TRANSMISSION LINES AND WAVEGUIDES

UNIT I - TRANSMISSION LINE THEORY

1. **Define – Characteristic Impedance** **[M/J–2006, N/D–2006]**

Characteristic impedance is defined as the impedance of a transmission line measured at the sending end. It is given by

$$Z_0 = \sqrt{Z/Y}$$

where Z = R + jωL is the series impedance
Y = G + jωC is the shunt admittance

2. **State the line parameters of a transmission line.**

The line parameters of a transmission line are resistance, inductance, capacitance and conductance.

Resistance (R) is defined as the loop resistance per unit length of the transmission line. Its unit is ohms/km.

Inductance (L) is defined as the loop inductance per unit length of the transmission line. Its unit is Henries/km.

Capacitance (C) is defined as the shunt capacitance per unit length between the two transmission lines. Its unit is Farad/km.

Conductance (G) is defined as the shunt conductance per unit length between the two transmission lines. Its unit is mhos/km.

3. **What are the secondary constants of a line?**

The secondary constants of a line are

i. Characteristic impedance, $Z_0 = \sqrt{Z/Y}$

ii. Propagation constant, γ = α + jβ

4. **Why the line parameters are called distributed elements?**

The line parameters R, L, C and G are distributed over the entire length of the transmission line. Hence they are called distributed parameters. They are also called primary constants.

<u>The infinite line, wavelength, velocity, propagation & Distortion line, the telephone cable</u>

5. **What is an infinite line?** **[M/J–2012, A/M–2004]**

An infinite line is a line where length is infinite. For an infinite line, the input impedance is equal to its characteristic impedance. A finite line, which is terminated by characteristic impedance is also called infinite line.

6. **Define – Propagation Constant** **[N/D–2007, M/J–2009]**

Propagation constant is defined as the natural logarithm of the ratio of the sending end current or voltage to the receiving end current or voltage of a line. It gives the manner in which the wave is propagated along the line. It specifies the variation of voltage and current in the line as a function of its length.

7. **How does frequency distortion occur in a line?** **[M/J–2007]**

When signals having many frequency components are transmitted along a line, different frequency components have different attenuations. Hence the receiving end waveform will not be identical with the input waveform at the sending end. This type of distortion is called frequency distortion.

8. **What is an equalizer in transmission line?** **[A/M–2005]**

An equalizer is a network whose frequency and phase characteristics are adjusted to the inverse the line. This results in a uniform frequency response over the desired frequency band. Hence the attenuation is equal for all the frequencies.

9. What is delay distortion? **[A/M–2011, M/J–2006, M/J–2007]**

When a signal having many frequency components is transmitted along a line, all the components will not have same transmission time, some components of the signal get delayed more than the others. So the receiving end signal and sending end signal will not be identical. This type of distortion is called delay distortion.

10. What is a distortion less line? **[A/M–2010]**

A transmission line, which has neither frequency distortion nor phase distortion is called a distortion less line.

11. What is the condition for a distortion less line? **[M/J–2009]**

The condition for a distortion less line is RC = LG.

where, R - Resistance
C - Capacitance
L - Inductance
G - Conductance

12. What is a finite line and state its significance?

A finite line is a line in which the length of the line is finite. Its input impedance is equal to its characteristic impedance. ($Z_s = Z_0$)

13. What is meant by the wavelength of a line?

The distance over which a wave travels along a line while the phase angle changes through 2π radians is called wavelength.

14. What is meant by line distortion?

If the output waveform and the corresponding input waveform of a transmission line are not identical, it is called line distortion.

15. What are the different types of line distortions?

The different types of line distortions are

i. Frequency distortion
ii. Phase or delay distortion

16. How is the frequency distortion avoided in a transmission line?

The frequency distortions can be avoided using the following methods:

i. The attenuation constant α should be made independent of frequency
ii. By placing equalizers at the line terminal

17. How is distortion avoided in a telephone line?

Distortion is avoided in a telephone line by decreasing R/G ratio or by increasing L/C ratio.

