radio station? Which combinations are forbidden to be used as call-sign? Explain.

ii) What are the operating frequencies and corresponding transmission power authorised for Amatenr grade-II and II R?

Q.3(i) Draw a proforma with atleast two entries for the LOG of Amateur.

ii) What are the precantions supposed to be taken to ensure non-interference to other users?

Q.4 (i) What do you understand by Safety and Distress signals ? Explain.

ii) What are the different frequencies authorised for Distress communications?

Q.5 Write short notes (any Four) on the followings:

(a) Silence Period (b) Call-Signs (c) Test Signal
(d) Amateur Satellite Service (e) Experimental station.

MODEL PAPER - IV

Max Marks : 100 **Time : 1 Hours**

Note : (I) Section A & B are compulsory

SECTION A (TECHNICAL THEORY) MAX MARKS. 50

Q.1 (A) Choose correct answers (any eight) Each question carries 1.5 marks.

i) With two resistances connected in parallel, if each dissipates 10 Watts; The total power supplied by the voltage source equals.
(a) 10-Watts (b) 20-Watts (c) 5-Watts (d) 100-Watts

ii) A clsed switch has a resistance of :
(a) At least 1000-Ω (b)Infinity
(c) About 100-Ω at room temperature (d) Zero-Ω

iii) With resistances of 100, 200, 300, 400 and 5000-Ω in parallel; the RT (equivalent resistance) will be:
(a) Less than 100-Ω (b) More than 1-MΩ
(c) About 5000-Ω (d) About 1-KΩ

iv) For a carbon-composition resister color-coded with Yellow, Grey, Green and Gold stripes from left to right, the resistence and tolerance are:

(a) 590-KΩ ±10% (b) 480-KΩ ±5%
(c) 4800-KΩ ±5% (d) 490-MΩ ±10%

v) If the length of a copper wire is doubled, then it's specific resistance becomes:

(a) Half (b) Double (c) No Change (d) None of above

vi) The ddirection of transmission and reception for a HORIZONTAL DIPOLE antenna is :

(a) Parallel to the length of antenna
(b) Perpendicular to the length of antenna
(c) At an angle of 45* to the length of antenna
(d) All directions

vii) A conductive plate inserted exactly in between the two plates of a capacitor, it's capacity:

(a) Decreases (b) Increases

(c) Makes no change (d) Short circuits

viii) If the Q-Factor of a coil is increased, then the Bandwidth of that resonant circuit will:
(a) Increase (b) Decrease
(c) Not Effected (d) None of above

ix) For the direct current (DC) in a circuit; the impedance offered by capacitor will be:

(a) Equivalent to its capacity (b) Zero
(c) Infinite (d) Can't be measured

x) The input impedance of a Radio Receiver as compared with the impedance of antenna and antenna cable should be:

(a) Very High (b) Very Low

(c) Approximately equal (d) None of above

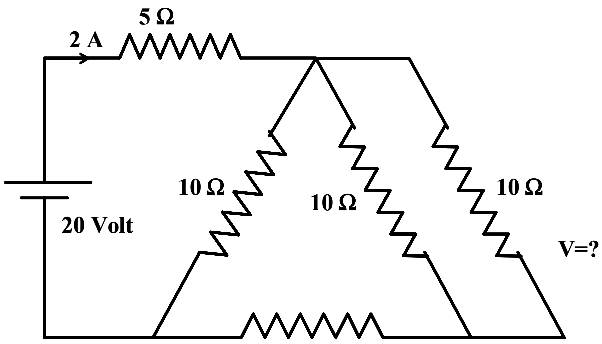
(B) Give the brief answers (any two) of the following questions. Each carries 2 Marks.

i) What is the frequency range of MF and UHF bands respectively?

ii) What will be the specific gravity of the electrolyte (H_2SO_4) with reference to the water in a fully charged and discharged battery respectively?

iii) What do you mean by H3E and F3E emission?

Q.2 What do you mean by kirchhoff's current law? Calculate the voltage V in the following circuit.



Q.3 What are the differences between step-down transformer? If the turns ratio between secondary and primary windings is 20 and primary current is 0.3 milli ampere; Calculate the current in secondery winding.

Q.4(i) Explain the terms of Modulation and percentage of Modulation? Why do you aim for high percentage of modulation?

ii) What are the differences between AM and FM?

