Scilab Textbook Companion for
Microwave Engineering
by M. Kulkarni[1]

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Scilab numbering policy used in this document and the relation to the above book.

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

AP Appendix to Example(Scilab Code that is an Appednix to a particular Example of the above book)

For example, Exa 3.51 means solved example 3.51 of this book. Sec 2.3 means a scilab code whose theory is explained in Section 2.3 of the book.

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Chapter 3

Transmission Lines

Scilab code Exa 3.1 Program to find value of terminating impedance of lossless tra

```
1 //Caption:Program to find value of terminating
     impedance of lossless transmission line.
2 //Exa:3.1
3 clc;
4 clear;
5 close;
6 //Given:
7 Z_ch=100;//in ohms
8 S=5;//VSWR (unitless)
9 Z=Z_ch*S;
10 printf("\n\n\t The terminating impedence = %d ohms "
     ,Z);
```

Scilab code Exa 3.2 Calculate the charcteristic impedance and attenuation constant

```scilab
 1  //Caption:Calculate the charcteristic impedance,
        attenuation constant, phase constant of
        transmission line Calculate power delivered to
        load , if line length=500 km.
 2  //Exa:3.2
 3  clc;
 4  clear;
 5  close;
 6  e=2.718;
 7  //Given:
 8  R=8;//in ohm/kilometer
 9  L=2*10^-3;//in henry/kilometer
10  C=0.002*10^-6;//in farad/kilometer
11  G=0.07*10^-6;//second/kilometer
12  f=2000;//in hertz
13  //Since [w=2*(pi)*f] & [Zch={(R+jwL)/(G+jwC)}^0.5]
14  w=2*%pi*f;//in radians
15  Z_ch={(R+%i*w*L)/(G+%i*w*C)}^0.5;//computing
        characteristic impedance
16  disp(Z_ch,"Characteristic impedance (in ohms) =");
17  y={(R+%i*w*L)*(G+%i*w*C)}^0.5;
18  a=real(y);//atteneuation constant
19  b=imag(y);//phase constant
20  disp(a,"Atteneuation constant (in NP/km) =");
21  disp(b,"Phase constant (in radian/km) =");
22  V_in=2;//in volts
23  l=500;//in kilometers
24  Z_in=Z_ch;//Since line terminated at its char. imped
        . so, Z_in=Z_ch=Z(load)
25  I_s=V_in/Z_in;
26  Imag=[[{{real(I_s)}^2}+{{imag(I_s)}^2}]^0.5]*10^3;//
        in milliampere
27  Iang=atan(imag(I_s)/real(I_s))*(180/%pi);//in
        degrees
28  I=Imag*e^-1.99;//I=Is*e^-yl
29  //P(power delivered)=I*I*REAL(Z_ch)
30  P=I*I*real(Z_ch);
31  disp(P,"Power delivered to load (in microwatt =)");
```

10

Scilab code Exa 3.3 Calculate phase velocity of the wave that propogates on line

```
1  //Caption:Calculate phase velocity of the wave that
       propogates on line as given in example 3.2
2  //Exa:3.3
3  clc;
4  clear;
5  close;
6  w=4*%pi*10^3;//in rad/sec
7  b=0.02543;//in rad/km
8  V_p=w/b;// phase velocity
9  disp(V_p,"Phase velocity (in km/sec) =");
```

Scilab code Exa 3.4 Calculate Current drawn from generator and Magnitune and phase

```
1  //Caption:Calculate (a)−Current drawn from generator
       . (b)−Magnitune & phase of load current. (c)−
       Power delivered to load.
2  //Exa: 3.4
3  clc;
4  clear;
5  close;
6  f=37.5*10^6;//frequency(in hertz)
```

```
7  wl=(3*10^8)/f;//wavelength (in meters)
8  Z_l=100;//in ohms
9  Z_o=200;//in ohms
10 l=5*wl/4;//length of line (in meters)
11 b=2*%pi/wl;
12 //At generator end,
13 Z_i=Z_o*(Z_l+%i*Z_o*tan(b*l))/(Z_o+%i*Z_l*tan(b*l));
14 V_s=200*Z_i/(200+Z_i);
15 I_s=200/(200+Z_i);
16 disp(real(I_s),"Current drawn from generator(in amps
       ) =");
17 //for a lossless line , P(avg)*I_input=P(avg)*I_load
18 P_avg=V_s*I_s;//in watts
19 disp(real(P_avg),"Power delivered to load (in watts)
        =)");
20 //Real(Vs*Is)=Real(Vs*I_load)
21 I_load=(P_avg/Z_l)^0.5;//in amps
22 disp(real(I_load),"Current flowing in load (in amps)
        =)");
```

Scilab code Exa 3.5 Calculate VSWR and reflection coefficient

```
1  //Caption:Calculate VSWR & reflection coefficient.
2  //Exa: 3.5
3  clc;
4  clear;
5  close;
6  Z_o=50;//in ohms
7  f=300*10^6;//in Hz
8  Z_l=50+%i*50;//in ohms
9  wl=(3*10^8)/f;//wavelength(in meters)
```

```
10 P=[(Z_l-Z_o)/(Z_l+Z_o)];
11 P_mag={(real(P)^2)+(imag(P)^2)}^0.5;
12 P_ang=atan(imag(P)/real(P))*180/%pi;//in degrees
13 S={1+P_mag}/{1-P_mag};
14 disp(P,"Reflection coefficient =");
15 disp(P_mag,"Magnitude of reflection coeffcient =");
16 disp(P_ang,"Angle (in degree) =");
17 disp(S,"VSWR =");
```

Scilab code Exa 3.6 Determine point of attachment and length of stub

```
1 //Caption:Determine point of attachment & length of
       stub.
2 //Exa 3.6
3 clc;
4 clear;
5 close;
6 Z_l=100;//in ohms
7 Z_o=600;//in ohms
8 f=100*10^6;//in Hz
9 wl=(3*10^8)/f;
10 //Position of stub is :
11 m=((Z_l*Z_o)/(Z_l-Z_o))^0.5;
12 pos={wl/(2*%pi)}*atan((Z_l/Z_o)^0.5);//in meters
13 l={wl/(2*%pi)}*{atan(m)};//in meters
14 disp(pos,"Position of stub (in meters) =");
15 disp(abs(l),"Length of stub (in meters) =");
```

Scilab code Exa 3.7 `Calculate terminating impedance`

```
1  //Caption:Calculate terminating impedance.
2  //Exa: 3.7
3  clc;
4  clear;
5  close;
6  Z_o=50;
7  S=3.2;
8  X_min=0.23;//in terms of wavelength(wl))
9  //So :
10 Z_l=Z_o*[[1-%i*S*tan(2*%pi*X_min)]/[S-%i*tan(2*%pi*
       X_min)]];//in ohms
11 Z_lmag=[(real(Z_l)^2)+(imag(Z_l)^2)]^0.5;
12 Z_lang=atan(imag(Z_l)/real(Z_l));
13 disp("The load impedance");
14 disp(Z_lmag,"magnitude (in ohms) =");
15 disp(Z_lang*180/%pi,"angle (in degrees) =");
```

Scilab code Exa 3.8 `Determine the VSWR and Position of 1st Vmin to Vmax and Vmin a`

```
1  //Caption:Determine:(a)VSWR; (b)Position of 1st Vmin
       & Vmax; (c)Vmin & Vmax; (d)Impedance at Vmin &
     Vmax.
```

```scilab
2  //Exa: 3.8
3  clc;
4  clear;
5  close;
6  Z_o=50;//in ohms
7  Z_l=100;//in ohms
8  f=300*10^3;//in Hz
9  P_l=50*10^-3;//in watts
10 wl=(3*10^8)/f;
11 p=(Z_l-Z_o)/(Z_l+Z_o);
12 S=(1+abs(p))/(1-abs(p));
13 disp(S,"VSWR =");
14 //Since real Zl > Zo ,
15 pos=wl/4;
16 disp("First Vmax is located --->at the load ");
17 disp("First Vmin is located at --->(wavelength/4)= "
       );
18 disp(pos,"(in meters)");
19 V_max=(P_l*Z_l)^0.5;
20 V_min=V_max/S;
21 disp(V_max,"Vmax (in volts) =");
22 disp(V_min,"Vmin (in volts) =");
23 disp(Z_o/S,"Zin at Vmin (in ohms) =:");
24 disp(Z_o*S,"Zin at Vmax (in ohms) =");
```

Scilab code Exa 3.9 Determine in dB the reflection loss and transmission line and

```scilab
1  //Caption:Determine in dB: (a)-reflection loss, (b)-
      transmission line (c)-return loss.
2  //Exa: 3.9
3  clc;
```

```
 4 clear;
 5 close;
 6 Z_o=600;//in ohm
 7 Z_s=50;//in ohm
 8 l=200;//in meter
 9 Z_l=500;//in ohm
10 p=(Z_l-Z_o)/(Z_l+Z_o);
11 ref_los=10*(log(1/(1-(abs(p))^2)))/(log(10));//in dB
12 disp(ref_los,"Reflection loss (in dB) =");
13 //attenuation loss= 0 dB
14 //Transmisson loss = (attenuation loss)+(reflection
      loss) = (reflection loss)
15 tran_los=ref_los;
16 disp(tran_los,"Transmisson loss (in dB) =");
17 ret_los=10*((log(abs(p)))/(log(10)));
18 disp(ret_los,"Return loss(in dB) =");
```

