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

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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.

Contents

List of Scilab Codes

Chapter 3

Transmission Lines

Scilab code Exa 3.1 Terminating Impedance

```
//chapter-3 page 47 example 3.1
//==============================================================================

clc;
clear;

Z0=100;//Characteristic Impedance in ohms
S=5;//Voltage Standing Wave Ratio(VSWR)

//CALCULATION
Zm=Z0*S;//Termainating impedance at a max of the
    voltage standing wave
Zl=Zm;//Loading Impedance

//OUTPUT
mprintf('Terminating impedance at a maximum of the
    voltage standing wave is Zl= %3.0f ohms',Zl);

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

Scilab code Exa 3.2 power

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

clc;
clear;

R=8;//Resistance of a transmission line in ohm/km
L=0.002;//Inductance of a transmission line in henry/km
C=0.002*(10^(-6));//Capacitance of a transmission line in Farads
G=0.07*(10^(-6));//Conductance of a transmission line in siemens/km
f=2000;//Frequency in Hz
w=2*(%pi)*f;//Angular Frequency in rad/sec
Vs=2;//Input Voltage in volts
l=500;//Length of Transmission line in km

//CALCULATIONS
Z0=sqrt((R+(w*L*(%i)))/(G+(w*C*(%i))));//Characteristic Impedance
x=real(Z0);
y=imag(Z0);
disp('Characteristic Impedance in ohms is');
disp(Z0);
g=sqrt((R+(w*L*(%i)))*(G+(w*C*(%i))));//Propagation Constant
a=real(g);//Attenuation Constant in NP/km
b=imag(g);//Phase Constant in rad/km
Is=Vs/Z0;
I0=Is*exp(-(g*l));//Load current
```

```
m=sqrt((real(I0))^2+(imag(I0)^2));
P=(m^2)*x;//Power delivered to the load in watts

//OUTPUT
mprintf('\nAttenuation Constant is a=%1.6f NP/km \nPhase Constant is b=%1.6f rad/km \nPower delivered to the load is P=%1.6f watts',a,b,P);

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

Scilab code Exa 3.3 phase velocity

```
//chapter-3 page 48 example 3.3
//==================================================================================

clc;
clear;

w=4*(%pi);//Angular Frequency in rad/sec
b=0.02543;//Phase Constant in rad/km

//CALCULATION
Vp=w/b;//Phase Velocity in km/sec

//OUTPUT
mprintf('Phase Velocity is Vp=%3.2f km/sec',Vp);

//==========END OF PROGRAM==============================

//NOTE:CHECK THE CALCULATION PART GIVEN IN THE TEXTBOOK
    //GIVEN ANSWER 494.22 KM/SEC
    //GETTING ANSWER 494.16 KM/SEC
```

Scilab code Exa 3.4 power

```
//chapter-3 page 48 example 3.4
//
clc;
clear;

f=37.5*10^6;//Frequency in Hz
c=3*10^8;//Velocity of Light in m/sec
l1=10;//Length of line in met
Vg=200;//Generator Voltage in volts(rms)
Zint=200;//Internal Resistance of Generator in ohms
Z0=200;//Characteristic Impedance in ohms
Zl=100;//Load impedance in ohms

//CALCULATIONS
w=c/f;//Wave Length in met
b=2*(%pi)/w;
l1=(5/4)*w;//For Lossless Line
Zi=Z0*((Zl+(Z0*(%i)*tan(b*l1)))/(Z0+(Zl*(%i)*tan(b*l1))));//Input Impedance at Generator end
Vs=Vg*(Zi/(Zi+Z0));//Voltage in line in volts
Is=Vg/(Zi+Z0);//Current in Line drawn from Generator in amps
Ps=Vs*Is;//Power drawn in line
Pl=Ps;//For Lossless Lines Power delivered to load is equal to the Power drawn in line
Il=sqrt((Pl/Zl));//Current flowing in the load
m=real(Il);//Magnitude of Current flowing in the load
p=imag(Il);//Phase of Current flowing in the load

```

```
//CALCULATIONS
mprintf('\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 Pl=%2.2f watts',Is,m,p,Pl);

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

Scilab code Exa 3.5 VSWR and Reflection coefficient

```
//chapter-3 page 50 example 3.5
//==================================================================================================================

clc;
clear;

Z0=50;//Characteristic Impedance in ohms
f=300*10^6;//Frequency in Hz
Zl=50+(50*(%i));//Terminating load impedance in ohms
w=((3*10^8)/f);//Wave Length

//CALCULATIONS
p=((Zl-Z0)/(Zl+Z0));//Reflection Coefficient(Complex Form)
y=real(p);
z=imag(p);
x=sqrt(y^2+z^2);//Reflection Coefficient Value
s=((1+x)/(1-x));//Voltage Standing Wave Ratio(VSWR)

//OUTPUT
mprintf('\nReflection Coefficient is x=%1.4f \
```

```
nVoltage Standing Wave Ratio(VSWR) is s=%1.2f',x,
   s);

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

Scilab code Exa 3.6 point of attachment

```
//chapter-3 page 50 example 3.6
//
   =============================================================

clc;
clear;

Z1=100;//Pure Load resistance of a dipole antenna in
    ohms
Z0=600;//Characteristic Impedance of a wire feeder
   in ohms
f=100*10^6;//Frequency in Hz
c=3*10^8;//Velocity of Light in m/sec

//CALCULATIONS
w=c/f;//Wave Length in met
l=((w/(2*(%pi)))*atan(sqrt(Z1/Z0)));//The position
   of the Stub in met
x=atand(sqrt((Z1*Z0))/(Z1-Z0));
y=180+x;//In Degrees
l1=((w/(2*(%pi)))*y);//Length of Short Circuited
   Stub in met
l0=l1*((%pi)/180);

//OUTPUTS
mprintf('\nThe Point of Attachment is l=%1.3f met \
   nLength of SC Stub is l1=%1.2f met',l,l0);
```

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

Scilab code Exa 3.7 Terminating Impedance

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

clc;
clear;

Z0=50;//Characteristic Impedance in ohms
S=3.2;//Voltage Standing Wave Ratio(VSWR)

//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
//CALCULATIONS
w=1;//Assume Wavelength in met
Xmin=0.23*w;//Distance from the load to the nearest
   voltage minimum in met
b=(2*(%pi))/w;
Zl=Z0*((1-(S*(%i)*tan(b*Xmin)))/(S-((%i)*tan(b*Xmin)
   )));//Load impedance in ohms
disp('Load impedance in ohms is');
disp(Zl);


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

```

//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

```
//chapter-3 page 51 example 3.8
//
clc;
clear;

Z0=50;//Characteristic Impedance in ohms
Zl=100;//Load impedance in ohms
f=300*10^3;//Frequency in Hz
Pl=0.05;//Load Power in watts
c=3*10^8;//Velocity of Light in m/sec

//CALCULATIONS
w=c/f;//Wave Length in met
p=((Zl-Z0)/(Zl+Z0));//Reflection Coefficient
S=((1+p)/(1-p));//Voltage Standing Wave Ratio(VSWR)

//Since Zl>Z0, first Vmax is located at the load and
     first Vmin is located at Wavelength/4
x1max=0;//Position of first Vmax (located at the
    load) from load in met
x1min=w/4;//Position of first Vmin from load in met
Vmax=sqrt(Pl*Zl);//Value of maximum voltage in volts
Vmin=Vmax/S;//Value of minimum voltage in volts
Zmax=Z0*S;//Impedance at Vmax in ohms
Zmin=Z0/S;//Impedance at Vmin in ohms

//OUTPUTS
```

```
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);

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

Scilab code Exa 3.9 Reflection loss

```
//chapter-3 page 52 example 3.9
//==============================================================================
clc;
clear;

Z0=600;//Characteristic Impedance in ohms
Zs=50;//Generator impedance in ohms
l=200;//Length of transmission line in met
Zl=500;//Load impedance in ohms

//CALCULATIONS
p=((Zl-Z0)/(Zl+Z0));//Reflection Coefficient
x=abs(p);
Lr=10*log10(1/(1-x^2));//Reflection loss in dB
La=0;//Since the line is lossless,attenuation loss is zero dB
Lt=La+Lr;//Transmission loss in dB
```

```
Lrt=10*log10(x);//Return loss in dB

//OUTPUT
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);

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

Scilab code Exa 3.10 Characteristic Impedance

```
//chapter-3 page 52 example 3.10
//
   ===================================================

clc;
clear;

f=1000;//Frequency in Hz
l=10000;//Length of open wire transmission line in
   met
z1=2930;//Magnitude of a short circuit impedance in
   ohms
p1=26;//Phase of a short circuit impedance in deg
z2=260;//Magnitude of a open circuit impedance in
   ohms
p2=-32;//Phase of a open circuit impedance in deg
//CALCULATIONS
Zsc=((z1*cosd(p1))+((%i)*(z1*sind(p1))));
Zoc=((z2*cosd(p2))+((%i)*(z2*sind(p2))));
Z0=sqrt(Zsc*Zoc);//Characteristic Impedance in ohms
disp('Characteristic Impedance in ohms is');
[ro,theta]=polar(Z0)
```

```
disp(ro);
disp(theta*180/%pi);
g=((1/l)*(atanh(sqrt(Zsc/Zoc))));//Propagation
    Constant
disp(g)
b=imag(g);//Phase Constant
w=2*f*(%pi);//Angular Frequency in rad/sec
Vp=w/b;//Phase Velocity in m/sec
disp(Vp)
//OUTPUT
mprintf('\nPhase Velocity is Vp=%5.2f m/sec',Vp);

//=================================END OF PROGRAM
    ==================================================================================


//Note: Check the calculation once
```

Chapter 4

Microwave Transmission Lines

Scilab code Exa 4.1 Characteristic Impedance

```
//chapter-4 page 141 example 4.1
//==============================================================================

clc;
clear;

d=0.0049;//Diameter of inner conductor in met
D=0.0110;//Inner Diameter of outer conductor in met
er=2.3;//Polyethylene dielectric
c=3*10^8;//Velocity of Light in m/sec

//CALCULATIONS
x=log(D/d);
L=(2*10^(-1)*x);//Inductance per unit lengths in microH/m
C=(55.56*(er/x));//The Capacitance per unit lengths in picoF/m
R0=(x*(60/sqrt(er)));//The Characteristic Impedance in ohms
V=(c/sqrt(er))/(10^3);//The Velocity of propagation
```

```
    in Km/s

//OUTPUT
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);

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

Scilab code Exa 4.2 attenuation and phase constants

```
//chapter-4 page 142 example 4.2
//
    ==============================================================================

clc;
clear;

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

```

```
//CALCULATIONS
Z0=sqrt(L/C);
A=(R/(2*Z0));//Attenuation Constant in NP/m
w=(2*(%pi)*f);//Angular Frequency in rad/sec
B=(w*sqrt(L*C));//Phase Constant in rad/m
Vp=(1/sqrt(L*C))/(10^3);//Phase Velocity in Km/s
er=(((c/V)^2)/e0);//Relative Permittivity
Pl=(2*Pin*l);//Power Loss in watts

//OUTPUT
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);

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

Scilab code Exa 4.3 breakdown power

```
//chapter-4 page 142 example 4.3
//==============================================================================

clc;
clear;

//For an air filled coaxial cable
f=9.375*10^9;//operating frequency in Hz
c=3*10^10;//Velocity of Light in cm/sec
disp('Assuming a ratio of (b/a)=2.3 and (b+a)<(w/pi) to exclude higher order modes and a dominant mode propagating');
a=0.36432;//length of coaxial cable in cm
```

```
x=2.3;//ratio of b/a

//CALCULATION
w0=(c/f);//free space wavelength in cm
Pbd=(3600*(a^2)*log(x));//Breakdown power of a coaxial cable in kW

//OUTPUT
mprintf('\nBreakdown power of a coaxial cable is Pbd=%3.0f kW',Pbd);

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

Scilab code Exa 4.4 Characteristic Impedance

