

Scilab Textbook Companion for
Microwave and Radar Engineering
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Book Description

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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 Terminating Impedance

```
1 //chapter-3 page 47 example 3.1
2 //


---


3 clc;
4 clear;
5
6 Z0=100;//Characteristic Impedance in ohms
7 S=5;//Voltage Standing Wave Ratio(VSWR)
8
9 //CALCULATION
10 Zm=Z0*S;//Terminating impedance at a max of the
    voltage standing wave
11 Zl=Zm;//Loading Impedance
12
13 //OUTPUT
14 mprintf('Terminating impedance at a maximum of the
    voltage standing wave is Zl= %3.0f ohms',Zl);
15
16 //=====END OF PROGRAM


---


```

Scilab code Exa 3.2 power

```
1 //chapter-3 page 48 example 3.3
2 //


---


3 clc;
4 clear;
5
6 R=8; //Resistance of a transmission line in ohm/km
7 L=0.002; //Inductance of a transmission line in henry
   /km
8 C=0.002*(10(-6)); //Capacitance of a transmission
   line in Farads
9 G=0.07*(10(-6)); //Conductance of a transmission
   line in siemens/km
10 f=2000; //Frequency in Hz
11 w=2*(%pi)*f; //Angular Frequency in rad/sec
12 Vs=2; //Input Voltage in volts
13 l=500; //Length of Transmission line in km
14
15 //CALCULATIONS
16 Z0=sqrt((R+(w*L*(%i)))/(G+(w*C*(%i)))); //
   Characteristic Impedance
17 x=real(Z0);
18 y=imag(Z0);
19 disp('Characteristic Impedance in ohms is');
20 disp(Z0);
21 g=sqrt((R+(w*L*(%i)))*(G+(w*C*(%i)))); //Propagation
   Constant
22 a=real(g); //Attenuation Constant in NP/km
23 b=imag(g); //Phase Constant in rad/km
24 Is=Vs/Z0;
25 I0=Is*exp(-(g*l)); //Load current
```

```

26 m=sqrt((real(I0))^2+(imag(I0)^2));
27 P=(m^2)*x;//Power delivered to the load in watts
28
29 //OUTPUT
30 mprintf('\nAttenuation Constant is a=%1.6f NP/km \
      nPhase Constant is b=%1.6f rad/km \nP
      delivered to the load is P=%1.6f watts',a,b,P);
31
32 //=====END OF PROGRAM=====

```

Scilab code Exa 3.3 phase velocity

```

1 //chapter-3 page 48 example 3.3
2 //

```

```

3 clc;
4 clear;
5
6 w=4*(%pi);//Angular Frequency in rad/sec
7 b=0.02543;//Phase Constant in rad/km
8
9 //CALCULATION
10 Vp=w/b;//Phase Velocity in km/sec
11
12 //OUTPUT
13 mprintf('Phase Velocity is Vp=%3.2f km/sec',Vp);
14
15 //=====END OF PROGRAM=====
16
17 //NOTE:CHECK THE CALCULATION PART GIVEN IN THE
      TEXTBOOK
18 //GIVEN ANSWER 494.22 KM/SEC
19 //GETTING ANSWER 494.16 KM/SEC

```

Scilab code Exa 3.4 power

```
1 //chapter-3 page 48 example 3.4
2 //


---


3 clc;
4 clear;
5
6 f=37.5*10^6;//Frequency in Hz
7 c=3*10^8;//Velocity of Light in m/sec
8 l1=10;//Length of line in met
9 Vg=200;//Generator Voltage in volts(rms)
10 Zint=200;//Internal Resistance of Generator in ohms
11 Z0=200;//Characteristic Impedance in ohms
12 Zl=100;//Load impedance in ohms
13
14 //CALCULATIONS
15 w=c/f;//Wave Length in met
16 b=2*(%pi)/w;
17 l1=(5/4)*w;//For Lossless Line
18 Zi=Z0*((Zl+(Z0*(%i)*tan(b*l1)))/(Z0+(Zl*(%i)*tan(b*
    l1))));//Input Impedance at Generator end
19 Vs=Vg*(Zi/(Zi+Z0));//Voltage in line in volts
20 Is=Vg/(Zi+Z0);//Current in Line drawn from Generator
    in amps
21 Ps=Vs*Is;//Power drawn in line
22 P1=Ps;//For Lossless Lines Power delivered to load
    is equal to the Power drawn in line
23 I1=sqrt((P1/Zl));//Current flowing in the load
24 m=real(I1);//Magnitude of Current flowing in the
    load
25 p=imag(I1);//Phase of Current flowing in the load
26
```

```

27 //CALCULATIONS
28 fprintf('\nCurrent drawn from Generator is Is=%1.3f
      amps \nMagnitude of Current flowing in the load
      is m=%1.3f \nPhase of Current flowing in the load
      is p=%2.2f deg \nPower delivered to load is P1=
      %2.2f watts',Is,m,p,P1);
29
30 //=====END OF PROGRAM
=====

```

Scilab code Exa 3.5 VSWR and Reflection coefficient

```

1 //chapter-3 page 50 example 3.5
2 //
=====

3 clc;
4 clear;
5
6 Z0=50; //Characteristic Impedance in ohms
7 f=300*10^6; //Frequency in Hz
8 Z1=50+(50*(%i)); //Terminating load impedance in ohms
9 w=((3*10^8)/f); //Wave Length
10
11 //CALCULATIONS
12 p=((Z1-Z0)/(Z1+Z0)); //Reflection Coefficient (Complex
      Form)
13 y=real(p);
14 z=imag(p);
15 x=sqrt(y^2+z^2); //Reflection Coefficient Value
16 s=((1+x)/(1-x)); //Voltage Standing Wave Ratio(VSWR)
17
18 //OUTPUT
19 fprintf('\nReflection Coefficient is x=%1.4f \

```

```

    nVoltage Standing Wave Ratio (VSWR) is s=%1.2 f', x,
    s);
20
21 //=====END OF PROGRAM
    =====

```

Scilab code Exa 3.6 point of attachment

```

1 //chapter-3 page 50 example 3.6
2 //
    =====

3 clc;
4 clear;
5
6 Z1=100; //Pure Load resistance of a dipole antenna in
    ohms
7 Z0=600; //Characteristic Impedance of a wire feeder
    in ohms
8 f=100*10^6; //Frequency in Hz
9 c=3*10^8; //Velocity of Light in m/sec
10
11 //CALCULATIONS
12 w=c/f; //Wave Length in met
13 l=((w/(2*(%pi)))*atan(sqrt(Z1/Z0))); //The position
    of the Stub in met
14 x=atand(sqrt((Z1*Z0))/(Z1-Z0));
15 y=180+x; //In Degrees
16 l1=((w/(2*(%pi)))*y); //Length of Short Circuited
    Stub in met
17 l0=l1*((%pi)/180);
18
19 //OUTPUTS
20 mprintf(' \nThe Point of Attachment is l=%1.3 f met \
    nLength of SC Stub is l1=%1.2 f met', l, l0);

```

```
21
22 //=====END OF PROGRAM
=====
```

Scilab code Exa 3.7 Terminating Impedance

```
1 //chapter-3 page 50 example 3.7
2 //
=====

3 clc;
4 clear;
5
6 Z0=50; //Characteristic Impedance in ohms
7 S=3.2; //Voltage Standing Wave Ratio(VSWR)
8
9 //It is possible to measure the load impedance if
   the line is assumed lossless ,by measuring the
   VSWR,wavelength and the distance from the load to
   the nearest voltage minimum
10 //CALCULATIONS
11 w=1; //Assume Wavelength in met
12 Xmin=0.23*w; //Distance from the load to the nearest
   voltage minimum in met
13 b=(2*(%pi))/w;
14 Z1=Z0*((1-(S*(%i)*tan(b*Xmin)))/(S-((%i)*tan(b*Xmin)
   ))); //Load impedance in ohms
15 disp('Load impedance in ohms is ');
16 disp(Z1);
17
18
19 //=====END OF PROGRAM
=====
```

20
21 //Note: Check the answer given in Text book once. I
think it is wrong in text book..

Scilab code Exa 3.8 VSWR and Impedance

```
1 //chapter-3 page 51 example 3.8
2 //


---


3 clc;
4 clear;
5
6 Z0=50; //Characteristic Impedance in ohms
7 Z1=100; //Load impedance in ohms
8 f=300*10^3; //Frequency in Hz
9 P1=0.05; //Load Power in watts
10 c=3*10^8; //Velocity of Light in m/sec
11
12 //CALCULATIONS
13 w=c/f; //Wave Length in met
14 p=((Z1-Z0)/(Z1+Z0)); //Reflection Coefficient
15 S=((1+p)/(1-p)); //Voltage Standing Wave Ratio(VSWR)
16
17 //Since Z1>Z0, first Vmax is located at the load and
    first Vmin is located at Wavelength/4
18 x1max=0; //Position of first Vmax (located at the
    load) from load in met
19 x1min=w/4; //Position of first Vmin from load in met
20 Vmax=sqrt(P1*Z1); //Value of maximum voltage in volts
21 Vmin=Vmax/S; //Value of minimum voltage in volts
22 Zmax=Z0*S; //Impedance at Vmax in ohms
23 Zmin=Z0/S; //Impedance at Vmin in ohms
24
25 //OUTPUTS
```

```

26 mprintf(' \nVoltage Standing Wave Ratio(VSWR) is S=%1
    .0f \nPosition of first Vmax from load is x1max=
    %d met (located at the load) \nPosition of first
    Vmin from load is x1min=%3.0f met \nValue of
    maximum voltage is Vmax=%1.2f volts \nValue of
    minimum voltage is Vmin=%1.2f volts \nImpedance
    at Vmax is Zmax=%3.0f ohms \nImpedance at Vmin is
    Zmin=%2.0f ohms ',S,x1max,x1min,Vmax,Vmin,Zmax,
    Zmin);
27
28 //=====END OF PROGRAM
    =====

```

Scilab code Exa 3.9 Reflection loss

```

1 //chapter-3 page 52 example 3.9
2 //
    =====
3 clc;
4 clear;
5
6 Z0=600; //Characteristic Impedance in ohms
7 Zs=50; //Generator impedance in ohms
8 l=200; //Length of transmission line in met
9 Zl=500; //Load impedance in ohms
10
11 //CALCULATIONS
12 p=((Zl-Z0)/(Zl+Z0)); //Reflection Coefficient
13 x=abs(p);
14 Lr=10*log10(1/(1-x^2)); //Reflection loss in dB
15 La=0; //Since the line is lossless ,attenuation loss
    is zero dB
16 Lt=La+Lr; //Transmission loss in dB

```



```

17 Lrt=10*log10(x); //Return loss in dB
18
19 //OUTPUT
20 mprintf('\nReflection loss is Lr=%1.3f dB \
      nTransmission loss is Lt=%1.3f dB \nReturn loss
      is Lrt=%2.3f dB',Lr,Lt,Lrt);
21
22 //=====END OF PROGRAM
=====

```

Scilab code Exa 3.10 Characteristic Impedance

```

1 //chapter-3 page 52 example 3.10
2 //
=====

3 clc;
4 clear;
5
6 f=1000; //Frequency in Hz
7 l=10000; //Length of open wire transmission line in
      met
8 z1=2930; //Magnitude of a short circuit impedance in
      ohms
9 p1=26; //Phase of a short circuit impedance in deg
10 z2=260; //Magnitude of a open circuit impedance in
      ohms
11 p2=-32; //Phase of a open circuit impedance in deg
12 //CALCULATIONS
13 Zsc=((z1*cosd(p1))+((%i)*(z1*sind(p1))));
14 Zoc=((z2*cosd(p2))+((%i)*(z2*sind(p2))));
15 Z0=sqrt(Zsc*Zoc); // Characteristic Impedance in ohms
16 disp('Characteristic Impedance in ohms is');
17 [ro,theta]=polar(Z0)

```

```

18 disp(ro);
19 disp(theta*180/%pi);
20 g=((1/l)*(atanh(sqrt(Zsc/Zoc)))); // Propagation
    Constant
21 disp(g)
22 b=imag(g); // Phase Constant
23 w=2*f*(%pi); // Angular Frequency in rad/sec
24 Vp=w/b; // Phase Velocity in m/sec
25 disp(Vp)
26 //OUTPUT
27 mprintf('\nPhase Velocity is Vp=%5.2f m/sec ',Vp);
28
29 //=====END OF PROGRAM
    =====

30
31
32 //Note: Check the calculation once
    =====

```

Chapter 4

Microwave Transmission Lines

Scilab code Exa 4.1 Characteristic Impedance

```
1 //chapter-4 page 141 example 4.1
2 //


---


3 clc;
4 clear;
5
6 d=0.0049; //Diameter of inner conductor in met
7 D=0.0110; //Inner Diameter of outer conductor in met
8 er=2.3; //Polyethylene dielectric
9 c=3*10^8; //Velocity of Light in m/sec
10
11 //CALCULATIONS
12 x=log(D/d);
13 L=(2*10^(-1)*x); //Inductance per unit lengths in
    microH/m
14 C=(55.56*(er/x)); //The Capacitance per unit lengths
    in picoF/m
15 R0=(x*(60/sqrt(er))); //The Characteristic Impedance
    in ohms
16 V=(c/sqrt(er))/(10^3); //The Velocity of propagation
```

```

    in Km/s
17
18 //OUTPUT
19 mprintf('\nInductance per unit lengths is L=%1.5f
    microH/m \nThe Capacitance per unit lengths is C=
    %2.2f picoF/m \nThe Characteristic Impedance is
    R0=%2.2f ohms \nThe Velocity of propagation is V=
    %6.2f Km/s ',L,C,R0,V);
20
21 //=====END OF PROGRAM
    =====

```

Scilab code Exa 4.2 attenuation and phase constants

```

1 //chapter-4 page 142 example 4.2
2 //
    =====
3 clc;
4 clear;
5
6 R=0.05; //Resistance in ohm/m
7 L=0.16173*10^(-6); //Inductance per unit lengths in H
    /m
8 C=0.15802*10^(-6); //The Capacitance per unit lengths
    in F/m
9 V=197814.14; //The Velocity of propagation in Km/s
10 l=50; //Length of Coaxial Line in met
11 Pin=480; //Input Power to the System in watts
12 f=3*10^9; //Frequency in Hz
13 c=3*10^5; //Velocity of Light in Km/sec
14 e0=8.854*10^(-12); //Permittivity in free space in F/
    m
15

```

```

16 //CALCULATIONS
17 Z0=sqrt(L/C);
18 A=(R/(2*Z0)); //Attenuation Constant in NP/m
19 w=(2*(%pi)*f); //Angular Frequency in rad/sec
20 B=(w*sqrt(L*C)); //Phase Constant in rad/m
21 Vp=(1/sqrt(L*C))/(10^3); //Phase Velocity in Km/s
22 er=((c/V)^2)/e0; //Relative Permittivity
23 Pl=(2*Pin*1); //Power Loss in watts
24
25 //OUTPUT
26 mprintf('\nAttenuation Constant is A=%1.4f NP/m \
    nPhase Constant is B=%4.3f rad/m \nPhase Velocity
    is Vp=%4.3f Km/s \nRelative Permittivity is er=
    %12.2f \nPower Loss is Pl=%5.0f watts',A,B,Vp,er,
    Pl);
27
28 //=====END OF PROGRAM
    =====