Q.5 (i) Draw the block daigram of superheterodyne receiver and Explain the functions of each stage.

(ii) Define the term sensitivity and selectivity.

SECTION-B (Radio Regulations) **MAX MARKS : 50**

Q.1 (A) Choose correct answers (any eight). Each question carries 1 ½ marks.

i) The "Q" code for "Shall I send or reply on this frequency with emissions of class.....?" is:

(a) QRS? (b) QSU? (c) QRE? (D) QSV?

ii) The "Q" code for "Shall I stop seuding?" is:

(a) QRF? (b) QRY? (c) QRT? (d) QTC?

iii) What is meaning of abbreviation "Lima lima" used by amatcurs?

(a) Land lord (b) Land line(telephone)

(c) Long life (d) Last location

iv) What is R-S-T system code for a "Strong signal with filtered rectified AC, but strongly ripple modulated"?

(a) R-2, S-3 (b) S-8, T-6 (c) R-4, T-5 (d) S-8, T-5

v) "QRP?" is meant for:

(a) Shall I increase power? (b) Shall I decrease power?

(c) Decrease your power (d) Increase your power

vi) What do you mean by "QSB?" in abbreviation Q-code?
(a) Your signals are fading
(b) What is the readablity of my signals?
(c) Shall I begin my transmission?
(d) Are my signals fading?

vii) 400 Watt power can be used on some certain frequencies by
(a) Advanced Grade (b) Grade-I
(c) Both ADvanced Grade & Grade-I (d) None

viii) IST time corresponding to 1030 UTC is
(a) 1030 Hrs (b) 3- Unit (c) 4- Unit (d) 5- Unit

(B) Give the brief answers (any two) of the following questions. Each carries 2 Marks.

i) Write the Call-Sign blocks alloted to the INDIA, USA, PAKISTAN and JAPAN (One for each cuntry)

ii) Give the LOCATION and CALL-SIGN of REPEATERS (any two) in INDIA.

iii) What are the phonetic and code words to be used for the followings?

(a) W............... (b) Z.............. (c) 1................ (d) 7............

Q.2 i) Explain how an amateur station can establish contact with another stations?

ii) What do you understand by "Amateur Service" mentioned in The indian Wireless Telegraph (Amateur Service) Rules, 1978?

Q.3 i) What is a QSL card ? Explain showing a sample entry in this card.

ii) What are the precautions supposed to be taken to ensure non-interference to others?

Q.4 i) What do you understand by Safety, Urgency and Distress signals? Explain.

ii) What are the different frequency bands, emissions and power used by Amateurs ?

Q.5 Write short notes (any three) on the followings:

(a) Silence Period (b) LOG of Amateur
(c) Test Signal (d) Equipment Register
(e) Experimental static

MODEL PAPER - V

Max Marks : 100 **Time : 1 Hours**

Note : (I) Section A & B are compulsory

SECTION A (TECHNICAL THEORY) **MAX MARKS. 50**

Q.1 (A) Choose correct answers (any eight) Each question carries 1.5 marks.

i) The net reactance of 2 series resonant circuit is -
(a) One (b) Equal to Resistance of circuti
(c) zero (d) Equal to Impedance of the circuit

ii) The turns ration in an isolation transformer is
(a) 1:1 (b) Infinity (c) No ration (d) None of above

iii) The following oscillatior is more stable-
(a) Colpitts Oscillator (b) Crystal Oscillator
(c) Hartley Oscillatior (d) RC Phase-Shift Oscillator

iv) For a carbon-composition resister color-coded with Yellow, Violet, Gold and No colour stripes from left to right, the resistace and tolerance are :
(a) 580 KΩ ± 10% (b) 4.7 KΩ ± 20%
(c) 4.7- KΩ ± 20% (d) 47 - KΩ ± 5%

v) The batteries are rated in :
(a) Volt-Ampere (VA) (b) Ampere-Hour (AH) (c) Watts (d) Coulombs

vi) The class of amplifier operation characterised by hieghest efficiency, high distortion :-
(a) Class "A" (b) Class"B" (c) Class"C" (d) Class"AB"

vii) A conductive plate inserted exactly in between the two plates of a capacitor, it's capacity :-
(a) decreases (b) increases
(c) makes no change (d) Short circuit

viii) The radiation resistance of an antenna is defined as the :
(a) Resistance offered at input by antena
(b) Total radiated power divided by the square of antenna currenct
(c) Total sum of oltage divided by the antenna current
(d) None of above

ix) The P-side of a semi-conductor P-N junction is grounded and the N-side is applied a voltage of 2-Volts through a resistance of 100 Ω. The semi-conductor junction is :
(a) Forward Biased (b) Reverse Biased
(c) Likely to get damaged (d) None of above

x) The input impedance of a Radio Receiver as compared with the impendance of antenna and antenna cable should be :-

