CHAPTER-2

Q-2.1 A wave propagates in a non-magnetic media having relative dielectric constant ε_r. Find its value if (a) η = 180Ω, (b) the wavelength at 10GHz is 2cm and (c) β = 0.001, f = 25000Hz

MATLAB CODE

```
% For nonmagnetic media mur = 1 or mu = mu0

mu0 = 4*pi*10^-7;   aps0 = 8.854*10^-12;

% Required relation v = 1/sqrt(mu*aps), eta = sqrt(mu/aps), beta =2*pi/lemda

%and lemda = v/f =v0/(f*sqrt(mur*apsr)

muap = mu0*aps0;  apmu = mu0/aps0; v0 = 1/sqrt(muap);   eta0 = sqrt(apmu);

% (a) Given

eta = 180;

% From relation eta = sqrt(mu/aps) the obtained value of apsr is:

apsr1 = (eta0/eta)^2

% (b) Given

lemda = 2*10^-2;          f = 10^10;         v = f*lemda;

% From the relations lemda = v/f, v = v0/sqrt(apsr)

apsr2 = (v0/v)^2

% (c ) Given

beta = 0.001;        f = 25000;

% From the relation β = 2π/λ=2πf/υ=2πf/(υ0/√εr)

apsr3 = ((beta*v0)/(2*pi*f))^2
```

ANSWER: **(a)** ε_r = 4.3805 (b) ε_r = 2.2469 (c) ε_r = 3.6426011

Q-2.2 A wave propagates at 100MHz in a dielectric media having some component of conductivity (σ) of the order of 10^{-5} Ʊ/m. and $\mu = \mu_0$. Find the values of α, β, υ and η

MATLAB CODE

```
% Given
pi = 3.1415;    f0 = 10^8;   sigma=10^-5;   i = sqrt(-1);
mu0 = 4*pi*10^-7;   aps0 = 8.854*10^-12;    mur =1;     apsr =1;
mu = mu0*mur;       aps = aps0*apsr;           muap = mu0*aps0;
muapt = sqrt(muap);          apmu = mu0/aps0;
v0 = 1/muapt
eta0 = sqrt(apmu)
w = 2*pi*f0;      wv = w/v0;
alfa = sigma*eta0/2
ws = w^2;          apss = aps^2;          sigs = sigma^2;
A1 = 8*ws*apss;
A11 = sigs/A1
A2 = 1+A11;
beta = wv*A2
% v =v0*(1-A11)
A4 = sigma/(2*w*aps);
eta=eta0*(1+i*A4)
```

ANSWER:

v0 = 2.9980e+008   eta0 = 376.7288   alfa = 0.0019   beta = 2.0957

$\upsilon \approx$ **2.9980e+008** (1 - **4.0392e-007**) **eta = 3.7673e+002 +3.3860e-001i**

Q-2.3 Find the depth of penetration at 1000Hz in (a) silver ($\sigma = 6.17 \times 10^7$ Ʊ/m), (b)

Aluminium (σ = 3.72 x 10^7 Ʊ/m), (c) Brass (1.5 x 10^7Ʊ/m) and (d) fresh water (σ = 10^{-3} Ʊ/m)

MATLAB CODE

```
% Relation for Rs is given by Eqn.(2.17)
% Also given
f = 1000;     pi = 3.1416;     mu = 4*pi*10^-7;   k = pi*mu*f;     k1 = sqrt(1/k);
% (a)  for silver
sigma= 6.17*10^7;     sig = sqrt(sigma);
delta = k1/sig
% (b)  for Aluminium
sigma= 3.72*10^7;     sig = sqrt(sigma);
delta = k1/sig
% (c)  for brass
sigma= 1.5*10^7;     sig = sqrt(sigma);
delta = k1/sig
% (a)  for fresh water
sigma= 10^-3;          sig = sqrt(sigma);
delta = k1/sig
```

ANSWER:

delta =: (a) 0.002m (b) 0.0026m (c) 0.0041m (d) 503.2909m

Q-2.4 The conductivity (σ) and depth of penetration (δ) at 1000Hz are given for slabs made of: (a) silver σ = 6.17 x 10^7 Ʊ/m, δ = 0.00202m (b) copper σ = 5.8 x 10^7 Ʊ/m, δ = 0.00209m (c) aluminium σ = 3.72 x 10^7 Ʊ/m, δ = 0.00261m and (d) brass σ = 1.5 x 10^7 Ʊ/m, δ = 0.00411m. Find the surface resistance of these slabs at 1000Hz. Also find the change if this frequency is raised to 10MHz.

MATLAB CODE

```
% In view of Eqn. (2.19b) Rs = 1/ (sigma*delta)

% Thus Rs at 1000Hz for:

%(a) Silver:

sigma = 6.17*10^7;     delta = 0.00202;          A1 = sigma*delta;

Rssi = 1/A1

%(b) Copper:

sigma = 5.8*10^7;            delta = 0.00209;         A2 = sigma*delta;

Rscu = 1/A2

%(c) Aluminium:

sigma = 3.72*10^7;               delta = 0.00261;         A3 = sigma*delta;

Rsal = 1/A3

%(d) Brass:

sigma = 1.5*10^7;                delta = 0.00411;          A4 = sigma*delta;

Rsbr = 1/A4

% In view of the relation Rs = (1/σ) (1/δ) = (1/σ) √(πμσ) √f, Rs is proportional

% to √f.   If all other parameters are constant Rs = k √f. Thus at f1 Rs1 = k %√f1. and at f2

Rs2 = k √f2. The change in Rs will correspond to

% Rs2 = Rs1 x sqrt(f2/f1)

f1 = 10^3;          f2 = 10^7;            fr = sqrt(f2/f1);

% New values of Rs are

%(a) Silver:

Rssin = Rssi*fr

%(b) Copper:
```

Rscun = Rscu*fr

%(c) Aluminium:

Rsaln = Rsal*fr

%(d) Brass:

