Electrical Engineering - Optional For IAS (UPSC)

E.M Theory - 2015-2021

UPSC – ELECTRICAL Engineering optional – 2015 Questions

1. A voltage of a wave travelling in a non-magnetic medium is given by the equation

$\overline{\mathrm{E}} = 4\sin(2\pi \times 10^7 t - 0.8x)\hat{a}_z\ \mathrm{V/m}$. **[10M]**

Find:

(a) ε_r, η

(b) The time-average power carried by the wave.

2. A distortionless line has $z_0 = 60\Omega, \alpha = 20\, mNp/m,\ \ u = 0.6\, c$ where c is the velocity of the wave in vacuum. Find R, L, G, C and λ at 100 MHz. **[20M]**

UPSC – ELECTRICAL Engineering optional – 2016 Questions

1. Derive an expression for Maxwell's equation in integral form from Ampere's law. **[10M]**

2. (i) A transmission line has the following parameters: $Z_L = (200 - j200)\Omega,\ Z_0 = 200\Omega$ Determine the voltage standing wave ratio and reflection coefficient of the line**.**

(ii) Write the significance of Smith chart.

(iii) Find the length of x of the 100Ω transmission line which converts a load impedance $z_L = (100 + j100)\Omega$ to a pure resistance. Also find the value of the resistanceR_x. Assume $VSWR = 2.6$. **[20M]**

3. (i) Determine the propagation constant γ for a material having **[20M]**

$\mu_r = 1, \varepsilon_r = 8\ and\ \ \sigma = 0.25\ \ \mathrm{pS}/m$, if the wave frequency is 1.6 MHz.

(ii) Find the skin depth δ at a frequency of 1.6 MHz in aluminium, where $\sigma = 38.2\ \ \mathrm{MS/m}$ and $\mu_r = 1$. Also find γ and the wave velocity u.

4. If a propagating wave in free space has a potential gradient at any point (x, y, z) as

$\bar{E} = \left(-\bar{\imath} - 2\sqrt{3}\,\bar{\jmath} + 3\bar{k}\right)e^{-j0.04\pi}\left(\sqrt{3}x - 2y - 3z\right)$ V/m then determine– **[10M]**

(i) the vertical direction of propagation;

(ii) the wavelength of the propagating wave;

(iii) the frequency of the propagating wave;

(iv) the phase velocity and phase velocity vector.

What are the apparent velocities and wavelengths along x, y and z directions?

UPSC – ELECTRICAL Engineering optional – 2017 Questions

1. Show that for a distortionless transmission line, the attenuation constant α does not depend on frequency, whereas the phase constant β depends linearly on it. **[10M]**

2. **(i)** What is meant by an infinite transmission line? Also, explain the term 'electrical length' of a transmission line. In what units is it measured?

(ii) Determine the electrical length of a 20 m long transmission line operating at 1 MHz, if $u = 0.7c$ on the line. Take $c = 3 \times 10^8\, m/s$. **[20M]**

3. The electric field and magnetic field in free space are given by

$$E = \frac{100}{\rho}\cos(2 \times 10^7 t + \beta z)\hat{a}_\phi \text{ V/m}$$

$$H = \frac{H_0}{\rho}\cos(2 \times 10^7 t + \beta z)\hat{a}_\rho \text{ A/m}$$

Express these fields in phasor form and determine the constants H_0 and β such that these fields satisfy Maxwell's equations. The permeability and permittivity of the free space are $4\pi \times 10^{-7}\, H/m$ and $8.854 \times 10^{-12}\, F/m$ respectively. **[20M]**

UPSC – ELECTRICAL Engineering optional – 2018 Questions

1. A low loss transmission line has characteristic impedance $Z_0 = 70\Omega$ and is terminated by another impedance of $115 - j80\Omega$. The wavelength on the line is $2.5m$. Find:

I. SWR (Standing Wave Ratio)

II. Maximum and minimum line impedance, Z_{1max} and Z_{1min} **[10M]**

2. If the input impedances of a short and open circuited transmission line of length 1.5 m are $Z_{SC} = -j78\Omega$ and $Z_{OC} = -j90\ \Omega$ respectively, determine the characteristic impedance Z_0 and propagation constant γ of the line. **[10M]**

3. **(i)** Derive the Maxwell's equation for time varying magnetic field based on Ampere's circuital law.

(ii) A parallel plate capacitor with plate area of 5 cm^2 and plate separation of 3 mm has a voltage of $50 \sin 10^3 t$ V applied to its plates. Calculate the displacement current assuming $\varepsilon = 2\varepsilon_0$. **[10M]**

4. A travelling $\overline{E}$ field in the free space of amplitude 100 V/m strikes a perfect dielectric as shown in Figure 7(a)(i). Determine the value of E_t. **[10M]**

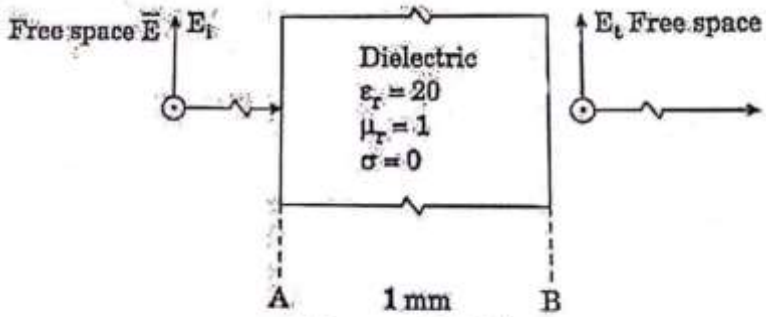

Figure 7(a)(i)