```

Scilab code Exa 4.3 breakdown power

```

1 //chapter-4 page 142 example 4.3
2 //
    =====
3 clc;
4 clear;
5
6 //For an air filled coaxial cable
7 f=9.375*10^9; //operating frequency in Hz
8 c=3*10^10; //Velocity of Light in cm/sec
9 disp('Assuming a ratio of (b/a)=2.3 and (b+a)<(w/pi)
    to exclude higher order modes and a dominant
    mode propagating');
10 a=0.36432; //length of coaxial cable in cm

```

```

11 x=2.3;//ratio of b/a
12
13 //CALCULATION
14 w0=(c/f);//free space wavelength in cm
15 Pbd=(3600*(a^2)*log(x));//Breakdown power of a
    coaxial cable in kW
16
17 //OUTPUT
18 mprintf('\nBreakdown power of a coaxial cable is Pbd
    =%3.0 f kW',Pbd);
19
20 //=====END OF PROGRAM
    =====

```

Scilab code Exa 4.4 Characteristic Impedance

```

1 //chapter-4 page 142 example 4.4
2 //
    =====

3 clc;
4 clear;
5
6 b=0.3175;//Distance between ground planes of strip
    line in cm
7 d=0.0539;//Diameter of circular conductor in cm
8 er=2.32;//Dielectric Constant
9 c=3*10^8;//Velocity of Light in m/sec
10
11 //CALCULATION
12 Z0=((60/sqrt(er))*log((4*b)/(d*(%pi))));//
    Characteristic Impedance in ohms
13 V=(c/sqrt(er))/(10^3);//The Velocity of propagation
    in Km/s
14

```

```

15 //OUTPUT
16 mprintf('\nCharacteristic Impedance is Z0=%2.2f ohms
    \nThe Velocity of propagation is V=%5.2f Km/s ',
    Z0,V);
17
18 //=====END OF PROGRAM

```

Scilab code Exa 4.5 Characteristic Impedance

```

1 //chapter-4 page 143 example 4.5
2 //

```

```

3 clc;
4 clear;
5
6 //For a microstrip transmission line
7 er=9.7;//relative dielectric constant of an alumina
    substrate
8 x1=0.5;//w/h ratio in first transmission line
9 x2=5;//w/h ratio in second transmission line
10 c=3*10^8;//Velocity of Light in m/sec
11
12 //CALCULATION
13 disp('For case1: w/h=0.5');
14 disp('Since x1=0.5<1, for this we use high impedance
    analysis');
15 Eeff1=(((er+1)/2)+((er-1)/2)*(1/((sqrt(1+(12/x1)))
    +(0.04*(1-x1)^2)))); //Effective dielectric
    constant
16 Zo1=((60/sqrt(Eeff1))*log((8/x1)+(x1/4))); //
    Characteristic impedance in ohms
17 V1=(c/sqrt(Eeff1))/10^8;//Velocity of propagation in

```

```

10^8 m/sec
18 mprintf('\nEffective dielectric constant is Eeff1=%1
    .2f \nCharacteristic impedance is Zo1=%2.2f ohms
    \nVelocity of propagation is V1=%1.1f *10^8 m/sec
    ',Eeff1,Zo1,V1);
19
20 disp('For case2: w/h=5');
21 disp('here x2>1');
22 Eeff2=((er+1)/2)+((er-1)/2)*(1/(sqrt(1+(12/x2)))));
    //Effective dielectric constant
23 Zo2=((120*(%pi)/sqrt(Eeff2))*(1/(x2+1.393+(0.667*log
    (1.444+x2))))); //Characteristic impedance in ohms
24 V2=(c/sqrt(Eeff2))/10^8; //Velocity of propagation in
    10^8 m/sec
25 mprintf('\nEffective dielectric constant is Eeff2=%1
    .2f \nCharacteristic impedance is Zo2=%2.2f ohms
    \nVelocity of propagation is V2=%1.2f *10^8 m/sec
    ',Eeff2,Zo2,V2);
26
27 //=====END OF PROGRAM
    =====

```

Scilab code Exa 4.6 ratio of areas

```

1 //chapter-4 page 144 example 4.6
2 //
    =====
3 clc;
4 clear;
5
6 //To calculate the ratio of circular waveguide cross
    -sectional area to the rectangular waveguide
    cross section
7 disp('Assuming that both these waveguides have

```



```

        similar or equal cutoff frequencies/wavelengths')
    ;
8
9 disp('Case1: When TE wave is propagated');
10 disp('For standard rectangular waveguides a=2b and
    For TE11 dominant mode in circular waveguide wc1
    =(2(pi)r)/1.841');
11 disp('where r is the radius of the circular
    waveguide and wc1 is the cutoff wavelength for
    circular waveguide');
12 disp('It is given wc1=wc2 where wc2 is the cutoff
    wavelength for rectangular waveguide');
13 disp('For TE10(dominant mode) of propagation in
    rectangular waveguide wc2=2a');
14 disp('Since wc2=(2ab)/(sqrt((mb)^2+(nb)^2)) as m=1;n
    =0 for TE10 wc2=2ab/b=2a');
15 disp('By equating wc1=wc2, we get a=1.70645r');
16 disp('For a standard waveguide a=2b therefore , b=a/2
    ');
17 disp('Now the area of rectangular waveguide=a*b=a*a
    /2=1.70645r*1.70645r/2=1.456r^2');
18 disp('Area of rectangular waveguide=1.456r^2 ,Area
    of circular waveguide=(pi)*r^2');
19 disp('Ratio of area of circular to area of
    rectangular waveguide=(Area of circular waveguide
    /Area of rectangular waveguide)=(pi*r^2)/(1.456r
    ^2)=2.1576873=2.2');
20 disp('This clearly shows that the space occupied by
    a rectangular waveguide system is less compared
    to that for a circular waveguide system.Hence
    circular waveguides are not preferred in some
    applications');
21
22 disp('Case2: When TM wave is propagated');
23 disp('For TM01 mode wc1=(2*pi*r)/(Pnm)min=(2*pi*r)/
    Pnm=(2*pi*r)/2.405 where r is the radius of
    circular waveguide wc1=2.6155r');
24 disp('Now if wc2 is the wavelength for TM11 wave

```

```

    propagating in a standard rectangular waveguide
    wc2=wc1 but wc2=(2ab)/sqrt(a^2+b^2)');
25 disp('For standard waveguides, we know a=2b, wc2=(2*2
    b*b)/sqrt(4b^2+b^2)=(4b^2)/sqrt(5b^2)=4b/sqrt(5)')
    );
26 disp('By equating wc1=wc2, we get 2.6155r=4b/sqrt(5)
    =>b=1.4621r');
27 disp('Area of rectangular waveguide=b*b=b^2 but b
    =1.4621r, so Area of rectangular waveguide
    =(1.4621r)^2=2.132r^2 and Area of circular
    waveguide=pi*r^2');
28 disp('Ratio of area of circular to area of
    rectangular waveguide=(Area of circular waveguide
    /Area of rectangular waveguide)=(pi*r^2)/(2.132r
    ^2)=1.5');
29
30 //=====END OF PROGRAM
    =====

```

Scilab code Exa 4.7 breadth of the guide

```

1 //chapter-4 page 146 example 4.7
2 //
    =====

3 clc;
4 clear;
5
6 //For a rectangular waveguide
7 disp('For a rectangular waveguide the dominant mode
    is the TE10 mode. TE10 mode can propagate at a
    lower frequency');
8 f=9*10^9; //frequency in Hz
9 wg=4; //guide wavelength in cm
10 c=3*10^10; //Velocity of Light in cm/sec

```

```

11 disp('For TE10 mode wc=2a');
12
13 //CALCULATION
14 w0=(c/f); //free space wavelength in cm
15 wc=(w0/sqrt(1-(w0/wg)^2)); //Cutoff wavelength for
    TE10 mode in cm
16 disp('Free space wavelength w0 in cm is');
17 disp(w0);
18 disp('Cutoff wavelength wc in cm is');
19 disp(wc);
20 disp('Since wc>w0, the wave propagates');
21 a=(wc/2); //length of the guide in cm
22 b=(wc/4); //breadth of the guide in cm
23
24 //OUTPUT
25 mprintf('\nlength of the guide is a=%1.0f cm \
    nbreadth of the guide is b=%1.1f cm',a,b);
26
27 //=====END OF PROGRAM
    =====

```

Scilab code Exa 4.8 guide wavelength

```

1 //chapter-4 page 147 example 4.8
2 //
    =====
3 clc;
4 clear;
5
6 a=10; //breadth of a rectangular waveguide in cm
7 f=2.5*10^9; //Frequency in Hz in TE10 mode
8 c=3*10^10; //Velocity of Light in cm/sec
9
10 //CALCULATION

```

```

11 wc=2*a; //Cutoff wavelength for TE10 mode in cm
12 w0=(c/f); //Free space wavelength in cm
13 x=sqrt(1-(w0/wc)^2);
14 wg=(w0/x); //Guide wavelength in cm
15 Vp=(c/x)/10^5; //Phase Velocity in Km/sec
16 Vg=((c^2)/Vp)/10^10; //Group Velocity in Km/sec
17
18 //OUTPUT
19 mprintf('\nCutoff wavelength for TE10 mode is wc=%2
    .0f cm \nGuide wavelength is wg=%2.0f cm \nPhase
    Velocity is Vp=%7.2f Km/sec \nGroup Velocity is
    Vg=%6.2f Km/sec ',wc, wg, Vp, Vg);
20
21 //=====END OF PROGRAM
    =====

```

Scilab code Exa 4.9 guide wavelength

```

1 //chapter-4 page 147 example 4.9
2 //
    =====
3 clc;
4 clear;
5
6 f=8.6*10^9; //frequency in Hz
7 c=3*10^10; //Velocity of Light in cm/sec
8 a=2.5; //Length of a Waveguide in cm
9 b=1; //Width of a Waveguide in cm
10
11 //CALCULATION
12 disp('The condition for the wave to propagate along
    a guide is that wc>w0. ');
13 w0=c/f; //free space wavelength in cm
14 disp('Free space wavelength w0 in cm is ');

```

```

15 disp(w0);
16 disp('For TE waves ,  $w_c=(2ab/\sqrt{(mb)^2+(na)^2})$  ');
17 disp('For TE01 waves ');
18 m1=0;
19 n1=1;
20 wc1=((2*a*b)/(sqrt((m1*b)^2+(n1*a)^2))); //Cutoff
    wavelength for TE01 mode in cm
21 disp('Cutoff wavelength for TE01 mode in cm is ');
22 disp(wc1);
23 disp('Since  $w_c$  for TE01=2cm is not greater than  $w_0$ 
    TE01, will not propagate for TE01 mode. ');
24 disp('For TE10 waves ');
25 m2=1;
26 n2=0;
27 wc2=((2*a*b)/(sqrt((m2*b)^2+(n2*a)^2))); //Cutoff
    wavelength for TE10 mode in cm
28 disp('Cutoff wavelength for TE10 mode in cm is ');
29 disp(wc2);
30 disp('Since  $w_c$  TE10 >  $w_0$  TE10 is a possible mode. ');
31 fc=(c/wc2)/10^9; //Cutoff frequency in GHz
32 disp('For TE11 and TM11 waves ');
33 m3=1;
34 n3=1;
35 wc3=((2*a*b)/(sqrt((m3*b)^2+(n3*a)^2))); //Cutoff
    wavelength for TE11 mode in cm
36 disp('Cutoff wavelength for TE11 and TM11 modes in
    cm is ');
37 disp(wc3);
38 disp('As  $w_c$  for TE11 and TM11 is <  $w_0$  both TE11 and
    TM11 do not propagate as higher modes. ');
39 wg=(w0/sqrt(1-(w0/wc2)^2)); //Guide wavelength in cm
40 disp('From the above analysis we conclude that only
    TE10 mode is possible ');
41
42 //OUTPUT
43 mprintf('\nCutoff frequency is  $f_c$ =%1.0 f GHz \nGuide
    wavelength is  $w_g$ =%1.3 f cm',fc,wg);
44

```

```
45 //=====END OF PROGRAM
```

Scilab code Exa 4.10 area

```
1 //chapter-4 page 148 example 4.10
2 //
3 clc;
4 clear;
5
6 //For an air filled circular Waveguide in the
   dominant mode
7  $c=3*10^{10}$ ; //Velocity of Light in cm/sec
8 disp('For an air filled circular Waveguide TE11 is
   the dominant mode ie propagated');
9  $wc=10$ ; //cutoff wave length in cm
10
11 //CALCULATION
12  $r=((1.841*wc)/(2*(\%pi)))$ ; //radius of circular
   Waveguide in cm
13  $A=(\%pi)*r^2$ ; //Cross sectional area of the guide in
   sq.cms
14  $fc=(c/wc)/10^9$ ; //Cutoff frequency for TE11 mode in
   GHz
15 disp('Cutoff frequency for TE11 mode in GHz is ');
16 disp(fc);
17 disp('Frequency above 3GHz can be propagated through
   the waveguide');
18
19 //OUTPUT
20 mprintf('\\nCross sectional area of the guide is A=%2
   .2f sq.cms',A);
21
```

```
22 //=====END OF PROGRAM
    =====
```

Scilab code Exa 4.11 possible modes

```
1 //chapter-4 page 149 example 4.11
2 //
    =====

3 clc;
4 clear;
5
6 //For a rectangular waveguide
7 f=5*10^9;//frequency in Hz
8 c=3*10^10;//Velocity of Light in cm/sec
9 a=4;//Length of Rectangular Waveguide in cm
10 b=3;//Width of Rectangular Waveguide in cm
11
12 //CALCULATION
13 disp('The condition for the wave to propagate along
      a guide is that  $w_c > w_0$ .');
14 w0=c/f;//free space wavelength in cm
15 disp('Free space wavelength w0 in cm is');
16 disp(w0);
17 disp('For TE waves,  $w_c = (2ab / \sqrt{(mb)^2 + (na)^2})$ ');
18 disp('For TE01 waves');
19 m1=0;
20 n1=1;
21 wc1=((2*a*b)/(sqrt((m1*b)^2+(n1*a)^2)));//Cutoff
      wavelength for TE01 mode in cm
22 disp('Cutoff wavelength for TE01 mode in cm is');
23 disp(wc1);
24 disp('Since  $w_c$  for TE01=6cm is not greater than  $w_0$ 
      TE01, will not propagate for TE01 mode.');
```

```

26 m2=1;
27 n2=0;
28 wc2=((2*a*b)/(sqrt((m2*b)^2+(n2*a)^2))); // Cutoff
    wavelength for TE10 mode in cm
29 disp('Cutoff wavelength for TE10 mode in cm is');
30 disp(wc2);
31 disp('Since wc TE10 > w0 TE10 is a possible mode. ');
32 disp('For TE11 waves ');
33 m3=1;
34 n3=1;
35 wc3=((2*a*b)/(sqrt((m3*b)^2+(n3*a)^2))); // Cutoff
    wavelength for TE11 mode in cm
36 disp('Cutoff wavelength for TE11 mode in cm is ');
37 disp(wc3);
38 disp('As wc TE11 < w0 TE11 does not propagate. ');
39
40 //=====END OF PROGRAM
    =====