```
//chapter-4 page 142 example 4.4
//==============================================================================================

clc;
clear;

b=0.3175;//Distance between ground planes of strip line in cm
d=0.0539;//Diameter of circular conductor in cm
er=2.32;//Dielectric Constant
c=3*10^8;//Velocity of Light in m/sec

//CALCULATION
Z0=((60/sqrt(er))*log((4*b)/(d*(%pi))));//Characteristic Impedance in ohms
V=(c/sqrt(er))/(10^3);//The Velocity of propagation in Km/s

```

```
//OUTPUT
mprintf('\nCharacteristic Impedance is Z0=%2.2f ohms
    \nThe Velocity of propagation is  V=%5.2f Km/s',
   Z0,V);

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

Scilab code Exa 4.5 Characteristic Impedance

```
//chapter-4 page 143 example 4.5
//
    ==========================================================================

clc;
clear;

//For a microstrip transmission line
er=9.7;//relative dielectric constant of an alumina
   substrate
x1=0.5;//w/h ratio in first transmission line
x2=5;//w/h ratio in second transmission line
c=3*10^8;//Velocity of Light in m/sec

//CALCULATION
disp('For case1: w/h=0.5');
disp('Since x1=0.5<1, for this we use high impedance
    analysis');
Eeff1=(((er+1)/2)+((er-1)/2)*(1/((sqrt(1+(12/x1)))
   +(0.04*(1-x1)^2))));//Effective dielectric
   constant
Zo1=((60/sqrt(Eeff1))*log((8/x1)+(x1/4)));//
   Characteristic impedance in ohms
V1=(c/sqrt(Eeff1))/10^8;//Velocity of propagation in
```

```
    10^8 m/sec
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);

disp('For case2: w/h=5');
disp('here x2>1');
Eeff2=(((er+1)/2)+((er-1)/2)*(1/(sqrt(1+(12/x2)))));
    //Effective dielectric constant
Zo2=((120*(%pi)/sqrt(Eeff2))*(1/(x2+1.393+(0.667*log
    (1.444+x2)))));//Characteristic impedance in ohms
V2=(c/sqrt(Eeff2))/10^8;//Velocity of propagation in
    10^8 m/sec
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);

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

Scilab code Exa 4.6 ratio of areas

```
//chapter-4 page 144 example 4.6
//
    ==========================================================================================

clc;
clear;

//To calculate the ratio of circular waveguide cross
    -sectional area to the rectangular waveguide
    cross section
disp('Assuming that both these waveguides have
```

```
similar or equal cutoff frequencies/wavelengths')
;

disp('Case1: When TE wave is propagated');
disp('For standard rectangular waveguides a=2b and
For TE11 dominant mode in circular waveguide wc1
=(2(pi)r)/1.841');
disp('where r is the radius of the circular
waveguide and wc1 is the cutoff wavelength for
circular waveguide');
disp('It is given wc1=wc2 where wc2 is the cutoff
wavelength for rectangular waveguide');
disp('For TE10(dominant mode) of propagation in
rectangular waveguide wc2=2a');
disp('Since wc2=(2ab)/(sqrt((mb)^2+(nb)^2)) as m=1;n
=0 for TE10 wc2=2ab/b=2a');
disp('By equating wc1=wc2, we get a=1.70645r');
disp('For a standard waveguide a=2b therefore, b=a/2
');
disp('Now the area of rectangular waveguide=a*b=a*a
/2=1.70645r*1.70645r/2=1.456r^2');
disp('Area of rectangular waveguide=1.456r^2 ,Area
of circular waveguide=(pi)*r^2');
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');
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');

disp('Case2: When TM wave is propagated');
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');
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)');
disp('For standard waveguides,we know a=2b, wc2=(2*2b*b)/sqrt(4b^2+b^2)=(4b^2)/sqrt(5b^2)=4b/sqrt(5)');
disp('By equating wc1=wc2, we get 2.6155r=4b/sqrt(5)=>b=1.4621r');
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');
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');

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

Scilab code Exa 4.7 breadth of the guide

```
//chapter-4 page 146 example 4.7
//==============================================================================

clc;
clear;

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

```
disp('For TE10 mode wc=2a');

//CALCULATION
w0=(c/f);//free space wavelength in cm
wc=(w0/sqrt(1-(w0/wg)^2));//Cutoff wavelength for TE10 mode in cm
disp('Free space wavelength w0 in cm is');
disp(w0);
disp('Cutoff wavelength wc in cm is');
disp(wc);
disp('Since wc>w0, the wave propagates');
a=(wc/2);//length of the guide in cm
b=(wc/4);//breadth of the guide in cm

//OUTPUT
mprintf('\nlength of the guide is a=%1.0f cm \nbreadth of the guide is b=%1.1f cm',a,b);

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

Scilab code Exa 4.8 guide wavelength

```
//chapter-4 page 147 example 4.8
//==============================================================================================

clc;
clear;

a=10;//breadth of a rectangular waveguide in cm
f=2.5*10^9;//Frequency in Hz in TE10 mode
c=3*10^10;//Velocity of Light in cm/sec

//CALCULATION
```

```
wc=2*a;//Cutoff wavelength for TE10 mode in cm
w0=(c/f);//Free space wavelength in cm
x=sqrt(1-(w0/wc)^2);
wg=(w0/x);//Guide wavelength in cm
Vp=(c/x)/10^5;//Phase Velocity in Km/sec
Vg=((c^2)/Vp)/10^10;//Group Velocity in Km/sec

//OUTPUT
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);

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

Scilab code Exa 4.9 guide wavelength

```
//chapter-4 page 147 example 4.9
//
    ==============================================================================

clc;
clear;

f=8.6*10^9;//frequency in Hz
c=3*10^10;//Velocity of Light in cm/sec
a=2.5;//Length of a Waveguide in cm
b=1;//Width of a Waveguide in cm

//CALCULATION
disp('The condition for the wave to propagate along
    a guide is that wc>w0.');
w0=c/f;//free space wavelength in cm
disp('Free space wavelength w0 in cm is');
```

```
disp(w0);
disp('For TE waves, wc=(2ab/sqrt((mb)^2+(na)^2))');
disp('For TE01 waves');
m1=0;
n1=1;
wc1=((2*a*b)/(sqrt((m1*b)^2+(n1*a)^2)));//Cutoff wavelength for TE01 mode in cm
disp('Cutoff wavelength for TE01 mode in cm is');
disp(wc1);
disp('Since wc for TE01=2cm is not greater than w0 TE01,will not propagate for TE01 mode.');
disp('For TE10 waves');
m2=1;
n2=0;
wc2=((2*a*b)/(sqrt((m2*b)^2+(n2*a)^2)));//Cutoff wavelength for TE10 mode in cm
disp('Cutoff wavelength for TE10 mode in cm is');
disp(wc2);
disp('Since wc TE10 > w0 TE10 is a possible mode.');
fc=(c/wc2)/10^9;//Cutoff frequency in GHz
disp('For TE11 and TM11 waves');
m3=1;
n3=1;
wc3=((2*a*b)/(sqrt((m3*b)^2+(n3*a)^2)));//Cutoff wavelength for TE11 mode in cm
disp('Cutoff wavelength for TE11 and TM11 modes in cm is');
disp(wc3);
disp('As wc for TE11 and TM11 is < w0 both TE11 and TM11 do not propagate as higher modes.');
wg=(w0/sqrt(1-(w0/wc2)^2));//Guide wavelength in cm
disp('From the above analysis we conclude that only TE10 mode is possible');

//OUTPUT
mprintf('\nCutoff frequency is fc=%1.0f GHz \nGuide wavelength is wg=%1.3f cm',fc,wg);

```

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

Scilab code Exa 4.10 area

```
//chapter-4 page 148 example 4.10
//==============================================================================================

clc;
clear;

//For an air filled circular Waveguide in the dominant mode
c=3*10^10;//Velocity of Light in cm/sec
disp('For an air filled circular Waveguide TE11 is the dominant mode ie propagated');
wc=10;//cutoff wave length in cm

//CALCULATION
r=((1.841*wc)/(2*(%pi)));//radius of circular Waveguide in cm
A=(%pi)*r^2;//Cross sectional area of the guide in sq.cms
fc=(c/wc)/10^9;//Cutoff frequency for TE11 mode in GHz
disp('Cutoff frequency for TE11 mode in GHz is');
disp(fc);
disp('Frequncy above 3GHz can be propagated through the waveguide');

//OUTPUT
mprintf('\nCross sectional area of the guide is A=%2.2f sq.cms',A);

```

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

Scilab code Exa 4.11 possible modes

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

clc;
clear;

//For a rectangular waveguide
f=5*10^9;//frequency in Hz
c=3*10^10;//Velocity of Light in cm/sec
a=4;//Length of Rectangular Waveguide in cm
b=3;//Width of Rectangular Waveguide in cm

//CALCULATION
disp('The condition for the wave to propagate along a guide is that wc>w0.');
w0=c/f;//free space wavelength in cm
disp('Free space wavelength w0 in cm is');
disp(w0);
disp('For TE waves, wc=(2ab/sqrt((mb)^2+(na)^2))');
disp('For TE01 waves');
m1=0;
n1=1;
wc1=((2*a*b)/(sqrt((m1*b)^2+(n1*a)^2)));//Cutoff wavelength for TE01 mode in cm
disp('Cutoff wavelength for TE01 mode in cm is');
disp(wc1);
disp('Since wc for TE01=6cm is not greater than w0 TE01,will not propagate for TE01 mode.');
disp('For TE10 waves');
```

```
m2=1;
n2=0;
wc2=((2*a*b)/(sqrt((m2*b)^2+(n2*a)^2)));//Cutoff
    wavelength for TE10 mode in cm
disp('Cutoff wavelength for TE10 mode in cm is');
disp(wc2);
disp('Since wc TE10 > w0 TE10 is a possible mode.');
disp('For TE11 waves');
m3=1;
n3=1;
wc3=((2*a*b)/(sqrt((m3*b)^2+(n3*a)^2)));//Cutoff
    wavelength for TE11 mode in cm
disp('Cutoff wavelength for TE11 mode in cm is');
disp(wc3);
disp('As wc TE11 < w0 TE11 does not propagate.');

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

Scilab code Exa 4.12 guide wavelength

```
//chapter-4 page 149 example 4.12
//
    ==============================================================================

clc;
clear;

//For an air filled circular Waveguide in the
    dominant mode
D=4;//Inner diameter of an air filled circular
    Waveguide in cm
c=3*10^10;//Velocity of Light in cm/sec

//CALCULATION
```

```
disp('The dominant mode in the circular waveguide
    would be like TE11,wc is maximum');
r=D/2;//radius in cm
wc=((2*(%pi)*r)/1.841);//Cutoff wavelength in cms
fc=(c/wc)/10^9;//Cutoff frequency in GHz
mprintf('\nCutoff wavelength is wc=%1.4f cms \
    nCutoff frequency is fc=%1.3f GHz',wc,fc);
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');
f=5*10^9;//frequency of signal in Hz
w0=(c/f);//free space wavelength in cm
wg=(w0/sqrt(1-(w0/wc)^2));//Guide wavelength in cm
mprintf('\nWave length in the guide is wg=%2.2f cm',
    wg);