<u>Reflection on a line not terminated in Zo, Reflection Coefficient, Open and short circuited lines & Insertion loss</u>

18. What is loading? **[N/D–2004]**

Loading is the process of increasing the inductance value of the line by placing lumped inductors at specific intervals along the line. This avoids distortion.

19. Define – Reflection Coefficient **[N/D–2007]**

Reflection coefficient is defined as the ratio of the reflected voltage at the receiving end to the incident voltage at the receiving end of the line.

Reflection coefficient, K = Reflected voltage at load/Incident voltage at the load

$$K = V_r/V_i$$

20. Define – Reflection Loss **[M/J–2006, A/M–2008]**

Reflection loss is defined as the number of nepers or decibels by which the current in the load under image matched condition would exceed the current actually flowing in the load.

21. Define – Insertion Loss **[N/D–2006, M/J–2007]**

Insertion loss of a line or network is defined as the number of nepers or decibels by which the current in the load is changed by an insertion.

$$\text{Insertion Loss} = \frac{\text{Current flowing in the load without insertion of the network}}{\text{Current flowing in the load with insertion of the network}}$$

22. What are the different types of loading?

The different types of loading are

i. Continuous loading
ii. Patch loading
iii. Lumped loading

23. What is continuous loading?

Continuous loading is the process of increasing the inductance of a line by placing an iron core or a magnetic tape over the conductor of the line.

24. What is patch loading?

Patch loading is the process of using sections of continuously loaded cables separated by sections of unloaded cables. This increases the inductance value of the line.

25. What is lumped loading?

Lumped loading is the process of increasing the inductance of a line by placing lumped inductors at specific intervals along the line.

26. What is the purpose of impedance matching?

If the load impedance is not equal to the source impedance, then all the power that is transmitted from the source will not reach the load end and hence some power is wasted. For proper maximum power transfer, the impedance in the sending and receiving ends are matched.

27. When does reflection occur in a line?

Reflection occurs in a line under the following conditions

i. When the load end is open circuited
ii. When the load end is short circuited
iii. When the line is not terminated in its characteristic impedance

28. What are the conditions for a perfect line?

For a perfect line, the resistance and the leakage conductance values are neglected. The condition for a perfect line is R = G = 0.

29. What is a smooth line?

A smooth line is one in which the load is terminated by its characteristic impedance. No reflection occurs in such a line. It is also called flat line.

UNIT II - HIGH FREQUENCY TRANSMISSION LINES

<u>Parameters of open wire line and Coaxial cable at RF & Line constants for dissipation - voltages and currents on the dissipation less line</u>

1. What is dissipation less line? **[A/M–2011]**

A transmission line is called dissipation less line if the resistance of the line is negligible compare to other parameters of the line.

2. What are the assumptions for the analysis of radio frequency line?

The following assumptions are made for the analysis of radio frequency line

i. Due to the skin effect, the currents are assumed to flow on the surface of the conductor
ii. The leakage conductance (G) is zero
iii. The resistance R increases with $\sqrt{f}$ while inductance L increases with f. Hence L>>R.

3. What is the nature and value of Z_0 for the dissipation less line?

For the dissipation less line, the Z_0 is purely resistive and it is given by

$$\omega Z_0 = R_0 = \sqrt{L/_C}$$

4. What are nodes and antinodes on a line?

Nodes are the points over the line where magnitude of voltage or current is zero. Antinodes are the points over the line magnitude of voltage or current is maximum.

<u>Standing waves – nodes – standing wave ratio, Input impedance of open and short circuited lines - Power and impedance measurement on lines – λ / 4 line</u>

5. Define – Standing Wave Ratio **[N/D–2011, M/J–2007]**

Standing wave ratio is the ratio of the maximum to minimum magnitude of voltages or currents over a line.

$$S = \frac{|E_{max}|}{|E_{min}|} = \frac{|I_{max}|}{|I_{min}|}$$

6. What is the relationship between standing wave ratio and reflection coefficient? [M/J–2012]

The relationship between standing wave ratio and reflection coefficient is given by

$$S = \frac{1+|K|}{1-|K|}$$

7. What is the use of an eighth wave line? **[N/D–2006]**

An eighth wave is used to obtain a magnitude match between a resistance of any value with source of internal resistance R_0.