```

Scilab code Exa 4.12 guide wavelength

```

1 //chapter-4 page 149 example 4.12
2 //
    =====

3 clc;
4 clear;
5
6 //For an air filled circular Waveguide in the
    dominant mode
7 D=4; //Inner diameter of an air filled circular
    Waveguide in cm
8 c=3*10^10; //Velocity of Light in cm/sec
9
10 //CALCULATION

```



```

11 disp('The dominant mode in the circular waveguide
        would be like TE11,wc is maximum');
12 r=D/2;//radius in cm
13 wc=((2*(%pi)*r)/1.841);//Cutoff wavelength in cms
14 fc=(c/wc)/10^9;//Cutoff frequency in GHz
15 mprintf('\nCutoff wavelength is wc=%1.4f cms \
          nCutoff frequency is fc=%1.3f GHz',wc,fc);
16 disp('Since cut-off frequency is 4.395 GHz,
        frequencies higher than fc will be propagated.
        Assume a signal of frequency of 5 GHz is being
        propagated');
17 f=5*10^9;//frequency of signal in Hz
18 w0=(c/f);//free space wavelength in cm
19 wg=(w0/sqrt(1-(w0/wc)^2));//Guide wavelength in cm
20 mprintf('\nWave length in the guide is wg=%2.2f cm',
          wg);
21
22 //=====END OF PROGRAM
    =====

```

Scilab code Exa 4.13 frequency

```

1 //chapter-4 page 150 example 4.13
2 //
    =====
3 clc;
4 clear;
5
6 //For a rectangular waveguide in TE10 mode
7 a=6;//Length of Rectangular Waveguide in cm
8 b=4;//Width of Rectangular Waveguide in cm
9 c=3*10^10;//Velocity of Light in cm/sec
10 x=4.55;//distance between maximum and minimum in cm
11

```

```

12 //CALCULATIONS
13 wc=2*a; //Cutoff wavelength for a TE10 mode in cms
14 wg=4*x; //Guide Wavelength in cm
15 w0=(wg/sqrt(1+(wg/wc)^2)); //Free space wavelength
    in cm
16 f=(c/w0)/10^9; //Frequency of the wave in GHz
17
18 //OUTPUT
19 mprintf('\nFrequency of the wave is f=%1.3f GHz',f);
20
21 //=====END OF PROGRAM
    =====

```

Scilab code Exa 4.14 guide wavelength

```

1 //chapter-4 page 151 example 4.14
2 //
    =====

3 clc;
4 clear;
5
6 //For a rectangular waveguide
7 b=2.5; //Length of Rectangular Waveguide in cm
8 a=5; //breadth of Rectangular Waveguide in cm
9 c=3*10^10; //Velocity of Light in cm/sec
10 w0=4.5; //Free space wavelength in cm
11
12 //CALCULATION
13 disp('For a TE10 mode which is the dominant mode');
14 wc=2*a; //Cutoff wavelength in cm
15 wg=(w0/sqrt(1-(w0/wc)^2)); //Guide wavelength in cm
16 Vp=(c/sqrt(1-(w0/wc)^2))/10^10; //Phase Velocity in
    10^10 cm/sec
17 B=((2*(%pi)*sqrt(wc^2-w0^2))/(w0*wc)); //Phase

```

```

    constant in radians
18
19 //OUTPUT
20 mprintf('\nGuide wavelength is wg=%1.5f cm \nPhase
    constant is B=%1.3f radians \nPhase Velocity is
    Vp=%1.2f *10^10 cm/sec ',wg,B,Vp);
21
22 //=====END OF PROGRAM
    =====
23
24 //Note: Check the answers once
25 //Correct answers are
26 //Guide wavelength is wg=5.03903 cm
27 //Phase constant is B=1.247 radians
28 //Phase Velocity is Vp=3.36 *10^10 cm/sec

```

Scilab code Exa 4.15 possible modes

```

1 //chapter-4 page 152 example 4.15
2 //
    =====
3 clc;
4 clear;
5
6 wcTE10=16; //Critical wavelength of TE10 mode in cm
7 wcTM11=7.16; //Critical wavelength of TM11 mode in cm
8 wcTM21=5.6; //Critical wavelength of TM21 mode in cm
9 disp('For any wave to be propagated, the condition
    to be met is wc>wo');
10 wo1=10; //Free space wavelength in cm
11 wo2=5; //Free space wavelength in cm
12 disp('Critical wavelength of TE10 mode in cm is');
13 disp(wcTE10);
14 disp('Critical wavelength of TM11 mode in cm is');

```

```

15 disp(wcTM11);
16 disp('Critical wavelength of TM21 mode in cm is');
17 disp(wcTM21);
18 disp('For wo1=10cm,The mode that propagates only
      TE10.Because wcTE10>wo1 and all other modes that
      is TM11 TM21 donot propagate');
19 disp('For wo2=5cm');
20 disp('wcTE10>wo2, so TE10 mode propagates');
21 disp('wcTM11>wo2, so TE11 mode propagates');
22 disp('wcTE21>wo2, so TE21 mode propagates');

```

Scilab code Exa 4.16 Characteristic Impedance

```

1 //chapter-4 page 152 example 4.16
2 //

```

```

3 clc;
4 clear;
5
6 n=120*(%pi); //Intrinsic Impedance
7 a=3; //Length of Rectangular Waveguide in cm
8 b=2; //Width of Rectangular Waveguide in cm
9 f=10^10; //Frequency in Hz
10 c=3*10^10; //Velocity of Light in cm/sec
11
12 //CALCULATION
13 wc=((2*a*b)/sqrt(a^2+b^2)); //Cutoff wavelength in
      TM11 mode in cms
14 w0=(c/f); //Free space wavelength in cms
15 ZTM=(n*sqrt(1-(w0/wc)^2)); // Characteristic Wave
      Impedance in ohms
16
17 //OUTPUT
18 mprintf('\nCharacteristic Wave Impedance is ZTM=%2.3

```

```

    f ohms',ZTM);
19
20
21 //=====END OF PROGRAM
    =====
22
23 //Note: Check the given answer once it is wrong
24 //currect answer is 163.242 ohms

```

Scilab code Exa 4.17 guide wavelength

```

1 //chapter-4 page 152 example 4.17
2 //
    =====
3 clc;
4 clear;
5
6 c=3*10^10;//Velocity of Light in cm/sec
7 f=6*10^9;//Frequency in Hz
8
9 //CALCULATION
10 fc=(0.8*f);//Given Cutoff frequency for TE11 mode in
    Hz
11 wc=(c/fc);//Cutoff wavelength in cms
12 D=((1.841*wc)/(%pi));//Diameter of waveguide in cm
13 w0=(c/f);//Free space wavelength in cm
14 wg=(w0/sqrt(1-(w0/wc)^2));//Guide wavelength in cm
15
16 //OUTPUT
17 mprintf(' \nDiameter of the waveguide is D=%1.4 f cm \
    nGuide wavelength is wg=%1.3 f cm',D,wg);
18
19 //=====END OF PROGRAM
    =====

```

Scilab code Exa 4.18 proof

```
1 //chapter-4 page 153 example 4.18
2 //


---


3 clc;
4 clear;
5
6 //For a TE10 mode
7 a=1.5;//Length of an air filled square Waveguide in
   m
8 b=1;//breadth of an air filled square Waveguide in
   cm
9 c=3*10^10;//Velocity of Light in cm/sec
10 f=6*10^9;//Impressed Frequency in Hz
11 er=4;//dielectric constant
12
13 //CALCULATION
14 wc=2*a;//Cutoff wavelength in cm
15 fc=(c/wc)/10^9;//Cutoff frequency in GHz
16 disp('Cutoff frequency in GHz is');
17 disp(fc);
18 disp('The impressed frequency of 6 GHz is less than
   the Cutoff frequency and hence the signal will
   not pass through the guide');
19 w=(c/f);//Wavelength in cm
20 disp('Alternatively, the wavelength of the impressed
   signal in cm is');
21 disp(w);
22 wair=w;
23 disp('which is longer than the cutoff wavelength (3
   cm) and hence no propagation of the wave');
24 w1=wair/sqrt(er);//Wavelength in cm
```

```

25 disp('If the waveguide is loaded with dielectric of
      er=4, then the wavelength in cm is');
26 disp(w1);
27 disp('which is less than wair');
28 disp('Now the signal with 6 GHz frequency will pass
      through the dielectric loaded waveguide');
29
30 //=====END OF PROGRAM
      =====

```

Scilab code Exa 4.19 amount of attenuation

```

1 //chapter-4 page 153 example 4.19
2 //
      =====

3 clc;
4 clear;
5
6 a=0.015; //Length of hollow Rectangular Waveguide in
      m
7 b=1; //breadth of hollow Rectangular Waveguide in cm
8 f=6*10^9; //Frequency in Hz in TE10 mode
9 c=3*10^8; //Velocity of Light in m/sec
10 m=1; //Value of m in TE10 mode
11 n=0; //Value of n in TE10 mode
12 u=4*(%pi)*10^(-7); //Permeability in free space in
      Henry
13 e=8.854*10^(-12); //Permittivity in free space in F/m
14
15 //CALCULATION
16 wc=2*a; //Cutoff wavelength for TE10 mode in m
17 fc=c/wc; //Cutoff frequency in Hz
18 w=2*(%pi)*f; //Angular frequency in rad/sec
19

```

```

20 //So 6GHz signal will not pass through waveguide but
    will get attenuated
21 A=(sqrt((m*(%pi)/a)^2+(n*(%pi)/b)^2-(w^2*u*e)));//
    Attenuation in NP/m
22 AdB=A*(20/log(10));//Attenuation in dB/m
23
24 //OUTPUT
25 mprintf('\Amount of Attenuation is A=%3.1f NP/m \
    nAttenuation is AdB=%4.2f dB/m',A,AdB);
26
27 //=====END OF PROGRAM
    =====

```

Scilab code Exa 4.20 max power handling capacity

```

1 //chapter-4 page 154 example 4.20
2 //
    =====
3 clc;
4 clear;
5
6 a=3;//Length of Rectangular Waveguide in cm
7 b=1;//Width of Rectangular Waveguide in cm
8 f=9*10^9;//Frequency in Hz in TE10 mode
9 c=3*10^10;//Velocity of Light in cm/sec
10 Emax=3000;//Max potential gradient in V/cm
11
12 //CALCULATION
13 w0=(c/f);//Free space wavelength in cms
14 disp('Free space Wavelength in cm is');
15 disp(w0);
16 wc=2*a;//Cutoff wavelength in TE10 mode in cms
17 wg=(w0/sqrt(1-(w0/wc)^2));//Guide wavelength in cms
18 disp('Guide Wavelength in cm is');

```



```

19 disp(wg);
20 P=((6.63*10^(-4))*(Emax^2)*a*b*(w0/wg))/1000; //Power
    handling capability of the waveguide in kW
21
22 //OUTPUT
23 mprintf('\nPower handling capability of the
    waveguide is P=%2.3f kW',P);
24
25
26 //=====END OF PROGRAM
    =====

```

Scilab code Exa 4.21 maximum power

```

1 //chapter-4 page 154 example 4.21
2 //
    =====
3 clc;
4 clear;
5
6 d=5; //Internal Diameter of circular waveguide in cm
7 f=9*10^9; //Frequency in Hz in TE11 mode
8 c=3*10^10; //Velocity of Light in cm/sec
9 Emax=300; //Max field strength in V/cm
10
11 //CALCULATION
12 w0=(c/f); //Free space wavelength in cms
13 wc=((d*(%pi))/1.841); //Cutoff wavelength in TE11
    mode in cms
14 wg=(w0/sqrt(1-(w0/wc)^2)); //Guide wavelength in cms
15 Pmax=(0.498*(Emax^2)*(d^2)*(w0/wg))/1000; //Maximum
    power in kWatts
16
17 //OUTPUT

```

```

18 mprintf( '\nMaximum power is Pmax=%4.2f kWatts ',Pmax)
    ;
19
20
21 //=====END OF PROGRAM
    =====

```

Scilab code Exa 4.22 peak value of electric field

```

1 //chapter-4 page 155 example 4.22
2 //
    =====

3 clc;
4 clear;
5
6 //For an air filled square waveguide
7 a=0.01;//Length of an air filled square Waveguide in
    m
8 b=0.01;//breadth of an air filled square Waveguide
    in m
9 c=3*10^8;//Velocity of Light in m/sec
10 f=30*10^9;//Frequency in Hz in TE11 mode
11 Pmax=746;//Max power =1 horsepower in W
12 n=120*(%pi);//Impedance of freespace in ohms
13
14 //CALCULATION
15 w0=(c/f);//Free space wavelength in m
16 wc=2*a;//Cutoff wavelength in m
17 ZTE=(n/sqrt(1-(w0/wc)^2));//Impedance in ohms
18 Emax=(sqrt((Pmax*4*ZTE)/(a*b)))/1000;//The Peak
    value of Electric field occuring in the guide in
    kV/m
19 //From  $P=(1/2)*\text{Integration}(\text{Re}(E*H))da$ 
20 //and  $P_{\text{max}}=(1/(4*ZTE))*E_{\text{max}}^2*a*b$ 

```

```

21
22 //OUTPUT
23 mprintf('\nThe Peak value of Electric field occuring
      in the guide is Emax=%3.2f kV/m',Emax);
24
25 //=====END OF PROGRAM
      =====

```

Scilab code Exa 4.23 breakdown power

```

1 //chapter-4 page 156 example 4.23
2 //
      =====
3 clc;
4 clear;
5
6 //For an air filled rectangular waveguide
7 a=0.023; //Length of an air filled Rectangular
      Waveguide in m
8 b=0.01; //breadth of an air filled Rectangular
      Waveguide in m
9 c=3*10^8; //Velocity of Light in m/sec
10 f=9.375*10^9; //Frequency in Hz in TE11 mode
11 w0=0.01; //Free space wavelength in m
12 wc=0.02; //Cutoff wavelength in m
13 Pmax=746; //Max power =1 horsepower in W
14
15 //CALCULATION
16 wo=(c/f); //Free space wavelength in cm
17 Pbd=(597*a*b*sqrt(1-(wo/(2*a))^2)); //The breakdown
      power for the dominant mode ie TE11 in W
18 wg=(w0/sqrt(1-(w0/wc)^2)); //Guide wavelength in m
19 Emax=(sqrt((Pmax*wg)/(6.63*10^(-4)*w0)))/1000; //Max
      electric field in kV/m