Rsbrn = Rsbr*fr

ANSWER:

Values of Rs at 1000Hz for

Silver - Rssi = 8.0235e-006 Copper - Rscu = 8.2495e-006

Aluminium - Rsal = 1.0300e-005 Brass - Rsbr = 1.6221e-005

Values of Rs at 10MHz for

Silver - Rssin = 8.0235e-004 Copper - Rscun = 8.2495e-004

Aluminium - Rsaln = 0.0010 Brass - Rsbrn = 0.0016

Q-2.5 Find the time average power density at x = 1 if for a uniform plane wave is given by **E** = 30 $e^{-\alpha x}$ cos (10^8t – βx) $\mathbf{a_z}$ V/m and the dielectric constant of the propagating media is: (a) $\varepsilon = \varepsilon_0$, $\mu = \mu_0$ (b) $\varepsilon_r = 2.26$, $\sigma = 0$ and (c) $\varepsilon_r = 3.4$, $\sigma/\omega\varepsilon = 0.2$

MATLAB CODE

% Given **E** = 30 $e^{-\alpha x}$ cos (10^8t – βx) $\mathbf{a_z}$ V/m

% From the expression of E

E0z = 30; w = 10^8; x = 1; mu0 = 4*pi*10^-7; aps0 = 8.854*10^-12;

eta0 = sqrt(mu0/aps0)

% (a)

mur = 1; apsr = 1; mu = mur*mu0; aps = apsr*aps0;

eta1 = sqrt(mu/aps)

Pxav= (E0z^2)/(2*eta1)

```
% (b)
mur = 1;  apsr = 2.26;      mu = mur*mu0;       aps = apsr*aps0;
eta2 = sqrt(mu/aps)
Pxav= (E0z^2)/(2*eta2)
% (c)
mur = 1;  apsr = 3.4;      mu = mur*mu0;      aps = apsr*aps0;
eta3 = sqrt(mu/aps)
Px= (E0z^2)/(2*eta3);
% Given loss tangent tan(theta) = sigma/w*aps = 0.2
theta = atan (0.2);   cs = cos(theta);     sigma = 0.2*w*aps;
alfa = (sigma*eta3)/2;       Pxav = Px*exp(-2*alfa*x)*cs
```

ANSWER: (a) eta1 = 376.7347 Pxav = 1.1945

(b) eta2 = 250.6002 Pxav = 1.7957

(c) eta3 = 204.3131 Pxav = 1.9098

Q-2.6 Find the reflection and transmission coefficients for E and H of a uniform plane wave traveling in region-1 normally incident at the surface of region-2. The relative dielectric constants are: (a) $\varepsilon_1 = 2.53$ and $\varepsilon_2 = 1$ (b) $\varepsilon_1 = 1$ and $\varepsilon_2 = 2.53$ (c) $\varepsilon_1 = 2.53$ and $\varepsilon_2 = 2.26$.

MATLAB CODE

```
%(a)
aps1 = 2.53;      aps2 = 1;         a = sqrt(aps1);            b = sqrt(aps2);
c = a - b;     d = a + b;          e = b - a;
% Reflection coefficient for E
Taue = c/d
%Transmission coefficient for E
```

```
Touh=2*a/d

%Reflection coefficient for H

Te = e/d

%Transmission coefficient for H

Th=2*b/d

%(b)

aps1 = 1;   aps2 = 2.53;     a = sqrt(aps1);          b = sqrt(aps2);

c = a - b;          d = a + b;        e = b - a;

% Reflection coefficient for E

Taue = c/d

%Transmission coefficient for E

Touh=2*a/d

%Reflection coefficient for H

Te = e/d

%Transmission coefficient for H

Th=2*b/d

%(c)

aps1 = 2.53;      aps2 = 2.26;       a = sqrt(aps1);         b = sqrt(aps2);

c = a - b;         d = a + b;          e = b - a;

% Reflection coefficient for E

Taue = c/d

%Transmission coefficient for E

Touh=2*a/d

%Reflection coefficient for H

Te = e/d
```

```
%Transmission coefficient for H
Th=2*b/d
```

ANSWER:

(a) Taue = 0.2280 Touh = 1.2280 Te = -0.2280 Th = 0.7720

(b) Taue = -0.2280 Touh = 0.7720 Te = 0.2280 Th = 1.2280

(c) Taue = 0.0282 Touh = 1.0282 Te = -0.0282 Th = 0.9718

Q-2.7 Calculate the percentage of reflected and transmitted powers for a uniform plane wave traveling between two regions. The transmission and reflection coefficients for E and H are:

Reflection coefficient for: Transmission coefficient for:

```
%          E =RE           H = RH      E = TE      H = TH
%(a)    0.227977       - 0.227977      1.228       0.772
%(b)    -0.227977        0.227977      0.772       1.228
%(c)    0.02817         -0.02817       1.0282      0.97179
```

MATLAB CODE

```
%  Let Ei is the incident E and Hi is the incident H
% Er is the reflected E and Hr is the reflected H
% Et is the transmitted E and Ht is the transmitted H.
% Pin, Pr and Pt are the incident, reflected and transmitted powers
% RE is the reflection coefficient for E
% RH is the reflection coefficient for H
% TE is the transmission coefficient for E
% TH is the transmission coefficient for H
% Assuming
Ei =1;   Hi = 1;     Pin= Ei*Hi;
```

```
%(a) Given
RE = 0.227977;       RH = - 0.227977;     TE =1.228;      TH = 0.772;
Er = RE*Ei;      Hr = RH*Hi;
Pr = Er*Hr
Et = TE*Ei;      Ht = TH*Hi;
Pt= Et * Ht
%(b) Given
RE =-0.227977;     RH =0.227977;      TE =0.772;     TH =1.228;
Er = RE*Ei;       Hr = RH*Hi;
Pr = Er*Hr
Et = TE*Ei;       Ht = TH*Hi;
Pt= Et * Ht
%(c) Given
RE = 0.02817;      RH = -0.02817;     TE =1.0282;      TH = 0.97179;
Er = RE*Ei;        Hr = RH*Hi;
Pr = Er*Hr
Et = TE*Ei;        Ht = TH*Hi;
Pt= Et * Ht
```