8. Why is a quarter wave line called an impedance inverter? **[N/D–2003]**

A quarter wave line called an impedance inverter because the line can transform a low impendence in to a high impedance and vice versa.

9. **What is the significance of a half wavelength line?** [M/J–2007]

The significance of a half wavelength line is to connect load to a source where the load source cannot be made adjacent.

<u>Impedance matching – single and double-stub matching circle diagram, Smith chart and its applications & Problem solving using Smith chart</u>

10. List the applications of the smith chart. **[M/J–2012]**

The applications of the smith chart are:

i. It is used to find the input impendence and input admittance of the line
ii. The smith chart also used for lossy transmission lines
iii. To implement single stub matching

11. Why is double stub matching preferred over single stub matching? [M/J-2012, A/M-2005]

Double stub matching is preferred over single stub matching due to the disadvantages of single stub matching.

i. Single stub matching is useful for a fixed frequency. As the frequency changes the location of single stub will also changed. So Double stub matching is preferred.
ii. The single stub matching system is based on the measurement of voltage minimum. Hence for the coaxial line it is very difficult to get such voltage minimum, without using slotted line section.

12. When does standing wave occur in a transmission line?

The standing wave occurs in a transmission line when the line is not terminated with its characteristic impedance. Due to this there is a reflection wave along the line.

13. What is the input impendence of an eighth wave line terminated in a pure resistance R_R?

The input impendence of an eighth wave line terminated in a pure resistance R_R is given by

$$Z_{in} = R_0 [(R_R + jR_0) / (R_0 + jR_R)]$$

14. What is an impedance matching in stub?

An impedance matching in stub is the use of an open or short circuited line of suitable length as a reactance shunted across the transmission line at a designated distance from the load.

15. State reasons for preferring a short– circuited stub over an open circuited stub.

A short circuited stub is preferred to open circuited stub because of the following reason:

i. Easy in constructions
ii. Lower loss of energy due to radiation
iii. Effectively stopping all field propagation

16. What are the two independent measurements that must be made to find the location and length of the stub?

The standing wave ratio S and the position of a voltage minimum are the independent measurements that must be made to find the location and the length of the stub.

17. What is called double stub matching?

Double stub matching is the method of impedance matching which has two stubs and the locations of the stub are arbitrary.

18. Why an open line is not frequently employed for impedance matching?

An open line is rarely used for impedance matching because of radiation losses from the open end due to capacitance effects and the difficulty of a smooth adjustment of length.

UNIT III - IMPEDANCE MATCHING IN HIGH FREQUENCY LINES

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UNIT IV - PASSIVE FILTERS

<u>The Neper - the Decibel - Characteristic impedance of Symmetrical Networks</u>

1. What is Neper? [M/J–2012, A/M–2004]

Neper is the natural logarithmic measure of a ratio of two voltage magnitudes or current magnitudes. It is denoted as ‘N’.

$$1 \text{ Neper (1N)} = \ln|V_1/V_2| = \ln|I_1/I_2|$$

2. Define – Bel [M/J–2012,A/M–2004]

Bel is the logarithm of ratio of input power to the output power.

$$1 \text{ Bel} = \log (P_1/P_2)$$

3. When is a network said to be symmetrical? [N/D–2011]

A network is said to be symmetrical, when the two series arms of a T network are equal or the two shunt arms of a π network are equal.

4. Define – Decibel

Decibel is the logarithmic measure of power. It is the logarithmic ratio of two power levels. It is used to express ratios such as gain, loss and relative values. It is denoted as ‘dB’.

$$1 \text{ Decibel (1dB)} = 10 \log|P_1/P_2| = 20\log|V_1/V_2| = 20\log|I_1/I_2|$$

5. What is a ladder network?

Ladder network is a cascaded connection of several T or π networks.

Current and voltage ratios - Propagation constant, - Properties of Symmetrical Networks

6. What is meant by attenuation constant (α)? **[M/J–2012]**

Attenuation constant (α) is the magnitude of ratio between input and output quantities of the network. The unit of attenuation constant is Neper.