Scilab code Exa 3.10 Calculate the charcterstic impedance and phase velocity

```
 1 //Caption:Calculate the charcterstic impedance &
      phase velocity
 2 //Exa:3.10
 3 clc;
 4 clear;
 5 close;
 6 e=2.718;
 7 f=1000;//in Hz
 8 l=10000;//in meters
 9 Z_sc=(2631+%i*1289);//in ohms
10 Z_oc=(221-%i*137);//in ohms
11 Z_o=[Z_sc*Z_oc]^0.5;
```

```
12  Z_mag=[real(Z_o)^2+imag(Z_o)^2]^0.5;
13  Z_ang=[atan((imag(Z_o))/real(Z_o))]*180/%pi;
14  disp(Z_mag,"Characteristic impedance (in ohms) =");
15  disp(Z_ang,"Angle (in degrees) =");
16  x=[(Z_oc/Z_sc)^0.5];
17  //x=tanh(v*l)
18  //As, tanh(t)=[e^t-e^-t]/[e^t+e^-t]
19  v=(261+%i*2988)/l;
20  a=real(v);
21  b=imag(v);
22  disp(2*%pi*f/b,"Phase velocity (in meter per sec.) =
        ");
```

Chapter 4

Microwaves Transmission Lines

Scilab code Exa 4.1 Calculate the inductance per unit length and capacitance per u

```
1  //Caption:Calculate (i)-inductance per unit length ,(
       ii)-capacitance per unit length ,(iii)-
       charcteristic impedance ,(iv)-velocity of
       propagation
2  //Exa:4.1
3  clc;
4  clear;
5  close;
6  //Given:
7  d=0.49;//in cm
8  D=1.1;//in cm
9  e_r=2.3;
10 c=3*10^8;//in meter/second
11 L=2*(10^-7)*log(D/d);//in Henry/meter
12 C=55.56*(10^-12)*(e_r)/log(D/d);//in farad/meter
13 R_o=(60/sqrt(e_r)) *log(D/d);//in ohms
14 v=c/sqrt(e_r);//in meter/second
15 disp(L,'Inductance per unit length(in H/m) =');
16 disp(C,'Capacitance per unit length(in F/m) =');
17 disp(R_o,'Characteristic Impedance (in ohms) =');
18 disp(v,'Velocity of propagation (in m/s)=');
```

Scilab code Exa 4.2 Calculate the attenuation and phase constants and phase veloci

```scilab
1  //Caption:Calculate the attenuation, phase constants
        ,phase velocity,relative permittivity,power loss.
2  //Exa:4.2
3  clc;
4  clear;
5  close;
6  R=0.05;//in ohms
7  G=0;
8  l=50;//in meter
9  e=2.3;//dielectric constant
10 c=3*10^8;//in m/s
11 L=2*(10^-7);//from Exa:4.1
12 C=1.58*(10^-10);//from Exa:4.1
13 P_in=480;//in watts
14 f=3*10^9;//in hertz
15 Z_o=sqrt(L/C);
16 a=R/Z_o;//in Np/m
17 b=2*%pi*f*sqrt(L*C);//in rad/m
18 V_p=1/sqrt(L*C);
19 e_r=(c/V_p)^2;
20 P_loss=P_in*2*l;
21 disp(a,'Atteneuation (in Np/m) =');
22 disp(b,'Phase constant (in rad/m) =');
23 disp(V_p,'Phase velocity (in m/s) =');
24 disp(e_r,'Relative permittivity =');
25 disp(P_loss,'Power loss (in watts) =');
```

Scilab code Exa 4.3 Calculate the breakdown power of air filled coaxial cable

```
1  //Caption:Calculate the breakdown power of air
       filled coaxial cable at 9.375 GHz.
2  //Exa:4.3
3  clc;
4  clear;
5  close;
6  //Given:
7  a=2.42;//in cm
8  x=2.3;//x=(b/a)
9  P_bd=3600*a^2*log(x);//in kilowatts
10 disp(P_bd,'Breakdown Power (in kW) =');
11
12 //answer in book is wrongly written as 398 kW.
```

Scilab code Exa 4.4 Calculate charcteristic impedance and velocity of propagation

```
1  //Caption:Calculate charcteristic impedance &
       velocity of propagation.
2  //Exa:4.4
3  clc;
4  clear;
5  close;
```

```scilab
 6  b=0.3175;//in  cm
 7  d=0.0539;//in  cm
 8  c=3*10^8;//in  m/s
 9  e_r=2.32;
10  Z_o=60*log(4*b/(%pi*d))/sqrt(e_r);//in  ohms
11  V_p=c/sqrt(e_r);//in  m/s
12  disp(Z_o,'Charcteristic  impedance  (in  ohms)  =');
13  disp(V_p,'Velocity  of  propagation  (in  m/s)  =');
```

Scilab code Exa 4.5 Calculate charcteristic impedance and effective dielectric con

```scilab
 1  //Caption:Calculate  charcteristic  impedance  &
        effective  dielectric  constant  &  velocity  of
        propagation
 2  //Exa:4.5
 3  clc;
 4  clear;
 5  close;
 6  e_r=9.7;
 7  c=3*10^8;//in  m/s
 8  r_1=0.5;//when  ratio:  (W/h)=0.5
 9  r_2=5;//when  ratio:  (W/h)=5
10  //For  W/h  ratio=0.5
11  e_eff_1=(e_r+1)/2+((e_r-1)/2)*[1/{sqrt(1+12*(1/r_1))
        +0.04*(1-r_1)}];
12  Z_o_1=60*log(8/r_1+r_1/4)/sqrt(e_eff_1);
13  v_1=c/sqrt(e_eff_1);
14  disp("For  W/h=0.5  ,");
15  disp(e_eff_1,'Effective  dielectric  constant  =');
16  disp(Z_o_1,'Charcteristic  impedance  (in  ohms)  =');
17  disp(v_1,'Velocity  of  propagation  (in  m/s)  =');
```

```
18 //For W/h ratio=5
19 e_eff_2=(e_r+1)/2+((e_r-1)/2)*[1/{sqrt(1+12*(1/r_2))
      }];
20 Z_o_2=120*%pi*[1/{r_2+1.393+0.667*log(1.444+r_2)}]/
      sqrt(e_eff_2);
21 v_2=c/sqrt(e_eff_2);
22 disp("For W/h=5,");
23 disp(e_eff_2,'Effective dielectric constant =');
24 disp(Z_o_2,'Charcteristic impedance (in ohms) =');
25 disp(v_2,'Velocity of propagation (in m/s) =');
```

Scilab code Exa 4.6 Calculate ratio of circular waveguide crosssectional area to r

```
1 //Caption:Calculate ratio of circular waveguide
      cross-sectional area to rectangular waveguide
      cross-section
2 //Exa:4.6
3 clc;
4 clear;
5 close;
6 //For TE Wave propagated:
7 //for Rectangular , taking (a=2b)
8 r=100;//assume
9 //for TE11, wavelength=2*pi*r/1.841
10 //for TE10, wavelength=2a
11 a=(2*%pi*r/1.841)/2;
12 ar_rec_TE=(a)*(a/2);
13 ar_cir_TE=%pi*r^2;
14 ratio_TE=(ar_cir_TE)/(ar_rec_TE);
15 disp(ratio_TE,'Ratio of Circular & Rectangular coss-
      section area (in TE) =');
```

```
16  //For TM Wave propagated:
17  //for Rectangular , taking (a=2b)
18  //for TE01, wavelength=2.6155*r
19  //for TE11, wavelength=4b/sqrt(5)
20  b=(2.6155*r)/1.78885;
21  ar_rec_TM=(b)*(b);
22  ar_cir_TM=%pi*r^2;
23  ratio_TM=(ar_cir_TM)/(ar_rec_TM);
24  disp(ratio_TM,'Ratio of Circular & Rectangular coss-
        section area (in TM) =');
```

Scilab code Exa 4.7 Calculate breadth of rectangular waveguide

```
1  //Caption:Calculate breadth of rectangular waveguide
2  //Exa:4.7
3  clc;
4  clear;
5  close;
6  f=9*10^9;//in Hz
7  c=3*10^10;//in cm/s
8  wl_g=4;//in m
9  wl_o=c/f;
10 wl_c=[sqrt(1-((wl_o/wl_g)^2))/wl_o]^-1;
11 b=wl_c/4;
12 disp(b,'Breadth of rectangular waveguide (in cm) =')
        ;
```

Scilab code Exa 4.8 Calculate the cutoff wavelength and guide wavelength and group

```
1  //Caption:Calculate the cutoff wavelength, guide
       wavelength, group & phase velocities
2  //Exa:4.8
3  clc;
4  clear;
5  close;
6  a=10;//in cm
7  c=3*10^10;//in cm/s
8  wl_c=2*a;//in cm
9  f=2.5*10^9;//in Hz
10 wl_o=c/f;
11 wl_g=wl_o/(sqrt(1-(wl_o/wl_c)^2));//in cm
12 V_p=c/(sqrt(1-(wl_o/wl_c)^2));
13 V_g=c^2/V_p;
14 disp(wl_c,'Cut-off wavelength (in cm) =');
15 disp(wl_g,'Guide wavelength (in cm) =');
16 disp(V_p,'Phase velocity (in cm/s) =');
17 disp(V_g,'Group velocity (in cm/s) =');
```