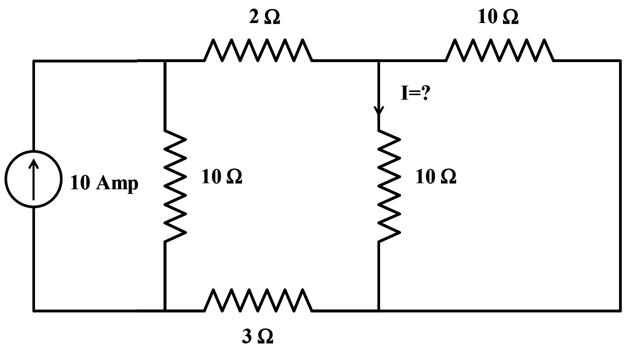
(a) Very high (b) Very low (c) Approximately equal (d) None of this.

(B) Give the brief answers (any two) of the following questions : Each caries 2 Marks .

(i) What would be the Capacitance between the plats separated by 'D' cm distance, having cross sectional area of 'A' cm^2 and filled-up with dielectric material of 'K' constant.

(ii) What will be the specific gravity of the electrolyte (H_2SO_4) with reference to the water in a fully charged and discharged battery respectively?

Q.No.2 What is difference between Kirchoff's current and Voltage law ? Calculate the Current I in the following circuit.



Q.No.3 (i) Explain operation of different stages SSB transmitter with block diagram.

(ii) What is difference between Bandwidth ad Beamwidth in concern with the arials ?

Q.No.4 (i) What are the different classifications of the amplifiers ?

(ii) Explain the operation of push-pull amplifier with block diagram.

Q.No.5 Write short notes on any of the FOUR followings :

(i) Dipole antena
(ii) Adjacent Channel Interference
(iii) Polarization in antenna
(iv) Squalach circuit
(v) Selectivity
(vi) L-C tanks Circuit
(vii) Diversity Receiptions

SECTION-B (Radio Regulations) MAX MARKS : 50

Q.1 (A) Choose correct answers (any eight). Each question carries 1 ½ marks.

i) The "Q" code for "Shall I send or reply on this frequency with emissions of class.....?" is:

(a) QRS? (b) QSU? (c) QRE? (D) QSV?

ii) The "Q" code for "Will you tell me exact frequency ?" is:
(a) QRF? (b) QRG? (c) QST? (d) QSY?

iii) What is meaning of abbreviation "WX" used by amateurs ?
(a) Was (b) Weather (c) Weaping child (d) Wrong Transmission

iv) What is R-S-T system code for "Strong signal with filtered rectified AC, but strongly ripple modulated"?
(a) R-2,S-3 (b) S-8,T-6 (c) R-4,T-5 (d) S-8,T-5

v) "QUM" is meant for :
(a) What is my frequency? (b) Is the distress traffic over ?
(c) Who are you ? (d) Is my signal interfering you ?

vi) What do you meant by "QSB" in abbreviation Q-code ?
(a) What is my frequency ? (b) What is readability of my signals ?
(c) Shall I begin my transmission (d) Are my signal fading ?

vii) 400 watt power can be used on some certain frequencies by
(a) Advanced Grade (b) Grade-I
(c) Both Advanced Grade and Grade-I (d) None

viii) The Amateur Satellite Service is permissible for the holders of :-
(a) Amateur Wireless Telegraph License, Grade-II
(b) Amateur Wireless Telegraph License, Grade-I
(c) Amateur Wireless Telegraph License, Advanced Grade
(d) Both 'b' and 'c'

ix) The holder of 'Amateur Wireless Telegraph Station License, Grade-II shall be entitled for radio telephony :
(a) After making 100 contacts using morse code
(b) Without making any contact using morse code
(c) After making 10 contacts using morse code
(d) None of above

x) If 'dit' and 'Dah' in morse code has a length of 1 unit and 3 units corresponidingly then What should be the gap between two characters in a message ?
(a) 1-Unit (b) 3-Unit (c) 4-Unit (d) 5-Unit

(B) Give the brief answers (any two) of the following questions. Each caries 2 marks.