7. What is meant by phase constant (β)? **[M/J–2012]**

Phase constant (β) is the phase angle between input and output quantities of network. The unit of phase constant is radian.

8. When is the image impedance said to be characteristic impedance?

The image impedance is said to be characteristic impedance (Iterative impedance), if the image impedances Z_{1i} and Z_{2i} of a symmetrical network are equal.

Filter fundamentals – Pass and Stop bands

9. Define – Filter

Filter is defined as the reactive network that will freely pass desired bands of frequencies while totally suppressing the other band of frequencies.

10. Define – Cutoff Frequency **[M/J–2007]**

Cutoff frequency is defined as the frequency at which the network changes from a pass band region to a stop band region or vice versa.

Constant K Filters - Low pass, High pass band, pass band elimination filters

11. What are called constant–k filters? **[A/M–2005,M/J–2006,N/D–2006,M/J–2007]**

If Z_1 and Z_2 are series and shunt arm impedances of a reactance network, then

$$Z_1 Z_2 = k^2$$

where k is real constant which is independent of frequency.

Networks or filter sections for which this relation holds are called Constant – k filters.

12. What are the disadvantages of constant–k filters? **[M/J–2012]**

The disadvantages of constant – k filters are:

i. The attenuation does not increases rapidly at cutoff

ii. The characteristic impedance varies widely over the pass band.

m - derived sections, Filter circuit design – Filter performance – Crystal Filters

13. What is a composite filter?

A composite filter is a combination of constant k filters, m derived filters and m derived half sections.

14. What are called crystal filters?

Filters made up of piezoelectric crystals are called crystal filters. It has lattice structure and has resonant frequency with high Q value. Hence it is possible to design narrow band crystal filters with sharp cutoff frequency.

UNIT V - WAVE GUIDES AND CAVITY RESONATORS

Application of the restrictions to Maxwell's equations, Transmission of TM waves between Parallel planes & Transmission of TEwaves between Parallel planes

1. What is called dominant mode? **[M/J–2012,M/J–2009]**

The mode which has lowest cut off frequency or highest cut of wavelength is called dominant mode.

2. What is called cutoff frequency? **[N/D–2007]**

The frequency at which the wave motion ceases is called cutoff frequency of the waveguide.

3. Distinguish between TE and TM waves. **[N/D–2012]**

TE	TM
Electric field strength E is entirely transverse.	Magnetic field strength is entirely transverse.
It has z component of magnetic field (H_z).	It has z component of electric field (E_z).
It has no z component of electric field (E_z).	It has no z component of magnetic field (H_z).

4. What are called guided waves?

The electromagnetic waves that are guided along or over conducting or dielectric surface are called guided waves. Examples of guided waves are parallel wires and transmission lines.

5. What is TE wave or H wave?

Transverse electric (TE) wave is a wave in which the electric field strength E is entirely transverse. It has a magnetic field strength H_z in the direction of propagation and no component of electric field E_z in the direction of wave propagation.

6. What is TM wave or E wave?

Transverse magnetic (TM) wave is a wave in which the magnetic field strength H is entirely transverse. It has a electric field strength E_z in the direction of wave propagation and no component of magnetic field H_z in the direction of wave propagation.

7. What are the dominant modes for TE and TM waves in parallel plane waveguides?

The Dominant modes in parallel plane waveguides for TE and TM waves are TE_{10} and TM_{10} respectively.

8. What is called cutoff wavelength?

The frequency at which the wave motion ceases is called cutoff frequency of the waveguide.

9. Write down the expression for cutoff frequency when the wave is propagated between two parallel planes.

The cutoff frequency when the wave is propagated between two parallel plates, is given by

$$f_c = {}^{m}\!/\left(2a(\sqrt{\mu\varepsilon})\right)$$

$$f_c = {}^{mv}\!/(2a)$$

where, m – mode
a – distance of seperation
v – velocity of propagation
μ – permeability
ε – permitivity