Scilab code Exa 4.9 Calculate the possible modes and cutoff frequencies and guide

24

```
1  //Caption:Calculate (i)−possible modes,(ii)−cut−off
       frequencies ,(iii)−guide wavelength
2  //Exa:4.9
3  clc;
4  clear;
5  close;
6  //For TE mode:
7  a=2.5;//in cm
8  b=1;//in cm
9  f=8.6*10^9;//in Hz
10 c=3*10^10;//in cm/s
11 wl_o=c/f;
12 wl_c_1=2*b;//for TE01
13 wl_c_2=2*a;//for TE10
14 disp( 'Only TE10 mode is possible');
15 f_c=c/wl_c_2;
16 wl_c_3=2*a*b/sqrt(a^2+b^2);//for TE11 & TM11
17 wl_g_TE10=wl_o/(sqrt(1-(wl_o/wl_c_2)^2));//for TE10
18 disp(f_c,'Cut−off frequency(in Hz) =');
19 disp(wl_g_TE10,'Guide wavelength for TE10 (in cm) ='
       );
20 //For TM mode:
21 disp('TM11 also propagates');
22 wl_c_TM11=wl_c_3;
23 wl_g_TM11=wl_o/(sqrt(1-(wl_o/wl_c_2)^2));//for TM11
24 disp(wl_g_TM11,'Guide wavelength for TM11 (in cm) ='
       );
```

Scilab code Exa 4.10 Calculate the required size of guide and frequencies that can

```
1  //Caption:Calculate (i)−required size of guide ,(ii)−
       frequencies that can be used for this mode of
       propagation
```

```
2  //Exa:4.10
3  clc;
4  clear;
5  close;
6  wl_c=10;//in cm
7  c=3*10^10;//in cm/s
8  r=wl_c/(2*%pi/1.841);//in cm
9  area=%pi*r^2;//in sq. cm
10 f_c=c/wl_c;
11 disp(r,'Radius of circular waveguide(in cm) =');
12 disp(area,'Area of cross-section of circular
      waveguide(in cm) =');
13 disp('Frequency above');
14 disp(f_c);
15 disp('can be propagated');
```

Scilab code Exa 4.11 Find all modes that can propagate at 5000MHz

```
1  //Caption:Find all modes that can propagate at 5000
      MHz.
2  //Exa:4_11
3  clc;
4  clear;
5  close;
6  a=4;//in cm
7  b=3;//in cm
8  f=5*10^9;//in Hz
9  c=3*10^10;//in cm/s
10 wl_o=c/f;
11 //For TE waves:
12 wl_c_TE01=2*b;//for TE01
```

```
13  wl_c_TE10 =2* a ;// for  TE10
14  wl_c_TE11 =2* a * b / sqrt ( a ^2+ b ^2) ;// for  TE11
15  if ( wl_c_TE01 > wl_o )
16      disp ( 'TE01  can  propagate ') ;
17  else
18      disp ( 'TE01  cannot  propagate ') ;
19  end
20  if ( wl_c_TE10 > wl_o )
21      disp ( 'TE10  can  propagate ') ;
22  else
23      disp ( 'TE10  cannot  propagate ') ;
24  end
25  if ( wl_c_TE11 > wl_o )
26      disp ( 'TE11  can  propagate ') ;
27  else
28      disp ( 'TE11  cannot  propagate ') ;
29  end
```

Scilab code Exa 4.12 Calculate the cutoff wavelength and cutoff frequency and wave

```
1  // Caption : Find  all  modes  that  can  propagate  at  5000
       MHz .
2  // Exa :4 _11
3  clc ;
4  clear ;
5  close ;
6  a =4; // in  cm
7  b =3; // in  cm
8  f =5*10^9; // in  Hz
9  c =3*10^10; // in  cm / s
10  wl_o = c / f ;
```

```
11  //For TE waves:
12  wl_c_TE01=2*b;//for TE01
13  wl_c_TE10=2*a;//for TE10
14  wl_c_TE11=2*a*b/sqrt(a^2+b^2);//for TE11
15  if(wl_c_TE01>wl_o)
16      disp('TE01 can propagate');
17  else
18      disp('TE01 cannot propagate');
19  end
20  if(wl_c_TE10>wl_o)
21      disp('TE10 can propagate');
22  else
23      disp('TE10 cannot propagate');
24  end
25  if(wl_c_TE11>wl_o)
26      disp('TE11 can propagate');
27  else
28      disp('TE11 cannot propagate');
29  end
```

Scilab code Exa 4.13 Calculate the frequency of the wave

```
1  //Caption:Calculate (i)-cutoff wavelength,(ii)-
       cutoff frequency,(iii)-wavelength in guide
2  //Exa:4.12
3  clc;
4  clear;
5  close;
6  c=3*10^10;//in cm/s
7  d=4;//in cm
8  r=d/2;//in cm
```

```
9  wl_c=2*%pi*r/1.841;//in cm
10 f_c=c/wl_c;
11 f_signal=5*10^9;//in Hz
12 wl_o=c/f_signal;
13 wl_g=wl_o/sqrt(1-(wl_o/wl_c)^2);
14 disp(wl_c,'Cut-off wavelength (in cm) =');
15 disp(f_c,'Cut-off frequency (in Hz) =');
16 disp(wl_g,'Guide wavelength (in cm) =');
```

Scilab code Exa 4.14 Calculate the guide wavelength and phase constant and phase v

```
1  //Caption:Calculate (i)-guide wavelength,(ii)-phase
       constant,(iii)-phase velocity for dominant mode
2  //Exa:4.14
3  clc;
4  clear;
5  close;
6  c=3*10^10;//in cm/s
7  a=5;//in cm
8  b=2.5;//in cm
9  wl_o=4.5;//in cm
10 //For TE10 mode:
11 wl_c=2*a;
12 wl_g=wl_o/sqrt(1-(wl_o/wl_c)^2);
13 V_p=c/sqrt(1-(wl_o/wl_c)^2);
14 w=2*%pi*c/wl_o;
15 w_c=2*%pi*c/wl_c;
16 b=sqrt(w^2-w_c^2)/c;
17 disp(wl_g,'Guide wavelength (in cm) =');
18 disp(b,'Phase constant =');
19 disp(V_p,'Phase velocity (in cm/s) =');
```

```
20
21  //answer in book is wrongly written as guide
        wavelength =7.803 cm
22  //answer in book is wrongly written as Phase
        velocity = 5.22*10^10 cm/s
```

Scilab code Exa 4.15 Calculate what modes propagate at free space wavelength of 10

```
 1  //Caption:Calculate what modes propagate at free
        space wavelength of (i)10 cm,(ii)5 cm
 2  //Exa:4.15
 3  clc;
 4  clear;
 5  close;
 6  c=3*10^10;//in cm/s
 7  wl_c_TE10=16;//Critical wavelength of TE10
 8  wl_c_TM11=7.16;//Critical wavelength of TM11
 9  wl_c_TM21=5.6;//Critical wavelength of TM21
10  //For (i): 10 cm
11  wl_o=10;//in cm
12  disp(wl_o,'For free space wavelength (in cm) =');
13  if(wl_c_TE10>wl_o)
14      disp('    TE10 can propagate');
15  else
16      disp('    TE10 cannot propagate');
17  end
18  if(wl_c_TM11>wl_o)
19      disp('    TM11 can propagate');
20  else
21      disp('    TM11 cannot propagate');
22  end
```

```
23  if ( wl_c_TM21 > wl_o )
24      disp ( '     TM21  can  propagate ' ) ;
25  else
26      disp ( '     TM21  cannot  propagate ' ) ;
27  end
28  // For  ( i i ) :  5  cm
29  wl_o =5; // in  cm
30  disp ( wl_o , ' For  free  space  wavelength  ( in  cm )  =' ) ;
31  if ( wl_c_TE10 > wl_o )
32      disp ( '     TE10  can  propagate ' ) ;
33  else
34      disp ( '     TE10  cannot  propagate ' ) ;
35  end
36  if ( wl_c_TM11 > wl_o )
37      disp ( '     TM11  can  propagate ' ) ;
38  else
39      disp ( '     TM11  cannot  propagate ' ) ;
40  end
41  if ( wl_c_TM21 > wl_o )
42      disp ( '     TM21  can  propagate ' ) ;
43  else
44      disp ( '     TM21  cannot  propagate ' ) ;
45  end
```

Scilab code Exa 4.16 Determine the charcteristic wave impedance

```
1  // Caption : Determine  the  charcteristic  wave  impedance
2  // Exa : 4.16
3  clc ;
4  clear ;
5  close ;
```

```
6  c=3*10^10;//in cm/s
7  f=10*10^9;//in Hz
8  a=3;//in cm
9  b=2;//in cm
10 n=120*%pi;
11 wl_o=c/f;
12 wl_c=2*a*b/sqrt(a^2+b^2);
13 Z_TM=n*sqrt(1-(wl_o/wl_c)^2);
14 disp(Z_TM,'Characteristic impedance (in ohms) =');
15
16 //answer in book is wrongly written as 61.618 ohms
```