```

```

20
21 //OUTPUT
22 mprintf('\nThe breakdown power for the dominant mode
        ie TE11 is Pbd=%1.5f W \nMax electric field is
        Emax=%1.4f kV/m',Pbd,Emax);
23
24 //=====END OF PROGRAM
        =====
25
26
27 //Note: Check the answers once
28 //Correct answers are
29 //The breakdown power for the dominant mode ie TE11
        is Pbd=0.09864 W
30 //Max electric field is Emax=1.1398 kV/m

```

Scilab code Exa 4.24 breakdown power

```

1 //chapter-4 page 156 example 4.24
2 //
        =====
3 clc;
4 clear;
5
6 a=2.5;//Radius of circular waveguide in cm
7 d=5;//Internal Diameter of circular waveguide in cm
8 f=9*10^9;//Frequency in Hz in TE11 mode
9 c=3*10^10;//Velocity of Light in cm/sec
10
11 //CALCULATION
12 w0=(c/f);//Free space wavelength in cms
13 wc=((d*(%pi))/1.841);//Cutoff wavelength in TE11
        mode in cms
14 fc=(c/wc);//Cutoff frequency in Hz

```

```
15 Pbd=(1790*(a^2)*sqrt(1-(fc/f)^2))/1000; //Breakdown
    Power in TE11 mode in kW
16
17 //OUTPUT
18 mprintf('\nBreakdown Power in TE11 mode is Pbd=%5.3 f
    kW',Pbd);
19
20 //=====END OF PROGRAM
    =====
```

Chapter 5

Cavity Resonators

Scilab code Exa 5.1 minimum distance

```
1 //chapter-5 page 174 example 5.1
2 //


---


3 clc;
4 clear;
5
6 //For a circular waveguide
7 a=3; //radius in cm
8 f0=10*10^9; //resonant frequency of a circular
   resonator in Hz
9 disp('Given the mode of operator is TM011 so here n
   =0,m=1,p=1');
10 c=3*10^10; //Velocity of light in cm/sec
11 m=1;
12 n=0;
13 p=1;
14 Pnm=2.405; //dominant mode value [TM01]
15
16 //CALCULATION
17 d=((p*(%pi))/(sqrt((2*(%pi)*f0/c)^2-(Pnm/a)^2))); //
```

```

    The minimum distance between the two end plates
    in cms
18
19 //OUTPUT
20 mprintf(' \nThe minimum distance between the two end
    plates of a circular waveguide is d=%1.2f cms ',d)
    ;
21
22 //=====END OF PROGRAM
    =====

```

Scilab code Exa 5.2 lowest resonant frequency

```

1 //chapter-5 page 174 example 5.2
2 //
    =====

3 clc;
4 clear;
5
6 //For a rectangular cavity resonator
7 a=2; //breadth in cm
8 b=1; //height in cm
9 l=3; //length of rectangular waveguide in cm
10 disp('Lowest resonant frequency is obtained for the
    dominant mode TE10[f=c/w where w increases as f
    decreases. In dominant mode wc is maximum]');
11 disp('So the dominant mode is TE101 so here m=1,n=0,
    p=1');
12 c=3*1010; //Velocity of light in cm/sec
13 m=1;
14 n=0;
15 p=1;
16
17 //CALCULATION

```

```

18 f0=((c/2)*sqrt((m/a)^2+(n/b)^2+(p/l)^2))/10^9; //The
    resonant frequency of a rectangular cavity
    resonator in GHz
19
20 //OUTPUT
21 mprintf('\nThe resonant frequency of a rectangular
    cavity resonator is f0=%1.0f GHz',f0);
22
23 //=====END OF PROGRAM
    =====

```

Scilab code Exa 5.3 resonant frequency

```

1 //chapter-5 page 175 example 5.3
2 //
    =====

3 clc;
4 clear;
5
6 //For a circular resonator
7 D=12.5; //diameter in cm
8 l=5; //length of circular waveguide in cm
9 disp('Given the mode of operator is TM012 so here n
    =0,m=1,p=2');
10 c=3*10^10; //Velocity of light in cm/sec
11 m=1;
12 n=0;
13 p=2;
14 Pnm=2.405; //dominant mode value[TM01]
15
16 //CALCULATION
17 a=D/2; //radius in cm
18 f0=((c/(2*(%pi)))*sqrt((Pnm/a)^2+((p*(%pi))/l)^2))
    /10^9; //The resonant frequency of a circular

```



```

    resonator in GHz
19
20 //OUTPUT
21 mprintf('\\nThe resonant frequency of a circular
    resonator is f0=%1.2 f GHz',f0);
22
23 //=====END OF PROGRAM
    =====

```

Scilab code Exa 5.4 resonant frequency

```

1 //chapter-5 page 175 example 5.4
2 //
    =====

3 clc;
4 clear;
5
6 //For a circular resonator
7 a=3;//radius in cm
8 b=2;//dimension in cm
9 l=4;//length of circular waveguide in cm
10 disp('Given the mode of operator is TE101 so here m
    =1,n=0,p=1');
11 c=3*10^10;//Velocity of light in cm/sec
12 m=1;
13 n=0;
14 p=1;
15
16 //CALCULATION
17 f0=((c/2)*sqrt((m/a)^2+(n/b)^2+(p/l)^2))/10^9;//The
    resonant frequency of a circular resonator in GHz
18
19 //OUTPUT
20 mprintf('\\nThe resonant frequency of a circular

```

```
    resonator is f0=%1.2 f GHz',f0);  
21  
22 //=====END OF PROGRAM  
    =====  


---


```

Chapter 6

Microwave Components

Scilab code Exa 6.2 distance to be shifted

```
1 //Chapter -6, Example 6.2, Page 234
2 //


---


3 //Input parameters
4 //[s]=[0,(0.3+(%i)*(0.4));(0.3+(%i)*(0.4)),0];//
   scattering matrix of a two port
5 //Calculations
6 //to find l such that S12 and S21 will be real when
   port1 is shifted lm to the left
7 //let port 1 be shifted by phi1 degree to the left
   and port2 position be remained unchanged i.e.,
   phi2=delta
8 //Then [phi]=[e^-(j*phi1),0;0,1]
9 //[S']=[phi]*[s]*[phi]
10 //for S12 and S21 to be real
11 phi1=53.13;//in degrees
12 phi1=phi1*(%pi/180);//phi in radians
13 b=34.3;//measured in rad/m
14 l=(phi1)/b;//distance of shift in m
15 //Output
```

```

16 mprintf("distance that the position of part1 should
    be shifted to the left so that S21 and S12 will
    be real numbers is %1.4f m",1)
17 //=====END OF PROGRAM
    =====

```

Scilab code Exa 6.3 Scattering parameters

```

1 //Chapter-6, Example 6.3, Page 236
2 //
    =====

3 clc;
4 //Input parameters
5 D=30; //directivity in dB
6 VSWR=1; //VSWR at each port under matched conditions
7 C=10; //coupling factor
8 //Calculations
9 S41=sqrt(0.1);
10 S14=S41; //under matched and lossless conditions
11 S31=sqrt(((S41)^2)/(10)^(D/10));
12 S13=S31;
13 S11=(VSWR-1)/(VSWR+1);
14 S22=S11;
15 S33=S22;
16 S44=S33;
17 //let input power is given at port1
18 //p1=p2+P3+p4
19 S21=sqrt(1-(S41)^2-(S31)^2);
20 S12=S21;
21 S34=sqrt((0.5)*(1+(S12)^2-0.1-0.0001));
22 S43=S34
23 S23=sqrt(1-10^-4-(S34)^2)
24 S32=S23;
25 S24=sqrt(1-0.1-(S34)^2)

```

```

26 S42=S24;
27 [S]=[S11 ,S12 ,S13 ,S14 ;S21 ,S22 ,S23 ,S24 ;S31 ,S32 ,S33 ,S34
    ;S41 ,S42 ,S43 ,S44];
28 //Output
29 mprintf("The scattering matrix is");
30 disp([S])
31 //=====END OF PROGRAM
    =====

```

Scilab code Exa 6.4 powers in the remaining ports

```

1 //Chapter –6, Example 6.4, Page 238
2 //
    =====

3 clc;
4 //Input parameters
5 a1=32*10^-3;//power in watts
6 a2=0;
7 a3=0;
8 //Calculations
9 [S]=[0.5 , -0.5 ,0.707 ; -0.5 ,0.5 ,0.707 ;0.707 ,0.707 ,0] ; //
    S-matrix for H-plane tee
10 // [B]=[b1 ,b2 ,b3]
11 [B]=[S].*[a1 ,0 ,0 ;0 ,0 ,0 ;0 ,0 ,0];
12 b1=(0.5)^2*a1;//power at port 1
13 b2=(-0.5)^2*a1;//power at port 2
14 b3=(0.707)^2*a1;//power at port 3
15 //Output
16 mprintf("Thus b1 ,b2 ,b3 are %g W,%g W,%g W
    respectively" ,b1 ,b2 ,b3);
17 //=====END OF PROGRAM
    =====

```

Scilab code Exa 6.5 power

```
1 //Chapter -6, Example 6.5, Page 239
2 //


---


3 clc;
4 //Input parameters
5 [S]=[0.5,-0.5,0.707;-0.5,0.5,0.707;0.707,0.707,0];
6 R1=60;//load at port1 in ohms
7 R2=75;//load at port2 in ohms
8 R3=50;//characteristic impedance in ohms
9 P3=20*10^-3;//power at port 3 in Watts
10 //calculations
11 p1=(R1-R3)/(R1+R3);
12 p2=(R2-R3)/(R2+R3);
13 P1=0.5*P3*(1-(p1)^2);//power delivered to the port1
    in Watts
14 P2=0.5*P3*(1-(p2)^2);//power delivered to the port2
    in Watts
15 //Output
16 mprintf("Thus power delivered to the port1 and port2
    are %g W,%g W respectively",P1,P2);
17 //=====END OF PROGRAM


---


```

Scilab code Exa 6.6 Reflected power

```
1 //Chapter -6, Example 6.6, Page 239
2 //


---


```

```

3  clc;
4  //Input parameters
5  p1=0.5; //reflection coefficient at port 1
6  p2=0.6; //reflection coefficient at port 2
7  p3=1; //reflection coefficient at port 3
8  p4=0.8; //reflection coefficient at port 4
9  // [S
      ]=[0,0,0.707,0.707;0,0,0.5,-0.707;0.707,0.707,0,0;-0.707,0.707,0,0,
      S matrix of magic Tee
10 //solving for b1,b2,b3,b4 we get it as
11 //calculations
12 b1=0.6566;
13 b2=0.7576;
14 b3=0.6536;
15 b4=0.0893;
16 P1=(b1)^2; //power at port1 in watts
17 disp(P1);
18 P2=(b2)^2; //power at port2 in watts
19 disp(P2);
20 P3=(b3)^2; //power at port3 in watts
21 disp(P3);
22 P4=(b4)^2; //power at port4 in watts
23 disp(P4);
24 //=====END OF PROGRAM
      =====

```

Scilab code Exa 6.7 Scattering matrix

```

1 //Chapter -6, Example 6.7, Page 240
2 //
      =====
3 clc;
4 //Input parameters
5 ins=0.5; //insertion loss in db

```

```

6 iso=30; //isolation loss in db
7 // Calculations
8 S21=10^-(ins/20); //insertion loss=0.5=-20*log[S21]
9 S12=10^-(iso/20); //isolation loss=30=-20*log[s12]
10 S11=0;
11 S22=0;
12 [S]=[S11 , S12 ; S21 , S22];
13 disp(S);
14 //=====END OF PROGRAM
    
```

Scilab code Exa 6.9 Scattering matrix

```

1 //Chapter-6, Example 6.9, Page 241
2 //
    
```

```

3 clc;
4 //Input parameters
5 ins=0.5; //insertion loss in db
6 iso=20; //isolation loss in db
7 S=2; //VSWR
8 // Calculations
9 S21=10^-(ins/20); //insertion loss=0.5=-20*log[S21]
10 S13=S21;
11 S32=S13;
12 S12=10^-(iso/20); //isolation loss=30=-20*log[s12]
13 S23=S12;
14 S31=S23;
15 p=(S-1)/(S+1);
16 S11=p;
17 S22=p;
18 S33=p;
19 [S]=[S11 , S12 , S13 ; S21 , S22 , S23 ; S31 , S32 , S33];
20 disp(S);
    
```



```

21 //for a perfectly matched ,non-reciprocal ,lossless 3-
    port circulator ,[S] is given by
22 // [S]=[0 ,0 ,S13 ;S21 ,0 ,0 ; ,0 ,S32 ,0]
23 // i . e . ,S13=S21=S32=1
24 // [S]=[0 ,0 ,1 ;1 ,0 ,0 ;0 ,1 ,0]
25 //=====END OF PROGRAM
    =====

```

Scilab code Exa 6.10 output powers

```

1 //Chapter -6, Example 6.10, Page 242
2 //
    =====

3
4 clc ;
5 clear ;
6 close ;
7 In_loss =0.5; // i n s e r t i o n l o s s ( i n dB)
8 C =20; //coupling coefficient i n dB
9 D =35; //directivity i n dB
10 Pi_Pf =10^( C /10) ;
11 Pi =90; // i n Watts
12 Pf=Pi/ Pi_Pf ;
13 Pf_Pb =10^( D /10) ;
14 Pb=Pf/ Pf_Pb ;
15 P_rec =(Pi -Pf -Pb); //Power r e c e i v e d ( i n
    Watts )
16 P_rec_dB =10* log (Pi/ P_rec )/log (10) ;
17 P_rec_eff = P_rec_dB - In_loss ; // E f f e c t i v e
    e power r e c e i v e d ( i n dB)
18 disp ( Pf , 'Output power through coupled port ( i n
    Watts)= ' );
19 disp ( Pb , 'Output power through isolated port ( i
    n Watts)= ' );

```

```

20 disp ( P_rec_dB , ' Power r e c e i v e d ( i n dB)=
    ' );
21 disp ( P_rec_eff , ' E f f e c t i v e power r e c e
    i v e d ( i n dB)= ' );
22
23
24 //=====END OF PROGRAM
    =====

```

Scilab code Exa 6.11 coupling isolation directivity

```

1 //Chapter -6, Example 6.11, Page 242
2 //
    =====
3 clc;
4 // Calculations
5 S13=0.1*(cos(90*%pi/180)+(%i)*sin(90*%pi/180));//
    conversion from polar to rectangular
6 S13=abs(S13);
7 C=-20*log10(S13);//coupling coefficient in dB
8 S14=0.05*(cos(90*%pi/180)+(%i)*sin(90*%pi/180));//
    conversion from polar to rectangular
9 S14=abs(S14);
10 D=20*log10(S13/S14);//directivity in dB
11 I=-20*log10(S14);//isolation in dB
12 mprintf("Thus coupling , directivity and isolation are
    %1.0f dB,%1.2f dB and %2.2f dB respetively ",C,D
    ,I);
13 //=====END OF PROGRAM
    =====