ANSWER:

(a) Pr = -0.0520 or 5.2% Pt = 0.9480 or 94.8%

(b) Pr = -0.0520 or 5.2% Pt = 0.9480 or 94.8%

(c) Pr = -7.9355e-004 or o.o79355% Pt = 0.9992 or 99.92%

Q-2.8 Find the reflection coefficients for a vertically polarized wave obliquely incident on the interface between two regions making 30° angle with the perpendicular drawn at the boundary surface. The relative dielectric constants of regions- 1 and 2 are: (a) $\varepsilon_1 = 2.53$ and $\varepsilon_2 = 1$ (b) $\varepsilon_1 = 1$ and $\varepsilon_2 = 2.53$ (c) $\varepsilon_1 = 2.53$ and $\varepsilon_2 = 2.26$.

MATLAB CODE

```
% For a vertically polarized wave the reflection coefficient is given by
% Er/Ei = [cosθ1 - √{(ε2/ε1) - sin²θ1}]/[cosθ1 +√{(ε2/ε1)- sin²θ1}]
% Given
pi = 3.1415;    theta = pi/6;        Cs = cos(theta);      Ss = sin(theta);        Sst = Ss^2;
%(a)
aps1 = 2.53;        aps2 = 1;           aps21= (aps2/aps1);
A1 = (aps21-Sst);          A2 = sqrt(A1);
RC= (Cs-A2)/(Cs+A2)
%(b)
aps1 = 1;     aps2 = 2.53;         aps21= (aps2/aps1);
A1 = (aps21-Sst);              A2 = sqrt(A1);
RC= (Cs-A2)/(Cs+A2)
%(c)
aps1 = 2.53;     aps2 = 2.26;       aps21= (aps2/aps1);
A1 = (aps21-Sst);          A2 = sqrt(A1);
RC= (Cs-A2)/(Cs+A2)
```

ANSWER: RC =: (a) 0.3888 (b) -0.2710 (c) 0.0384

Q-2.9 Find the reflection coefficients for a parallel polarized wave obliquely incident on the interface between two regions making an angle of 30^o with the perpendicular drawn at the boundary surface. The relative dielectric constants of the two regions are: (a) $\varepsilon_1 = 2.53$ and ε_2

= 1, (b) $\varepsilon_1 = 1$ and $\varepsilon_2 = 2.53$ (c) $\varepsilon_1 = 2.53$ and $\varepsilon_2 = 2.26$.

$E_r/E_i = [(\varepsilon_2/\varepsilon_1) \cos\theta_1 - \sqrt{\{(\varepsilon_2/\varepsilon_1) - \sin^2\theta_1\}}] / [(\varepsilon_2/\varepsilon_1) \cos\theta_1 - \sqrt{\{(\varepsilon_2/\varepsilon_1) - \sin^2\theta_1\}}]$

MATLAB CODE

```
% For a parallel polarized wave the reflection coefficient is given by
% Er/Ei=[(ε2/ε1)cosθ1 -√{(ε2/ε1)–sin²θ1}] / [(ε2/ε1)cosθ1-√{(ε2/ε1)– sin²θ1}]
% Given
pi = 3.1415;    theta = pi/6;    Cs = cos(theta);    Ss = sin(theta);    Sst = Ss^2;
%(a)
aps1 = 2.53;        aps2 = 1;          aps21= (aps2/aps1);
A1 = (aps21-Sst);      A2 = sqrt(A1);        A3 = aps21*Cs;
RC= (A3-A2)/(A3+A2)
%(b)
aps1 = 1;       aps2 = 2.53;              aps21= (aps2/aps1);
A1 = (aps21-Sst);              A2 = sqrt(A1);           A3 = aps21*Cs;
RC= (A3-A2)/(A3+A2)
%(c)
aps1 = 2.53;    aps2 = 2.26;       aps21= (aps2/aps1);
A1 = (aps21-Sst);        A2 = sqrt(A1);       A3 = aps21*Cs;
RC= (A3-A2)/(A3+A2)
```

ANSWER: RC =: (a) -0.0537 (b) 0.1840 (c) -0.0181

Q-2.10 Find the Brewster's angle if the relative dielectric constants for the two regions are:

(a) $\varepsilon_1 = 2.53$ and $\varepsilon_2 = 1$ (b) $\varepsilon_1 = 1$ and $\varepsilon_2 = 2.53$ (c) $\varepsilon_1 = 2.53$ and $\varepsilon_2 = 2.26$.

MATLAB CODE

% The Brewster's angle is given as $\theta_1 = \tan^{-1} \sqrt{(\varepsilon_2/\varepsilon_1)}$

```
%(a)

aps1 = 2.53;     aps2 = 1;        aps21= (aps2/aps1);

saps = sqrt(aps21);      thetar = atan(saps);

thetad = thetar*180/pi

%(b)

aps1 = 1;       aps2 = 2.53;           aps21= (aps2/aps1);

saps = sqrt(aps21);     thetar = atan(saps);

thetad = thetar*180/pi

%(c)

aps1 = 2.53;        aps2 = 2.26;            aps21= (aps2/aps1);

saps = sqrt(aps21);           thetar = atan(saps);

thetad = thetar*180/pi
```

ANSWER: θ_1 =: (a) 32.1583^o (b) 57.8444^o (c) 43.3856^o

Q-2.11 A wave propagates between two parallel planes separated by 3cm. The space between planes is filled by a non-magnetic material having relative dielectric constant ε_r where (a) $\varepsilon_r = 1$ (b) $\varepsilon_r = 2.26$ and (c) $\varepsilon_r = 2.53$. Find the cutoff frequencies for m = 1, 2 and 3.