10. Write the expression for cutoff wavelength of the wave which is propagated in between two parallel planes.

The cutoff wavelength of the wave which is propagated in between two parallel planes is given by,

$$\lambda_c = 2a / m$$

where, m – mode
a – distance of seperation

11. Write the expression for guide wavelength when the wave is transmitted between two parallel planes.

The expression for guide wave length when the wave is transmitted in between two parallel planes is given by

$$\lambda_g = 2\pi \Big/ \left[\omega^2 \mu \varepsilon - \left(m\pi / a^2\right)\right]$$

where, m − mode; a − distance of seperation; ω − angular frequency; μ − permeability; ε − permitivity

12. Find the frequency of minimum attenuation for TM mode.

The attenuation α_{TM} reaches a minimum value at the frequency equal to $\sqrt{3}$ times the cutoff frequency.

$$f = \sqrt{3} f_c$$

13. State the relation between the attenuation factor for TE waves and TM waves for parallel plane waveguide.

The relation between the attenuation factor for TE waves and TM waves for parallel plate waveguide is given by,

$$\alpha_{TE} = \alpha_{TM} \left(f_c / f\right)^2$$

<u>Transmission of TEM waves between Parallel planes</u>

14. What is a TEM wave or principal wave? [A/M–2008]

The Transverse Electromagnetic (TEM) waves are waves in which both electric and magnetic fields are transverse entirely but have no components of E_z and H_z. It is also called the principal wave.

15. What are the characteristics of TEM waves? [N/D–2006, M/J–2009]

The characteristics of TEM waves are:

i. The amplitude of field component is constant
ii. The velocity of propagation and the wave impedance are independent of frequency of the wave
iii. TEM waves cannot exist in a single conductor hollow waveguide
iv. The cut – off frequency of TEM wave is zero
v. The ratio of amplitudes of E to H is intrinsic impedance.
vi. It doesn't have either E_z or H_z component.

<u>Manner of wave travel, Velocities of the waves & Characteristic impedance - Attenuators</u>

16. Define – Phase Velocity and Group Velocity [M/J–2007]

Phase velocity (v_p) is defined as the velocity of propagation of equiphase surfaces along a guide. It is given by,

$$v_p = \omega/\beta$$

Group velocity (v_g) is defined as the velocity with which the energy propagates along a guide. It is given by,

$$v_g = d\omega/d\beta$$

17. State the relation between phase velocity and group velocity. [N/D–2011]

The relation between phase velocity and group velocity is given by,

$$v_p v_g = c^2$$

18. Define – Attenuation Factor

Attenuation factor is defined as the ratio of power loss per unit length to twice the transmitted power.

Attenuation factor = (Power lost per unit length) / (2 x power transmitted)

19. Define – Wave Impedance

Wave impedance is defined as the ratio of electric field strength to magnetic field strength, which is given by

$Z_{xy} = {E_x}/{H_y}$, in the positive direction and

$Z_{xy} = -{E_x}/{H_y}$, in the negative direction.

20. Define – Wave Impedance [N/D–2007]

Wave impedance is defined as the ratio of electric field intensity to the magnetic field intensity.

21. What is the dominant mode for the TE waves in the rectangular waveguide? [N/D–2012]

The dominant mode for the TE waves in the rectangular waveguide is TE_{10} mode.

22. What is the dominant mode for the TM waves in the rectangular waveguide?[N/D–2012]

The dominant mode for the TM waves in the rectangular waveguide is TM_{11} mode.

23. What are the degenerate modes in a rectangular waveguide? [N/D–2006]

The higher order modes which are having the same cut off frequency are called degenerate modes. In a rectangular waveguide, $TE_{m,n}$ and $TM_{m,n}$ modes (both m = 0 and n = 0) are always degenerate mode.

24. What is a waveguide?

A hollow conducting metallic tube of uniform cross section which is used for propagating electromagnetic wave is called wave guide.

25. Why are rectangular waveguides preferred to circular waveguides?

Rectangular wave-guides are preferred to circular waveguides because of the following reasons:

i. Rectangular waveguide is smaller in size than a circular waveguide of the same operating frequency.
ii. The frequency difference between the lowest frequency on dominant mode and the next mode of a rectangular wave guide is bigger than in a circular wave guide.

26. Why is waveguide taken either in circular or in rectangular form?

Waveguides usually take the forms of circular or rectangular because of its simplicity and less expensive to manufacture.