```

Scilab code Exa 6.12 VSWR

```

1 //chapter-6 page 244 example 6.12
2 //


---


3 clc;
4 clear;
5
6 x=3.5;//distance between two minimas in cm
7 y=0.25;//distance between twice minimum power points
   in cm
8
9 //CALCULATION
10 wg=2*x;//guided wavelength in cm
11 S=(wg/(y*(%pi)));//Voltage Standing Wave Ratio(VSWR)
12
13 //OUTPUT
14 mprintf(' \nVoltage Standing Wave Ratio(VSWR) is S=%1
   .4f ',S);
15
16 //=====END OF PROGRAM


---



```

Scilab code Exa 6.13 phase shift

```

1 //chapter-6 page 244 example 6.13
2 //


---


3 clc;
4 clear;
5
6 wg=7.2;//guide wavelength in cm
7 x=10.5;//Position of reference null without the
   waveguide component in cm
8 y=9.3;//Position of reference null with the

```

```
    waveguide component in cm
9
10 //CALCULATION
11 z=x-y;//Path difference introduced due to the
    component in cm
12 p=(2*(%pi)*(z/wg));//Phase difference introduced in
    rad
13 Pd=(p*180)/(%pi);//Phase shift introduced in deg
14
15 //OUTPUT
16 mprintf('\\nPhase shift introduced is Pd=%2.0f deg',
    Pd);
17
18 //=====END OF PROGRAM
    =====
```

Chapter 7

Microwave Measurements

Scilab code Exa 7.1 measured distance

```
1 //chapter-7 page 278 example 7.1
2 //


---


3 clc;
4 clear;
5
6 a=4; //Length of Waveguide in cm
7 b=2.5; //breadth Waveguide in cm
8 f=10^10; //Frequency in Hz
9 x=0.1; //distance between twice minimum power points
   in cm
10 c=3*10^10; //Velocity of Light in cm/sec
11
12 //CALCULATION
13 wc=2*a; //Cutoff wavelength in TE10 mode in cms
14 w0=(c/f); //Free space wavelength in cms
15 wg=(w0/sqrt(1-(w0/wc)^2)); //Guide wavelength in cms
16 S=(wg/(x*(%pi))); //Voltage Standing Wave Ratio(VSWR)
   for double minimum method
17
```

```

18 //OUTPUT
19 fprintf('\nFor double minimum method, Voltage
    Standing Wave Ratio(VSWR) is S=%2.1f',S);
20
21 //=====END OF PROGRAM
    =====

```

Scilab code Exa 7.2 VSWR and Reflected power

```

1 //chapter-7 page 279 example 7.2
2 //
    =====

3 clc;
4 clear;
5
6 x=3;//O/P incident power from first directional
    coupler in mW
7 y=0.1;//O/P reflected power from second directional
    coupler in mW
8
9 //CALCULATION
10 Pi=x*100;//Incident Power in mW
11 Pr=y*100;//Reflected Power in mW
12 p=sqrt(Pr/Pi);//Reflection Coefficient
13 S=((1+p)/(1-p));//Voltage Standing Wave Ratio(VSWR)
14
15 //OUTPUT
16 fprintf('\nVoltage Standing Wave Ratio(VSWR) in the
    main waveguide is S=%1.2f \nReflected Power is Pr
    =%2.0f mW',S,Pr);
17
18 //=====END OF PROGRAM
    =====

```

Scilab code Exa 7.3 VSWR

```
1 //chapter-7 page 279 example 7.3
2 //


---


3 clc;
4 clear;
5
6 Pi=2.5; //Incident Power from one directional coupler
      in mW
7 Pr=0.15; //Reflected Power from other directional
      coupler in mW
8
9 //CALCULATION
10 p=sqrt(Pr/Pi); //Reflection Coefficient
11 S=((1+p)/(1-p)); //Voltage Standing Wave Ratio(VSWR)
12
13 //OUTPUT
14 mprintf('\nVoltage Standing Wave Ratio(VSWR) in the
      waveguide is S=%1.2f',S);
15
16 //=====END OF PROGRAM


---


```

Scilab code Exa 7.4 Reflected power

```
1 //chapter-7 page 279 example 7.4
2 //


---


3 clc;
```

```

4 clear;
5
6 S=2; //Voltage Standing Wave Ratio(VSWR)
7 C=30; //Coupling Power of a Directional Coupler in dB
8 Pf=4.5; //Coupler Incident Sampling Power in mW
9
10 //CALCULATION
11 p=((S-1)/(S+1)); //Reflection Coefficient
12 Pi=Pf*10^(C/10); //Incident Power in mW [From C=10log
    (Pi/Pf)]
13 Pr=(Pi*(p^2))/10^3; //Reflected Power in W [From p=
    sqrt(Pr/Pi)]
14
15 //OUTPUT
16 mprintf('\nValue of Reflected Power is Pr=%1.2f W',
    Pr);
17
18 //=====END OF PROGRAM
    =====

```

Chapter 8

Microwave Tubes and Circuits

Scilab code Exa 8.1 electron velocity and etc

```
1 //chapter-8 page 336 example 8.1
2 //


---


3 clc;
4 clear;
5
6 //For a four cavity Klystron
7 V0=14500;//Beam voltage in V
8 I=1.4;//Beam current in A
9 f=10^10;//Operation frequency in Hz
10 p0=10^(-6);//dc electron charge density in C/m^3
11 p=10^(-8);//RF charge density in C/m^3
12 V=10^5;//Velocity perturbations in m/sec
13 e0=8.854*10^(-12);//Permittivity of free space in F/
    m
14 R=0.4;
15
16 //CALCULATION
17 v0=(0.593*10^6*sqrt(V0))/10^8;//The dc electron
    velocity in 10^8 m/sec
```

```

18 w=2*(%pi)*f;//angular frequency in rad/sec
19 v=v0*10^8;
20 c=(w/v);//The dc Phase Constant
21 wp=(sqrt(1.759*10^11*(p0/e0)))/10^8;//The Plasma
    Frequency in 10^8 rad/sec
22 wp1=wp*10^8;
23 wq=(R*wp1)/10^8;//The Reduced Plasma Frequency in
    10^8 rad/sec
24 J0=p0*v;//The dc beam current density in A/sqm
25 J=(p*v)+(p0*V);//The instantaneous beam current
    density in A/sqm
26
27 //OUTPUT
28 mprintf('\nThe dc electron velocity is v0=%2.3f
    *10^8 m/sec \nThe dc Phase Constant is c=%1.2f
    rad/sec\nThe Plasma Frequency is wp=%1.2f *10^8
    rad/sec \nThe Reduced Plasma Frequency is wq=%1.3
    f *10^8 rad/sec \nThe dc beam current density is
    J0=%2.1f A/sqm \nThe instantaneous beam current
    density is J=%1.3f A/sqm',v0,c,wp,wq,J0,J);
29
30 //=====END OF PROGRAM
    =====

```

Scilab code Exa 8.2 power and etc

```

1 //chapter-8 page 337 example 8.2
2 //
    =====
3 clc;
4 clear;
5
6 //For a 2 cavity klystron amplifier
7 Av=15;//Voltage gain in dB

```

```

8 Pin=0.005; //I/P power in W
9 Rin=30000; //Rsh of i/p cavity in ohms
10 R0=40000; //Rsh of o/p cavity in ohms
11 Rl=40000; //load impedance in ohms
12 R=20000; //Parallel resistance of R0 and Rl (R0//Rl)
    in ohms
13
14 //CALCULATION
15 Vin=sqrt(Pin*Rin); //The input rms voltage in V [
    From Pin=Vin^2/Rin]
16 V0=Vin*10^(Av/20); //The output rms voltage in V [
    From Av=20log(V0/Vin)]
17 P0=(V0^2)/R; //The Power delivered to the load in W
18
19 //OUTPUT
20 mprintf('\n\nThe input rms voltage is Vin=%2.2f V \
    \n\nThe output rms voltage is V0=%2.2f V \n\nThe Power
    delivered to the load is P0=%1.4f W',Vin,V0,P0);
21
22 //=====END OF PROGRAM
    =====

```

Scilab code Exa 8.3 efficiency and etc

```

1 //chapter-8 page 338 example 8.3
2 //
    =====
3 clc;
4 clear;
5
6 //For a reflex klystron
7 n=2; //peak mode value
8 V0=300; //beam voltage in V
9 I0=0.02; //beam current in A

```

```

10 Vs=40; //signal voltage in V
11 J1=1.25; //bessel coefficient for n=2
12
13 //CALCULATION
14 Pdc=V0*I0; //The input power in watts
15 Pac=((2*Pdc*J1)/((2*n*(%pi))-((%pi)/2))); //The
    output power in watts
16 n=(Pac/Pdc)*100; //Efficiency in percentage
17
18 //OUTPUT
19 mprintf('\nThe input power is Pdc=%1.0f watts \nThe
    output power is Pac=%1.2f watts \nEfficiency is n
    =%2.1f percentage ',Pdc ,Pac ,n);
20
21 //=====END OF PROGRAM
    =====

```

Scilab code Exa 8.4 electron velocity and etc

```

1 //chapter-8 page 338 example 8.4
2 //
    =====
3 clc;
4 clear;
5
6 //For a 2 cavity klystron amplifier
7 V0=900; //Beam voltage in V
8 I0=0.03; //Beam current in A
9 f=8*10^9; //frequency in Hz
10 d=0.001; //gap spacing in either cavity in m
11 L=0.04; //spacing between centers of cavities in m
12 Rsh=49000; //Effective shunt impedance in ohms
13 J1=0.582; //value of J1(X)
14 X=1.841; //bunching parameter

```

```

15
16 //CALCULATION
17 v0=(0.593*10^6*sqrt(V0))/10^6; //velocity of electron
    in 10^6 m/sec
18 w=2*(%pi)*f; //angular frequency in rad
19 v=v0*10^6;
20 T0=(L/v)/10^(-8); //dc transit time of electrons in
    10^(-8) sec
21 a=w*T0*10^(-8); //transit angle in rad
22 tg=w*d/v; //average gap transit angle in rad
23 Tg=tg*(180/(%pi));
24 Bi=(sind(Tg/2))/(tg/2); //beam coupling coefficient
25 Bo=Bi; //output cavity coupling coefficient
26 V1max=((3.68*V0)/(Bi*a)); //Input voltage for Maximum
    output voltage in V
27 R0=V0/I0; //impedance in ohms
28 Av=(Bo^2*a*Rsh*J1)/(R0*X); //Voltage gain
29 AvdB=20*log10(Av); //Voltage gain in dB
30
31 //OUTPUT
32 mprintf('\nVelocity of electron is v0=%2.2f *10^6 m/
    sec \nThe dc transit time of electrons is T0=%1.3
    f *10^(-8) sec \nInput voltage for Maximum output
    voltage is V1max=%2.3f V \nVoltage gain is Av=%2
    .2f \nThe Voltage gain in dB is AvdB=%2.2f dB',v0
    ,T0,V1max,Av,AvdB);
33
34 //=====END OF PROGRAM
    =====
35
36 //Note: Check the calculation given in text book for
    voltage gain Rsh=49 kohms
37 //but, taken as 40 kohms
38 //correct answers areVoltage gain is Av=28.52
39 //The Voltage gain in dB is AvdB=29.10 dB

```

Scilab code Exa 8.5 efficiency and etc

```
1 //chapter-8 page 339 example 8.5
2 //


---


3 clc;
4 clear;
5
6 //For a 2 cavity klystron amplifier
7 V0=1200; //Beam voltage in V
8 I0=0.028; //Beam current in A
9 f=8*10^9; //frequency in Hz
10 d=0.001; //gap spacing in either cavity in m
11 L=0.04; //spacing between centers of cavities in m
12 Rsh=40000; //Effective shunt impedance in ohms
13 J1=0.582; //value of J1(X)
14 X=1.841; //bunching parameter
15
16 //CALCULATION
17 w=2*(%pi)*f; //angular frequency in rad
18 v0=0.593*10^6*sqrt(V0); //velocity of electron in m/
    sec
19 Vomax=((3.68*V0*v0)/(w*L)); //max output power in V
20 tg=(w*d)/v0; //avg gap transit angle in rad
21 Tg=tg*(180/(%pi));
22 Bi=(sind(Tg/2))/(tg/2); //beam coupling coefficient
23 Bo=Bi; //output cavity coupling coefficient
24 Vimax=Vomax/Bi; //The input microwave voltage in
    order to generate maximum output voltage in V
25 t0=w*L/v0; //transit angle in rad
26 R0=V0/I0; //impedance in ohms
27 Av=((Bo^2*J1*t0*Rsh)/(R0*X)); //Voltage gain
28 I2=2*I0*J1;
```

```

29 V2=Bo*I2*Rsh;
30 disp('neglecting beam loading');
31 Eff=0.58*(V2/V0)*100;//Efficiency in %
32 G0=1/R0;
33 GB=(G0/2)*(Bo*(Bo-cos(Tg/2)));//Beam loading
    conductance in mhos
34 RB=(1/GB)/1000;//Beam loading resistance in Kohms
35 disp('Beam loading resistance in Kohms is');
36 disp(RB);
37 disp('The value 73 kohms is very much comparable to
    Rsh and cannot be neglected because Tg is quite
    high');
38
39 //OUTPUT
40 mprintf('\n\nThe input microwave voltage in order to
    generate maximum output voltage is Vimax=%2.2f V
    \n\nThe voltage gain is Av=%2.2f percentage \n\nBeam
    loading conductance is GB=%1.10f mhos',Vimax,Av,
    GB);
41
42 //=====END OF PROGRAM
    =====

```

Scilab code Exa 8.6 electronic efficiency and etc

```

1 //chapter-8 page 338 example 8.4
2 //
    =====
3 clc;
4 clear;
5
6 //For a reflex klystron
7 n=2;//peak mode value
8 V0=500;//beam voltage in V

```

```

 9 Rsh=20000; //Shunt resistance in ohms
10 L=0.001; //distance in m
11 f=8*10^(9); //Operation frequency in Hz
12 V1=200; //microwave gap voltage in V
13 x=1.759*10^11; //e/m value in C/kg
14 J1=0.582;
15
16 //CALCULATION
17 disp('Assume the gap transit time and beam loading
      are neglected');
18 w=2*(%pi)*f; //angular frequency in rad
19 VR=(V0+((sqrt(8*V0/x)*w*L)/((2*(%pi)*n)-((%pi)/2))))
      ; //Repeller voltage in V
20 disp('Assuming output coupling coefficient Bo=1');
21 I0=(V1/(2*J1*Rsh))/10^(-3); //Beam current necessary
      to obtain an microwave gap voltafe of 200V in mA
22 v0=0.593*10^6*sqrt(V0); //velocity of electron in m/
      sec
23 t0=((w*2*L*v0)/(x*(VR+V0))); //transit angle in rad
24 Bi=1; //beam coupling coefficient [assume]
25 X=((Bi*V1*t0)/(2*V0));
26 disp('Since X=1.51, from graph ,J1(X)=0.84');
27 XJ1=0.84;
28 Eff=((2*(XJ1))/((2*n*(%pi))-((%pi)/2)))*100 //
      Efficiency in %
29
30 //OUTPUT
31 mprintf('\nRepeller voltage is VR=%3.2f V \nThe dc
      necessary to give an microwave gap voltafe of 200
      V is I0=%1.2f mA \nElectronic Efficiency is Eff=
      %2.2f percentage',VR,I0,Eff);
32
33 //=====END OF PROGRAM
      =====
34
35 //Note: Check the answer for VR once
36 //Correct answer is Repeller voltage is VR=1189.36 V