5. A uniform plane wave in air partially reflects from the surface of a material whose properties are unknown. Measurements of the electric field in front of the interface region yield a 1.5 m spacing between maxima, with the first maximum occurring 0.75 m from the interface. A standing wave ratio of 5 is measured. Determine the intrinsic impedance η_w of the unknown material. **[10M]**

UPSC – ELECTRICAL Engineering optional – 2019 Questions

1. Two extensive homogeneous isotropic dielectrics meet on a plane at $z = 0$.For $z > 0$, $\varepsilon_{r_1} = 4$ and for $z < 0, \varepsilon_{r_2} = 3$.A uniform electric field $\vec{E}_1 = 5\ \hat{a}_x - 2\hat{a}_y + 3\ \hat{a}_z\ \mathrm{kV/m}$ exists for $z \geq 0$.

Find :

(i) $\vec{E}_2$for $z \leq 0$

(ii) The energy densities $(\text{in } \mathrm{J/m^3})$ in both dielectrics **[10M]**

2. A lossless line has a characteristic impedance of $50\ \Omega$ and is terminated in a load resistance of $75\ \Omega$. The line is energized by a generator which has an output impedance of $50\ \Omega$ and an open circuit output voltage of $30\ \mathrm{V_{rms}}$. The line is assumed to be 2.25 wavelength long. Determine:

(i) The output impedance

(ii) The magnitude of the instantaneous load

(iii) The instantaneous power delivered to the load. **[10M]**

3. (i) A two-dimensional electric field is given by $\vec{E} = x^2\hat{a}_x + x\hat{a}_y\ V/m$. Show that this electric field cannot arise form a static distribution of charge.

(ii) A transmisstion line of length 5 m is tested at a frequency of 20 MHz. When the far end of the line is short circuited, the impedance measured at the sending end is $4.61\ \Omega$ and when the far end is open circuited, the impedance becomes $1390\ \Omega$. Calculate the characteristic impedance and propagation constant of the line. **[10M]**

4. An aeroplane files over the surface of the ocean for which $\sigma = 4\ \mathrm{S/m}$, $\varepsilon_r = 81$ and $\mu_r = 1$.The aeroplane transmits the signal in the form of 1 MHz plane wave having an electric field intensity of $1000\ \mathrm{V/m}$ and propagating vertically downward. If a submarine requires a minimum signal of $20\mu\mathrm{V/m}$ for adequate reception, determine the maximum communication depth of the submarine. **[20M]**

UPSC – ELECTRICAL Engineering optional – 2020 Questions

1. A parallel plate capacitor is made of circular discs of radius 0.1 m. The medium inside is air. The spacing between the two plates is 0.05 m. A voltage of $50 \cos 10^4 t$ volts is applied between the two plates. Find the rms value of the displacement current flowing through the capacitor using Maxwell's equations. Also show that the rms value of the total capacitor current calculated from voltage equation is same as the displacement current. Assume permittivity of free space $\varepsilon_0 = \frac{1}{36\pi} \times 10^{-9}\, F/m$. **[10M]**

2. A uniform plane wave travelling in air is having an electric field of $50\ V/m$ and is normally incident on an infinitely thick slab of dielectric constant 10. Find the electric and magnetic fields just inside the slab surface. Also find the penetrated power inside the slab and the reflected electric and magnetic fields from the slab surface.
Assume $\mu_0 = 4\pi \times 10^{-7}\, H/m$ and $\varepsilon_0 = \frac{1}{36\pi} \times 10^{-9}\, F/m$. **[10M]**

3. Under what conditions do the attenuation constant α and the velocity of propagation v, for a distortionless transmission line, become independent of the frequency simultaneously? Why is it not practical to have such a transmission line? **[10M]**

UPSC – ELECTRICAL Engineering optional – 2021 Questions

1. In certain material with $\sigma = 0, \varepsilon = \varepsilon_0\ \varepsilon_r$ and $\mu = \mu_0\ \mu_{r,}$ the magnetic field intensity component is given by $H = 10 \sin(10^8 t - 2x) a_z\, A/m$. **[10M]**
Find the following:
(i) Displacement current density
(ii) Electric field intensity

2. The magnetic field intensity of a linearly polarized uniform plane wave propagating in the $+Y$-direction in sea water ($\varepsilon_r = 80,\ \mu_r = 1,\ \sigma = 4\ S/m$) is
$H = 0.1 \sin\left(10^{10}\pi t - \frac{\pi}{3}\right) a_x\, A/m$
At $Y = 0$, determine the following: **[20M]**

(i) The attenuation constant, intrinsic impedance, the wavelength and skin depth.

(ii) The location at which the amplitude of H is $0.01\ A/m$.

(iii) The expression for $E(y,t)$ and $H(y,t)$ at $Y = 0.5\ (m)$ as functions of t.

3. A lossless transmission line has characteristic impedance $Z_0 = 50\Omega$. its length is 30 m and operates at 5 MHz. the line is terminated with a load $Z_L = 60 + j50\Omega$. If the phase velocity $u = 0.6c$ on the line, find the following: **[10M]**

(i) The reflection coefficient 'Γ'

(ii) The standing wave ratio 'S'

(iii) The input impedance 'Z_{in}'