MATLAB CODE

```
% Given

mu0 = 4*pi*10^-7;       aps0 = 8.854*10^-12;        pi = 3.1416;

v0 = 3*10^8;         a = 3*10^-2;       v = v0/(2*a);

% In view of Eqn.(2.) fc = v0(m/2a)/sqrt(apsr)

% (a)

apsr =1;          aps = 1/sqrt(apsr);
```

```
for m = 1:1:3
fc = m*(v/aps)
end
% (b)
apsr =2.26;     aps = 1/sqrt(apsr);
for m = 1:1:3
fc = m*(v/aps)
end
% (c)
apsr =2.53;     aps = 1/sqrt(apsr);
for m = 1:1:3
fc = m*(v/aps)
end
```

ANSWER: Cutoff frequency (fc) in Hz

m =:	**1**	**2**	**3**
(a)	**5.0000e+009**	**1.0000e+010**	**1.5000e+010**
(a)	**7.5166e+009**	**1.5033e+010**	**2.2550e+010**
(b)	**7.9530e+009**	**1.5906e+010**	**2.3859e+010**

Q-2.12 A 10GHz, TE_{10} wave propagates between two parallel planes separated by 5cm. The space between planes is filled by a non-magnetic material with $\varepsilon_r = 2.26$. Find β, $\lambda$and υ.

MATLAB CODE

% The required relations are: $\beta = \sqrt{[\omega^2\mu\varepsilon - (m\pi/a)^2]}$ $\lambda = (2\pi/\beta)$ $\upsilon = \lambda f$

```
 % Given TE10 mode
pi = 3.1415;    a = 5*10^-2;   muo = 4*pi*10^-7;    aps0 = 8.854*10^-12;    apsr = 2.26;   mur
```

= 1;   f0 = 10^10;   m = 1;   w = 2*pi*f0;   wt = w^2;

muap = mu0*aps0;   muapr = mur*apsr*muap;   A1 = wt*muapr;

mpa = m*pi/a;   mpas = mpa^2;   A2 = A1-mpas;

beta = sqrt(A2)

lemda = (2*pi/beta)

v = lemda*f0

ANSWER: **beta = 308.7288rad./m**   **lemda = 0.0204cm**

v = 2.0351e+008 m/sec

Q-2.13 The cutoff frequency of a wave is 80% of its operating frequency. Find the wave impedances for TE and TM waves if its characteristic impedance is 120π.

MATLAB CODE

% The required relations are: For TE wave: $Z_{yx}^{+} = \eta/\sqrt{\{1-(f_c/f)^2\}}$

% For TM wave: $Z_{xy}^{+} = \eta \sqrt{\{1-(\mathbf{f_c}/\mathbf{f})^2\}}$

% Given

fc = 0.8*f0;   pi=3.14;   fc0 = 0.8;   fcs = fc0^2;

A1 = 1 - fcs;   A2 = sqrt(A1);   eta=120*pi;

%For TE wave:

Zyx = eta/A2

%For TM wave:

Zxy = eta*A2

ANSWER: $\mathbf{Z_{yx}^{+}}$ = 628.0000Ω Z_{xy}^{+} = **226.0800Ω**

Q-2.14 A 20GHz, TE_{10} wave propagates between two parallel planes 3cm apart. Find wave impedance if the space between planes is occupied by a material having $\mu_r = 2$ and $\varepsilon_r = 2.5$.

MATLAB CODE

% The required relation is: $\boldsymbol{Z_{yx}}^{+} = \boldsymbol{\eta}/\sqrt{\{1\text{-}(\boldsymbol{m\lambda/2a})^2\}}$

% Given

pi = 3.1415; a = 3*10^-2; muo = 4*pi*10^-7; aps0 = 8.854*10^-12; apsr = 2.5; mur = 2; f = 2*10^10; m = 1; muap = mu0*aps0;

muapr = mur*apsr*muap; v = 1/sqrt(muapr); lemda = v/f;

A1 = m*lemda/(2*a); A2 = A1^2; A3 = 1 - A2;

A4 = sqrt(A3); eta0 = 120*pi;

Zyx = eta0/A4

ANSWER: Zyx = 379.3552Ω

Q-2.15 A 10GHz wave propagates between two parallel planes separated by 5cm. Find attenuation constants (α) for TE_{10} wave if the space between planes is filled with a material having $\mu_r = 1.2$ and $\sigma_m = 5.8 \times 10^7$ ℧/m and $\varepsilon_r = 2$.

MATLAB CODE

% The required relations are given below:

% Given TE10 mode

pi = 3.1415; a = 5*10^-2; muo = 4*pi*10^-7; aps0 = 8.854*10^-12; apsr = 2; mur = 1.2; f = 10^10; m = 1; sigma = 5*10^7; ac = a^3;

mps = (m*pi)^2; mpa=m*pi/a; mpas=mpa^2; w = 2*pi*f;

ws=w^2; mu = mur*mu0; aps = apsr*aps0; muap = mu*aps;

musig = mu/(2*sigma); wma = ws*muap; A1 = wma-mpas;

beta = sqrt(A1)

A2 = (w*mu)/(2*sigma);

```
Rs = sqrt(A2)
A4 = beta*w*mu*ac;
Alpha =( 2*mps*Rs)/A4
```

ANSWER: β **= 318.5317rad/m** R_s **= 0.0308Ω** α **=1.6105e-004nepers/m**

Q-2.16 Two strip shaped conductors of width b (= 5cm) and thickness t (= 1cm) in a two parallel wire transmission line are separated by a distance a (= 10cm). Calculate the inductance, capacitance and conductance, velocity of propagation and the characteristic impedance if $\mu = \mu_0$, $\varepsilon = \varepsilon_0$ and $\sigma = 3.72 \times 10^7$℧/m.