```

Scilab code Exa 8.7 efficiency and etc

```
1 //chapter-8 page 342 example 8.7
2 //


---


3 clc;
4 clear;
5
6 //For a reflex klystron
7 n=1;//mode value
8 Pi=0.04;//the dc input power in W
9 x=0.278;//ratio of V1 over V0
10
11 //CALCULATION
12 X=x*3*(%pi)/4;
13 J1=0.3205;//bessel coefficient value [JI(X')]
14 ef=((2*X*J1)/((2*(%pi)*n)-((%pi)/2)))*100;//
    Efficiency of the reflex klystron in %
15 Pout=((ef/100)*Pi)/10^(-3);//Total power output in
    mW
16 p=20;//percentage of the power delivered by the
    electron beam dissipated in the cavity walls
17 Pd=Pout*(100-p)/100;//Power delivered to load in mW
18
19 //OUTPUT
20 mprintf('\nEfficiency of the reflex klystron is ef=
    %1.2f percentage\nTotal power output is Pout=%1.3
    f mW \nIf the 20 percentage of the power
    delivered by the electron beam is dissipated in
    the cavity walls then the Power delivered to load
    is Pd=%1.2 f mW',ef,Pout,Pd);
21
22 //=====END OF PROGRAM
```

Scilab code Exa 8.8 cyclotron frequency and etc

```
1 //chapter-8 page 342 example 8.8
2 //
3 clc;
4 clear;
5
6 //For a circular magnetron
7 a=0.15; //inner radius in m
8 b=0.45; //outer radius in m
9 B=1.2*10^(-3); //magnetic flux density in Wb/sqm
10 x=1.759*10^11; //Value of e/m in C/kg
11 V=6000; //beam voltage in V
12
13 //CALCULATION
14 V0=((x/8)*(B^2)*(b^2)*(1-(a/b)^2)^2)/1000; //Hull cut
    -off voltage in kV
15 Bc=((sqrt(8*(V/x)))/(b*(1-(a/b)^2)))*1000; //Cut-off
    magnetic flux density in mWb/sqm
16 fc=((x*B)/(2*(%pi)))/10^9; //Cyclotron frequency in
    GHz
17
18 //OUTPUT
19 mprintf('\nHull cut-off voltage is V0=%2.3f kV\nCut-
    off magnetic flux density is Bc=%1.6f mWb/sqm \
    nCyclotron frequency is fc=%1.4f GHz',V0,Bc,fc);
20
21 //=====END OF PROGRAM
22
23
```

```

24 //Check the answers once
25 //Correct answers are
26 //Hull cut-off voltage is V0=5.066 kV
27 //Cut-off magnetic flux density is Bc=1.305953 mWb/
    sqm
28 //Cyclotron frequency is fc=0.0336 GHz

```

Scilab code Exa 8.9 phase velocity and anode voltage

```

1 //chapter-8 page 343 example 8.9
2 //

```

```

3 clc;
4 clear;
5
6 //For a helical TWT
7 c=3*10^8;//Velocity of light in m/sec
8 d=0.002;//diameter in m
9 x=5000;//no.of turns per m
10 m=9.1*10^(-31);//mass of an electron in kg
11 e=1.6*10^(-19);//charge of an electron in C
12
13 //CALCULATION
14 y=(%pi)*d;//circumference in m
15 p=1/x;//pitch in m
16 Vp=(c*p)/y;//Axial phase velocity in m/sec
17 V0=((m*Vp^2)/(2*e));//The Anode voltage at which the
    TWT can be operated for useful gain in V
18
19 //OUTPUT
20 mprintf(' \nAxial phase velocity is Vp=%6.2f m/sec \
    nThe Anode voltage at which the TWT can be
    operated for useful gain is V0=%2.2f V',Vp,V0);
21

```

```
22 //=====END OF PROGRAM
```

Scilab code Exa 8.10 electron velocity and etc

```
1 //chapter-8 page 344 example 8.10
2 //
3 clc;
4 clear;
5
6 //For a 2 cavity klystron amplifier
7 V0=900; //Beam voltage in V
8 I0=0.03; //Beam current in A
9 f=8*10^9; //frequency in Hz
10 d=0.001; //gap spacing in either cavity in m
11 L=0.04; //spacing between centers of cavities in m
12 Rsh=40000; //Effective shunt impedance in ohms
13 y=0.582; //value of J1(X)
14 X=1.841;
15
16 //CALCULATION
17 v0=(0.593*sqrt(V0)*10^6)/10^7; //The electron
    velocity in 10^7 m/sec
18 v=v0*10^7;
19 t0=(d/v)/10^(-10); //Transit time in 10^(-10) sec
20 t=t0*10^(-10);
21 a=2*(%pi)*f*t; //Gap transit angle in rad
22 Bi=(sin(a/2))/(a/2); //Beam coupling coefficient
23 Bo=Bi;
24 to=(2*(%pi)*f*L)/v; //dc transit angle in rad
25 disp('For maximum outout voltage ,V2 J1(X)=0.582,X
    =1.841 ');
26 V1=((2*V0*X)/(Bo*to)) //The input voltage for maximum
```

```

        output voltage in V
27 Ro=(V0/I0);
28 Av=((Bo^2*t0*y*Rsh)/(Ro*X)); //Voltage gain
29 AvdB=10*log10(Av); //Voltage gain in dB
30
31 //OUTPUT
32 mprintf('\nThe electron velocity is v0=%1.1f *10^7 m
        /sec \nThe dc electron Transit time is t0=%1.2f
        *10^(-10) sec \nThe input voltage for maximum
        output voltage is V1=%2.2f V \nVoltage gain is Av
        =%2.2f \nVoltage gain in dB is AvdB=%2.2f dB',v0,
        t0,V1,Av,AvdB);
33
34 //=====END OF PROGRAM
        =====

```

Scilab code Exa 8.11 dc electron velocity and etc

```

1 //chapter-8 page 345 example 8.11
2 //
        =====
3 clc;
4 clear;
5
6 //For a four cavity Klystron
7 V0=20000; //Beam voltage in V
8 I=2; //Beam current in A
9 f=9*10^9; //Operation frequency in Hz
10 p0=10^(-6); //dc electron charge density in C/m^3
11 p=10^(-8); //RF charge density in C/m^3
12 V=10^5; //Velocity perturbations in m/sec
13 e0=8.854*10^(-12); //Permittivity of free space in F/
        m
14 R=0.5;

```

```

15
16 //CALCULATION
17 v0=(0.593*10^6*sqrt(V0))/1000;//The dc electron
    velocity in Km/sec
18 w=2*(%pi)*f;//angular frequency in rad/sec
19 v=v0*1000;
20 c=(w/v);//The dc Phase Constant
21 wp=(sqrt(1.759*10^11*(p0/e0)))/10^8;//The Plasma
    Frequency in 10^8 rad/sec
22 wp1=wp*10^8;
23 wq=(R*wp1)/10^8;//The Reduced Plasma Frequency in
    10^8 rad/sec
24 J0=p0*v;//The dc beam current density in A/sqm
25 J=(p*v)-(p0*V);//The instantaneous beam current
    density in A/sqm
26
27 //OUTPUT
28 mprintf('\n\nThe dc electron velocity is v0=%4.2f Km/
    sec \n\nThe dc Phase Constant is c=%3.2f rad/sec \
    \n\nThe Plasma Frequency is wp=%1.2f *10^8 rad/sec \
    \n\nThe Reduced Plasma Frequency is wq=%1.3f *10^8
    rad/sec \n\nThe dc beam current density is J0=%2.2f
    A/sqm \n\nThe instantaneous beam current density
    is J=%1.4f A/sqm ',v0,c,wp,wq,J0,J);
29
30 //=====END OF PROGRAM
    =====

```

Scilab code Exa 8.12 gap transit angle

```

1 //chapter-8 page 345 example 8.12
2 //
3 clc;

```

```

4 clear;
5
6 //For a reflex klystron
7 f=5*10^9; //Frequency of operation in hz
8 V0=1000; //anode voltage in V
9 d=0.002; //cavity gap in m
10 Vr=-500; //repeller voltage in V
11
12 //CALCULATION
13 N=7/4; //mode value
14 VR=abs(Vr);
15 L=((VR+V0)*N)/(6.74*10^(-6)*f*sqrt(V0))/10^(-3); //
    Optimum length of the drift region in mm
16 u=5.93*10^5*sqrt(V0); // in m/sec
17 w=2*(%pi)*f; //angular frequency in rad
18 Tg=(w*d)/u; //Gap transit angle in rad
19
20 //OUTPUT
21 mprintf('\nOptimum length of the drift region is L=
    %1.3f mm \nGap transit angle is Tg=%1.3f rad',L,
    Tg);
22
23 //=====END OF PROGRAM
    =====

```

Scilab code Exa 8.13 efficiency and etc

```

1 //chapter-8 page 346 example 8.13
2 //
    =====
3 clc;
4 clear;
5
6 //For a 2 cavity klystron amplifier

```

```

7 V0=1200; //Beam voltage in V
8 I0=0.03; //Beam current in A
9 f=10*10^9; //frequency in Hz
10 d=0.001; //gap spacing in either cavity in m
11 L=0.04; //spacing between centers of cavities in m
12 Rsh=40000; //Effective shunt impedance in ohms
13 J1=0.582; //value of J1(X)
14 X=1.841; //bunching parameter
15
16 //CALCULATION
17 v0=0.593*10^6*sqrt(V0); //velocity of reference
    electron in m/sec
18 w=2*(%pi)*f; //angular frequency in rad
19 a=w*L/v0; //transit angle without RF voltage in rad
20 tg=a*d/L; //average gap transit angle in rad
21 Bi=(sin(tg/2))/(tg/2); //beam coupling coefficient
22 V1max=((2*X*V0)/(Bi*a)); //Input RF voltage for
    Maximum output voltage in V
23 B0=Bi; //output cavity coupling coefficient
24 V2=2*B0*I0*J1*Rsh; //in V
25 Av=V2/V1max; //Voltage gain
26 AvdB=20*log10(Av); //Voltage gain in dB
27 n=0.58*(V2/V0)*100; //Maximum efficiency in %
28
29 //OUTPUT
30 fprintf('\nInput RF voltage for Maximum output
    voltage is V1max=%2.2f V \nThe Voltage gain is
    AvdB=%2.2f dB \nMaximum efficiency is I0=%2.2f
    percentage ',V1max,AvdB,n);
31
32 //=====END OF PROGRAM
    =====
33
34 //Note: Check the answers once
35 //There are slight changes in values
36 //Input RF voltage for Maximum output voltage is
    V1max=55.28 V
37 //The Voltage gain is AvdB=24.35 dB

```


38 //Maximum efficiency is $I_0=44.11$ percentage

Scilab code Exa 8.14 cyclotron angular frequency and etc

```
1 //chapter-8 page 347 example 8.14
2 //


---


3 clc;
4 clear;
5
6 //For aa X-band cylindrical magnetron
7 a=0.04; //inner radius in m
8 b=0.08; //outer radius in m
9 B=0.01; //magnetic flux density in Wb/sqm
10 x=1.759*10^11; //Value of e/m in C/kg
11 V=30000; //beam voltage in V
12
13 //CALCULATION
14 w=(x*B)/10^9; //Cyclotron angular frequency in 10^9
    rad/sec
15 VHC=((x/8)*(B^2)*(b^2)*(1-(a/b)^2)^2)/1000; //Hull
    cut-off voltage in kV
16 Bc=((sqrt(8*(V/x)))/(b*(1-(a/b)^2)))*1000; //Cut-off
    magnetic flux density in mWb/sqm
17
18 //OUTPUT
19 mprintf(' \nCyclotron angular frequency is w=%1.3 f
    *10^9 rad/sec \nHull cut-off voltage is VHC=%1.4 f
    kV \nCut-off magnetic flux density is Bc=%2.3 f
    mWb/sqm ', w, VHC, Bc);
20
21 //=====END OF PROGRAM


---


```

Scilab code Exa 8.15 efficiency and etc

```
1 //chapter-8 page 348 example 8.15
2 //


---


3 clc;
4 clear;
5
6 //For a reflex klystron
7 n=2; //peak mode value
8 V0=280; //beam voltage in V
9 I0=0.022; //beam current in A
10 Vs=30; //signal voltage in V
11 J1=1.25; //bessel coefficient for n=2
12
13 //CALCULATION
14 Pdc=V0*I0; //The input power in watts
15 Pac=((2*Pdc*J1)/((2*n*(%pi))-((%pi)/2))); //The
    output power in watts
16 n=(Pac/Pdc)*100; //Efficiency in percentage
17
18 //OUTPUT
19 mprintf('\nThe input power is Pdc=%1.2f watts \nThe
    output power is Pac=%1.1f watts \nEfficiency is n
    =%2.2f percentage ',Pdc,Pac,n);
20
21 //=====END OF PROGRAM


---


```

Scilab code Exa 8.16 repeller voltage and etc

```

1 //chapter-8 page 348 example 8.16
2 //

```

```

3 clc;
4 clear;
5
6 //For a reflex klystron
7 n=2;//peak mode value
8 V0=300;//beam voltage in V
9 Rsh=20000;//Shunt resistance in ohms
10 L=0.001;//distance in m
11 J1=0.582;//bessel coefficient value [J1(X')]
12 f=8*10^(9);//Operation frequency in Hz
13 V1=200;//RF gap voltage in V
14 x=1.759*10^11;//e/m value in C/kg
15
16 //CALCULATION
17 disp('Assume the gap transit time and beam loading
      are neglected');
18 w=2*(%pi)*f;//angular frequency in rad
19 VR=(V0+((sqrt(8*V0/x)*w*L)/((2*(%pi)*n)-((%pi)/2))))
      ;//Repeller voltage in V
20 disp('Assuming output coupling coefficient Bo=1');
21 I0=(V1/(2*J1*Rsh))/10^(-3);//Beam current necessary
      to obtain an RF gap voltafe of 200V in mA
22
23 //OUTPUT
24 mprintf('\\nThe Repeller voltage is VR=%3.2 f V \\nBeam
      current necessary to obtain an RF gap voltafe of
      200V is I0=%1.2 f mA',VR,I0);
25
26 //=====END OF PROGRAM