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

Scilab code Exa 4.13 frequency

```
//chapter-4 page 150 example 4.13
//
    ================================================================================

clc;
clear;

//For a rectangular waveguide in TE10 mode
a=6;//Length of Rectangular Waveguide in cm
b=4;//Width of Rectangular Waveguide in cm
c=3*10^10;//Velocity of Light in cm/sec
x=4.55;//distance between maximum and minimum in cm

```

```
//CALCULATIONS
wc=2*a;//Cutoff wavelength for a TE10 mode in cms
wg=4*x;//Guide Wavelength in cm
w0=(wg/sqrt(1+(wg/wc)^2));////Free space wavelength in cm
f=(c/w0)/10^9;//Frequency of the wave in GHz

//OUTPUT
mprintf('\nFrequency of the wave is f=%1.3f GHz',f);

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

Scilab code Exa 4.14 guide wavelength

```
//chapter-4 page 151 example 4.14
//==============================================================================

clc;
clear;

//For a rectangular waveguide
b=2.5;//Length of Rectangular Waveguide in cm
a=5;//breadth of Rectangular Waveguide in cm
c=3*10^10;//Velocity of Light in cm/sec
w0=4.5;//Free space wavelength in cm

//CALCULATION
disp('For a TE10 mode which is the dominant mode');
wc=2*a;//Cutoff wavelength in cm
wg=(w0/sqrt(1-(w0/wc)^2));//Guide wavelength in cm
Vp=(c/sqrt(1-(w0/wc)^2))/10^10;//Phase Velocity in 10^10 cm/sec
B=((2*(%pi)*sqrt(wc^2-w0^2))/(w0*wc));//Phase
```

```
constant in radians

//OUTPUT
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);

//=========================END OF PROGRAM=========================================

//Note: Check the answers once
//Correct answers are
//Guide wavelength is wg=5.03903 cm
//Phase constant is B=1.247 radians
//Phase Velocity is Vp=3.36 *10^10 cm/sec
```

Scilab code Exa 4.15 possible modes

```
//chapter-4 page 152 example 4.15
//==================================================================================

clc;
clear;

wcTE10=16;//Critical wavelength of TE10 mode in cm
wcTM11=7.16;//Critical wavelength of TM11 mode in cm
wcTM21=5.6;//Critical wavelength of TM21 mode in cm
disp('For any wave to be propagated, the condition to be met is wc>wo');
wo1=10;//Free space wavelength in cm
wo2=5;//Free space wavelength in cm
disp('Critical wavelength of TE10 mode in cm is');
disp(wcTE10);
disp('Critical wavelength of TM11 mode in cm is');
```

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

Scilab code Exa 4.16 Characteristic Impedance

```
//chapter-4 page 152 example 4.16
//

clc;
clear;

n=120*(%pi);//Intrinsic Impedance
a=3;//Length of Rectangular Waveguide in cm
b=2;//Width of Rectangular Waveguide in cm
f=10^10;//Frequency in Hz
c=3*10^10;//Velocity of Light in cm/sec

//CALCULATION
wc=((2*a*b)/sqrt(a^2+b^2));//Cutoff wavelength in
   TM11 mode in cms
w0=(c/f);//Free space wavelength in cms
ZTM=(n*sqrt(1-(w0/wc)^2));//Characteristic Wave
   Impedance in ohms

//OUTPUT
mprintf('\nCharacteristic Wave Impedance is ZTM=%2.3
```

```
f ohms',ZTM);


//==================================END OF PROGRAM==================================

//Note: Check the given answer once it is wrong
 //currect answer is 163.242 ohms
```

Scilab code Exa 4.17 guide wavelength

```
//chapter-4 page 152 example 4.17
//==============================================================================

clc;
clear;

c=3*10^10;//Velocity of Light in cm/sec
f=6*10^9;//Frequency in Hz

//CALCULATION
fc=(0.8*f);//Given Cutoff frequency for TE11 mode in Hz
wc=(c/fc);//Cutoff wavelength in cms
D=((1.841*wc)/(%pi));//Diameter of waveguide in cm
w0=(c/f);//Free space wavelength in cm
wg=(w0/sqrt(1-(w0/wc)^2));//Guide wavelength in cm

//OUTPUT
mprintf('\nDiameter of the waveguide is D=%1.4f cm \nGuide wavelength is wg=%1.3f cm',D,wg);

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

Scilab code Exa 4.18 proof

```
//chapter-4 page 153 example 4.18
//==============================================================================

clc;
clear;

//For a TE10 mode
a=1.5;//Length of an air filled square Waveguide in m
b=1;//breadth of an air filled square Waveguide in cm
c=3*10^10;//Velocity of Light in cm/sec
f=6*10^9;//Impressed Frequency in Hz
er=4;//dielectric constant

//CALCULATION
wc=2*a;//Cutoff wavelength in cm
fc=(c/wc)/10^9;//Cutoff frequency in GHz
disp('Cutoff frequency in GHz is');
disp(fc);
disp('The impressed frequency of 6 GHz is less than the Cutoff frequency and hence the signal will not pass through the guide');
w=(c/f);//Wavelength in cm
disp('Alternatively, the wavelength of the impressed signal in cm is');
disp(w);
wair=w;
disp('which is longer than the cutoff wavelength (3 cm) and hence no propagation of the wave');
w1=wair/sqrt(er);//Wavelength in cm
```

```
disp('If the waveguide is loaded with dielectric of
   er=4, then the wavelength in cm is');
disp(w1);
disp('which is lessthan wair');
disp('Now the signal with 6 GHz frequency will pass
   through the dielectric loaded waveguide');

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

Scilab code Exa 4.19 amount of attenuation

```
//chapter-4 page 153 example 4.19
//
   ==========================================================================================

clc;
clear;

a=0.015;//Length of hollow Rectangular Waveguide in
   m
b=1;//breadth of hollow Rectangular Waveguide in cm
f=6*10^9;//Frequency in Hz in TE10 mode
c=3*10^8;//Velocity of Light in m/sec
m=1;//Value of m in TE10 mode
n=0;//Value of n in TE10 mode
u=4*(%pi)*10^(-7);//Permeability in free space in
   Henry
e=8.854*10^(-12);//Permittivity in free space in F/m

//CALCULATION
wc=2*a;//Cutoff wavelength for TE10 mode in m
fc=c/wc;//Cutoff frequency in Hz
w=2*(%pi)*f;//Angular frequency in rad/sec

```

```
//So 6GHz signal will not pass through waveguide but
    will get attenuated
A=(sqrt((m*(%pi)/a)^2+(n*(%pi)/b)^2-(w^2*u*e)));//
   Attenuation in NP/m
AdB=A*(20/log(10));//Attenuation in dB/m

//OUTPUT
mprintf('\Amount of Attenuation is A=%3.1f NP/m \
   nAttenuation is AdB=%4.2f dB/m',A,AdB);

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

Scilab code Exa 4.20 max power handling capacity

```
//chapter-4 page 154 example 4.20
//
   ==================================================================================

clc;
clear;

a=3;//Length of Rectangular Waveguide in cm
b=1;//Width of Rectangular Waveguide in cm
f=9*10^9;//Frequency in Hz in TE10 mode
c=3*10^10;//Velocity of Light in cm/sec
Emax=3000;//Max potential gradient in V/cm

//CALCULATION
w0=(c/f);//Free space wavelength in cms
disp('Free space Wavelength in cm is');
disp(w0);
wc=2*a;//Cutoff wavelength in TE10 mode in cms
wg=(w0/sqrt(1-(w0/wc)^2));//Guide wavelength in cms
disp('Guide Wavelength in cm is');
```

```
disp(wg);
P=((6.63*10^(-4))*(Emax^2)*a*b*(w0/wg))/1000;//Power handling capability of the waveguide in kW

//OUTPUT
mprintf('\nPower handling capability of the waveguide is P=%2.3f kW',P);


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

Scilab code Exa 4.21 maximum power

```
//chapter-4 page 154 example 4.21
//==============================================================================

clc;
clear;

d=5;//Internal Diameter of circular waveguide in cm
f=9*10^9;//Frequency in Hz in TE11 mode
c=3*10^10;//Velocity of Light in cm/sec
Emax=300;//Max field strength in V/cm

//CALCULATION
w0=(c/f);//Free space wavelength in cms
wc=((d*(%pi))/1.841);//Cutoff wavelength in TE11 mode in cms
wg=(w0/sqrt(1-(w0/wc)^2));//Guide wavelength in cms
Pmax=(0.498*(Emax^2)*(d^2)*(w0/wg))/1000;//Maximum power in kWatts

//OUTPUT
```

```
mprintf('\nMaximum power is Pmax=%4.2f kWatts',Pmax)
    ;


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

Scilab code Exa 4.22 peak value of electric field

```
//chapter-4 page 155 example 4.22
//
    ============================================================================================

clc;
clear;

//For an air filled square waveguide
a=0.01;//Length of an air filled square Waveguide in
     m
b=0.01;//breadth of an air filled square Waveguide
    in m
c=3*10^8;//Velocity of Light in m/sec
f=30*10^9;//Frequency in Hz in TE11 mode
Pmax=746;//Max power =1 horsepower  in W
n=120*(%pi);//Impedance of freespace in ohms

//CALCULATION
w0=(c/f);//Free space wavelength in m
wc=2*a;//Cutoff wavelength in m
ZTE=(n/sqrt(1-(w0/wc)^2));//Impedance in ohms
Emax=(sqrt((Pmax*4*ZTE)/(a*b)))/1000;//The Peak
    value of Electric field occuring in the guide in
    kV/m
//From P=(1/2)*Integration(Re(E*H))da
//and Pmax=(1/(4*ZTE))*Emax^2*a*b
```

```
//OUTPUT
mprintf('\nThe Peak value of Electric field occuring in the guide is Emax=%3.2f kV/m',Emax);

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

Scilab code Exa 4.23 breakdown power

```
//chapter-4 page 156 example 4.23
//==============================================================================

clc;
clear;

//For an air filled rectangular waveguide
a=0.023;//Length of an air filled  Rectangular Waveguide in m
b=0.01;//breadth of an air filled Rectangular Waveguide in m
c=3*10^8;//Velocity of Light in m/sec
f=9.375*10^9;//Frequency in Hz in TE11 mode
w0=0.01;//Free space wavelength in m
wc=0.02;//Cutoff wavelength in m
Pmax=746;//Max power =1 horsepower  in W

//CALCULATION
wo=(c/f);//Free space wavelength in cm
Pbd=(597*a*b*sqrt(1-(wo/(2*a))^2));//The breakdown power for the dominant mode ie TE11 in W
wg=(w0/sqrt(1-(w0/wc)^2));//Guide wavelength in m
Emax=(sqrt((Pmax*wg)/(6.63*10^(-4)*w0)))/1000;//Max electric field in kV/m
```

```

//OUTPUT
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);

//=================================END OF PROGRAM
   ==========================================


//Note: Check the answers once
//Correct answers are
//The breakdown power for the dominant mode ie TE11
   is Pbd=0.09864 W
//Max electric field is Emax=1.1398 kV/m
```

Scilab code Exa 4.24 breakdown power

```
//chapter-4 page 156 example 4.24
//
   ============================================================================

clc;
clear;

a=2.5;//Radius of circular waveguide in cm
d=5;//Internal Diameter of circular waveguide in cm
f=9*10^9;//Frequency in Hz in TE11 mode
c=3*10^10;//Velocity of Light in cm/sec

//CALCULATION
w0=(c/f);//Free space wavelength in cms
wc=((d*(%pi))/1.841);//Cutoff wavelength in TE11
   mode in cms
fc=(c/wc);//Cutoff frequency in Hz
```