MATLAB CODE

```
% Given
a=10*10^-2;     b=5*10^-2;   t= 10^-2;   pi=3.14;   mu0 = 4*pi*10^-7;   aps0 =
8.854*10^-12;   sigma =3.72*10^7;    mu = mu0;    aps = aps0;
L = mu*(a/b)
C = aps*(b/a)
G = b*(sigma/a)
v = 1/sqrt(L*C)
Z = sqrt(L/C)
```

ANSWER: **L = 2.5120e-006H/m** **C = 4.4270e-012F/m**

G = 18600000℧/m **v =2.9987e+008 m/sec** **Z = 753.2776Ω**

Q-2.17 A transmission line carries a sinusoidal signal of 10^9rad/sec. Find the velocity of propagation if its parameters are: inductance L (= 0.4μH/m) and capacitance C (= 40pF/m) and (a) R = 0, G = 0 (b) R = 0.1Ω/m, G = 10^{-5}℧/m and (c) R = 300Ω/m, G = 0.

MATLAB CODE

```
% Given
L = 0.4*10^-6;        C = 40*10^-12;      w = 10^9;      i = sqrt(-1);
WL =w*L;         WC =w*C ;
% (a)
R = 0;     G = 0;    A1 = R + i*WL;    A2 = G + i*WC;    gama = sqrt(A1*A2);
alpha = real(gama);       beta = imag(gama);
v = w/beta
%(b)
R = 0.1;      G = 10^-5;     A1 = R + i*WL;   A2 = G + i*WC;
gama = sqrt(A1*A2);     alpha = real(gama);    beta = imag(gama);
 v = w/beta
%(c)
R = 300;    G = 0;       A1 = R + i*WL;          A2 = G + i*WC;
gama = sqrt(A1*A2);           alpha = real(gama);         beta = imag(gama);
v = w/beta
```

ANSWER: v =: (a) 250000000m/s (b) 250000000m/s (c) 2.3570e+008

Q-2.18 A 10cm long lossless transmission line has a characteristic impedance of 50Ω . Find its input impedance at 50MHz if it is terminated in (a) open circuit (b) short circuit and (c) 10pF capacitor.

MATLAB CODE

```
% Given
f = 50*10^6;     Z0 = 50;         L =  0.1;           w = 2*pi*f;         v = 3*10^8;
beta = w/v;       bet = beta*L;            SN = sin(bet);
```

```
CS = cos(bet);          TN = tan(bet);              CT = cot(bet) ;
%(a) Line is open circuit or ZR is infinite
Zin = -i*Z0*CT
%(b) Line is short circuited or ZR = 0
Zin = i*Z0*TN
%(c) Line is terminated in 10pF capacitor
C = 10^-11;      WC = w*C;            ZR = -i*(1/WC);
A1 = ZR*CS + i*Z0*SN;              A2 = Z0*CS + i*ZR*SN;
Zin = Z0*(A1/A2)
```

ANSWER : Zin =: (a) 0 -4.7596e+002i (b) 0 + 5.2525i

(c) 0 -1.8766e+002i

Q-2.19 A 100MHz transmission line has inductance L (= 0.4μH/m), capacitance C (= 40pF/m), resistance R (= 0.1Ω/m), and conductance G (= 10^{-5}℧/m) Find propagation velocity, phase shift constant (β), characteristic impedance (Z_0), and attenuation constant (α).

MATLAB CODE

```
% Given
L = 0.4*10^-6;  C = 40 *10^-12;   R = 0.1;   G = 10^-5;   f = 10^8;      pi=3.14;
i=sqrt(-1);       w = 2*pi*f;
v = 1/sqrt(L*C)
beta = w/v
XL = w*L;       XC = w*C;       Z = R + i*XL;    Y = G + i*XC;
gama = sqrt(Z*Y);
Z0 = sqrt(Z/Y)
alfa = (R/2)*sqrt(C/L) + (G/2)*sqrt(L/C)
```

ANSWER: **v =2.5000e+008 m/s** **beta = 2.5120 rad/m**

Z0 = 1.0000e+002 -2.7623e-018i ≈ 100 Ω **alfa = 1.0000e-003 nepers/m**

Q-2.20 A 50MHz transmission line with characteristic impedance of 50Ω is terminated in 200Ω. Find its reflection coefficient (Γ) and VSWR (s). Also find its quality factor (Q) if this line is a resonant section and its inductance is L (= 0.4μH), capacitance C (= 40pF/m), resistance is R (= 0.1Ω) and conductance G (= 10^{-5} ℧/m).

MATLAB CODE

```
% Given
ZR = 200;  Z0 = 50;  L = 0.4*10^-6;   R = 0.1;  C = 40*10^-12;   G = 10^-5;
pi=3.14;  f=50*10^6;   alfa= 0.001;      f = 50*10^6;    w = 2*pi*f ;
% Reflection coefficient
RC = (ZR -Z0)/(ZR + Z0)
% Voltage standing wave ratio
SWR = (1 + RC)/(1 - RC)
% Quality factor
Q = (w*L)/R
```

ANSWER: **Γ = 0.6000** **ρ = 4** **Q = 1.2560e+003**

Q-2.21 A 300MHz transmission line of characteristic impedance 50Ω is terminated in an unknown impedance R + jX. The voltage standing wave ratio on the line is 3. Find R and X if the distance (L_2) between the first minima and the terminating end is (a) 70cm (b) 30cm.