Scilab code Exa 4.17 Determine the diameter of waveguide and guide wavelength

```
1  //Caption:Determine the diameter of waveguide &
       guide wavelength
2  //Exa:4.17
3  clc;
4  clear;
5  close;
6  c=3*10^10;//in cm/s
7  f=6*10^9;//in Hz
8  f_c=0.8*f;
9  wl_c=c/f_c;
10 D=1.841*wl_c/%pi;
11 wl_o=c/f;
12 wl_g=wl_o/sqrt(1-(wl_o/wl_c)^2);
13 disp(D,'Diameter of waveguide (in cm) =');
14 disp(wl_g,'Guide wavelength (in cm) =');
```

Scilab code Exa 4.18 Show TE01 mode propagates under given conditions

```
1 //Caption:Show TE01 mode propagates under given
       conditions
2 //Exa:4.18
3 clc;
4 clear;
5 close;
6 a=1.5;//in cm
7 b=1;//in cm
8 e_r=4;//dielectric
9 c=3*10^10;//in cm/s
10 wl_c=2*b;
11 f_c=c/wl_c;
12 f_imp=6*10^9;//impressed frequency (in Hz)
13 wl_air=c/f_imp;
14 //Inserting dielectric:
15 wl_dielec=wl_air/sqrt(e_r);
16 if(wl_dielec>wl_c)
17     disp('    TE01 can propagate');
18 else
19     disp('    TE01 cannot propagate');
20 end
```

Scilab code Exa 4.19 Calculate the amount of attenuation if signal of frequency is

```
1  //Caption:Calculate the amount of attenuation if
        signal of frequency is 6GHz
2  //Exa:4.19
3  clc;
4  clear;
5  close;
6  u=4*%pi*10^-7;
7  e=8.85*10^-12;
8  c=3*10^10;//in cm/s
9  f=6*10^9;//in Hz
10 a=1.5;//in cm
11 b=1;//in cm
12 //For TE10 mode:
13 m=1;
14 n=0;
15 wl_c=2*a;
16 f_c=c/wl_c;
17 t_1=(m*%pi/a)^2;
18 t_2=(n*%pi/b)^2;
19 t_3=(((2*%pi*f)^2)*u*e);
20 a=sqrt(t_1+t_2-t_3);//in neper/m
21 disp(a*20/log(10),'Attenuation (in dB/m) =');
```

Scilab code Exa 4.20 Calculate the maximum power handling capacity

```
1  //Caption:Calculate the maximum power handling
        capacity
2  //Exa:4.21
3  clc;
4  clear;
5  close;
```

```
 6  c=3*10^10;//in cm/s
 7  f=9*10^9;//inHz
 8  a=3;//in cm
 9  b=1;//in cm
10  E_max=3000;//in V/cm
11  wl_o=c/f;
12  wl_c=2*a;//in TE10
13  wl_g=ceil (wl_o/sqrt(1-(wl_o/wl_c)^2));
14  P_max=(6.63*10^-4)*E_max^2*a*b*(wl_o/wl_g);
15  disp(P_max/1000,'Maximum power for rectangular
        waveguide (in kilowatts)=');
```

Scilab code Exa 4.21 Calculate the maximum power

```
 1  //Caption:Calculate the maximum power
 2  //Exa:4.21
 3  clc;
 4  clear;
 5  close;
 6  c=3*10^10;//in cm/s
 7  f=9*10^9;//inHz
 8  E_max=300;//in V/cm
 9  d=5;
10  wl_o=c/f;
11  //For TE11
12  wl_c=d*%pi/1.841;
13  wl_g=wl_o/sqrt(1-(wl_o/wl_c)^2);
14  P_max=0.498*E_max^2*d^2*(wl_o/wl_g);
15  disp(P_max,'Maximum power (in watts) =');
```

Scilab code Exa 4.22 Calculate the peak value of electric feild occuring in the wa

```
1  //Caption:Calculate the peak value of electric feild
       occuring in the waveguide
2  //Exa:4.22
3  clc;
4  clear;
5  close;
6  c=3*10^10;//in cm/s
7  f=30*10^9;//inHz
8  a=1;//in cm
9  b=1;
10 P_max=746;//in watts
11 wl_o=c/f;
12 wl_c=2*a;
13 Z=120*%pi/sqrt(1-(wl_o/wl_c)^2);
14 E_max=sqrt(P_max*4*Z/(a*b/10000));
15 disp(E_max/1000,'Peak value of electric field (in kV
       /m) =');
```

Scilab code Exa 4.23 Calculate the breakdown power of air filled rectangular waveg

```
1  //Caption:Calculate the breakdown power of air
       filled rectangular waveguide for dominant mode at
```

```
        9.375 GHz.
2  //Exa:4.23
3  clc;
4  clear;
5  close;
6  //Given:
7  c=3*10^10;//in cm/s
8  a=2.3;//in cm
9  b=1;//in cm
10 f=9.375*10^9;//in Hz
11 wl_o=c/f;
12 P_bd_TE11=597*2.3*1*{1-{wl_o/(2*a)}^2}^0.5;
13 disp(P_bd_TE11,'Breakdown power for dominant mode (
      in kW) =');
```

Scilab code Exa 4.24 Calculate the breakdown power of circular waveguide

```
1  //Caption:Calculate the breakdown power of circular
      waveguide
2  //Exa:4.24
3  clc;
4  clear;
5  close;
6  //Given:
7  d=5;//in cm
8  c=3*10^10;//in cm/s
9  f=9*10^9;//inHz
10 //Dominant mode is TE11:
11 wl_o=c/f;
12 wl_c=%pi*d/1.841;
13 f_c=c/wl_c;
```

```
14  P_bd_TE11=1790*(d/2)^2*[1-{f_c/f}^2]^0.5;
15  disp(P_bd_TE11/1000,'Breakdown power (in kW) =');
```
_____

Chapter 5

Cavity Resonators

Scilab code Exa 5.1 Determine the minimum distance between two end plates

```
1  //Caption:Determine  the  minimum  distance  between  two
        end  plates
2  //Exa:5.1
3  clc;
4  clear;
5  close;
6  //Given:
7  a=3;//in  cm
8  c=3*10^10;//in  cm/s
9  f=10*10^9;//in  Hz
10  P_01=2.405;
11  d=%pi/sqrt(f^2*4*%pi^2/c^2-(P_01/a)^2);
12  disp(d,'Minimum  distance  (in  cm) =');
```

Scilab code Exa 5.2 Calculate the lowest frequency of a rectangular cavity resonat

```
1  //Caption:Calculate the lowest frequency of a
       rectangular cavity resonator
2  //Exa:5.2
3  clc;
4  clear;
5  close;
6  //Given:
7  c=3*10^10;//in cm/s
8  a=2;//in cm
9  b=1;//in cm
10 d=3; //in cm
11 disp('Dominant mode is TE101');
12 m=1;
13 n=0;
14 p=1;
15 f=(c/2)*[(m/a)^2+(n/b)^2+(p/d)^2]^0.5;
16 disp(f/10^9,'Lowest resonant frequency(in GHz) =');
```

Scilab code Exa 5.3 Calculate the resonant frequency of a circular cavity resonato

```
1  //Caption:Calculate the resonant frequency of a
       circular cavity resonator
2  //Exa:5.3
3  clc;
4  clear;
5  close;
6  //Given:
7  d=12.5;//diameter(in cm)
8  c=3*10^10;//in cm/s
9  l=5;//length(in cm)
10 a=d/2;
```

```
11  //For  TM012 mode:
12  n=0;
13  m=1;
14  p=2;
15  P=2.405;
16  f=(c/(2*%pi))*[(P/a)^2+(p*%pi/d)^2]^0.5;
17  disp(f/10^9, 'Resonant  frequency  (in  GHz)  =');
18
19  //Answer  in  book  in  wrongly  given  as  6.27GHz
```

Scilab code Exa 5.4 Calculate the resonant frequency of a circular cavity resonato

```
1  //Caption:Calculate  the  resonant  frequency  of  a
       circular  cavity  resonator
2  //Exa:5.4
3  clc;
4  clear;
5  close;
6  //Given:
7  c=3*10^10;//in  cm/s
8  a=3;//in  cm
9  b=2;//in  cm
10  d=4;//in  cm
11  //For  TE101:
12  m=1;
13  n=0;
14  p=1;
15  f=(c/2)*[(m/a)^2+(n/b)^2+(p/d)^2]^0.5;
16  disp(f/10^9, 'Resonant  frequency (in  GHz)  =');
```

Chapter 6

Microwave Components

Scilab code Exa 6.2 Find the distance that the position of port 1 should be shifte

```
1  // Caption: Find the distance that the position of
       port 1 should be shifted .
2  // Exa: 6.2
3  clc;
4  clear;
5  close;
6  Beeta=34.3; // in rad/m
7  // S=[0,0.5*%e^(%i*53.13);0.5*%e^(%i*53.13),0];
8  // S'=[0,0.5*%e^(%i*53.13-x);0.5*%e^(%i*53.13-x),0];
9  // For S12& S21 to be real ,
10 x=53.5; // in degrees
11 x_rad=53.5*%pi/180;
12 l=x_rad/Beeta;
13 disp(l*100,'Distance (in cm)=');
```