27. What is an evanescent mode?

When the operating frequency is lower than the cut-off frequency, the propagation constant becomes real. So the wave cannot be propagated for that frequency. This non-propagating mode is known as evanescent mode.

28. Which are the non-zero field components for the TM_{11} mode in a rectangular waveguide?

The non-zero field components for the TM_{11} mode in a rectangular waveguide are Hx, Hy, Ey and Ez.

29. Which are the non-zero field components for the TE_{10} mode in a rectangular waveguide?

The non-zero field components for the TE_{10} mode in a rectangular waveguide are H_x, H_z and Ey.

30. What are the cutoff wave length and cutoff frequency of the TE_{10} mode in a rectangular waveguide?

The cutoff wave length and cutoff frequency of the TE_{10} mode in a rectangular waveguide are given by,

Cut off wave length, $\lambda_c = 2a$ and

Cutoff frequency, $f_c = c/(2a)$

31. Why do TM_{01} and TM_{10} modes not exist in a rectangular waveguide?

For TM modes in rectangular waveguides, neither 'm' nor 'n' can be zero because all the field equations vanish (i.e., Hx, Hy, Ey and Ez = 0). If m = 0, n = 1 or m = 1, n = 0 no fields are present. Hence TM_{01} and TM_{10} modes in a rectangular waveguide do not exist.

<u>Cylindrical waveguides</u>

32. State the applications of circular waveguide.

Circular waveguides are used as attenuators and phase shifters.

33. Which mode in circular waveguide has attenuation effect decreasing with increase in frequency?

TE_{01} mode in circular wave guide has attenuation effect decreasing with increase in frequency.

<u>The TEM wave in coaxial lines, Excitation of wave guides</u>

34. Why is TEM mode not possible in a rectangular waveguide?

Since TEM wave do not have axial component of either E or H wave, it cannot propagate within a single conductor waveguide.

<u>Guide termination and resonant cavities</u>

35. What are the performance parameters of a microwave resonator? [A/M–2012]

The performance parameters of a microwave resonator are:

i. Resonant frequency
ii. Quality factor
iii. Input impedance

36. Define – Quality Factor of Microwave Resonator [A/M–2009,N/D–2011]

Quality factor of microwave resonator is defined as the measure of frequency selectivity of the resonator. It is given by,

$$Q = {f_0}/_{BW}$$

where f_0 − Resonant frequency BW − Bandwidth

37. What is resonant frequency of a microwave resonator?

Resonant frequency of a microwave resonator is the frequency at which the energy in the resonator attains maximum value, i.e., twice the electric or magnetic energy.

38. List the basic configurations of coaxial resonator.

The basic configurations of coaxial resonator are:

i. Quarter wave coaxial cavity
ii. Half wave coaxial cavity
iii. Capacitive and coaxial cavity

EC2305 – TRANSMISSION LINES AND WAVEGUIDES

UNIT I - FILTERS

1. **Draw a constant –k T section band elimination filter and explain the operation with necessary design equations.(16)**

2. **Draw a constant –k T section band pass filter and explain the operation with necessary design equations.(16)**

3. Derive the design equations of constant-k low pass filter. With neat diagram, explain the variations of characteristic impedance (Z_0), attenuation constant (α) and phase constant (β) with frequency.(16)

4. **Derive the design equations of constant-k high pass filter. With neat diagram, explain the variations of characteristic impedance (Z_0), attenuation constant (α) and phase constant (β) with frequency.(16)**

5. **Derive relevant equations of m-derived low pass filter and m-derived high pass filter.(12)**

6. **Derive the expression for the characteristic impedance and propagation constant of a symmetrical T network**. **(12)**

7. Derive the expression for the characteristic impedance and propagation constant of a symmetrical π network.(12)

8. Design a constant-k T section of band pass filter with cut-off frequencies of 1 kHz and 4 kHz. The design impedance is 600 Ω.(8)

9. **Design m-derived T type low pass filter to work into load of 500 Ω with cut-off frequency at 4 kHz and peak attenuation at 4.15 kHz.**(8)

UNIT II – TRANSMISSION LINE PARAMETERS

1. **Derive the general transmission line equations for voltage and current at any point on a line. (16)**