```
Pbd=(1790*(a^2)*sqrt(1-(fc/f)^2))/1000;//Breakdown Power in TE11 mode in kW

//OUTPUT
mprintf('\nBreakdown Power in TE11 mode is Pbd=%5.3f kW',Pbd);

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

Chapter 5

Cavity Resonators

Scilab code Exa 5.1 minimum distance

```
//chapter-5 page 174 example 5.1
//==============================================================================
clc;
clear;

//For a circular waveguide
a=3;//radius in cm
f0=10*10^9;//resonant frequency of a circular
    resonator in Hz
disp('Given the mode of operator is TM011 so here n
    =0,m=1,p=1');
c=3*10^10;//Velocity of light in cm/sec
m=1;
n=0;
p=1;
Pnm=2.405;//dominant mode value[TM01]

//CALCULATION
d=((p*(%pi))/(sqrt((2*(%pi)*f0/c)^2-(Pnm/a)^2)));//
```

```
The minimum distance between the two end plates in cms

//OUTPUT
mprintf('\nThe minimum distance between the two end plates of a circular waveguide is d=%1.2f cms',d);

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

Scilab code Exa 5.2 lowest resonant frequency

```
//chapter-5 page 174 example 5.2
//==============================================================================

clc;
clear;

//For a rectangular cavity resonator
a=2;//breadth in cm
b=1;//height in cm
l=3;//length of rectangular waveguide in cm
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]');
disp('So the dominant mode is TE101 so here m=1,n=0,p=1');
c=3*10^10;//Velocity of light in cm/sec
m=1;
n=0;
p=1;

//CALCULATION
```

```
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

//OUTPUT
mprintf('\nThe resonant frequency of a rectangular cavity resonator is f0=%1.0f GHz',f0);

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

Scilab code Exa 5.3 resonant frequency

```
//chapter-5 page 175 example 5.3
//==============================================================================================

clc;
clear;

//For a circular resonator
D=12.5;//diameter in cm
l=5;//length of circular waveguide in cm
disp('Given the mode of operator is TM012 so here n=0,m=1,p=2');
c=3*10^10;//Velocity of light in cm/sec
m=1;
n=0;
p=2;
Pnm=2.405;//dominant mode value[TM01]

//CALCULATION
a=D/2;//radius in cm
f0=((c/(2*(%pi)))*sqrt((Pnm/a)^2+((p*(%pi))/l)^2))/10^9;//The resonant frequency of a circular
```

```
    resonator in GHz

//OUTPUT
mprintf('\nThe resonant frequency of a circular
    resonator is f0=%1.2f GHz',f0);

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

Scilab code Exa 5.4 resonant frequency

```
//chapter-5 page 175 example 5.4
//
    ==========================================================================

clc;
clear;

//For a circular resonator
a=3;//radius in cm
b=2;//dimension in cm
l=4;//length of circular waveguide in cm
disp('Given the mode of operator is TE101 so here m
    =1,n=0,p=1');
c=3*10^10;//Velocity of light in cm/sec
m=1;
n=0;
p=1;

//CALCULATION
f0=((c/2)*sqrt((m/a)^2+(n/b)^2+(p/l)^2))/10^9;//The
    resonant frequency of a circular resonator in GHz

//OUTPUT
mprintf('\nThe resonant frequency of a circular
```

```
    resonator is f0=%1.2f GHz',f0);

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

Chapter 6

Microwave Components

Scilab code Exa 6.2 distance to be shifted

```
//Chapter-6, Example 6.2, Page 234
//=============================================================================
//Input parameters
//[s]=[0,(0.3+(%i)*(0.4));(0.3+(%i)*(0.4)),0];//scattering matrix of a two port
//Calculations
//to find l such that S12 and S21 will be real when port1 is shifted lm to the left
//let port 1 be shifted by phi1 degree to the left and port2 position be remained unchanged i.e., phi2=delta
//Then [phi]=[e^-(j*phi1),0;0,1]
//[S']=[phi]*[s]*[phi]
//for S12 and S21 to be real
phi1=53.13;//in degrees
phi1=phi1*(%pi/180);//phi in radians
b=34.3;//measured in rad/m
l=(phi1)/b;//distance of shift in m
//Output
```

```
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",l)
//==========================================END OF PROGRAM==================================
```

Scilab code Exa 6.3 Scattering parameters

```
//Chapter-6, Example 6.3, Page 236
//=============================================================================
clc;
//Input parameters
D=30;//directivity in dB
VSWR=1;//VSWR at each port under matched conditions
C=10;//coupling factor
//Calculations
S41=sqrt(0.1);
S14=S41;//under matched and lossless conditions
S31=sqrt(((S41)^2)/(10)^(D/10));
S13=S31;
S11=(VSWR-1)/(VSWR+1);
S22=S11;
S33=S22;
S44=S33;
//let input power is given at port1
//p1=p2+P3+p4
S21=sqrt(1-(S41)^2-(S31)^2);
S12=S21;
S34=sqrt((0.5)*(1+(S12)^2-0.1-0.0001));
S43=S34
S23=sqrt(1-10^-4-(S34)^2)
S32=S23;
S24=sqrt(1-0.1-(S34)^2)
```

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

Scilab code Exa 6.4 powers in the remaining ports

```
//Chapter-6, Example 6.4, Page 238
//=============================================================================
clc;
//Input parameters
a1=32*10^-3;//power in watts
a2=0;
a3=0;
//Calculations
[S]=[0.5,-0.5,0.707;-0.5,0.5,0.707;0.707,0.707,0];//S-matrix for H-plane tee
//[B]=[b1,b2,b3]
[B]=[S].*[a1,0,0;0,0,0;0,0,0];
b1=(0.5)^2*a1;//power at port 1
b2=(-0.5)^2*a1;//power at port 2
b3=(0.707)^2*a1;//power at port 3
//Output
mprintf("Thus b1,b2,b3 are %g W,%g W,%g W respectively",b1,b2,b3);
//==================================================END OF PROGRAM==================================================
```

Scilab code Exa 6.5 power

```
//Chapter-6, Example 6.5, Page 239
//=============================================================================
clc;
//Input parameters
[S]=[0.5,-0.5,0.707;-0.5,0.5,0.707;0.707,0.707,0];
R1=60;//load at port1 in ohms
R2=75;//load at port2 in ohms
R3=50;//characteristic impedance in ohms
P3=20*10^-3;//power at port 3 in Watts
//calculations
p1=(R1-R3)/(R1+R3);
p2=(R2-R3)/(R2+R3);
P1=0.5*P3*(1-(p1)^2);//power delivered to the port1 in Watts
P2=0.5*P3*(1-(p2)^2);//power delivered to the port2 in Watts
//Output
mprintf("Thus power delivered to the port1 and port2 are %g W,%g W respectively",P1,P2);
//==================================END OF PROGRAM==================================
```

Scilab code Exa 6.6 Reflected power

```
//Chapter-6, Example 6.6, Page 239
//=============================================================================
```

```
clc;
//Input parameters
p1=0.5;//reflection coefficient at port 1
p2=0.6;//reflection coefficient at port 2
p3=1;//reflection coefficient at port 3
p4=0.8;//reflection coefficient at port 4
//[S
   ]=[0,0,0.707,0.707;0,0,0.5,-0.707;0.707,0.707,0,0;-0.707,0.707,0,
   S matrix of magic Tee
//solving for b1,b2,b3,b4 we get it as
//calculations
b1=0.6566;
b2=0.7576;
b3=0.6536;
b4=0.0893;
P1=(b1)^2;//power at port1 in watts
disp(P1);
P2=(b2)^2;//power at port2 in watts
disp(P2);
P3=(b3)^2;//power at port3 in watts
disp(P3);
P4=(b4)^2;//power at port4 in watts
disp(P4);
//==========================================END OF PROGRAM
   ========================================
```

Scilab code Exa 6.7 Scattering matrix

```
//Chapter-6, Example 6.7, Page 240
//
   ==========================================================================

clc;
//Input parameters
ins=0.5;//insertion loss in db
```

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

Scilab code Exa 6.9 Scattering matrix

```
//Chapter-6, Example 6.9, Page 241
//
=============================================================================

clc;
//Input parameters
ins=0.5;//insertion loss in db
iso=20;//isolation loss in db
S=2;//VSWR
//Calculations
S21=10^-(ins/20);//insertion loss=0.5=-20*log[S21]
S13=S21;
S32=S13;
S12=10^-(iso/20);//isolation loss=30=-20*log[s12]
S23=S12;
S31=S23;
p=(S-1)/(S+1);
S11=p;
S22=p;
S33=p;
[S]=[S11,S12,S13;S21,S22,S23;S31,S32,S33];
disp(S);
```

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

Scilab code Exa 6.10 output powers

```
//Chapter-6, Example 6.10, Page 242
//=============================================================================

clc ;
clear;
close;
In_loss =0.5; // insertion loss (in dB)
C =20; //coupling coefficient in dB
D =35; //directivity in dB
Pi_Pf =10^( C /10) ;
Pi =90; // in Watts
Pf=Pi/ Pi_Pf ;
Pf_Pb =10^( D /10) ;
Pb=Pf/ Pf_Pb ;
P_rec =(Pi -Pf -Pb); //Power received (in Watts )
P_rec_dB =10* log (Pi/ P_rec )/log (10) ;
P_rec_eff = P_rec_dB - In_loss ; // Effective power received (in dB)
disp ( Pf , 'Output power through coupled port (in Watts)=' );
disp ( Pb , 'Output power through isolated port (in Watts)=' );
```

```
disp ( P_rec_dB , ' Power r e c e i v e d ( i n dB)=
    ' );
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)=' );


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

Scilab code Exa 6.11 coupling isolation directivity

```
//Chapter -6, Example 6.11 , Page 242
//
   =========================================================================

clc;
//Calculations
S13=0.1*(cos(90*%pi/180)+(%i)*sin(90*%pi/180));//
   conversion from polar to rectangular
S13=abs(S13);
C=-20*log10(S13);//coupling coefficient in dB
S14=0.05*(cos(90*%pi/180)+(%i)*sin(90*%pi/180));//
   conversion from polar to rectangular
S14=abs(S14);
D=20*log10(S13/S14);//directivity in dB
I=-20*log10(S14);//isolation in dB
mprintf("Thus coupling,directivity and isolation are
    %1.0f dB,%1.2f dB and %2.2f dB respetively ",C,D
   ,I);
//====================================END OF PROGRAM
   ==================================
```

Scilab code Exa 6.12 VSWR

```
//chapter-6 page 244 example 6.12
//
    ==========================================================================================================
clc;
clear;

x=3.5;//distance between two minimas in cm
y=0.25;//distance between twice minimum power points
    in cm

//CALCULATION
wg=2*x;//guided wavelength in cm
S=(wg/(y*(%pi)));//Voltage Standing Wave Ratio(VSWR)

//OUTPUT
mprintf('\nVoltage Standing Wave Ratio(VSWR) is S=%1
   .4f',S);

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

Scilab code Exa 6.13 phase shift

```
//chapter-6 page 244 example 6.13
//
    ==========================================================================================================
clc;
clear;

wg=7.2;//guide wavelength in cm
x=10.5;//Position of reference null without the
   waveguide component in cm
y=9.3;//Position of reference null with the
```

```
waveguide component in cm

//CALCULATION
z=x-y;//Path difference introduced due to the
    component in cm
p=(2*(%pi)*(z/wg));//Phase difference introduced in
    rad
Pd=(p*180)/(%pi);//Phase shift introduced in deg

//OUTPUT
mprintf('\nPhase shift introduced is Pd=%2.0f deg',
    Pd);

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

Chapter 7

Microwave Measurements

Scilab code Exa 7.1 measured distance

