Scilab Textbook Companion for Modern Physics by K. S. Krane[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 1

Introduction

Scilab code Exa 1.1 Mass difference between a proton and a neutron

```
clear
clc
disp('Exa-1.1');
Mn=1.008665;Mp=1.007276
                                                //Given mass
    of an electron and a proton in terms of u
Md= Mn-Mp;

    //mass difference
printf('Mass difference in terms of U is %f ',Md);
Md=Md*931.50;
                                                            //
    converting u into Mev/c^2 by multiplying by 931.5
     MeV/c^2
printf('which equals %.3f Mev/c^2.',Md);
```

Scilab code Exa 1.2 Total mass of proton and electron

```
clear
clc
disp('Exa-1.2');
Mp=1.007276 ; Me=5.4858*10^-4; //mass of proton and
    electron in terms of U
Mt=Mp+Me;                     //Total mass= sum of
    above masses
printf('The combined mass of an electron and a
    proton was found out to be %f U.',Mt);
```

Scilab code Exa 1.3 Value of hc

```
clear
clc
disp('Exa-1.3');
h=6.621*10^-34 ; c=2.9979*10^8;                    //
    h is in J/s and c is  in m/s
hc=h*c*((10^9)/(1.6022*10^-19));                //1e
    =1.602*10^-19 J and 1 m=10^9 nm
printf('The value of hc is %f eV.nm\n',hc);
printf('Rounding off to 4 digits , we obtain %4.f eV.
    nm.',hc);
disp('Hence zero at the end is significant.');
```

Chapter 2

The Special Theroy of Relativity

Scilab code Exa 2.1 Speed of A wrt B

```
clear
clc
disp('Exa-2.1');
v1=60; v2=40        //Velocities of cars wrt to
   observer in km/hr
vr=v1-v2;           //relative velocity
printf('The value of relative velocity is %4.f km/h.
   ',vr);
```

Scilab code Exa 2.2 Velocity of plane wrt ground

```
clear
clc
disp('Exa-2.2');
```

```
Va_w=[320 0]; Vw_g=[0 65];              //Vp/q=[X Y]=> velocity of object p wrt q along X(east) and Y(north) directions.
Va_g=Va_w + Vw_g;                       //net velocity
k=norm(Va_g);                           //magnitude
s=atan(Va_g(1,2)/Va_g(1,1))*180/%pi;    //angle in rad*180/pi for conversion to degrees
printf('The magnitude of velocity Va/g(airplane wrt ground) is %.3f Km/h at %.3f degrees north of east.',k,s);
```

Scilab code Exa 2.3 Time taken in each case

```
clear
clc
disp('Exa-2.3'); // The problem is entirely theoretical hence following the standard procedure we obtain
printf('The time required for round trip is 2*L/(c*(1-(u/c)^2)). \n');
printf('The time required to swim across and return is 2*L/(c*sqrt((1-(u/c)^2)))');
```

Scilab code Exa 2.4 Minimum speed for suvival of muons

```
clear
clc
disp('Exa-2.3');
```

```
Lo=100*(10^3);c=3*(10^8); //Given values//all the
   quantities are converted to SI units
d=2.2*(10^-6);      //time between its birth and
   decay
t=Lo/c              //where Lo is the distance from
   top of atmosphere to the Earth. c is the velocity
    of light. t is the time taken
u=sqrt(1-((d/t)^2));   // using time dilaion fromula
    for finding u where u is the minimum velocity in
    terms of c;
printf('Hence the minimum speed required is %f c.',u
   );
```

Scilab code Exa 2.5 Apparent thickness of Earth atmosphere

```
clear
clc
disp('Exa-2.5');
Lo=100*(10^3);  //Lo is converted to Km
u=0.999978;      ////u/c is taken as u since u is
   represented in terms of c.
L=Lo*(sqrt(1-u^2)); // from the length contraction
   formula
printf('Hence the apparent thickness of the Earth''s
    surface is %.2f metres.',L);
```

Scilab code Exa 2.6 Solution for a b c d e

```
clear
```

```
clc
disp('Exa-2.6(a)');
L=65; c=3*10^8;u=0.8*c;
t=L/u ;             //The value of time taken as measured by the observer
printf('The time for rocket to pass a point as measured by O is %.2e.\n',t);          //The value of time taken as measured by the observer
disp('Exa-2.6(b)');
Do=65;                              //given length
Lo= L/sqrt(1-(u/c)^2);                  //contracted length of rocket
printf('Actual length according to O is %.2f.\n',Lo);
disp('Exa-2.6(c)');
D=Do*(sqrt(1-(u/c)^2));         //contracted length of platform.
printf('Contracted length according to O'' is %.2e.\n',D);
disp('Exa-2.6(d)');
t1=Lo/u;                        //time needed to pass according to O'.
printf('Time taken according to O is %.2e.\n',t1);
disp('Exa-2.6(e)');
t2=(Lo-D)/u;                        //time intervals between the two instancs
printf('Time taken according to O'' is %.2e.\n',t2);
disp('The value of t1 and t2 did not match');
```