2. **Deduce the expressions for characteristic impedance and propagation constant of a line of cascaded identical and symmetrical T sections of impedance. (8)**

3. **Derive an expression for the attenuation constant and phase constant of a transmission line in terms of the line constants R, L, G and C. (8)**

4. **Explain the physical significance of the transmission line general solution equations derived for E and I in terms of E_R and I_R. (8)**

5. **Derive an expression for the input impedance and transfer impedance of a transmission line. (8)**

6. **Derive the conditions required for a distortion less line. (8)**

7. Explain the reflection on lines not terminated in characteristic impedance with phasor diagrams.Define reflection coefficient and reflection loss. (8)

8. Explain the significance of reflection coefficient and insertion loss. (8)

9. **A line has the following primary constants:**
   R = 100 Ω/km, L = 0.001 H/km, G = 1.5 μmho/km, C = 0.062 μF/km.

Find the characteristic impedance, propagation constant, velocity of propagation and wavelength. (16)

10. **The characteristic impedance of a 805 m long transmission line is 94∟-23.2º Ω, the attenuation constant is 74.5 x 10^{-6} Np/m and the phase shift constant is 174 x 10^{-6} rad/m at 5 kHz. Calculate the line parameters R, L, G and C per meter and the phase velocity on the line. (16)**

11. **A generator of 1V, 1 kHz supplies power to a 100 km open wire line terminated in 200 Ω resistance. The line parameters are R = 10 Ω/km, L = 3.8 mH/km, G = 1x10^{-6} mho/km, C = 0.0085 µF/km.**
    Calculate the input impedance, reflection coefficient, the input power, and the output power and transmission efficiency. (16)

12. A distortion less transmission line has attenuation constant (α) 1.15x10^{-3} Np/m and capacitance of 0.1x10^{-9} per meter. The characteristic resistance $\sqrt{(L/C)}$ = 50 Ω. Find the resistance, inductance and conductance per meter of the line. (6)

13. A telephone cable 64 km long has a resistance of 13Ω/km and a capacitance of 0.008 µF/km. Calculate the attenuation constant, velocity and wavelength of the line at 1000 Hz. (6)

UNIT III – THE LINE AT RADIO FREQUENCY

1. **Discuss the various parameters of open-wire and co-axial lines at radio frequency. (16)**
2. **Define standing wave ratio and obtain the expression of VSWR in terms of reflection co-efficient. (8)**
3. **Derive the expression for the input impedance of a lossless line. (8)**
4. **Derive the expressions for the input impedance of open and short circuited lines. (8)**
5. **Derive the expression that permit easy measurement of power flow on a line of negligible losses. (8)**
6. **Draw and explain the operation of half wave and quarter wave line. (8)**
7. **Obtain the expression for the length and location of a short circuited stub for impedance matching on a transmission line. (16)**
8. Explain the method of single stub matching using smith chart. (8)
9. Draw and explain the principle of double stub matching. (16)
10. A loss less line has a characteristic impedance of 400 Ω. Determine the standing wave ratio if the receiving end impedance is 800+j0.0 Ω. (8)
11. A UHF lossless transmission line working at 1 GHz is connected to an unmatched line producing a voltage reflection coefficient of 0.5 (0.866 + j 0.5). Calculate the length and position of the stub to match the line. (8)
12. Consider a 30 m long lossless transmission line with the characteristic impedance of 50 Ω operating at 2 MHz, if the line is terminated in impedance (60+j40) Ω. Calculate the reflection coefficient, the standing wave ratio, the input impedance, if the velocity on the line is v= 0.6c (c =3x10^8 m/s). (16)

13. **A 50 Ω lossless transmission line is terminated in a load impedance of Z_L = (25+j50) Ω. Use the smith chart to find**
    a). Voltage reflection coefficient
    b). VSWR
    c). Input impedance of the line, given that the line is 3.3λ long
    d). Input admittance of the line.
    (16)

UNIT IV – GUIDED WAVES BETWEEN PARALLEL PLANES

1. **Discuss in detail guided waves between parallel planes with neat diagram. 16)**