MATLAB CODE

```
% Given
```

```
f = 300*10^6;     R0 = 50;       ro = 3;     v = 3*10^8;   pi = 3.1416;

w = 2*pi*f;     beta = w/v;

%(a)

L2 = 0.7;          va = beta*L2;          vs=sin(va);      vss = vs^2;

vc = cos(va);        vcs = vc^2;       ros = ro^2;         A1 = ro*R0;

A2 = ros*vcs + vss;

R = A1/A2

A3 = R0*(ros - 1)*vs*vc;

X = -A3 /A2

%(b)

L2 = 0.3;           va = beta*L2;         vs=sin(va);          vss = vs^2;

vc = cos(va);          vcs = vc^2;          ros = ro^2;

A1 = ro*R0;               A2 = ros*vcs + vss;

R = A1/A2

A3 = R0*(ros - 1)*vs*vc;

X = -A3 /A2
```

ANSWER: **R = 85.0396 Ω** **X = -66.6448 Ω**

R = 85.0363 Ω **X = 66.6449 Ω**

Q-2.22 Calculate the inductance (L) and capacitance (C), velocity of propagation (υ), wavelength (λ) and the characteristic impedance (Z_0) for a lossless coaxial line operating at 3GHz and having:

(a) a = 1mm, b = 3mm, $\mu_r = \varepsilon_r = 1$

(b) a = 1mm, b = 3mm, $\mu_r = 1$ and $\varepsilon_r = 3$

(c) a = 1mm, b = 5mm, μ_r = 1 and ε_r = 3

MATLAB CODE

```
% Given
f = 3*10^9;    mu0 = 4*pi*10^-7;   aps0 = 8.854*10^-12;
muap0 = mu0*aps0;           v0 = 1/sqrt(muap0);           lemda0 = v0/f
%(a)
a = 10^-3;     b = 3*10^-3;    mur = 1;      apsr = 1;      mu = mu0*mur;
aps = aps0*apsr;           muapr = mur*apsr;      muaprs = sqrt(muapr);
v = v0/muaprs
lemda = lemda0/muaprs
Lba = log (b/a);
L = (mu/(2*pi))*Lba
C = (2*pi*aps)/Lba
Z0 = 60*muaprs*Lba
%(b)
a = 10^-3;     b = 3*10^-3;    mur = 1;  apsr = 3;     mu = mu0*mur
aps = aps0*apsr;       muapr = mur*apsr;         muaprs = sqrt(muapr);
v = v0/muaprs
lemda = lemda0/muaprs
Lba = log (b/a);
L = (mu/(2*pi))*Lba
C = (2*pi*aps)/Lba
Z0 = 60*muaprs*Lba
%(c)
a = 10^-3;     b = 5*10^-3;    mur = 1;  apsr = 3;     mu = mu0*mur;
```

```
aps = aps0*apsr;      muapr = mur*apsr;    muaprs = sqrt(muapr);
v = v0/muaprs
lemda = lemda0/muaprs
Lba = log (b/a);
L = (mu/(2*pi))*Lba
C = (2*pi*aps)/Lba
Z0 = 60*muaprs*Lba
```

ANSWER:

(a) L = 2.1972e-007 H/m   C = 5.0638e-011F/m   v =2.9980e+008 m/s

lemda = 0.0999m   Z0 = 65.9167 Ω

(b)   L = 2.1972e-007 H/m   C = 1.5191e-010 F/m   v = 1.7309e+008 m/s

lemda = 0.0577m   Z0 = 114.1711 Ω

(c) L = 3.2189e-007 H/m   C = 1.0370e-010 F/m   v = 1.7309e+008 m/s

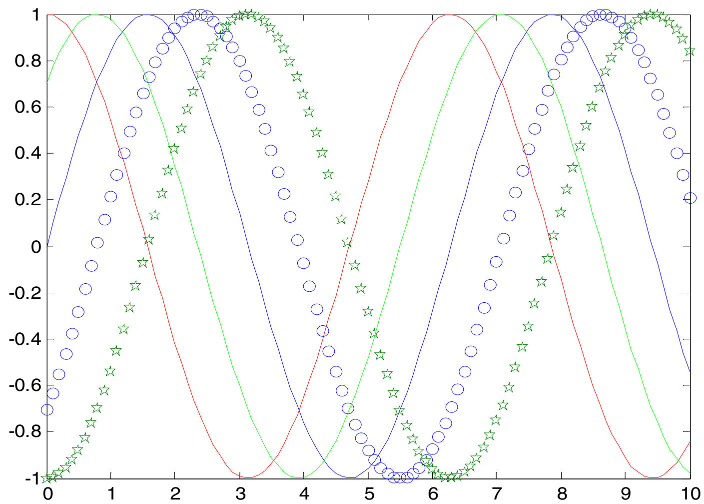
lemda = 0.0577m   Z0 = 167.2577 Ω

Q-2.23 The real component of a wave traveling in x-direction in a lossless media is expressed by the relation $\mathrm{Re}[E_y(x,t)] = C_1\cos(\omega t - \beta x)$. Plots E_y for $\omega t = 0, \pi/4, \pi/2, 3\pi/4$ and π if $C_1 = 1$ and $\beta = 1$ rad./m. Take x = 0, 0.1, 0.2, …10

MATLAB CODE

```
%Given
C1 = 1;   bta = 1;     x = 0:0.1:10;   t = bta*x;     y = C1*cos(t);         y1 = C1*cos(t- pi/4);
y2 = C1*cos(t- pi/2);          y3 = C1* cos(t-3 *pi/4);         y4 = C1*cos(t- pi);
plot(t,y,'r',t,y1,'g',t,y2,'b',t,y3,'o',t,y4,'p ')
```