```
//chapter-7 page 278 example 7.1
//==============================================================================
clc;
clear;

a=4;//Length of Waveguide in cm
b=2.5;//breadth Waveguide in cm
f=10^10;//Frequency in Hz
x=0.1;//distance between twice minimum power points in cm
c=3*10^10;//Velocity of Light in cm/sec

//CALCULATION
wc=2*a;//Cutoff wavelength in TE10 mode in cms
w0=(c/f);//Free space wavelength in cms
wg=(w0/sqrt(1-(w0/wc)^2));//Guide wavelength in cms
S=(wg/(x*(%pi)));//Voltage Standing Wave Ratio(VSWR) for double minimum method

```

```
//OUTPUT
mprintf('\nFor double minimum method, Voltage Standing Wave Ratio(VSWR) is S=%2.1f',S);

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

Scilab code Exa 7.2 VSWR and Reflected power

```
//chapter-7 page 279 example 7.2
//==============================================================================================

clc;
clear;

x=3;//O/P incident power from first directional coupler in mW
y=0.1;//O/P reflected power from second directional coupler in mW

//CALCULATION
Pi=x*100;//Incident Power in mW
Pr=y*100;//Reflected Power in mW
p=sqrt(Pr/Pi);//Reflection Coefficient
S=((1+p)/(1-p));//Voltage Standing Wave Ratio(VSWR)

//OUTPUT
mprintf('\nVoltage Standing Wave Ratio(VSWR)in the main waveguide is S=%1.2f \nReflected Power is Pr=%2.0f mW',S,Pr);

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

Scilab code Exa 7.3 VSWR

```
//chapter-7 page 279 example 7.3
//==============================================================================

clc;
clear;

Pi=2.5;//Incident Power from one directional coupler
    in mW
Pr=0.15;//Reflected Power from other directional
   coupler in mW

//CALCULATION
p=sqrt(Pr/Pi);//Reflection Coefficient
S=((1+p)/(1-p));//Voltage Standing Wave Ratio(VSWR)

//OUTPUT
mprintf('\nVoltage Standing Wave Ratio(VSWR)in the
   waveguide is S=%1.2f',S);

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

Scilab code Exa 7.4 Reflected power

```
//chapter-7 page 279 example 7.4
//==============================================================================

clc;
```

```
clear;

S=2;//Voltage Standing Wave Ratio(VSWR)
C=30;//Coupling Power of a Directional Coupler in dB
Pf=4.5;//Coupler Incident Sampling Power in mW

//CALCULATION
p=((S-1)/(S+1));//Reflection Coefficient
Pi=Pf*10^(C/10);//Incident Power in mW [From C=10log
    (Pi/Pf)]
Pr=(Pi*(p^2))/10^3;//Reflected Power in W [From p=
    sqrt(Pr/Pi)]

//OUTPUT
mprintf('\nValue of Reflected Power is Pr=%1.2f W',
    Pr);

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

Chapter 8

Microwave Tubes and Circuits

Scilab code Exa 8.1 electron velocity and etc

```
//chapter-8 page 336 example 8.1
//==============================================================================

clc;
clear;

//For a four cavity Klystron
V0=14500;//Beam voltage in V
I=1.4;//Beam current in A
f=10^10;//Operation frequency in Hz
p0=10^(-6);//dc electron charge density in C/m^3
p=10^(-8);//RF charge density in C/m^3
V=10^5;//Velocity perturbations in m/sec
e0=8.854*10^(-12);//Permittivity of free space in F/m
R=0.4;

//CALCULATION
v0=(0.593*10^6*sqrt(V0))/10^8;//The dc electron velocity in 10^8 m/sec
```

```
w=2*(%pi)*f;//angular frequency in rad/sec
v=v0*10^8;
c=(w/v);//The dc Phase Constant
wp=(sqrt(1.759*10^11*(p0/e0)))/10^8;//The Plasma Frequency in 10^8 rad/sec
wp1=wp*10^8;
wq=(R*wp1)/10^8;//The Reduced Plasma Frequency in 10^8 rad/sec
J0=p0*v;//The dc beam current density in A/sqm
J=(p*v)+(p0*V);//The instantaneous beam current density in A/sqm

//OUTPUT
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=%1.3f *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);

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

Scilab code Exa 8.2 power and etc

```
//chapter-8 page 337 example 8.2
//==================================================================================

clc;
clear;

//For a 2 cavity klystron amplifier
Av=15;//Voltage gain in dB
```

```
Pin=0.005;//I/P power in W
Rin=30000;//Rsh of i/p cavity in ohms
R0=40000;//Rsh of o/p cavity in ohms
Rl=40000;//load impedance in ohms
R=20000;//Parallel resistance of R0 and Rl (R0//Rl)
    in ohms

//CALCULATION
Vin=sqrt(Pin*Rin);//The input rms voltage in V  [
    From Pin=Vin^2/Rin]
V0=Vin*10^(Av/20);//The output rms voltage in V [
    From Av=20log(V0/Vin)]
P0=(V0^2)/R;//The Power delivered to the load in W

//OUTPUT
mprintf('\nThe input rms voltage is Vin=%2.2f V \
    nThe output rms voltage is V0=%2.2f V \nThe Power
     delivered to the load is P0=%1.4f W',Vin,V0,P0);

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

Scilab code Exa 8.3 efficiency and etc

```
//chapter-8 page 338 example 8.3
//
    ==========================================================================

clc;
clear;

//For a reflex klystron
n=2;//peak mode value
V0=300;//beam voltage in V
I0=0.02;//beam current in A
```

```
Vs=40;//signal voltage in V
J1=1.25;//bessel coefficient for n=2

//CALCULATION
Pdc=V0*I0;//The input power in watts
Pac=((2*Pdc*J1)/((2*n*(%pi))-((%pi)/2)));//The output power in watts
n=(Pac/Pdc)*100;//Efficiency in percentage

//OUTPUT
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);

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

Scilab code Exa 8.4 electron velocity and etc

```
//chapter-8 page 338 example 8.4
//==============================================================================================

clc;
clear;

//For a 2 cavity klystron amplifier
V0=900;//Beam voltage in V
I0=0.03;//Beam current in A
f=8*10^9;//frequency in Hz
d=0.001;//gap spacing in either cavity in m
L=0.04;//spacing between centers of cavities in m
Rsh=49000;//Effective shunt impedance in ohms
J1=0.582;//value of J1(X)
X=1.841;//bunching parameter
```

```
//CALCULATION
v0=(0.593*10^6*sqrt(V0))/10^6;//velocity of electron in 10^6 m/sec
w=2*(%pi)*f;//angular frequency in rad
v=v0*10^6;
T0=(L/v)/10^(-8);//dc transit time of electrons in 10^(-8) sec
a=w*T0*10^(-8);//transit angle in rad
tg=w*d/v;//average gap transit angle in rad
Tg=tg*(180/(%pi));
Bi=(sind(Tg/2))/(tg/2);//beam coupling coefficient
Bo=Bi;//output cavity coupling coefficient
V1max=((3.68*V0)/(Bi*a));//Input voltage for Maximum output voltage in V
R0=V0/I0;//impedance in ohms
Av=(Bo^2*a*Rsh*J1)/(R0*X);//Voltage gain
AvdB=20*log10(Av);//Voltage gain in dB

//OUTPUT
mprintf('\nVelocity of electron is v0=%2.2f *10^6 m/sec \nThe dc transit time of electrons is T0=%1.3f *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);

//==============================END OF PROGRAM==============================

//Note: Check the calculation given in text book for voltage gain Rsh=49 kohms
//but, taken as 40 kohms
//correct answers areVoltage gain is Av=28.52
//The Voltage gain in dB is AvdB=29.10 dB
```

Scilab code Exa 8.5 efficiency and etc

```
//chapter-8 page 339 example 8.5
//
clc;
clear;

//For a 2 cavity klystron amplifier
V0=1200;//Beam voltage in V
I0=0.028;//Beam current in A
f=8*10^9;//frequency in Hz
d=0.001;//gap spacing in either cavity in m
L=0.04;//spacing between centers of cavities in m
Rsh=40000;//Effective shunt impedance in ohms
J1=0.582;//value of J1(X)
X=1.841;//bunching parameter

//CALCULATION
w=2*(%pi)*f;//angular frequency in rad
v0=0.593*10^6*sqrt(V0);//velocity of electron in m/sec
Vomax=((3.68*V0*v0)/(w*L));//max output power in V
tg=(w*d)/v0;//avg gap transit angle in rad
Tg=tg*(180/(%pi));
Bi=(sind(Tg/2))/(tg/2);//beam coupling coefficient
Bo=Bi;//output cavity coupling coefficient
Vimax=Vomax/Bi;//The input microwave voltage in order to generate maximum output voltage in V
t0=w*L/v0;//transit angle in rad
R0=V0/I0;//impedance in ohms
Av=((Bo^2*J1*t0*Rsh)/(R0*X));//Voltage gain
I2=2*I0*J1;
```

```
V2=Bo*I2*Rsh;
disp('neglecting beam loading');
Eff=0.58*(V2/V0)*100;//Efficiency in %
G0=1/R0;
GB=(G0/2)*(Bo*(Bo-cos(Tg/2)));//Beam loading conductance in mhos
RB=(1/GB)/1000;//Beam loading resistance in Kohms
disp('Beam loading resistance in Kohms is');
disp(RB);
disp('The value 73 kohms is very much comparable to Rsh and cannot be neglected because Tg is quite high');

//OUTPUT
mprintf('\nThe input microwave voltage in order to generate maximum output voltage is Vimax=%2.2f V \nThe voltage gain is Av=%2.2f percentage \nBeam loading conductance is GB=%1.10f mhos',Vimax,Av,GB);

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

Scilab code Exa 8.6 electronic efficiency and etc

```
//chapter-8 page 338 example 8.4
//==============================================================================

clc;
clear;

//For a reflex klystron
n=2;//peak mode value
V0=500;//beam voltage in V
```

```
Rsh=20000;//Shunt resistance in ohms
L=0.001;//distance in m
f=8*10^(9);////Operation frequency in Hz
V1=200;//microwave gap voltage in V
x=1.759*10^11;//e/m value in C/kg
J1=0.582;

//CALCULATION
disp('Assume the gap transit time and beam loading are neglected');
w=2*(%pi)*f;//angular frequency in rad
VR=(V0+((sqrt(8*V0/x)*w*L)/((2*(%pi)*n)-((%pi)/2))));//Repeller voltage in V
disp('Assuming output coupling coefficient Bo=1');
I0=(V1/(2*J1*Rsh))/10^(-3);//Beam current necessary to obtain an microwave gap voltafe of 200V in mA
v0=0.593*10^6*sqrt(V0);//velocity of electron in m/sec
t0=((w*2*L*v0)/(x*(VR+V0)));//transit angle in rad
Bi=1;//beam coupling coefficient [assume]
X=((Bi*V1*t0)/(2*V0));
disp('Since X=1.51, from graph,J1(X)=0.84');
XJ1=0.84;
Eff=((2*(XJ1))/((2*n*(%pi))-((%pi)/2)))*100//Efficiency in %

//OUTPUT
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);

//==============================END OF PROGRAM==============================

//Note: Check the answer for VR once
//Correct answer is Repeller voltage is VR=1189.36 V
```

Scilab code Exa 8.7 efficiency and etc

```
//chapter-8 page 342 example 8.7
//==============================================================================

clc;
clear;

//For a reflex klystron
n=1;//mode value
Pi=0.04;//the dc input power in W
x=0.278;//ratio of V1 over V0