(i) Write the Call-sign Blocks allocated for INDIA, PAKISTAN, World Meteorological Organization (one for each)

(ii) Give the LOCATION and CALL-SIGN of REPEATERS (any two) in INDIA.

(iii) Give the name of region under which INDIA falls as per the ITU's regionalization of the world.

Q.No.2 (i) Draw a proforma with atleast two entries for the LOG of Amateurs.

(ii) What do you understand by "Amateur Service" mentioned in The Indian Wireless Telegraph (Amateur Service) Rules, 1978 ?

Q.No.3 (i) What are frequencies, Emission and corresponding Power allotted to Grade-II and Grade-II Restricted Amateurs ?

(ii) What precautions would you take for making Test Transmission.

(iii) How would you make a distress call ? Explain with a specimen message.

Q.No.4 (i) What do you understand by Urgency and Distress Signals ? Explain

(ii) How would you make a distress call ? Explain with a specimen message.

Q.no.6 Write short notes (any three) on followings :

(a) HF Beacons (b) Time Signal Station (c) Test signal
(d) IMI (e) Experimentals

Applicaton form for examination

APPENDIX - II

Application form an individual for a license to Establish, Maintain and Work an Amateur Wireless Telegraph Station in India

1. NAME:-
2. Father's name:

   and address:

3. Address (Present):-
4. Address (Permanent):
5. Date Of Birth Place of Birth Nationality
6. (a) Category of license applied for (b) Exact location of the Station
7. Do you hold Radiotelegraph Operator's Certificate? If yes, give particulars:-

Name of certificate	**No.**	**Date of issue**

8. Particulars of Amateur Station Operator's Examination:-

Name	**Station**	**Month of Examination**

9. Particulars of apparatus to be used:-

Apparatus Name	**Manufacturer's No**	**Type**	**Frequency Range**	**RF Power Output**
Transmitter				
Receiver				
Frequency-Measuring Device				

10. If appeared in any of the Amateur Station Operator's Examination : YES/ No
    If yes, indicate the date of the Examination.

DECLARATION

I hereby solemnly declare that the foregoing facts are true and correct and nothing is false therein and nothing material has been concealed therefrom. I also agree that in case any information given by me hereinbefore is found false at a later date, the license, if granted, will be cancelled.

I further solemnly give an undertaking that I will not either directly or indirectly divulge to any persons, except when lawfully authorized or directed to do so, the purport of any message which I may transmit or receive by means of any wireless apparatus operated by me or which may come to my knowledge in connection with the operation of said apparatus.

I have carefully read and understood the rules contained in the Indian Wireless Telegraphs (Amateur Service) Rules, 1978 and undertake to abide by them and observe the conditions of the license. The licensed station shall not be made accessible to any unauthorised person at anytime.

Signature of witness:............................ Signature of applicant:.......................

Name: Name:

(in block letters) (in block letters)

Address: Date:

Date: Place:

Note:

1. An attested copy of birth certificate or school leaving certificate must be accompanied along with the application.
2. Enclose a certificate in support of nationality in the prescribed proforma, indicated in Appendix III, from one of the officers.

APPENDIX – III

NATIONALITY CERTIFICATE

Certified that I have known Mr./Ms. ___________________________ son/ daughter of Mr./Ms. ______________________________ for the last _______ years and that to the best of my knowledge and belief he/she bears a good moral character. He/She is of ________________nationality. He/She is not related to me.

Date : ____________________

Signature : ________________________

Address : ________________________

Name : ___________________________

____

Designation :

____

Office seal :

PERSONAL DETAILS OF APPLICANT

1.	Name in Full (Capital)	:
2.	Date and Place of birth	:
3.	Age	:
4.	Height	:
5.	Colour of	
	(i) eyes	:
	(ii) Hair	:
6.	Complexion	:
7.	Any special particular or marks	:
8.	Present address	:
9.	Occupation	:
10.	Nationality	:
11.	Father's name and hometown	:
12.	Type of license applied for	:
13.	Proposed location of the station	:

Date :

Place:

(...........................)

Signature of the candidate