Scilab code Exa 6.3 Determine the scattering parameters for 10 dB direction couple

```
1  //Caption:Determine the scattering parameters for 10
       dB direction coupler
2  //Exa:6.3
3  clc;
4  clear;
5  close;
6  D=30;//in dB
7  VSWR=1;
8  C=10;
9  //p1_p4 = p1/p4
10 p1_p4=10^(C/-10);
11 S_41=sqrt(p1_p4);
12 S_14=S_41;//As matched & lossless
13 S_31=S_41^2/10^(D/10);
14 S_11=(VSWR-1)/(VSWR+1);
15 S_22=S_11;
16 S_44=S_11;
17 S_33=S_11;
18 S_21=sqrt(1-0.1-10^-4);
19 S_12=S_21;
20 S_34=sqrt(1-0.1-10^-4);
21 S_43=S_34;
22 S_24=sqrt(1-0.1-S_34^2);
23 S_42=S_24;
24 S_23=S_41;
25 S_32=S_23;
26 S_13=S_31;
27 S=[S_11,S_12,S_13,S_14;S_21,S_22,S_23,S_24;S_31,S_32
       ,S_33,S_34;S_41,S_42,S_43,S_44];
28 disp(S,'Required Scattering Parameters are');
```

Scilab code Exa 6.4 Determine the powers in the remaining ports

```
1  //Caption:Determine the powers in the remaining
       ports
2  //Exa:6.4
3  clc;
4  clear;
5  close;
6  a_2=0;
7  a_3=0;
8  a_1=32;//in mW
9  b_1=(a_1/2^2)+(a_2/-2)+(a_3/sqrt(2));
10 b_2=(a_1/(-2)^2)+(a_2/-2)+(a_3/sqrt(2));
11 b_3=(a_1/2)+(a_2/sqrt(2))+(a_3/-sqrt(2));
12 disp(b_1,'Power at port1(in mW)=');
13 disp(b_2,'Power at port2(in mW) =');
14 disp(b_3,'Power at port3(in mW) =');
```

Scilab code Exa 6.5 Determine the powers in the remaining ports

```
1  //Caption:Determine the powers in the remaining
       ports
2  //Exa:6.5
3  clc;
```

```
 4 clear;
 5 close;
 6 b_1=20;
 7 b_2=20;
 8 p_1=abs((60-50)/(60+50));
 9 p_2=abs((75-50)/(75+50));
10 P_1=b_1*(1-p_1^2)/2;
11 P_2=b_2*(1-p_2^2)/2;
12 disp(P_1,'Power in port1 (in mW) =');
13 disp(P_2,'Power in port2 (in mW) =');
```

Scilab code Exa 6.6 Determine the powers reflected at port 3 and power divisions a

```
 1 //Caption:Determine the powers reflected at port 3 &
        power divisions at other ports.
 2 //Exa:6.6
 3 clc;
 4 clear;
 5 close;
 6 p_1=0.5;
 7 p_2=0.6;
 8 p_4=0.8;
 9 b_1=0.6566;
10 b_2=0.7576;
11 b_3=0.6536;
12 b_4=0.00797;
13 a_1=p_1*b_1;
14 a_2=p_2*b_2;
15 a_3=1;//in Watts
16 a_4=p_4*b_4;
17 disp(b_1^2,'Power at port 1(in W)=');
```

```
18  disp(b_2^2,'Power at  port  2(in  W)=');
19  disp(b_3^2,'Power at  port  3(in  W)=');
20  disp(b_4^2,'Power at  port  4(in  W)=');
```

Scilab code Exa 6.7 Calculate the scattering matrix

```
1  //Caption:Calculate  the  scattering  matrix.
2  //Exa:6.7
3  clc;
4  clear;
5  close;
6  In_loss=0.5;//in dB
7  S_21=10^(-In_loss/20);
8  Isolation=30;//in dB
9  S_12=10^(-Isolation/20);
10  S_11=0;
11  S_22=0;
12  S=[S_11,S_12;S_21,S_22];
13  disp(S,'Scattering  matrix =');
```

Scilab code Exa 6.9 Calculate the scattering matrix

```
1  //Caption:Calculate  the  scattering  matrix.
2  //Exa:6.9
3  clc;
```

```
4  clear;
5  close;
6  VSWR=1;
7  In_loss=0.5;//in dB
8  S_21=10^(-In_loss/20);
9  Isolation=20;//in dB
10 S_12=10^(-Isolation/20);
11 S_23=S_12;
12 S_31=S_12;
13 S_32=S_21;
14 S_13=S_21;
15 p=(VSWR-1)/(VSWR+1);
16 S_11=p;
17 S_22=p;
18 S_33=p;
19 S=[S_11,S_12,S_13;S_21,S_22,S_23;S_31,S_32,S_33];
20 disp(S,'Scattering matrix =');
```

Scilab code Exa 6.10 Calculate the scattering matrix

```
1  //Caption:Calculate the scattering matrix.
2  //Exa:6.10
3  clc;
4  clear;
5  close;
6  In_loss=0.5;//insertion loss(in dB)
7  C=20;//in dB
8  D=35;//in dB
9  Pi_Pf=10^(C/10);
10 Pi=90;//in Watts
11 Pf=Pi/Pi_Pf;
```

```
12  Pf_Pb=10^(D/10);
13  Pb=Pf/Pf_Pb;
14  P_rec=(Pi-Pf-Pb);//Power received (in Watts)
15  P_rec_dB=10*log(Pi/P_rec)/log(10);
16  P_rec_eff=P_rec_dB-In_loss;//Effective power
        received (in dB)
17  disp(P_rec_eff,'Effective power received (in dB)=');
```

Scilab code Exa 6.11 Calculate the directivity and coupling and isolation

```
1   //Caption:Calculate (i)-directivity ,(ii)-coupling,
        (iii)-isolation
2   //Exa:6.11
3   clc;
4   clear;
5   close;
6   S_13=0.1;
7   S_14=0.05;
8   C=-20*log(S_13)/log(10);
9   D=20*log(S_13/S_14)/log(10);
10  I=C+D;
11  disp(C,'Coupling (in dB) =');
12  disp(D,'Directivity (in dB)) =');
13  disp(I,'Isolation (in dB) =');
```

Scilab code Exa 6.12 Calculate the value of VSWR

```
1  //Caption:Calculate the value of VSWR
2  //Exa:6.12
3  clc;
4  clear;
5  close;
6  D=3.5;//distance of seperation(in cm)
7  w_l=2*D;//wavelength
8  d2_d1=2.5;//d2-d1(in m)
9  S=w_l/(%pi*d2_d1*10^-1);
10 disp(S,'VSWR =');
```

Scilab code Exa 6.13 Calculate the phase shift of the component

```
1  //Caption:Calculate the phase shift of the component
2  //Exa:6.13
3  clc;
4  clear;
5  close;
6  w_l=7.2;//wavelength (in cm)
7  x=10.5-9.3;
8  Phase_shift=(2*%pi*x)/(w_l);
9  disp(Phase_shift*180/%pi,'Phase Shift (in degree) ='
     );
```

Chapter 7

Microwave Measurements

Scilab code Exa 7.1 Calculate the SWR of the transmission line

```
1 //Caption:Calculate the SWR of the transmission line
2 //Exa:7.1
3 clc;
4 clear;
5 close;
6 //Given:
7 c=3*10^10;//in cm/s
8 a=4;//in cm
9 b=2.5;//in cm
10 f=10*10^9;//in Hz
11 d=0.1;//distance between 2 minimum power points(in
      cm)
12 //For TE10 mode:
13 wl_c=2*a;
14 wl_o=c/f;
15 wl_g=wl_o/sqrt(1-(wl_o/wl_c)^2);
16 S=wl_g/(%pi*d);
17 disp(S,'Voltage standing wave ratio =');
```

Scilab code Exa 7.2 Calculate the SWR of the main waveguide

```
1  //Caption:Calculate the SWR of the main waveguide
2  //Exa:7.2
3  clc;
4  clear;
5  close;
6  //Given:
7  P_i=300;//in mW
8  P_r=10;//in mW
9  p=sqrt(P_r/P_i);
10 S=(1+p)/(1-p);
11 disp(S,'Voltage standing wave ratio =');
```

Scilab code Exa 7.3 Calculate the SWR of the waveguide

```
1  //Caption:Calculate the SWR of the waveguide
2  //Exa:7.3
3  clc;
4  clear;
5  close;
6  //Given:
7  P_i=2.5;//in mW
8  P_r=0.15;//in mW
```

```
9  p=sqrt(P_r/P_i);
10 S=(1+p)/(1-p);
11 disp(S,'Voltage standing wave ratio =');
```

Scilab code Exa 7.4 Calculate the value of reflected power

```
1  //Caption:Calculate the value of reflected power
2  //Exa:7.4
3  clc;
4  clear;
5  close;
6  //Given:
7  P_i=4.5;//in mW
8  S=2;//VSWR
9  C=30;//in dB
10 p=(S-1)/(S+1);
11 P_f=P_i/(10^(C/10));
12 P_r=p^2*P_i;
13 disp(P_r,'Reflected power (in watts) =');
```