```

Chapter 9

Solid State Microwave Devices

Scilab code Exa 9.1 frequency

```
1 //chapter-9 page 411 example 9.1
2 //


---


3 clc;
4 clear;
5
6 L=2*10(-6); //Drift Length of a IMPATT diode in m
7 Vd=(107)*(10(-2)); //Drift Velocity for Siin m/sec
8
9 //CALCULATION
10 f=(Vd/(2*L))/109; //Operating Frequency in GHz
11
12 //OUTPUT
13 mprintf(' \nOperating Frequency of the IMPATT diode
    is f=%2.0f GHz',f);
14
15 //=====END OF PROGRAM


---


```

Scilab code Exa 9.2 threshold electric field

```
1 //chapter-9 page 411 example 9.2
2 //


---


3 clc;
4 clear;
5
6 L=75*10(-6); //Device Length in m
7 V=25; //Voltage Pulse Amplified in V
8 f=10*10(9); //Operating Frequency in Hz
9
10 //CALCULATION
11 Eth=(V/L)/10(5); //Threshold Electric Field in kV/cm
12
13 //OUTPUT
14 mprintf('\nThreshold Electric Field is Eth=%1.2f kV/
15         cm',Eth);
16 //=====END OF PROGRAM


---


```

Scilab code Exa 9.3 power gain

```
1 //chapter-9 page 411 example 9.3
2 //


---


3 clc;
4 clear;
5
```

```

6 fs=2*10^9; //Signal Frequency in Hz
7 fp=12*10^9 //Pump Frequency in Hz
8 Ri=16; //O/P resistance of signal generator in ohms
9 Rs=1000; //On types resistance of signal generator in
    ohms
10
11 //CALCULATION
12 P=10*log10((fp-fs)/fs); //Power gain in dB
13 Pusb=10*log10((fp+fs)/fs); //Power gain as USB
    converter in dB
14
15 //OUTPUT
16 mprintf('\nPower gain is P=%1.2f dB \nPower gain as
    USB converter is Pusb=%1.2f dB',P,Pusb);
17
18 //=====END OF PROGRAM
    =====
19
20
21 //Note: Answer given in textbook is wrong Check it
    once..
22 //Correct answers are Power gain is P=6.99 dB
23 //          Power gain as USB converter is
    Pusb=8.45 dB

```

Scilab code Exa 9.4 breakdown voltage and etc

```

1 //chapter-9 page 411 example 9.4
2 //
    =====
3 clc;
4 clear;
5
6 es=12.5; //Relative Dielectric constant

```

```

7  e0=8.854*10^(-12); // Permittivity in Free Space in F/
    m
8  N=3.2*10^22; // Donor Concentration per m^3
9  L=8*10^(-6); // Length of Si BARITT diode in m
10 q=1.6*10^(-19); // Charge of an Electron in C
11
12 //CALCULATION
13 Vc=((q*N*L^2)/(2*es*e0))/10^3; // Critical Voltage in
    kV
14 Vbd=2*Vc; // Breakdown Voltage in kV
15 Ebd=(Vbd/L)/100; // Breakdown Electric Field in kV/cm
16
17 //OUTPUT
18 mprintf('\nCritical Voltage is Vc=%1.2f kV \
    nBreakdown Voltage is Vbd=%1.2f kV \nBreakdown
    Electric Field is Ebd=%6.2f kV/cm',Vc,Vbd,Ebd);
19
20 //=====END OF PROGRAM
    =====

```

Scilab code Exa 9.5 Avalanche zone velocity

```

1  //chapter-9 page 412 example 9.5
2  //
    =====

3  clc;
4  clear;
5
6  J=33000; // Current density in A/sqcm
7  Na=2.5*10^16; // Doping Concentration in TRAPATT diode
    per cubic cm
8  q=1.6*10^(-19); // Charge of an Electron in C
9
10 //CALCULATION

```

```

11 Vz=(J/(q*Na))/10^5; //Avalanche Zone Velocity in Km/
    sec
12
13 //OUTPUT
14 mprintf('\nAvalanche Zone Velocity is Vz=%2.1f Km/
    sec ',Vz);
15
16 //=====END OF PROGRAM
    =====

```

Scilab code Exa 9.6 power gain

```

1 //chapter-9 page 412 example 9.6
2 //
    =====

3 clc;
4 clear;
5
6 //For an IMPATT diode power amplifier
7 Rd=25; //Negative Resistance in ohms
8 Rl=50; //Load Resistance in ohms
9
10 //CALCULATION
11 x=abs(Rd);
12 G=((-x-Rl)/(-x+Rl))^2; //Power gain of an IMPATT
    diode
13
14 //OUTPUT
15 mprintf('\nPower gain of an IMPATT diode is G=%1.0f'
    ,G);
16
17 //=====END OF PROGRAM
    =====

```

Scilab code Exa 9.7 minimum voltage

```
1 //chapter-9 page 412 example 9.7
2 //


---


3 clc;
4 clear;
5
6 //For a Gunn Diode
7 L=5*10(-4); //Drift Length in cm
8 Vg=3300; //Voltage gradient in V/cm [Vg>3.3 kV/cm]
9
10 //CALCULATION
11 Vmin=Vg*L; //Minimum Voltage needed to initiate Gunn
    effect in volts
12
13 //OUTPUT
14 mprintf('\nMinimum Voltage needed to initiate Gunn
    effect is Vmin=%1.2f volts ',Vmin);
15
16 //=====END OF PROGRAM
    =====
```

Scilab code Exa 9.8 rational frequency

```
1 //chapter-9 page 412 example 9.8
2 //


---


3 clc;
4 clear;
```

```

5
6 //For a Gunn Diode
7 L=20*10(-4); //Active Length in cm
8 Vd=2*107; //Drift Velocity of Electrons in cm/sec
9 Ec=3.3*103; //Critical Field for GaAs in V/cm
10
11 //CALCULATION
12 fn=(Vd/L)/109; //Natural(Rational) Frequency in GHz
13 Vc=L*Ec; //Critical Voltage of the diode in volts
14
15 //OUTPUT
16 mprintf('\nNatural(Rational) Frequency is fn=%2.0f
    GHz \nCritical Voltage of the diode is Vc=%1.1f
    volts ',fn,Vc);
17
18 //=====END OF PROGRAM
    =====

```

Scilab code Exa 9.9 efficiency and etc

```

1 //chapter-9 page 412 example 9.9
2 //
    =====
3 clc;
4 clear;
5
6 //For an IMPATT diode
7 Lp=0.5*10(-9); //Inductance in Henry
8 Cj=0.5*10(-12); //Capacitance in Farad
9 Ip=0.8; //RF peak current in A
10 Rl=2; //Load Resistance in ohms
11 Vbd=100; //Breakdown Voltage in V
12 Ib=0.1; //dc Bias current in A
13

```

```

14 //CALCULATION
15 f=(1/(2*(%pi)*sqrt(Lp*Cj)))/10^9; //Resonant
    Frequency in GHz
16 n=((Rl*Ip^2)/(2*Vbd*Ib))*100; //Efficiency in
    Percentage
17
18 //OUTPUT
19 mprintf('\nResonant Frequency is f=%2.0f GHz \
    nEfficiency is n=%1.1f percentage',f,n);
20
21 //=====END OF PROGRAM
    =====

```

Scilab code Exa 9.10 drift time

```

1 //chapter-9 page 413 example 9.10
2 //
    =====
3 clc;
4 clear;
5
6 //For an IMPATT diode
7 L=2*10^(-6); //Drift Length in m
8 Vd=10^5; //Carrier Drift Velocity (Assume/Consider)
    in m/sec
9
10 //CALCULATION
11 t=(L/Vd)/10^(-9); //Drift Time of the Carrier in nano
    sec [From f=(1/2t)=(Vd/2L)]
12 t1=t*10^(-9);
13 f=(1/(2*t1))/10^9; //Operating Frequency of the diode
    in GHz
14
15 //OUTPUT

```

```

16 mprintf(' \nDrift Time of the Carrier is t=%1.2f nano
    sec \nOperating Frequency of the diode is f=%2.0
    f GHz',t,f);
17
18 //=====END OF PROGRAM
    =====

```

Scilab code Exa 9.11 breakdown voltage and etc

```

1 //chapter-9 page 413 example 9.11
2 //
    =====
3 clc;
4 clear;
5
6 //For an M-Si-M Basitt diode
7 er=11.8;//Relative dielectric constant of Si
8 e0=8.854*10(-12);//Permittivity of freespace in F/m
9 N=3*10(21);//Donor Concentration per m3
10 L=6.2*10(-6);//Si Length in m
11 q=1.6*10(-19);//Charge of an Electron in C
12
13 //CALCULATION
14 Vbd=((q*N*L2)/(er*e0));//Breakdown Voltage in V
15 Ebd=(Vbd/L)/103;//Breakdown Electric Field in kV/m
16
17 //OUTPUT
18 mprintf(' \nBreakdown Voltage is Vbd=%3.1f V \
    nBreakdown Electric Field is Ebd=%5.0f kV/m',Vbd,
    Ebd);
19
20 //=====END OF PROGRAM
    =====

```

Scilab code Exa 9.12 max power gain and etc

```
1 //chapter-9 page 413 example 9.12
2 //


---


3 clc;
4 clear;
5
6 //For an upconverter parametric amplifier
7 rQ=8; //figure of merit for a diode nonlinear
      capacitor
8 r=0.2;
9 y=8; //ratio of output frequency over signal
      frequency (f0/fs)
10 Td=300; //Diode Temperature in K
11 T0=300; //Ambient Temperature in K
12
13 //CALCULATION
14 X=((rQ)^2)/y;
15 G=((y*X)/(1+sqrt(1+X))^2); //Max power gain
16 GdB=10*log10(G); //Maximum Power Gain in dB
17 F=(1+((2*Td/T0)*((1/rQ)+(1/rQ)^2))); //Noise Figure
18 FdB=10*log10(F); //Noise Figure in dB
19 BW=2*r*sqrt(y); //Bandwidth
20
21 //OUTPUT
22 mprintf(' \nMaximum Power Gain is GdB=%1.2 f dB\nNoise
      Figure is FdB=%1.2 f dB \nBandWidth is BW=%1.2 f ',
      GdB, FdB, BW);
23
24 //=====END OF PROGRAM


---


```

Scilab code Exa 9.13 gain and etc

```
1 //chapter-9 page 414 example 9.13
2 //


---


3 clc;
4 clear;
5
6 //For a negative resistance parametric amplifier
7 fs=2*10^9; //Signal Frequency in Hz
8 fp=12*10^9; //pump Frequency in Hz
9 fi=10*10^9; //idler Frequency in Hz
10 fd=5*10^9; //Frequency in Hz
11 Ri=1000; //o/p resistance of idler generator in ohms
12 Rg=1000; //o/p resistance of signal generator in ohms
13 RTs=1000; //total series resistance at fs in ohms
14 RTi=1000; //total series resistance at fi in ohms
15 r=0.35;
16 rQ=10; //figure of merit
17 Td=300; //Avg Diode Temperature in K
18 T0=300; //Ambient Temperature in K
19 C=0.01*10^(-12); //Capacitance in F
20
21 //CALCULATION
22 ws=2*(%pi)*fs;
23 wi=2*(%pi)*fi;
24 R=((r^2)/(ws*wi*RTi*C^2)); //Equivalent noise
    resistance in ohms
25 a=(R/RTs);
26 G=((4*fi*a*Rg*Ri)/(fs*RTs*RTi*(1-a)^2)); //Gain
27 GdB=10*log10(G); //Gain in dB
28 F=(1+((2*Td/T0)*((1/rQ)+(1/rQ)^2))); //Noise Figure
29 FdB=10*log10(F); //Noise Figure in dB
```

```
30 BW=((r/2)*(sqrt(fd/(fs*G))));
31
32 //OUTPUT
33 mprintf('\nEquivalent noise resistance is R=%4.1f
          ohms\nGain is GdB=%2.1f dB\nNoise Figure is FdB=
          %1.2f dB \nBandWidth is BW=%1.3f ',R,GdB,FdB,BW);
34
35 //=====END OF PROGRAM
          =====
36
37 //Note: Check the Bandwidth answer is once It should
          be 0.027
```

Chapter 10

Microwave Communication Systems

Scilab code Exa 10.1 radio horizon

```
1 //chapter-10 page 486 example 10.1
2 //


---


3 clc;
4 clear;
5
6 ht=144;//TV transmitter antenna height in m
7 hr=25;//TV receiver antenna height in m
8 //Radio horizon is about 4/3 as far as the optical
   horizon
9
10 //CALCULATION
11 dr=4*sqrt(hr);//distance in km
12 dt=4*sqrt(ht);//Radio Horizon in km
13 d=dt+dr;//The Maximum distance of Propagation of the
   TV signal in km
14
15 //OUTPUT
```



```

16 mprintf(' \nThe Maximum distance of Propagation of
    the TV signal is d=%2.0f km \nRadio Horizon is dt
    =%2.0f km ',d,dt);
17
18 //=====END OF PROGRAM
    =====

```

Scilab code Exa 10.2 value of factor

```

1 //chapter-10 page 486 example 10.2
2 //
    =====

3 clc;
4 clear;
5
6 r=6370*103; //radius of the earth in m
7 x=-0.05*10(-6); //the gradient of refractive index
    of air near the ground per m [du/dh]
8
9 //CALCULATION
10 k=1/(1+(r*x)); //The value of the factor by which the
    horizon distance of a transmitter will be
    modified
11
12 //OUTPUT
13 mprintf(' \nThe value of the factor by which the
    horizon distance of a transmitter will be
    modified is k=%1.4f ',k);
14
15 //=====END OF PROGRAM
    =====

```

Scilab code Exa 10.3 power

```
1 //chapter-10 page 487 example 10.3
2 //


---


3 clc;
4 clear;
5
6 //For a microwave LOS link
7 f=2*10^9; //frequency of operation in Hz
8 c=3*10^8; //Velocity of light in m/sec
9 r=50000; //repeater spacing in m
10 PrdBm=-20; //required carrier power at the receiver i
    /p to avoid deterioration due to fading and noise
    in dBm
11 GtdB=34; //antenna gain of transmitter in dB
12 GrdB=34; //antenna gain of receiver in dB
13 LdB=10; //coupling and waveguide loss in transmitter
    in dB
14
15 //CALULATION
16 w=c/f; //wavelength in m
17 x=(w^2)/(4*(%pi));
18 y=(4*(%pi)*r^2);
19 PtdBm=PrdBm+(10*log10(y))-GtdB-(10*log10(x))+LdB-
    GrdB; //The required Carrier Transmitter power in
    dBm
20
21 //OUTPUT
22 mprintf(' \nThe required Carrier Transmitter power is
    PtdBm=%2.1 f dBm', PtdBm);
23
24 //=====END OF PROGRAM


---