//CALCULATION
X=x*3*(%pi)/4;
J1=0.3205;//bessel coefficient value [JI(X')]
ef=((2*X*J1)/((2*(%pi)*n)-((%pi)/2)))*100;//
    Efficiency of the reflex klystron in %
Pout=((ef/100)*Pi)/10^(-3);//Total power output in
    mW
p=20;//percentage of the power delivered by the
    electron beam dissipated in the cavity walls
Pd=Pout*(100-p)/100;//Power delivered to load in mW

//OUTPUT
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=%1.2f mW',ef,Pout,Pd);

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

Scilab code Exa 8.8 cyclotron frequency and etc

```
//chapter-8 page 342 example 8.8
//
clc;
clear;

//For a circular magnetron
a=0.15;//inner radius in m
b=0.45;//outer radius in m
B=1.2*10^(-3);//magnetic flux density in Wb/sqm
x=1.759*10^11;//Value of e/m in C/kg
V=6000;//beam voltage in V

//CALCULATION
V0=((x/8)*(B^2)*(b^2)*(1-(a/b)^2)^2)/1000;//Hull cut-off voltage in kV
Bc=((sqrt(8*(V/x)))/(b*(1-(a/b)^2)))*1000;//Cut-off magnetic flux density in mWb/sqm
fc=((x*B)/(2*(%pi)))/10^9;//Cyclotron frequency in GHz

//OUTPUT
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);

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

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

Scilab code Exa 8.9 phase velocity and anode voltage

```
//chapter-8 page 343 example 8.9
//==============================================================================

clc;
clear;

//For a helical TWT
c=3*10^8;//Velocity of light in m/sec
d=0.002;//diameter in m
x=5000;//no.of turns per m
m=9.1*10^(-31);//mass of an electron in kg
e=1.6*10^(-19);//charge of an electron in C

//CALCULATION
y=(%pi)*d;//circumference in m
p=1/x;//pitch in m
Vp=(c*p)/y;//Axial phase velocity in m/sec
V0=((m*Vp^2)/(2*e));//The Anode voltage at which the TWT can be operated for useful gain in V

//OUTPUT
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);

```

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

Scilab code Exa 8.10 electron velocity and etc

```
//chapter-8 page 344 example 8.10
//==============================================================================================================

clc;
clear;

//For a 2 cavity klystron amplifier
V0=900;//Beam voltage in V
I0=0.03;//Beam current in A
f=8*10^9;//frequency in Hz
d=0.001;//gap spacing in either cavity in m
L=0.04;//spacing between centers of cavities in m
Rsh=40000;//Effective shunt impedance in ohms
y=0.582;//value of J1(X)
X=1.841;

//CALCULATION
v0=(0.593*sqrt(V0)*10^6)/10^7;//The electron velocity in 10^7 m/sec
v=v0*10^7;
t0=(d/v)/10^(-10);//Transit time in 10^(-10) sec
t=t0*10^(-10);
a=2*(%pi)*f*t;//Gap transit angle in rad
Bi=(sin(a/2))/(a/2);//Beam coupling coefficient
Bo=Bi;
to=(2*(%pi)*f*L)/v;//dc transit angle in rad
disp('For maximum outout voltage,V2 J1(X)=0.582,X=1.841');
V1=((2*V0*X)/(Bo*to))//The input voltage for maximum
```

```
output voltage in V
Ro=(V0/I0);
Av=((Bo^2*to*y*Rsh)/(Ro*X));//Voltage gain
AvdB=10*log10(Av);//Voltage gain in dB

//OUTPUT
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);

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

Scilab code Exa 8.11 dc electron velocity and etc

```
//chapter-8 page 345 example 8.11
//==============================================================================

clc;
clear;

//For a four cavity Klystron
V0=20000;//Beam voltage in V
I=2;//Beam current in A
f=9*10^9;//Operation frequency in Hz
p0=10^(-6);//dc electron charge density in C/m^3
p=10^(-8);//RF charge density in C/m^3
V=10^5;//Velocity perturbations in m/sec
e0=8.854*10^(-12);//Permittivity of free space in F/m
R=0.5;
```

```
//CALCULATION
v0=(0.593*10^6*sqrt(V0))/1000;//The dc electron velocity in Km/sec
w=2*(%pi)*f;//angular frequency in rad/sec
v=v0*1000;
c=(w/v);//The dc Phase Constant
wp=(sqrt(1.759*10^11*(p0/e0)))/10^8;//The Plasma Frequency in 10^8 rad/sec
wp1=wp*10^8;
wq=(R*wp1)/10^8;//The Reduced Plasma Frequency in 10^8 rad/sec
J0=p0*v;//The dc beam current density in A/sqm
J=(p*v)-(p0*V);//The instantaneous beam current density in A/sqm

//OUTPUT
mprintf('\nThe dc electron velocity is v0=%4.2f Km/sec \nThe dc Phase Constant is c=%3.2f rad/sec\nThe Plasma Frequency is wp=%1.2f *10^8 rad/sec \nThe Reduced Plasma Frequency is wq=%1.3f *10^8 rad/sec \nThe dc beam current density is J0=%2.2f A/sqm \nThe instantaneous beam current density is J=%1.4f A/sqm',v0,c,wp,wq,J0,J);

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

Scilab code Exa 8.12 gap transit angle

```
//chapter-8 page 345 example 8.12
//==============================================================================
clc;
```

```
clear;

//For a reflex klystron
f=5*10^9;//Frequency of operation in hz
V0=1000;//anode voltage in V
d=0.002;//cavity gap in m
Vr=-500;//repeller voltage in V

//CALCULATION
N=7/4;//mode value
VR=abs(Vr);
L=(((VR+V0)*N)/(6.74*10^(-6)*f*sqrt(V0)))/10^(-3);//Optimum length of the drift region in mm
u=5.93*10^5*sqrt(V0);// in m/sec
w=2*(%pi)*f;//angular frequency in rad
Tg=(w*d)/u;//Gap transit angle in rad

//OUTPUT
mprintf('\nOptimum length of the drift region is L=%1.3f mm \nGap transit angle is Tg=%1.3f rad',L,Tg);

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

Scilab code Exa 8.13 efficiency and etc

```
//chapter-8 page 346 example 8.13
//=================================================================================

clc;
clear;

//For a 2 cavity klystron amplifier
```

```
V0=1200;//Beam voltage in V
I0=0.03;//Beam current in A
f=10*10^9;//frequency in Hz
d=0.001;//gap spacing in either cavity in m
L=0.04;//spacing between centers of cavities in m
Rsh=40000;//Effective shunt impedance in ohms
J1=0.582;//value of J1(X)
X=1.841;//bunching parameter

//CALCULATION
v0=0.593*10^6*sqrt(V0);//velocity of reference electron in m/sec
w=2*(%pi)*f;//angular frequency in rad
a=w*L/v0;//transit angle without RF voltage in rad
tg=a*d/L;//average gap transit angle in rad
Bi=(sin(tg/2))/(tg/2);//beam coupling coefficient
V1max=((2*X*V0)/(Bi*a));//Input RF voltage for Maximum output voltage in V
B0=Bi;//output cavity coupling coefficient
V2=2*B0*I0*J1*Rsh;//in V
Av=V2/V1max;//Voltage gain
AvdB=20*log10(Av);//Voltage gain in dB
n=0.58*(V2/V0)*100;//Maximum efficiency in %

//OUTPUT
mprintf('\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);

//=================================END OF PROGRAM=======================================

//Note: Check the answers once
//There are slight changes in values
//Input RF voltage for Maximum output voltage is V1max=55.28 V
//The Voltage gain is AvdB=24.35 dB
```

```
//Maximum efficiency is I0=44.11 percentage
```

Scilab code Exa 8.14 cyclotron angular frequency and etc

```
//chapter-8 page 347 example 8.14
//==============================================================================
clc;
clear;

//For aa X-band cylindrical magnetron
a=0.04;//inner radius in m
b=0.08;//outer radius in m
B=0.01;//magnetic flux density in Wb/sqm
x=1.759*10^11;//Value of e/m in C/kg
V=30000;//beam voltage in V

//CALCULATION
w=(x*B)/10^9;//Cyclotron angular frequency in 10^9 rad/sec
VHC=((x/8)*(B^2)*(b^2)*(1-(a/b)^2)^2)/1000;//Hull cut-off voltage in kV
Bc=((sqrt(8*(V/x)))/(b*(1-(a/b)^2)))*1000;//Cut-off magnetic flux density in mWb/sqm

//OUTPUT
mprintf('\nCyclotron angular frequency is w=%1.3f*10^9 rad/sec \nHull cut-off voltage is VHC=%1.4f kV \nCut-off magnetic flux density is Bc=%2.3f mWb/sqm',w,VHC,Bc);

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

Scilab code Exa 8.15 efficiency and etc

```
//chapter-8 page 348 example 8.15
//==================================================================================

clc;
clear;

//For a reflex klystron
n=2;//peak mode value
V0=280;//beam voltage in V
I0=0.022;//beam current in A
Vs=30;//signal voltage in V
J1=1.25;//bessel coefficient for n=2

//CALCULATION
Pdc=V0*I0;//The input power in watts
Pac=((2*Pdc*J1)/((2*n*(%pi))-((%pi)/2)));//The
    output power in watts
n=(Pac/Pdc)*100;//Efficiency in percentage

//OUTPUT
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);

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

Scilab code Exa 8.16 repeller voltage and etc

```
//chapter-8 page 348 example 8.16
//==============================================================================================
clc;
clear;

//For a reflex klystron
n=2;//peak mode value
V0=300;//beam voltage in V
Rsh=20000;//Shunt resistance in ohms
L=0.001;//distance in m
J1=0.582;//bessel coefficient value [JI(X')]
f=8*10^(9);////Operation frequency in Hz
V1=200;//RF gap voltage in V
x=1.759*10^11;//e/m value in C/kg

//CALCULATION
disp('Assume the gap transit time and beam loading are neglected');
w=2*(%pi)*f;//angular frequency in rad
VR=(V0+((sqrt(8*V0/x)*w*L)/((2*(%pi)*n)-((%pi)/2))));//Repeller voltage in V
disp('Assuming output coupling coefficient Bo=1');
I0=(V1/(2*J1*Rsh))/10^(-3);//Beam current necessary to obtain an RF gap voltafe of 200V in mA

//OUTPUT
mprintf('\nThe Repeller voltage is VR=%3.2f V \nBeam current necessary to obtain an RF gap voltafe of 200V is I0=%1.2f mA',VR,I0);

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

Chapter 9

Solid State Microwave Devices

Scilab code Exa 9.1 frequency

```
//chapter-9 page 411 example 9.1
//==============================================================================

clc;
clear;

L=2*10^(-6);//Drift Length of a IMPATT diode in m
Vd=(10^7)*(10^(-2));//Drift Velocity for Siin m/sec

//CALCULATION
f=(Vd/(2*L))/10^9;//Operating Frequency in GHz

//OUTPUT
mprintf('\nOperating Frequency of the IMPATT diode
    is f=%2.0f GHz',f);

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

Scilab code Exa 9.2 threshold electric field

```
//chapter-9 page 411 example 9.2
//==============================================================================

clc;
clear;

L=75*10^(-6);//Device Length in m
V=25;//Voltage Pulse Amplified in V
f=10*10^9;//Operating Frequency in Hz

//CALCULATION
Eth=(V/L)/10^5;//Threshold Electric Field in kV/cm

//OUTPUT
mprintf('\nThreshold Electric Field is Eth=%1.2f kV/cm',Eth);

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

Scilab code Exa 9.3 power gain

```
//chapter-9 page 411 example 9.3
//==============================================================================

clc;
clear;

```

```
fs=2*10^9;//Signal Frequency in Hz
fp=12*10^9//Pump Frequency in Hz
Ri=16;//O/P resistance of signal generator in ohms
Rs=1000;//On types resistance of signal generator in ohms