Chapter 8

Microwave Tubes and Circuits

Scilab code Exa 8.1 Calculate the dc electron velocity and dc phase constant and p

```
1  //Caption:Calculate (i)-dc electron velocity,(ii)-dc
        phase constant, (iii)-plasma frequency, (iv)-
      reduced plasma frequency for R=0.4, (v)-dc beam
      current beam density, (vi)-instantaneous beam
      current density
2  //Exa:8.1
3  clc;
4  clear;
5  close;
6  V_o=14.5*10^3;//in volts
7  I_o=1.4;//in A
8  f=10*10^9;//in Hz
9  p_o=10^-6;//in c/m^3
10 p=10^-8;//in c/m^3
11 v=10^5;//in m/s
12 R=0.4;
13 v_o=0.593*10^6*sqrt(V_o);
14 k=2*%pi*f/v_o;
15 w_p=[1.759*10^11*(10^-6/(8.854*10^-12))]^0.5;
16 w_q=R*w_p;
17 J_o=p_o*v_o;
```

```
18  J=p*v_o+p_o*v;
19  disp(v_o,'Dc electron velocity (in m/s) =');
20  disp(k,'Dc phase constant (in rad/s) =');
21  disp(w_p,'Plasma frequency (in rad/s) =');
22  disp(w_q,'Reduced plasma frequency (in rad/s) =');
23  disp(J_o,'Dc beam current density (in A/sq. m) =');
24  disp(J,'Instantaneous beam current density(in A/sq.
       m) =');
25
26  //Answer in book are wrongly written as: (Dc phase
       constant =1.41* 10^8 rad/sec)
```

Scilab code Exa 8.2 Calculate the input rms voltage and output rms voltage and pow

```
1  //Caption:Calculate (i)-input rms voltage,(ii)-
      output rms voltage, (iii)-power delivered to load
2  //Exa:8.2
3  clc;
4  clear;
5  close;
6  A_v=15;//in dB
7  P_i=5*10^-3;//in W
8  R_sh_i=30000;//in ohms
9  R_sh_o=40000;//in ohms
10 R_l=20000;//in ohms
11 V_i=sqrt(P_i*R_sh_i);
12 V_o=10^((A_v/20))*12.25;
13 P_out=V_o^2/R_l;
14 disp(V_i,'Input rms voltage (in volts) =');
15 disp(V_o,'Output rms voltage (in volts) =');
16 disp(P_out,'Power delivered to load (in watts) =');
```

Scilab code Exa 8.3 Calculate the input power in watts and output power in watts a

```
1  //Caption:Calculate (i)-input power in watts,(ii)-
       output power in watts, (iii)-efficiency
2  //Exa:8.3
3  clc;
4  clear;
5  close;
6  n=2;
7  V_o=300;//in volts
8  I_o=20*10^-3;//in A
9  V_i=40;//in volts
10 J=1.25;//J(X')
11 P_dc=V_o*I_o;
12 P_ac=2*V_o*I_o*J/(2*n*%pi-%pi/2);
13 eff=(P_ac/P_dc)*100;
14 disp(P_dc,'Input power (in watts) =');
15 disp(P_ac,'Output power (in watts) =');
16 disp(eff,'Efficiency (in percent) =');
```

Scilab code Exa 8.4 Calculate the electron velocity and dc transit time and input

```
1  //Caption:Calculate (i)-electron velocity,(ii)-dc
       transit time, (iii)-input voltage for maximum
```

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```
        output  voltage ,( iv)−voltage  gain  in  dB
 2  //Exa:8.4
 3  clc;
 4  clear;
 5  close;
 6  V_o=900; //in  volts
 7  I_o=30*10^-3; //in  A
 8  f=8*10^9; //in  Hz
 9  d=0.001; //in  m
10  l=0.04; //in  m
11  R_sh=40*10^3; //in  ohm
12  v_o=0.593*10^6* sqrt(V_o);
13  T_o=l/v_o;
14  Theeta_o=(2*%pi*f)*T_o; //Transit  angles  between
        cavities (in  radian)
15  Theeta_g=(2*%pi*f)*d/v_o; //Average  gap  transit  angle
        (in  radian)
16  b=sin(Theeta_g/2)/(Theeta_g/2);
17  V_in_max=V_o*3.68/(b*Theeta_o);
18  //As,  {J(X)/X=0.582}
19  A_r=b^2*Theeta_o*0.582*R_sh/(30*10^3*1.841);
20  disp(v_o,'Electron  velocity  (in  m/s)  =');
21  disp(T_o,'Dc  Transit  Time  (in  sec)=');
22  disp(V_in_max,'Maximum  input  voltage  (in  volts)  =');
23  disp(A_r,'Voltage  gain  (in  dB)  =');
```

Scilab code Exa 8.5 Calculate the input microwave voltage and voltage gain and eff

```
 1  //Caption: Calculate  (i)−i/p  microwave  voltage ,( ii)−
        voltage  gain ,  (iii)−efficiency  of  amplifier ,( iv)−
        beam  loading  conductance
```

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```scilab
2  //Exa:8.5
3  clc;
4  clear;
5  close;
6  V_o=1200;//in volts
7  I_o=28*10^-3;//in A
8  f=8*10^9;//inHz
9  d=0.001;//in m
10 l=0.04;//in m
11 R_sh=40*10^3;//in ohms
12 V_p_max=1200*3.68*0.593*10^6*sqrt(V_o)/(2*%pi*f*l);
13 Theeta_g=(2*%pi*f)*d/(0.593*10^6*sqrt(V_o));//
      transit angle (in rad)
14 beeta=sin(Theeta_g/2)/(Theeta_g/2);
15 V_i_max=V_p_max/beeta;
16 Beeta_o=0.768;
17 J=0.582;//J(X)
18 A_v=(Beeta_o)^2*97.88*J*R_sh/(1200/(28*10^-3*1.841))
      ;//calculating voltage gain
19 eff=[0.58*[2*28*10^-3*J*Beeta_o*R_sh]/V_o]*100;//
      calculating efficiency
20 G_o=23.3*10^-6;
21 G_b=(G_o/2)*{Beeta_o^2-Beeta_o*cos(Theeta_g)};//beam
       loading conductance
22 R_b=1/(G_b*1000);//beam loading resistance(in kilo
      ohms)
23 disp(V_i_max,'Input microwave voltage(in volts) =');
24 disp(A_v,'Voltage gain =');
25 disp(eff,'Effeciency of amplifier (in percentage) ='
      );
26 disp(R_b,'Beam loading resistance(in kilo ohms) =');
27
28 //Answer in book is wrongly given as: Voltage gain
      =17.034
```

Scilab code Exa 8.6 Calculate the value of repeller voltage and beam current neces

```
1  //Caption:Calculate (i)-value of repeller voltage
       V_r ,(ii)-beam current necessary to give gap
       voltage of 200V, (iii)-electronic efficiency
2  //Exa:8.6
3  clc;
4  clear;
5  close;
6  e_m_ratio=1.759*10^11;//(e/m)
7  V_o=500;//in volts
8  R_sh=20*10^3;//in ohms
9  f=8*10^9;//inHz
10 w=2*%pi*f;
11 n=2;//mode
12 L=0.001;//spacing between repeller & cavity (in m)
13 x=0.023;
14 volt_diff=sqrt(V_o*(x));
15 V_r=volt_diff+V_o;//repeller volatge
16 Beeta_o=1;//Assuming
17 J=0.582;
18 V_1=200;//given (in volts)
19 I_o=V_1/(R_sh*2*J);
20 Theeta_o=2*%pi*f*J*10^6*2*10^-3*sqrt(V_o)
       /(1.579*10^11*(V_r+V_o));
21 X=V_1*Theeta_o/(2*V_o);//X'
22 j=0.84;//J(X')
23 eff=[2*j/(2*%pi*2-%pi/2)]*100;
24 disp(V_r,'Repeller voltage(in volts) =');
25 disp(I_o,'Necessary beam current (in Amp.s) =');
```

```
26  disp(eff,'Effeciency  (in percentage) =');
```

Scilab code Exa 8.7 Calculate the efficiency of reflex klystron and total output p

```
1  //Caption:Calculate (i)-efficiency of reflex
       klystron ,(ii)-total output power in mW, (iii)-
       power delivered to load
2  //Exa:8.7
3  clc;
4  clear;
5  close;
6  P_dc_in=40;//in mW
7  ratio=0.278;//V_1/V_o;
8  n=1;
9  X=ratio*(2*n*%pi-%pi/2);
10 J=2.35;
11 eff=ratio*J*100;//in percentage
12 P_out= 8.91*P_dc_in/100;
13 P_load=3.564*80/100;
14 disp(eff,'Effeciency  (in percentage) =');
15 disp(P_out,'Total power output (in mW) =');
16 disp(P_load,'Power delivered to load (in mW) =');
```

Scilab code Exa 8.8 Calculate the Hull cutoff voltage and cutoff magnetic flux den

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```
1  //Caption:Calculate (i)-Hull cut-off voltage ,(ii)-
       cut-off magnetic flux density if beam voltage V_o
        is 6000V, (iii)-cyclotron frequency in GHz
2  //Exa:8.8
3  clc;
4  clear;
5  close;
6  e_m_ratio=1.759*10^11;//(e/m)
7  R_a=0.15;//in m
8  R_o=0.45;//in m
9  B_o=1.2*10^-3;//in weber/m^2
10 V_o={(e_m_ratio)*B_o^2*R_o^2*[1-(R_a/R_o)^2]^2}/8;
11 //Given:
12 V=6000;//in volts
13 B_c=sqrt(8*V/e_m_ratio)/[[1-(R_a/R_o)^2]*(R_o)];//in
       weber/m^2
14 w_c=(e_m_ratio)*B_o;
15 f_c=w_c/(2*%pi);//in Hz
16 disp(V_o,'Cut-off voltage (in volts) =');
17 disp(B_c*10^5,'Cut-off magnetic flux density (in
       milli weber/sq. m) =');
18 disp(f_c*10^-9,'Cyclotron frequency (in GHz) =');
19
20 //Answer in book is wrongly given as: f_c=0.336Hz &
       V_o=50.666 kV
```

Scilab code Exa 8.9 Calculate the Axial phase velocity and Anode voltage at which