2. **Obtain the solution for the field components of TE waves between parallel plates, propagating in Z direction.(16)**

3. **Derive the expressions for the field components of TM waves between parallel planes.(16)**

4. Derive the expressions for the field components of TEM waves between parallel planes. Discuss the properties of TEM waves. (8)

5. Distinguish between the characteristics of TE and TM waves. (8)

6. Write a brief note on the manner of wave travel and their velocities between parallel planes. (8)

7. Explain wave impedance and obtain the expressions for wave impedance of TE, TM and TEM waves guided along parallel planes. Also sketch the variation of wave impedance with frequency. (8)

8. Discuss the attenuation of TE and TM waves between parallel planes with necessary expressions and diagram. (8)

9. **For a frequency of 5 GHz and plane separation of 8cm in air, find the following for TM_1 mode.**
   a) **Cut-off wavelength**
   b) **Characteristic impedance**
   c) **Phase constant**

10. **For a frequency of 10 GHz and plane separation of 5cm in air, find the following:**
    a) **Cu-off wavelength**
    b) **Phase velocity**
    c) **Group velocity**

11. **For a frequency of 6 GHz and plane separation of 3cm, find the group and phase velocities for the dominant mode.**

UNIT V - WAVEGUIDES

1. **Derive the equations to give the relationship among the fields within the rectangular guide.**

2. **Derive the field configuration, cut-off frequency and velocity of propagation for TM waves in rectangular waveguide.**

3. **Derive the field configuration, cut-off frequency and velocity of propagation for TE waves in rectangular waveguide.**

4. **A rectangular waveguide measuring a = 4.5 cm and b = 3 cm internally has a 9 GHz signal propagated in it. Calculate the cut-off frequency, guide wavelength, phase velocity, group velocity and characteristic wave impedance for TM_{11} mode.**

5. A TE_{10} mode is propagated through rectangular waveguide with a = 10 cm at a frequency of 2.5 GHz. Find cut-off wavelength, phase velocity, group velocity and wave impedance.

6. **A TE_{10} wave at 10 GHz propagates in a X-band copper rectangular waveguide with inner dimensions a = 2.3 cm and b = 1 cm which is filled with Teflon ($\varepsilon_r = 2.1$, $\mu_r = 1$). Calculate cut-off frequency, velocity of propagation, phase velocity, phase constant, guide wavelength and wave impedance.**

7. A rectangular waveguide with dimensions a = 2.5 cm and b = 1 cm is to operate below 15.1 GHz. How many TE and TM modes can the waveguide transmit if the guide is filled with a medium characterized by $\sigma = 0$, $\varepsilon_1 = 4\varepsilon_0$ and $\mu_r = 1$? Calculate cut-off frequencies of the modes.

8. **Derive the solution of field equations using cylindrical co-ordinates.**

9. **Explain the propagation of electromagnetic waves in a cylindrical waveguide with suitable expressions.**

10. **Discuss the propagation of TM waves in a circular waveguide with relevant expression for the field components.**

11. **Derive the expressions for the field components of TE waves guided along circular waveguide. (16)**

12. **Write a brief note on excitation of modes in circular waveguide. (12)**

13. **Calculate the cut-off wavelength, guide wavelength and wave impedance of a circular waveguide with an internal diameter of 4 cm for a 10 GHz signal propagated in it in the TE_{11} mode. (8)**

14. An air-filled circular waveguide having an inner radius of 1 cm is excited in dominant mode at 10 GHz. Find cut-off frequency of dominant mode, guide wavelength, wave impedance and the bandwidth for operation in dominant mode only. (Given [$X'_{11} = 1.84$; $X_{01} = 240$]) (8)

15. **Derive the expressions for the field components existing in a rectangular cavity. (8)**

16. **Obtain the expression for resonant frequency of circular cavity resonator. (8)**

17. **What is meant by quality factor of the cavity resonator? Derive the expression for the quality factor of rectangular and circular cavity resonator. (16)**

18. Find the resonant frequencies of first five lowest modes of an air-filled rectangular cavity of dimensions 5 cm x 4 cm x 2.5 cm. List them in ascending order. (8)