//CALCULATION
P=10*log10((fp-fs)/fs);//Power gain in dB
Pusb=10*log10((fp+fs)/fs);//Power gain as USB converter in dB

//OUTPUT
mprintf('\nPower gain is P=%1.2f dB \nPower gain as USB converter is Pusb=%1.2f dB',P,Pusb);

//=================================END OF PROGRAM========================================


//Note: Answer given in textbook is wrong Check it once..
//Correct answers are Power gain is P=6.99 dB
//                    Power gain as USB converter is Pusb=8.45 dB
```

Scilab code Exa 9.4 breakdown voltage and etc

```
//chapter-9 page 411 example 9.4
//==============================================================================

clc;
clear;

es=12.5;//Relative Dielectric constant
```

```
e0=8.854*10^(-12);//Permittivity in Free Space in F/
    m
N=3.2*10^22;//Donor Concentration per m^3
L=8*10^(-6);//Length of Si BARITT diode in m
q=1.6*10^(-19);//Charge of an Electron in C

//CALCULATION
Vc=((q*N*L^2)/(2*es*e0))/10^3;//Critical Voltage in
    kV
Vbd=2*Vc;//Breakdown Voltage in kV
Ebd=(Vbd/L)/100;//Breakdown Electric Field in kV/cm

//OUTPUT
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);

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

Scilab code Exa 9.5 Avalanche zone velocity

```
//chapter-9 page 412 example 9.5
//
    ================================================================================

clc;
clear;

J=33000;//Current density in A/sqcm
Na=2.5*10^16;//Doping Concentation in TRAPATT diode
    per cubic cm
q=1.6*10^(-19);//Charge of an Electron in C

//CALCULATION
```

```
Vz=(J/(q*Na))/10^5;//Avalanche Zone Velocity in Km/sec

//OUTPUT
mprintf('\nAvalanche Zone Velocity is Vz=%2.1f Km/sec',Vz);

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

Scilab code Exa 9.6 power gain

```
//chapter-9 page 412 example 9.6
//==============================================================================================

clc;
clear;

//For an IMPATT diode power amplifier
Rd=25;//Negative Resistance in ohms
Rl=50;//Load Resistance in ohms

//CALCULATION
x=abs(Rd);
G=((-x-Rl)/(-x+Rl))^2;//Power gain of an IMPATT diode

//OUTPUT
mprintf('\nPower gain of an IMPATT diode is G=%1.0f',G);

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

Scilab code Exa 9.7 minimum voltage

```
//chapter-9 page 412 example 9.7
//==============================================================================
clc;
clear;

//For a Gunn Diode
L=5*10^(-4);//Drift Length in cm
Vg=3300;//Voltage gradient in V/cm [Vg>3.3 kV/cm]

//CALCULATION
Vmin=Vg*L;//Minimum Voltage needed to initiate Gunn
    effect in volts

//OUTPUT
mprintf('\nMinimum Voltage needed to initiate Gunn
    effect is Vmin=%1.2f volts',Vmin);

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

Scilab code Exa 9.8 rational frequency

```
//chapter-9 page 412 example 9.8
//==============================================================================
clc;
clear;
```

```
//For a Gunn Diode
L=20*10^(-4);//Active Length in cm
Vd=2*10^7;//Drift Velocity of Electrons in cm/sec
Ec=3.3*10^3;//Criticl Field for GaAs in V/cm

//CALCULATION
fn=(Vd/L)/10^9;//Natural(Rational) Frequency in GHz
Vc=L*Ec;//Critical Voltage of the diode in volts

//OUTPUT
mprintf('\nNatural(Rational) Frequency is fn=%2.0f GHz \nCritical Voltage of the diode is Vc=%1.1f volts',fn,Vc);

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

Scilab code Exa 9.9 efficiency and etc

```
//chapter-9 page 412 example 9.9
//==============================================================================================

clc;
clear;

//For an IMPATT diode
Lp=0.5*10^(-9);//Inductance in Henry
Cj=0.5*10^(-12);//Capacitance in Farad
Ip=0.8;//RF peak current in A
Rl=2;//Load Resistance in ohms
Vbd=100;//Breakdown Voltage in V
Ib=0.1;//dc Bias current in A

```

```
//CALCULATION
f=(1/(2*(%pi)*sqrt(Lp*Cj)))/10^9;//Resonant Frequency in GHz
n=((Rl*Ip^2)/(2*Vbd*Ib))*100;//Efficiency in Percentage

//OUTPUT
mprintf('\nResonant Frequency is f=%2.0f GHz \nEfficiency is n=%1.1f percentage',f,n);

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

Scilab code Exa 9.10 drift time

```
//chapter-9 page 413 example 9.10
//==============================================================================================
clc;
clear;

//For an IMPATT diode
L=2*10^(-6);//Drift Length in m
Vd=10^5;//Carrier Drift Velocity (Assume/Consider) in m/sec

//CALCULATION
t=(L/Vd)/10^(-9);//Drift Time of the Carrier in nano sec [From f=(1/2t)=(Vd/2L)]
t1=t*10^(-9);
f=(1/(2*t1))/10^9;//Operating Frequency of the diode in GHz

//OUTPUT
```

```
mprintf('\nDrift Time of the Carrier is t=%1.2f nano sec \nOperating Frequency of the diode is f=%2.0f GHz',t,f);

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

Scilab code Exa 9.11 breakdown voltage and etc

```
//chapter-9 page 413 example 9.11
//==============================================================================

clc;
clear;

//For an M-Si-M Basitt diode
er=11.8;//Relative dielectric constant of Si
e0=8.854*10^(-12);//Permittivity of freespace in F/m
N=3*10^(21);//Donor Concentration per m^3
L=6.2*10^(-6);//Si Length in m
q=1.6*10^(-19);//Charge of an Electron in C

//CALCULATION
Vbd=((q*N*L^2)/(er*e0));//Breakdown Voltage in V
Ebd=(Vbd/L)/10^3;//Breakdown Electric Field in kV/m

//OUTPUT
mprintf('\nBreakdown Voltage is Vbd=%3.1f V \nBreakdown Electric Field is Ebd=%5.0f kV/m',Vbd,Ebd);

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

Scilab code Exa 9.12 max power gain and etc

```
//chapter-9 page 413 example 9.12
//
    ==============================================================================

clc;
clear;

//For an upconverter parametric amplifier
rQ=8;//figure of merit for a diode nonlinear
    capacitor
r=0.2;
y=8;//ratio of output frequency over signal
    frequency (f0/fs)
Td=300;//Diode Temperature in K
T0=300;//Ambient Temperature in K

//CALCULATION
X=((rQ)^2)/y;
G=((y*X)/(1+sqrt(1+X))^2);//Max power gain
GdB=10*log10(G);//Maximum Power Gain in dB
F=(1+((2*Td/T0)*((1/rQ)+(1/rQ)^2)));//Noise Figure
FdB=10*log10(F);//Noise Figure in dB
BW=2*r*sqrt(y);//Bandwidth

//OUTPUT
mprintf('\nMaximum Power Gain is GdB=%1.2f dB\nNoise
     Figure is FdB=%1.2f dB \nBandWidth is BW=%1.2f',
    GdB,FdB,BW);

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

Scilab code Exa 9.13 gain and etc

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

clc;
clear;

//For a negative resistance parametric amplifier
fs=2*10^9;//Signal Frequency in Hz
fp=12*10^9;//pump Frequency in Hz
fi=10*10^9;//idler Frequency in Hz
fd=5*10^9;//Frequency in Hz
Ri=1000;//o/p resistance of idler generator in ohms
Rg=1000;//o/p resistance of signal generator in ohms
RTs=1000;//total series resistance at fs in ohms
RTi=1000;//total series resistance at fi in ohms
r=0.35;
rQ=10;//figure of merit
Td=300;//Avg Diode Temperature in K
T0=300;//Ambient Temperature in K
C=0.01*10^(-12);//Capacitance in F

//CALCULATION
ws=2*(%pi)*fs;
wi=2*(%pi)*fi;
R=((r^2)/(ws*wi*RTi*C^2));//Equivalent noise
    resistance in ohms
a=(R/RTs);
G=((4*fi*a*Rg*Ri)/(fs*RTs*RTi*(1-a)^2));//Gain
GdB=10*log10(G);//Gain in dB
F=(1+((2*Td/T0)*((1/rQ)+(1/rQ)^2)));//Noise Figure
FdB=10*log10(F);//Noise Figure in dB
```

```
BW=((r/2)*(sqrt(fd/(fs*G))));

//OUTPUT
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);

//==============================END OF PROGRAM
   ======================================

//Note: Check the Bandwidth answer is once It should
    be 0.027
```

Chapter 10

Microwave Communication Systems

Scilab code Exa 10.1 radio horizon

```
//chapter-10 page 486 example 10.1
//
clc;
clear;

ht=144;//TV transmitter antenna height in m
hr=25;//TV receiver antenna height in m
//Radio horizon is about 4/3 as far as the optical horizon

//CALCULATION
dr=4*sqrt(hr);//distance in km
dt=4*sqrt(ht);//Radio Horizon in km
d=dt+dr;//The Maximum distance of Propagation of the TV signal in km

//OUTPUT
```

```
mprintf('\nThe Maximum distance of Propagation of
    the TV signal is d=%2.0f km \nRadio Horizon is dt
    =%2.0f km',d,dt);

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

Scilab code Exa 10.2 value of factor

```
//chapter-10 page 486 example 10.2
//
    ==============================================================================

clc;
clear;

r=6370*10^3;//radius of the earth in m
x=-0.05*10^(-6);//the gradient of refractive index
    of air near the ground per m [du/dh]

//CALCULATION
k=1/(1+(r*x));//The value of the factor by which the
     horizon distance of a transmitter will be
    modified

//OUTPUT
mprintf('\nThe value of the factor by which the
    horizon distance of a transmitter will be
    modified is k=%1.4f',k);

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

Scilab code Exa 10.3 power

```
//chapter-10 page 487 example 10.3
//==============================================================================================

clc;
clear;

//For a microwave LOS link
f=2*10^9;//frequency of operation in Hz
c=3*10^8;//Velocity of light in m/sec
r=50000;//repeater spacing in m
PrdBm=-20;//required carrier power at the receiver i/p to avoid deterioration due to fading and noise in dBm
GtdB=34;//antenna gain of transmitter in dB
GrdB=34;//antenna gain of receiver in dB
LdB=10;//coupling and waveguide loss in transmitter in dB

//CALULATION
w=c/f;//wavelength in m
x=(w^2)/(4*(%pi));
y=(4*(%pi)*r^2);
PtdBm=PrdBm+(10*log10(y))-GtdB-(10*log10(x))+LdB-GrdB;//The required Carrier Transmitter power in dBm

//OUTPUT
mprintf('\nThe required Carrier Transmitter power is PtdBm=%2.1f dBm',PtdBm);

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

Scilab code Exa 10.4 power

```
//chapter-10 page 487 example 10.4
//
clc;
clear;

//For a geostationary communication satellite
f=6*10^(9);//uplink frequency in Hz
Pt=1000;//Transmitter power in W
x=36000*10^3;//vertical distance between surface of earth and satellite in m
a=5;//antenna elevation angle in deg
GtdB=60;//antenna gain of transmitter in dB
GrdB=0;//antenna gain of receiver in dB
c=3*10^8;//Velocity of light in m/sec

//CALCULATION
Gt=10^(GtdB/10);//antenna gain of transmitter
Gr=10^(GrdB/10);//antenna gain of receiver
w=c/f;//wavelength in m
Ar=(w^2)*(Gr/(4*(%pi)));//area in sqm
r=x/(sind(a));//distance between transmitter and receiver in m [From Sine formula and diagram]
Pr=((Pt*Gt*Ar)/(4*(%pi)*r^2))/10^(-12);//The received power at the input of the satellite receiver in pico watts

//OUTPUT
mprintf('\nThe received power at the input of the satellite receiver is Pr=%1.2f pico watts(pW)',Pr);
```