```
1  //Caption:Calculate (i)-Axial phase velocity ,(ii)-
```

```
      Anode  voltage  at  which TWT can  be  operated  for
      useful  gain
 2  //Exa:8.9
 3  clc;
 4  clear;
 5  close;
 6  e_m_ratio=1.759*10^11;//(e/m)
 7  c=3*10^8;//in m/s
 8  d=0.002;//diameter(in m)
 9  pitch=(1/50)/100;//As,50 turns per cm (in m)
10  circum=%pi*d;
11  v_p=c*pitch/circum;
12  V_o=v_p^2/(2*e_m_ratio);
13  disp(v_p,'Axial phase velocity (in m/s) =');
14  disp(V_o,'Anode Voltage (in kV) =');
15
16  //Answer in book is wrongly given as V_o=25.92 V
```

Scilab code Exa 8.10 Calculate the electron velocity and dc transit time and input

```
 1  //Caption:Calculate (i)−electron velocity ,(ii)−dc
      transit time, (iii)−input voltage for maximum
      output voltage ,(iv)−voltage gain in dB
 2  //Exa:8.10
 3  clc;
 4  clear;
 5  close;
 6  V_o=900;//in volts
 7  I_o=30*10^-3;//in A
 8  f=8*10^9;//in Hz
 9  d=0.001;//in m
10  l=0.04;//in m
11  R_sh=40*10^3;//in ohm
```

```
12  v_o=0.593*10^6*sqrt(V_o);
13  T_o=l/v_o;
14  Theeta_o=(2*%pi*f)*T_o;//Transit angles between
       cavities(in radian)
15  Theeta_g=(2*%pi*f)*d/v_o;//Average gap transit angle
       (in radian)
16  b=sin(Theeta_g/2)/(Theeta_g/2);
17  V_in_max=V_o*3.68/(b*Theeta_o);
18  //As, {J(X)/X=0.582}
19  A_r=b^2*Theeta_o*0.582*R_sh/(30*10^3*1.841);
20  disp(v_o,'Electron velocity (in m/s) =');
21  disp(T_o,'Dc Transit Time (in sec)=');
22  disp(V_in_max,'Maximum input voltage (in volts) =');
23  disp(A_r,'Voltage gain (in dB) =');
```

Scilab code Exa 8.11 Calculate the dc electron velocity and dc phase constant and

```
1  //Caption:Calculate (i)-dc electron velocity,(ii)-dc
       phase constant, (iii)-plasma frequency, (iv)-
     reduced plasma frequency for R=0.5, (v)-dc beam
     current beam density, (vi)-instantaneous beam
     current density
2  //Exa:8.11
3  clc;
4  clear;
5  close;
6  V_o=20*10^3;//in volts
7  I_o=2;//in A
8  f=10*10^9;//in Hz
9  p_o=10^-6;//in c/m^3
10 p=10^-8;//in c/m^3
```

```
11  v=10^5; //in m/s
12  R=0.5;
13  v_o=0.593*10^6*sqrt(V_o);
14  k=2*%pi*f/v_o;
15  w_p=[1.759*10^11*(10^-6/(8.854*10^-12))]^0.5;
16  w_q=R*w_p;
17  J_o=p_o*v_o;
18  J=p*v_o-p_o*v;
19  disp(v_o,'Dc electron velocity (in m/s) =');
20  disp(k,'Dc phase constant (in rad/s) =');
21  disp(w_p,'Plasma frequency (in rad/s) =');
22  disp(w_q,'Reduced plasma frequency (in rad/s) =');
23  disp(J_o,'Dc beam current density (in A/sq. m) =');
24  disp(J,'Instantaneous beam current density(in A/sq.
      m) =');
```

Scilab code Exa 8.12 Calculate the gap transit angle

```
1  //Caption:Calculate the gap transit angle
2  //Exa:8.12
3  clc;
4  clear;
5  close;
6  V_o=1000; //Anode voltage(in volts)
7  gap=0.002; //in m
8  f=5*10^9; //in Hz
9  L=2.463*10^-3; //length of drift region (in m)
10  u_o=5.93*10^5*sqrt(V_o); //in m/s
11  Theeta_g=2*%pi*f*2*10^-3/u_o; //radians
12  disp(Theeta_g,'Transit angle(in radians) =');
```

Scilab code Exa 8.13 Calculate the input rf voltage and voltage gain and efficienc

```
1 //Caption:Calculate (i)-i/p rf voltage ,( ii )-voltage
      gain , ( iii )-efficiency
2 //Exa:8.13
3 clc;
4 clear;
5 close;
6 V_o=1200;//in volts
7 I_o=30*10^-3;//in A
8 f=10*10^9;//inHz
9 d=0.001;//in m
10 l=0.04;//in m
11 R_sh=40*10^3;//in ohms
12 v_o=0.593*10^6*sqrt(V_o);
13 Theeta_o=2*%pi*f*l/(20.54*10^6);
14 X=1.84;//for maximum output power
15 V_max=2*X*V_o/122.347;
16 Theeta_g=122.347*10^-3/(4*10^-2);
17 Beeta_i=sin(Theeta_g/2)/(Theeta_g/2);
18 V_1_max=V_max/Beeta_i;
19 J=0.58;
20 Beeta_o=Beeta_i;
21 I_2=2*I_o*J;
22 V_2=Beeta_o*I_2*R_sh;
23 A_v=V_2/V_1_max;//in dB
24 eff=0.58*(V_2/V_o)*100;//in percentage
25 disp(V_1_max,'Input rf voltage(in volts) =');
26 disp(A_v,'Voltage gain (in dB) =');
27 disp(eff,'Maximum efficiency (in percentage) =');
```

```
28
29 //Answer in book is wrongly given as: A_v=24.33 dB
```

Scilab code Exa 8.14 Calculate the cyclotron angular frequency and cutoff voltage

```
 1 //Caption:Calculate (i)−cyclotron angular frequency,
        (ii)−cut−off voltage, (iii)−cut−off magnetic
       flux
 2 //Exa:8.14
 3 clc;
 4 clear;
 5 close;
 6 e_m_ratio=1.759*10^11;//(e/m)
 7 a=0.04;
 8 b=0.08;
 9 V_o=30*10^3;//in volts
10 I_o=80;//in A
11 B_o=0.01;//in weber/sq.m
12 w=(e_m_ratio)*B_o;
13 disp(w,'Cyclotron angular frequency( in rad/s) =');
14 V_c={(e_m_ratio)*B_o^2*b^2*[1-(a/b)^2]^2}/8;
15 disp(V_c,'Cut−off voltage (in volts) =');
16 B_c=sqrt(8*V_o/e_m_ratio)/[[1-(a/b)^2]*(b)];//in
       weber/m^2
17 disp(B_c*10^3,'Cut−off magnetic flux density (in
        milli weber/sq. m) =');
```

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Scilab code Exa 8.15 Calculate the input power and output power in watts and effic

```
1 //Caption:Calculate (i)-input power ,(ii)-output
     power in watts, (iii)-efficiency
2 //Exa:8.15
3 clc;
4 clear;
5 close;
6 n=2;
7 V_o=280;//in volts
8 I_o=22*10^-3;//in A
9 V_i=30;//in volts
10 J=1.25;//J(X')
11 P_dc=V_o*I_o;
12 P_ac=2*V_o*I_o*J/(2*n*%pi-%pi/2);
13 eff=(P_ac/P_dc)*100;
14 disp(P_dc,'Input power (in watts) =');
15 disp(P_ac,'Output power (in watts) =');
16 disp(eff,'Efficiency (in percent) =');
```

Scilab code Exa 8.16 Calculate the repeller voltage and beam current necessary to

```
1 //Caption:Calculate (i)-repeller voltage V_r ,(ii)-
     beam current necessary to give gap voltage of 200
```

```scilab
     V
2  //Exa:8.16
3  clc;
4  clear;
5  close;
6  e_m_ratio=1.759*10^11;//(e/m)
7  V_o=300;//in volts
8  R_sh=20*10^3;//in ohms
9  f=8*10^9;//inHz
10 w=2*%pi*f;
11 n=2;//mode
12 L=0.001;//spacing between repeller & cavity (in m)
13 x=(e_m_ratio)*(2*%pi*n-%pi/2)^2/(8*w^2*L^2);
14 volt_diff=sqrt(V_o/(x));
15 V_r=(volt_diff)+V_o;//repeller volatge
16 J=0.582;
17 V_1=200;//given (in volts)
18 I_o=V_1/(R_sh*2*J);
19 disp(V_r,'Repeller voltage(in volts) =');
20 disp(I_o*10^3,'Necessary beam current (in milliAmp.s
      ) =');
```

Chapter 9

Solid State Microwave Devices

Scilab code Exa 9.1 Calculate i repeller voltage Vr ii beam current necessary to g