RESULT: Traveling wave pattern

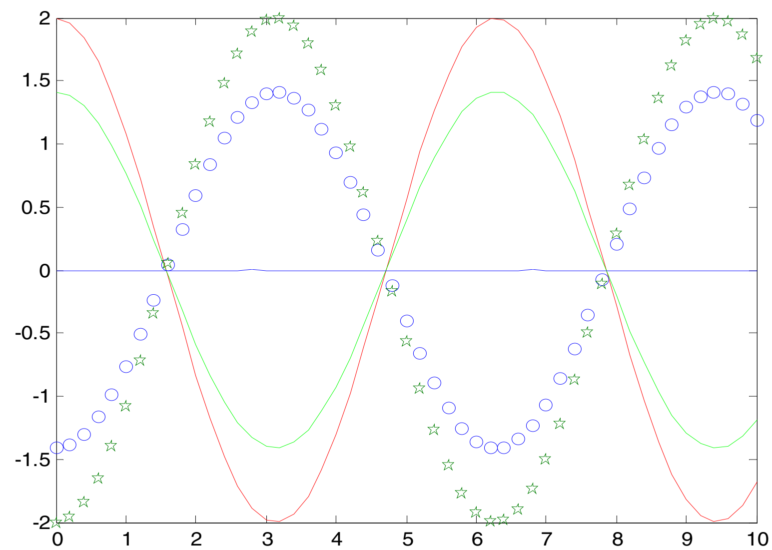


Q-2.24 The real component of a 10GHz wave traveling in a lossless media in x-direction and having forward and reflected components is expressed by the relation $\text{Re}[E_y(x,t)] = C_1 \cos(\omega t - \beta x) + C_2 \cos(\omega t + \beta x)$. Plots E_y for time instants t = 0, T/8, T/4, 3T/8 and T/2 if C_1 = 1 and C_2 = 0.5. Take x = 0, 0.1, 0.2, …1

MATLAB CODE

```
%Given
C1 = 1;   C2 = 1;   bta = 1;        x = 0:0.2:10;       t = bta*x;
y = C1*cos(t) + C2* cos(t);        y1 = C1*cos(t- pi/4) + C2*cos(t+ pi/4);
y2 = C1*cos(t- pi/2) + C2*cos(t+ pi/2);        y3 = C1* cos(t-3*pi/4) + C2* cos(t+3*pi/4);
y4 = C1*cos(t- pi) + C2*cos(t+ pi);
plot(t,y,'r',t,y1,'g',t,y2,'b',t,y3,'o',t,y4,'p ')
```

RRESULT: Standing wave pattern

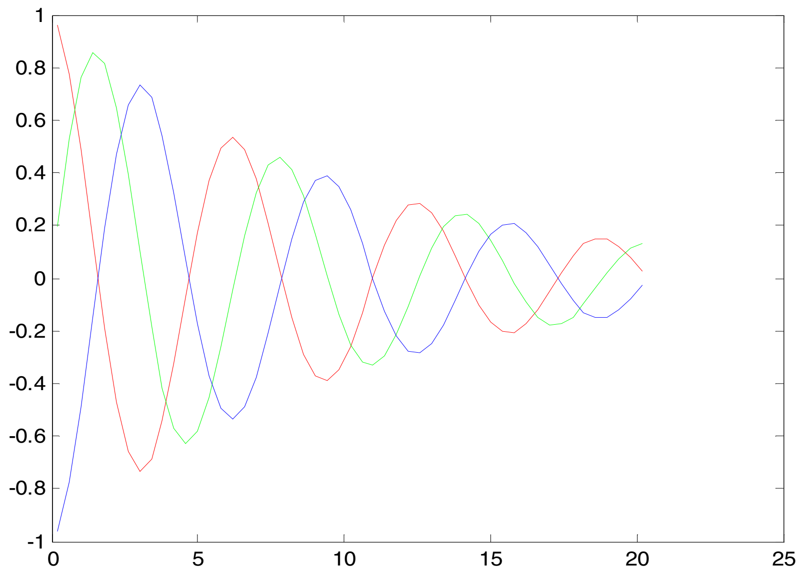


Q-2.25 The real component of a wave traveling in a lossy media in x-direction is expressed by the following relations $\text{Re}[E_y(x,t)] = C_1 e^{-\alpha x}\cos(\omega t - \beta x)$. Plots E_y for $\omega t = 0, \pi/4, \pi/2, 3\pi/4$ and π if $C_1 = 1$, $\alpha = 1.885 \times 10^{-3}$ Nep./m and $\beta = 0.001$ rad./m. Take x = 0, 0.1, 0.2, …1

MATLAB CODE

```
%Given
C1 = 1;   bta = 1;   alfa = 0.1;    x = 1:2:101;       x1 = 0.2*x;       t = bta*x1;
C = C1*exp(-alfa*x1);      D = cos (t);      D1 = cos (t-pi/2);    D2= cos(t-pi);
y = C.* D;       y1 = C.* D1;       y2 = C.* D2
plot(t,y,'r',t,y1,'g',t,y2,'b')
```

RESULT: Decaying traveling wave pattern

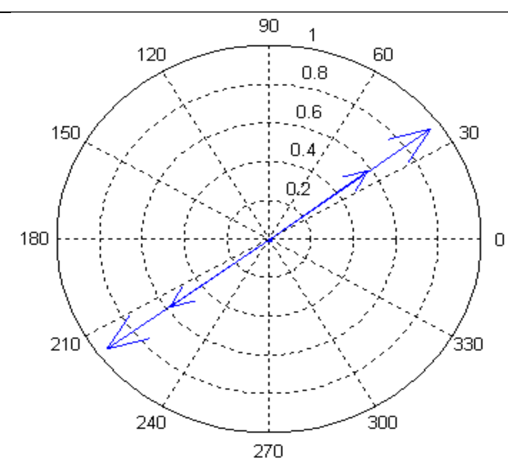


Q.2.26 Illustrate the orientation of E field vectors at different time instants for linearly polarized wave when the phase difference between Ex and Ey is (a) 0^o (b) 180^o. Assume E0x & E0y to be the max. amplitudes of Ex and Ey respectively.