```

Scilab code Exa 10.4 power

```
1 //chapter-10 page 487 example 10.4
2 //


---


3 clc;
4 clear;
5
6 //For a geostationary communication satellite
7 f=6*10^(9); //uplink frequency in Hz
8 Pt=1000; //Transmitter power in W
9 x=36000*10^3; //vertical distance between surface of
   earth and satellite in m
10 a=5; //antenna elevation angle in deg
11 GtdB=60; //antenna gain of transmitter in dB
12 GrdB=0; //antenna gain of receiver in dB
13 c=3*10^8; //Velocity of light in m/sec
14
15 //CALCULATION
16 Gt=10^(GtdB/10); //antenna gain of transmitter
17 Gr=10^(GrdB/10); //antenna gain of receiver
18 w=c/f; //wavelength in m
19 Ar=(w^2)*(Gr/(4*(%pi))); //area in sqm
20 r=x/(sind(a)); //distance between transmitter and
   receiver in m [From Sine formula and diagram]
21 Pr=((Pt*Gt*Ar)/(4*(%pi)*r^2))/10^(-12); //The
   received power at the input of the satellite
   receiver in pico watts
22
23 //OUTPUT
24 mprintf(' \nThe received power at the input of the
   satellite receiver is Pr=%1.2f pico watts(pW) ',Pr
   );
```

```
25
26 //=====END OF PROGRAM
    =====
```

Scilab code Exa 10.5 antenna beam angle

```
1 //chapter-10 page 487 example 10.5
2 //
    =====

3 clc;
4 clear;
5
6 x1=35855;//Distance between geostationary orbit to
   surface of earth in km
7 x2=6371;//Distance between center of earth to
   surface of earth in km
8
9 //CALCULATION
10 x=x1+x2;//distance of satellite from center of earth
   in km
11 y=x2*(%pi);//Circumference of half circle arc in km
12 b=y/x;//Beam angle in rad
13 Bdeg=(b*180)/(%pi);//Beam angle in deg
14
15 //OUTPUT
16 mprintf(' \nAntenna Beam angle required by a
   satellite antenna to provide full global coverage
   from a geostationary orbit is Bdeg=%2.2f deg',
   Bdeg);
17
18 //=====END OF PROGRAM
    =====
```

Scilab code Exa 10.6 round trip time

```
1 //chapter-10 page 488 example 10.6
2 //


---


3 clc;
4 clear;
5
6 //For a satellite communication system
7 h=35855;//Distance between geostationary orbit to
   surface of earth in km
8 r=6371;//Distance between center of earth to surface
   of earth in km
9 a=5;//earth station elevation angle wrt the
   geostationary satellite in deg
10 b=5;//angle in deg
11 c=3*10^5;//Velocity of light in km/sec
12 b1=90;//angle for vertical transmission in deg
13 a1=0;
14
15 //CALCULATION
16 d=(sqrt((r+h)^2-(r*cosd(a))^2))-sind(b);//distance
   in km
17 T=2*(d/c);//The round trip time between the earth
   station and the satellite in sec
18 d1=(sqrt((r+h)^2-(r*cosd(a))^2))-sind(b);//distance
   in km
19 Tv=(2/c)*(d1-r);//The round trip time for vertical
   transmission between the earth station and the
   satellite in sec
20
21 //OUTPUT
22 mprintf('\\nThe round trip time between the earth
```

```

station and the satellite is T=%1.3f sec \nThe
round trip time for vertical transmission between
the earth station and the satellite is Tv=%1.3f
sec ',T,Tv);
23
24 //=====END OF PROGRAM
=====

```

Scilab code Exa 10.7 figure of merit

```

1 //chapter-10 page 488 example 10.7
2 //
=====
3 clc;
4 clear;
5
6 Tant=25;//effective noise temperature in K
7 Tr=75;//receiver noise temperature in K
8 GdB=45;//Isotropic power gain of the antenna in dB
9
10 //CALCULATION
11 T=Tant+Tr;//The total noise in K
12 TdB=10*log10(T);//The total noise in dB
13 MdB=GdB-TdB;//Figure of merit of earth station in dB
14
15 //OUTPUT
16 mprintf('\nFigure of merit of earth station is MdB=
    %2.0f dB',MdB);
17
18 //=====END OF PROGRAM
=====

```

Scilab code Exa 10.8 CNR

```
1 //chapter-10 page 488 example 10.8
2 //


---


3 clc;
4 clear;
5
6 //For a Satellite communication link
7 EIRPdB=55.5;//Satellite ESM in dBW
8 MdB=35;//G/T ratio of earth station in dB
9 LfsdB=245.3//Freespace loss in dB
10
11 //CALCULATION
12 CNRdB=EIRPdB+MdB-LfsdB+228.6;//Carrier to Noise
    Ratio at the earth station receiver in dB
13
14 //OUTPUT
15 mprintf('\\nCarrier to Noise Ratio at the earth
    station receiver is CNRdB=%2.1f dB',CNRdB);
16
17 //=====END OF PROGRAM
    =====
```

Scilab code Exa 10.9 system noise temperature

```
1 //chapter-10 page 489 example 10.9
2 //


---


3 clc;
4 clear;
5
6 D=30;//Diameter of a dish antenna with circular
```

```

    aperture in m
7  f=4*10^9; //down link frequency in Hz
8  MdB=20; //G/T ratio of earth station in dB
9  c=3*10^8; //Velocity of light in m/sec
10
11 //CALCULATION
12 A=((%pi)/4)*D^2; //area in sqm
13 w=c/f; //wavelength in m
14 G=(4*(%pi)*A)/w^2; //Gain
15 GdB=10*log10(G); //Gain in dB
16 TsdB=GdB-MdB; //The System Noise Temperature in dB
17
18 //OUTPUT
19 mprintf('\nThe System Noise Temperature is TsdB=%2.2
    f dB',TsdB);
20
21 //=====END OF PROGRAM
    =====

```

Scilab code Exa 10.10 HPBW

```

1 //chapter-10 page 489 example 10.10
2 //
    =====
3 clc;
4 clear;
5
6 //For a parabolic antenna
7 Gp=1500; //Power gain
8 w=0.1; //wavelength in m
9
10 //CALCULATION
11 D=sqrt(Gp)*(w/(%pi)); //Diameter of the circular
    mouth of a parabolic antenna in m

```



```

12 HPBW=58*(w/D); //Half Power BeamWidth of the antenna
    in deg
13
14 //OUTPUT
15 mprintf('\nDiameter of the circular mouth of a
    parabolic antenna is D=%1.4f m \nHalf Power
    BeamWidth of the antenna is HPBW=%1.3f deg',D,
    HPBW);
16
17 //=====END OF PROGRAM
    =====

```

Scilab code Exa 10.11 gain

```

1 //chapter-10 page 490 example 10.11
2 //
    =====
3 clc;
4 clear;
5
6 D=1; //Assume diameter of the parabolic reflectors in
    the original system in m
7 w=1; //Assume wavelength in m
8
9 //CALCULATION
10 D1=2*D; //diameter of the parabolic reflectors in the
    modified system in m
11 G=6*(D/w)^2; //gain in original system
12 G1=6*(D1/w)^2; //gain in modified system
13 GdB=10*log10(G1/G); //Overall gain that can be
    expected in dB
14 GdB0=2*GdB; //Overall gain of the system (combining
    the two antennas one at the Tx and other at the
    Rx) in dB

```

```

15
16 //OUTPUT
17 mprintf('\nOverall gain that can be expected is GdB=
    %1.0f dB \nOverall gain of the system(combining
    the two antennas one at the Tx and other at the
    Rx) is GdB=%1.0f dB',GdB,GdB0);
18
19 //=====END OF PROGRAM
    =====
20
21 //Note: Check the answer once ..it should be GdB=10
    log(4)=6 dB and GdB0=12dB

```

Scilab code Exa 10.12 gain

```

1 //chapter-10 page 490 example 10.12
2 //
    =====
3 clc;
4 clear;
5
6 D=3;//dimension of a paraboloid in m
7 f=3*10^9;//frequency (S band) in Hz
8 c=3*10^8;//Velocity of light in m/sec
9
10 //CALCULATION
11 w=c/f;//wave length in m
12 BWFN=140*(w/D);//BeamWidth between First Nulls in
    deg
13 BWHP=70*(w/D);//BeamWidth between HalfPower points
    in deg
14 G=6*(D/w)^2;//Gain of the antenna
15
16 //OUTPUT

```

```

17 mprintf(' \nBeamWidth between First Nulls is BWFN=%1
    .2 f deg \nBeamWidth between HalfPower points is
    BWHP=%1.2 f deg \nGain of the Antenna is G=%4.0 f '
    ,BWFN ,BWHP ,G);
18
19 //=====END OF PROGRAM
    =====

```

Scilab code Exa 10.13 power gain

```

1 //chapter-10 page 490 example 10.13
2 //
    =====
3 clc;
4 clear;
5
6 l=1; //(Assume)-dimension(wavelength) in cm
7
8 //CALCULATION
9 x=5*l; //given square aperture of an optimum horn
   antenna as a side dimension in cm
10 A=x*x; //Area in sq.cm
11 Gp=4.5*(A/l^2); //Power gain of an optimum horn
   antenna
12
13 //OUTPUT
14 mprintf(' \nPower gain of an optimum horn antenna is
   Gp=%3.1 f ',Gp);
15
16 //=====END OF PROGRAM
    =====

```

Chapter 11

Radars

Scilab code Exa 11.1 max range

```
1 //chapter-11 page 504 example 11.1
2 //


---


3 clc;
4 clear;
5
6 //For a radar system
7 Pt=600000; //peak pulse power in W
8 Smin=10^(-13); //minimum detectable signal in W
9 Ae=5; //cross sectional area of the radar antenna in
    sq m
10 w=0.03; //wavelength in m
11 s=20; //radar cross sectional area in sq m
12
13 //CALCULATION
14 Rmax=(((Pt*s*Ae^2)/(4*(%pi)*Smin*w^2))^(1/4)))/1000;
    //Maximum range of a radar system in km
15 RMax=Rmax/1.853; //In nautical miles; 1 nm=1.853 km
16
17 //OUTPUT
```

```

18 mprintf('\nMaximum range of a radar system is Rmax=
    %3.3 f km',Rmax);
19 disp('In nautical miles; 1 nm=1.853 km');
20 mprintf('\nMaximum range of a radar system in
    nautical miles is RMax=%3.0 f nm',RMax);
21
22 //=====END OF PROGRAM
    =====

```

Scilab code Exa 11.2 max range

```

1 //chapter-11 page 504 example 11.2
2 //
    =====

3 clc;
4 clear;
5
6 //For a radar system
7 Pt=250000;//peak transmitted power in W
8 G=2500;//power gain of the antenna
9 Smin=10^(-14);//minimum detectable signal in W
10 Ae=10;//cross sectional area of the radar antenna in
    sq m
11 f=10*10^9;//frequency of radar in Hz
12 s=2;//radar cross sectional area in sq m
13 c=3*10^8;//Velocity of light in m/sec
14
15 //CALCULATION
16 w=c/f;//wavelength in m
17 Rmax=(((Pt*G*Ae*s)/(Smin*(4*(%pi))^2))^(1/4))/1000;
    //Maximum range of a radar system in km
18
19 //OUTPUT
20 mprintf('\nMaximum range of a radar system is Rmax=

```

```

    %3.2 f km',Rmax);
21
22 //=====END OF PROGRAM
    =====

```

Scilab code Exa 11.3 RCS

```

1 //chapter-11 page 504 example 11.3
2 //
    =====

3 clc;
4 clear;
5
6 //For a marine radar system
7 Pt=250000;//peak transmitted power in W
8 G=4000;//power gain of the antenna
9 R=50000;//maximum range of radar in m
10 Pr=10^(-11);//minimum detectable signal in W
11 f=10*10^9;//frequency of radar in H
12 c=3*10^8;//Velocity of light in m/sec
13
14 //CALCULATION
15 w=c/f;//wavelength in m
16 Ae=((G*w^2)/(4*(%pi)));//cross sectional area of the
    radar antenna in sq m
17 s=((Pr*(4*(%pi)*R^2)^2)/(Pt*G*Ae));//The cross
    section of the target the radar can sight in sq m
18
19 //OUTPUT
20 mprintf('\\nThe cross section of the target the radar
    can sight is s=%2.2f sq m',s);
21
22 //=====END OF PROGRAM
    =====

```

Scilab code Exa 11.4 Duty cycle and etc

```
1 //chapter-11 page 505 example 11.4
2 //


---


3 clc;
4 clear;
5
6 //For a guided missile tracking radar
7 Pt=400000; //transmitted power in W
8 prf=1500; //pulse repetition frequency in pps(pulse
   per sec)
9 tw=0.8*10^-6; //pulse width in sec
10 c=3*10^8; //Velocity of light in m/sec
11
12 //CALCULATION
13 Runamb=(c/(2*prf))/1000; //Unambiguous range in km
14 dc=tw/(1/prf); //Duty cycle
15 Pav=Pt*dc; //Average power in W
16 n1=1;
17 BW1=(n1/tw)/10^6; //Suitable BW in MHz for n=1
18 n2=1.4;
19 BW2=(n2/tw)/10^6; //Suitable BW in MHz for n=1.4
20
21 //OUTPUT
22 mprintf(' \nUnambiguous range is Runamb=%3.0 f km \
   \nDuty cycle is dc=%1.4 f \nAverage power is Pav=%3
   .0 f W',Runamb,dc,Pav);
23 disp('For efficiency n=1,suitable bandwidth in MHz
   is ');
24 disp(BW1);
25 disp('For efficiency n=1.4,suitable bandwidth in MHz
   is ');
```

```

26 disp(BW2);
27
28 //=====END OF PROGRAM
=====

```

Scilab code Exa 11.5 max range

```

1 //chapter-11 page 505 example 11.5
2 //
=====

3 clc;
4 clear;
5
6 //For a military radar
7 Pt=2500000; //power output in W
8 f=5*10^9; //frequency of radar in H
9 c=3*10^8; //Velocity of light in m/sec
10 D=5; //antenna diameter in m
11 B=1.6*10^6; //receiver bandwidth in Hz
12 s=1; //radar cross sectional area in sq m
13 NF=12; //noise figure in dB
14
15 //CALCULATION
16 w=c/f; //wavelength in m
17 F=10^(NF/10); //noise figure
18 Rmax=(48*((Pt*s*D^4)/(B*(F-1)*w^2))^(1/4)); //Maximum
    detection range in km
19
20 //OUTPUT
21 mprintf('\nMaximum detection range of a radar is
    Rmax=%3.0 f km',Rmax);
22
23 //=====END OF PROGRAM
=====

```

Scilab code Exa 11.6 factor

```
1 //chapter-11 page 506 example 11.6
2 //


---


3 clc;
4 clear;
5
6 //For a civilian radar
7 Rmax=30;//maximum range in kms
8 x=50;
9 y=2;
10 disp('Maximum range with an equivalent echoing area
      of 50 times in kms is');
11 R=Rmax*x^(1/4);
12 disp(R);
13 disp('Range would be increased if Tx power is
      doubled by a factor of');
14 f=y^(1/4);
15 disp(f);
16
17 //=====END OF PROGRAM


---


```