```
1 //Caption:Calculate operating frequency of IMPATT
     diode
2 //Exa:9.1
3 clc;
4 clear;
5 close;
6 v_d=10^7*10^-2;//drift velocity(in m/s)
7 L=2*10^-6;//drift length(in m)
8 f=v_d/(2*L);//in Hz
9 disp(f/10^9,'Operating Frequency (in GHz) =');
```

Scilab code Exa 9.2 Determine threshold electric field

```
1 //Caption:Determine threshold electric field
2 //Exa:9_2
```

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```
 3  clc;
 4  clear;
 5  close;
 6  f=10*10^9;//in Hz
 7  L=75*10^-6;//Device length (in m)
 8  V=25;//Voltage pulse amplified (in volts)
 9  E_th=V/L;
10  disp(E_th,'Threshold Electric field (in kV/cm) =');
```

Scilab code Exa 9.3 Calculate the power gain in dB and power gain if it is USB con

```
 1  //Caption:Calculate (i)−power gain in dB ,(ii)−power
        gain if it is USB converter.
 2  //Exa:9.3
 3  clc;
 4  clear;
 5  close;
 6  f_s=2*10^9;//in Hz
 7  f_p=12*10^9;//in Hz
 8  R_i=16;
 9  R_s=1000;
10  A_p=10*log((f_p-f_s)/f_s);
11  A_p_usb=10*log((f_p+f_s)/f_s);
12  disp(log(10),'Power gain (in dB) =');
13  disp(A_p_usb,'Power gain as USB converter (in dB) ='
        );
```

Scilab code Exa 9.4 Calculate the critical voltage and breakdown voltage and break

```
1  //Caption:Calculate (i)-critical voltage ,(ii)-
       breakdown voltage , (iii)-breakdown electric field
2  //Exa:9.4
3  clc;
4  clear;
5  close;
6  E_s=12.5;
7  E_o=8.85*10^-12;
8  E=E_o*E_s;
9  N=3.2*10^22;//per cubic meter
10 L=8*10^-6;//in m
11 q=1.6*10^-19;//in coulombs
12 V_c=q*N*L^2/(2*E);
13 V_bd=2*V_c;
14 E_bd=V_bd/L;
15 disp(V_c/10^3,'Critical voltage(in kV) =');
16 disp(V_bd/10^3,'Breakdown Voltage (in kV) =');
17 disp(E_bd,'Breakdown Electric field (in V/cm) =');
```

Scilab code Exa 9.5 Calculate the power gain in dB and power gain if it is USB con

```
1 //Caption:Calculate (i)−power gain in dB ,(ii)−power
      gain if it is USB converter.
2 //Exa:9.5
3 clc;
4 clear;
5 close;
6 N_a=2.5*10^16;//per cubic cm
7 J=33;//in kA/cm^2
8 q=1.6*10^-19;
9 V_z=J/(q*N_a);//Avalanche zone velocity (in cm/s)
10 disp(V_z,'Avalanche zone velocity (in cm/s) =');
```

Scilab code Exa 9.6 Calculate the power gain in dB

```
1 //Caption:Calculate the power gain in dB
2 //Exa:9.6
3 clc;
4 clear;
5 close;
6 R_neg=25;//in ohm
7 R_load=50;//in ohm
8 G={[- abs(R_neg)-R_load]/[- abs(R_neg)+R_load]}^2;
9 disp(G,'Power gain =');
```

Scilab code Exa 9.7 Calculate the minimum voltage needed to GUNN effect

```
1 //Caption:Calculate the minimum voltage needed to
      GUNN effect
2 //Exa:9.7
3 clc;
4 clear;
5 close;
6 volt_grad=3.3*10^3;//voltage gradient
7 L=5*10^-4;//in drift length
8 V_min=volt_grad*L;//in volts
9 disp(V_min,'Minimum voltage needed (in Volts) =');
```

Scilab code Exa 9.8 Calculate the rational frequency and critical velocity of diod

```
1 //Caption:Calculate the rational frequency &
      critical velocity of diode.
2 //Exa:9.8
3 clc;
4 clear;
5 close;
6 v_d=2*10^7;//in cm/s
7 L=20*10^-4;//in cm
8 f=v_d/L;
9 disp(f*10^-9,'Natural frequency (in GHz) =');
10 critical_field=3.3*10^3;
11 V=L*critical_field;
12 disp(V,'Critical voltage (in volts) =');
```

Scilab code Exa 9.9 Calculate the resonant frequency and efficiency

```
1 //Caption:Calculate the resonant frequency &
      efficiency.
2 //Exa:9.9
3 clc;
4 clear;
5 close;
6 L_p=0.5*10^-9;//in H
7 C_j=0.5*10^-12;//in F
8 V_bd=100;//breakdown voltage (in volts)
9 I_bias=100*10^-3;//bias current(in A)
10 I_rf_peak=0.8;
11 R_l=2;
12 f=1/(2*%pi*sqrt(L_p*C_j));
13 eff={(0.5*I_rf_peak^2*R_l)/(V_bd*I_bias)}*100;
14 disp(f*10^-9,'Resonant frequency (in GHz) =');
15 disp(eff,'Efficiency (in percentage) =');
```

Scilab code Exa 9.10 Calculate the drift time of carrier and operating frequency o

```
1 //Caption:Calculate (i)-drift time of carrier ,(ii)-
      operating frequency of diode
2 //Exa:9.10
3 clc;
4 clear;
```

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```
5  close ;
6  L=2*10^-6;//drift length (in m)
7  v_d=10^5;//in cm/s
8  drift_time=L/v_d;
9  f=1/(2*drift_time);
10 disp(drift_time,'Drift time (in sec) =');
11 disp(f*10^-9,'Operating Frequency (in GHz)=');
```

Scilab code Exa 9.11 Calculate the breakdown voltage and breakdown electric field

```
1  //Caption:Calculate (i)-breakdown voltage ,(ii)-
       breakdown electric field.
2  //Exa:9.11
3  clc ;
4  clear ;
5  close ;
6  E_r=11.8;
7  E_o=8.85*10^-12;
8  N=3*10^21;//in per cubic meter
9  L=6.2*10^-6;//in meter
10 q=1.6*10^-19;//in coulombs
11 V_bd=q*N*L^2/(E_o*E_r);
12 E_bd=V_bd/L;
13 disp(V_bd,'Breakdown voltage (in volts) =');
14 disp(E_bd,'Breakdown electric field (in V/m) =');
```

Scilab code Exa 9.12 Calculate the maximum power gain and noise figure and bandwid

```
1  // Caption : Calculate ( i )−maximum  power  gain  in  dBs
       ,( ii )−noise  figure  F  in  dBs ,  ( iii )−bandwidth  for
       r =0.2
2  //Exa : 9.12
3  clc ;
4  clear ;
5  close ;
6  ratio =8;
7  r =0.2;
8  r_Q =8;
9  T_d =300; // in  Kelvin
10 T_o =300; // in  Kelvin
11 X =8;
12 G =( ratio )*X /(1+ sqrt (1+X ))^2;
13 G_in_dB =(10* log (G ))/ log (10) ; // gain
14 disp ( G_in_dB , 'Maximum  Gain  ( in  dB)=') ;
15 F =[10* log (1+(2* T_d / T_o )*[(1/( r_Q ))+(1/( r_Q )^2)])]/
       log (10) ; // noise  figure
16 disp (F , 'Noise  figure  ( in  dB)  =') ;
17 B_W =2*r* sqrt ( ratio ) ; // bandwidth
18 disp ( B_W , 'bandwidth  =') ;
```

Scilab code Exa 9.13 Calculate the equivalent noise resistance and gain and noise

```scilab
1  //Caption:Calculate (i)-equivalent noise resistance,
       (ii)-gain, (iii)-noise figure, (iv)-bandwidth
2  //Exa:9.13
3  clc;
4  clear;
5  close;
6  f_s=2*10^9;//in Hz
7  f_p=12*10^9;//in Hz
8  f_i=10*10^9;//in Hz
9  f_d=5*10^9;//in Hz
10 R_i=1*10^3;//in ohm
11 R_g=1*10^3;//in ohm
12 R_T_s=1*10^3;//in ohm
13 R_T_i=1*10^3;//in ohm
14 T_d=300;//in Kelvin
15 T_o=300;//in Kelvin
16 w_s=2*%pi*f_s;
17 w_i=2*%pi*f_i;
18 r=0.35;
19 r_Q=10;
20 r_d=300;//in ohm
21 C=0.01*10^-12;//in Farad
22 R=r^2/(w_s*w_i*C^2*R_T_i);
23 a=R/R_T_s;
24 g=((4*f_i*R_g*R_i*a)/(f_s*R_T_s*R_T_i*(1-a)^2));//
       gain
25 Gain=[10*log(g)]/log(10);//gain in dB
26 f={1+((2*T_d)/T_o)*[(1/r_Q)+(1/r_Q^2)]};//noise
       figure
27 F=[10*log(f)]/log(10);//noise figure in dB
28 B_W=(r/2)*sqrt(f_d/(f_s*Gain));//bandwidth
29 disp(a,'Equivalent noise resistance (in ohm) =');
30 disp(Gain,'Gain (in dB) =');
31 disp(F,'Noise figure (in dB) =');
32 disp(B_W,'Bandwidth =');
```