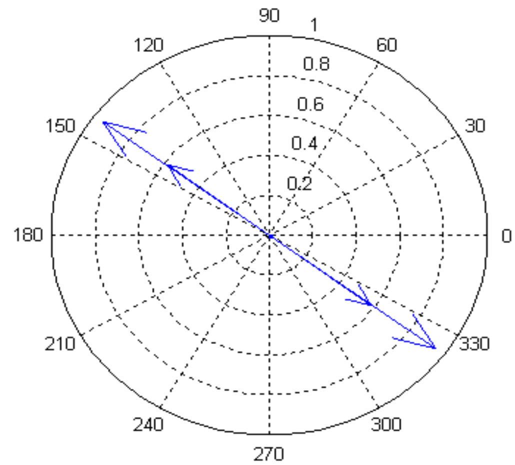
MATLAB CODE

```
% (a) Given phase difference = 0 rad.
E0x = 0.8;    E0y = 0.6;
phi = 0;      f = 1000;
T = 1/f;     w = 2*pi*f;
t = 0:0.1*T: T;
E = E0x.*sin(w.*t) + i*E0y.*sin(w.*t - phi);
compass(E);
```

RESULT:



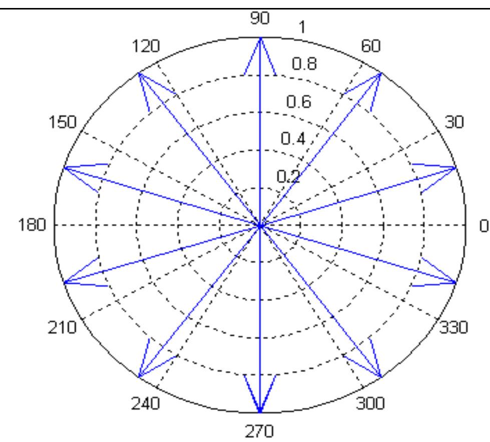
```
% (b) Given phase difference = pi rad.
E0x = 0.8;    E0y = 0.6;
phi = pi;     f = 1000;
T = 1/f;     w = 2*pi*f;
t = 0:0.1*T: T;
E = E0x.*sin(w.*t) + i*E0y.*sin(w.*t - phi);
compass(E);
```

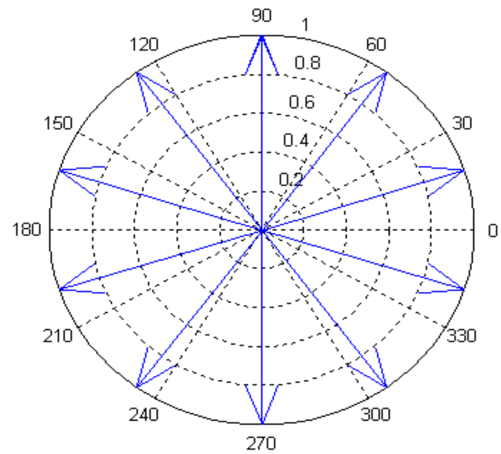


Q.2.27 Illustrate the orientation of E field vectors at different time instants for circularly polarized wave when the phase difference between Ex and Ey is (a) 90^o (b) 270^o. Assume E0x & E0y to be the maximum amplitudes of Ex and Ey respectively.

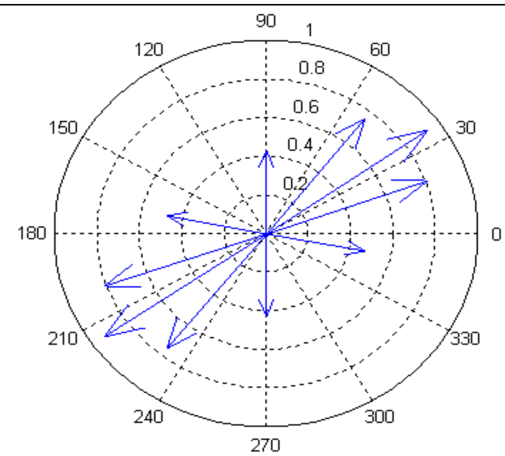
MATLAB CODE	RESULT:

```
% (a) Given phase difference = pi/2 rad.
E0x = 1;    E0y = 1;
phi = pi/2;      f = 1000;
T = 1/f;     w = 2*pi*f;
t = 0:0.1*T:T;
E = E0x.*sin(w.*t) + i*E0y.*sin(w.*t - phi);
compass(E);
```

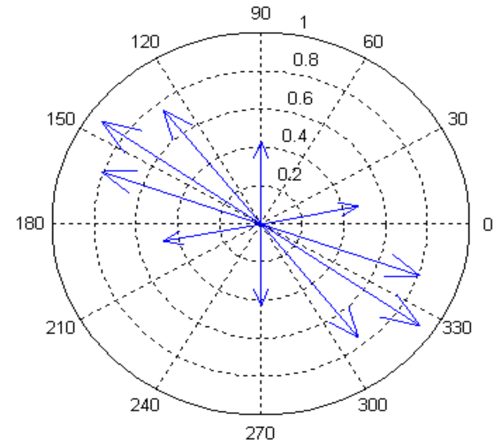


% (b) Given phase difference = 3pi/2 rad.
E0x = 1;   E0y = 1;
phi = 3*pi/2;   f = 1000;
T = 1/f;   w = 2*pi*f;
t = 0:0.1*T:T;
E = E0x.*sin(w.*t) + i*E0y.*sin(w.*t - phi);
compass(E);
	

Q.2.28 Illustrate the orientation of E field vectors at different time instants for elliptically polarized wave when the phase difference between Ex and Ey is (a) 45^o (b) 135^o. Assume E0x & E0y to be the maximum amplitudes of Ex and Ey respectively.	
MATLAB CODE	**RESULT:**

% (a) Given phase difference = pi/4 rad.
E0x = 0.8;   E0y = 0.6;
phi = pi/4;   f = 1000;
T = 1/f;   w = 2*pi*f;
t = 0:0.1*T:T;
E = E0x.*sin(w.*t) + i*E0y.*sin(w.*t - phi);
compass(E);
	
	Join the tips of arrows to get an ellipse

```
% (b) Given phase difference = 3pi/4 rad.

E0x = 0.8;    E0y = 0.6;

phi = 3*pi/4;      f = 1000;

T = 1/f;     w = 2*pi*f;

t = 0:0.1*T:T;

E = E0x.*sin(w.*t) + i*E0y.*sin(w.*t - phi);

compass(E);
```



Join the tips of arrows to get an ellipse