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

Scilab code Exa 10.5 antenna beam angle

```
//chapter-10 page 487 example 10.5
//
==========================================================================================
clc;
clear;

x1=35855;//Distance between geostationary orbit to
    surface of earth in km
x2=6371;//Distance between center of earth to
    surface of earth in km

//CALCULATION
x=x1+x2;//distance of satellite from center of earth
     in km
y=x2*(%pi);//Circumference of half circle arc in km
b=y/x;//Beam angle in rad
Bdeg=(b*180)/(%pi);//Beam angle in deg

//OUTPUT
mprintf('\nAntenna Beam angle required by a
    satellite antenna to provide full global coverage
     from a geostationary orbit is Bdeg=%2.2f deg',
    Bdeg);

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

Scilab code Exa 10.6 round trip time

```
//chapter-10 page 488 example 10.6
//
clc;
clear;

//For a satellite communication system
h=35855;//Distance between geostationary orbit to
    surface of earth in km
r=6371;//Distance between center of earth to surface
     of earth in km
a=5;//earth station elevation angle wrt the
    geostationary satellite in deg
b=5;//angle in deg
c=3*10^5;//Velocity of light in km/sec
b1=90;//angle for vertical transmission in deg
a1=0;

//CALCULATION
d=(sqrt((r+h)^2-(r*cosd(a))^2))-sind(b);//distance
    in km
T=2*(d/c);//The round trip time between the earth
    station and the satellite in sec
d1=(sqrt((r+h)^2-(r*cosd(a))^2))-sind(b);//distance
    in km
Tv=(2/c)*(d1-r);//The round trip time for vertical
    transmission between the earth station and the
    satellite in sec

//OUTPUT
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);

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

Scilab code Exa 10.7 figure of merit

```
//chapter-10 page 488 example 10.7
//
   ==========================================================================================


clc;
clear;

Tant=25;//effective noise temperature in K
Tr=75;//receiver noise temperature in K
GdB=45;//Isotropic power gain of the antenna in dB

//CALCULATION
T=Tant+Tr;//The total noise in K
TdB=10*log10(T);//The total noise in dB
MdB=GdB-TdB;//Figure of merit of earth station in dB

//OUTPUT
mprintf('\nFigure of merit of earth station is MdB=
    %2.0f dB',MdB);

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

Scilab code Exa 10.8 CNR

```
//chapter-10 page 488 example 10.8
//==============================================================================

clc;
clear;

//For a Satellite communication link
EIRPdB=55.5;//Satellite ESM in dBW
MdB=35;//G/T ratio of earth station in dB
LfsdB=245.3//Freespace loss in dB

//CALCULATION
CNRdB=EIRPdB+MdB-LfsdB+228.6;//Carrier to Noise Ratio at the earth station receiver in dB

//OUTPUT
mprintf('\nCarrier to Noise Ratio at the earth station receiver is CNRdB=%2.1f dB',CNRdB);

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

Scilab code Exa 10.9 system noise temperature

```
//chapter-10 page 489 example 10.9
//==============================================================================

clc;
clear;

D=30;//Diameter of a dish antenna with circular
```

```
aperture in m
f=4*10^9;//down link frequency in Hz
MdB=20;//G/T ratio of earth station in dB
c=3*10^8;//Velocity of light in m/sec

//CALCULATION
A=((%pi)/4)*D^2;//area in sqm
w=c/f;//wavelength in m
G=(4*(%pi)*A)/w^2;//Gain
GdB=10*log10(G);//Gain in dB
TsdB=GdB-MdB;//The System Noise Temperature in dB

//OUTPUT
mprintf('\nThe System Noise Temperature is TsdB=%2.2f dB',TsdB);

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

Scilab code Exa 10.10 HPBW

```
//chapter-10 page 489 example 10.10
//==============================================================================

clc;
clear;

//For a parabolic antenna
Gp=1500;//Power gain
w=0.1;//wavelength in m

//CALCULATION
D=sqrt(Gp)*(w/(%pi));//Diameter of the circular mouth of a parabolic antenna in m
```

```
HPBW=58*(w/D);//Half Power BeamWidth of the antenna in deg

//OUTPUT
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);

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

Scilab code Exa 10.11 gain

```
//chapter-10 page 490 example 10.11
//==============================================================================

clc;
clear;

D=1;//Assume diameter of the parabolic reflectors in the original system in m
w=1;//Assume wavelength in m

//CALCULATION
D1=2*D;//diameter of the parabolic reflectors in the modified system in m
G=6*(D/w)^2;//gain in original system
G1=6*(D1/w)^2;//gain in modified system
GdB=10*log10(G1/G);//Overall gain that can be expected in dB
GdBo=2*GdB;//Overall gain of the system(combining the two antennas one at the Tx and other at the Rx) in dB
```

```
//OUTPUT
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 GdBo=%1.0f dB',GdB,GdBo);

//==========================================END OF PROGRAM==========================================

//Note: Check the answer once ..it should be GdB=10 log(4)=6 dB and GdBo=12dB
```

Scilab code Exa 10.12 gain

```
//chapter-10 page 490 example 10.12
//==============================================================================

clc;
clear;

D=3;//dimension of a paraboloid in m
f=3*10^9;//frequency (S band) in Hz
c=3*10^8;//Velocity of light in m/sec

//CALCULATION
w=c/f;//wave length in m
BWFN=140*(w/D);//BeamWidth between First Nulls in deg
BWHP=70*(w/D);//BeamWidth between HalfPower points in deg
G=6*(D/w)^2;//Gain of the antenna

//OUTPUT
```

```
mprintf('\nBeamWidth between First Nulls is BWFN=%1
    .2f deg \nBeamWidth between HalfPower points is
    BWHP=%1.2f deg \nGain of the Antenna is G=%4.0f '
    ,BWFN,BWHP,G);

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

Scilab code Exa 10.13 power gain

```
//chapter-10 page 490 example 10.13
//
    ================================================================================

clc;
clear;

l=1;//(Assume)-dimension(wavelength) in cm

//CALCULATION
x=5*l;//given square aperture of an optimum horn
    antenna as a side dimension in cm
A=x*x;//Area in sq.cm
Gp=4.5*(A/l^2);//Power gain of an optimum horn
    antenna

//OUTPUT
mprintf('\nPower gain of an optimum horn antenna is
    Gp=%3.1f ',Gp);

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

Chapter 11

Radars

Scilab code Exa 11.1 max range

```
//chapter-11 page 504 example 11.1
//==============================================================================

clc;
clear;

//For a radar system
Pt=600000;//peak pulse power in W
Smin=10^(-13);//minimum detectable signal in W
Ae=5;//cross sectional area of the radar antenna in
    sq m
w=0.03;//wavelength in m
s=20;//radar cross sectional area in sq m

//CALCULATION
Rmax=(((Pt*s*Ae^2)/(4*(%pi)*Smin*w^2))^(1/4))/1000;
    //Maximum range of a radar system in km
RMax=Rmax/1.853;//In nautical miles; 1 nm=1.853 km

//OUTPUT
```

```
mprintf('\nMaximum range of a radar system is Rmax=%3.3f km',Rmax);
disp('In nautical miles; 1 nm=1.853 km');
mprintf('\nMaximum range of a radar system in nautical miles is RMax=%3.0f nm',RMax);

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

Scilab code Exa 11.2 max range

```
//chapter-11 page 504 example 11.2
//==============================================================================

clc;
clear;

//For a radar system
Pt=250000;//peak transmitted power in W
G=2500;//power gain of the antenna
Smin=10^(-14);//minimum detectable signal in W
Ae=10;//cross sectional area of the radar antenna in sq m
f=10*10^9;//frequency of radar in Hz
s=2;//radar cross sectional area in sq m
c=3*10^8;//Velocity of light in m/sec

//CALCULATION
w=c/f;//wavelength in m
Rmax=(((Pt*G*Ae*s)/(Smin*(4*(%pi))^2))^(1/4))/1000;//Maximum range of a radar system in km

//OUTPUT
mprintf('\nMaximum range of a radar system is Rmax=
```

```
%3.2f km',Rmax);

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

Scilab code Exa 11.3 RCS

```
//chapter-11 page 504 example 11.3
//==============================================================================

clc;
clear;

//For a marine radar system
Pt=250000;//peak transmitted power in W
G=4000;//power gain of the antenna
R=50000;//maximum range of radar in m
Pr=10^(-11);//minimum detectable signal in W
f=10*10^9;//frequency of radar in H
c=3*10^8;//Velocity of light in m/sec

//CALCULATION
w=c/f;//wavelength in m
Ae=((G*w^2)/(4*(%pi)));//cross sectional area of the radar antenna in sq m
s=((Pr*(4*(%pi)*R^2)^2)/(Pt*G*Ae));//The cross section of the target the radar can sight in sq m

//OUTPUT
mprintf('\nThe cross section of the target the radar can sight is s=%2.2f sq m',s);

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

Scilab code Exa 11.4 Duty cycle and etc

```
//chapter-11 page 505 example 11.4
//==============================================================================
clc;
clear;

//For a guided missile tracking radar
Pt=400000;//transmitted power in W
prf=1500;//pulse repitition frequency in pps(pulse per sec)
tw=0.8*10^(-6);//pulse width in sec
c=3*10^8;//Velocity of light in m/sec

//CALCULATION
Runamb=(c/(2*prf))/1000;//Unambiguous range in km
dc=tw/(1/prf);//Duty cycle
Pav=Pt*dc;//Average power in W
n1=1;
BW1=(n1/tw)/10^6;//Suitable BW in MHz for n=1
n2=1.4;
BW2=(n2/tw)/10^6;//Suitable BW in MHz for n=1.4

//OUTPUT
mprintf('\nUnambiguous range is Runamb=%3.0f km \nDuty cycle is dc=%1.4f \nAverage power is Pav=%3.0f W',Runamb,dc,Pav);
disp('For efficiency n=1,suitable bandwidth in MHz is');
disp(BW1);
disp('For efficiency n=1.4,suitable bandwidth in MHz is');
```

```
disp(BW2);

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

Scilab code Exa 11.5 max range

```
//chapter-11 page 505 example 11.5
//
==============================================================================

clc;
clear;

//For a military radar
Pt=2500000;//power output in W
f=5*10^9;//frequency of radar in H
c=3*10^8;//Velocity of light in m/sec
D=5;//antenna diameter in m
B=1.6*10^6;//receiver bandwidth in Hz
s=1;//radar cross sectional area in sq m
NF=12;//noise figure in dB

//CALCULATION
w=c/f;//wavelength in m
F=10^(NF/10);//noise figure
Rmax=(48*((Pt*s*D^4)/(B*(F-1)*w^2))^(1/4));//Maximum
    detection range in km

//OUTPUT
mprintf('\nMaximum detection range of a radar is
    Rmax=%3.0f km',Rmax);

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

Scilab code Exa 11.6 factor

```
//chapter-11 page 506 example 11.6
//==============================================================================
clc;
clear;

//For a civilian radar
Rmax=30;//maximum range in kms
x=50;
y=2;
disp('Maximum range with an equivalent echoing area of 50 times in kms is');
R=Rmax*x^(1/4);
disp(R);
disp('Range would be increased if Tx power is doubled by a factor of');
f=y^(1/4);
disp(f);

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