Scilab code Exa 2.7 Speed of missile wrt earth

```
clear
clc
```

```
disp('Exa-2.7');
v1=0.6; u=0.8; c=1; // all the values are measured in terms of c hence c=1
v= (v1+u)/(1+(v1*u/c^2));
printf('The speed of missile as measured by an observer on earth is %.2f c.',v);
```

Scilab code Exa 2.8 Speed of galaxy wrt earth

```
clear
clc
disp('Exa-2.8');
w1=600;w2=434;   // w1=recorded wavelength;w2=actual wavelength
                 // c/w1 = c/w2 *(sqrt(1-u/c)/(1+u/c))
k=w2/w1;
x=(1-k^2)/(1+k^2);          //solving for u/c
printf('The speed of galaxy wrt earth is %.2f c',x);
```

Scilab code Exa 2.9 Velocity of rocket2 wrt rocket1

```
clear
clc
disp('Exa-2.9');
v1x=0.6;v1y=0;v2x=0;v2y=.8;c=1;      // all the velocities are taken wrt c
v21x=(v2x-v1x)/(1-(v1x*v2x/c^2));    //using lorentz velocity transformation
v21y=(v2y*(sqrt(1-(v1x*c)^2)/c^2))/(1-v1y*v2y/c^2)
```

```
printf('The velocity of rocket 2 wrt rocket 1 along
    x and y directions is  %.2f c & %.2f c
    respectively',v21x,v21y);
```

Scilab code Exa 2.10 Time interval between the events

```
clear
clc
disp('Exa-2.10');
c=3*10^8;
u=0.8*c;L=65;              //all values are in terms of
     c
t=u*L/(c^2*(sqrt(1-((u/c)^2))));   //from the
    equation 2.31
printf('The time interval between the events is %e
    sec which equals %.2f usec.',t,t*10^6);
```

Scilab code Exa 2.11 momentum of proton

```
clear
clc
disp('Exa-2.11');
m=1.67*10^-27;c= 3*10^8;v=0.86*c;        //all the
    given values and constants
p=m*v/(sqrt(1-((v/c)^2)));               // in terms of
     Kgm/sec
printf('The value of momentum was found out to be %
    .3e Kg-m/sec.\n',p);
```

```
c=938;v=0.86*c;mc2=938                          // all the
   energies in MeV where mc2= value of m*c^2
pc=(mc2*(v/c))/(sqrt(1-((v/c)^2)));     //expressing
   in terms of Mev
printf('The value of momentum was found out to be %
   .2f Mev.',pc);
```

Scilab code Exa 2.12 Various energies of proton

```
clear
clc
disp('Exa-2.12');
pc=1580; mc2=938;E0=938;     // all the energies in
   MeV mc2=m*c^2 and pc=p*c
E=sqrt(pc^2+mc2^2);
printf('The relativistic total energy is %.2f MeV.\n
   ',E);          //value of Energy E
K=E-E0;                              //value of possible
   kinetic energy
printf('The kinetic energy of the proton is %.1f MeV
   .',K);
```

Scilab code Exa 2.13 Velocity and momentum of electron

```
clear
clc
disp('Exa-2.13');
E=10.51; mc2=0.511; //all the values are in MeV
p=sqrt(E^2-mc2^2);    //momentum of the electron
```

```
printf('The momentum of electron is %.1f MeV/c\n',p)
    ;
v=sqrt(1-(mc2/E)^2);   //velocity in terms of c
printf('The velocity of electron is %.4f c',v);
```

Scilab code Exa 2.14 Solution for a b

```
clear
clc
disp('Exa-2.14');
k=50;mc2=0.511*10^-3;c=3*10^8; // all the values of
    energy are in GeV and c is in SI units
v=sqrt(1-(1/(1+(k/mc2))^2));    //speed of the
    electron in terms of c
k=c-(v*c);                           //difference in
    velocities
printf('Speed of the electron as a  fraction of c is
    %.12f*10^-12.\n',v*10^12); // v=(v*10^12)
    *10^-12; so as to obtain desired accuracy in the
    result
printf('The difference in velocities is %.1f cm/s.',
    k*10^2);
```

Scilab code Exa 2.15 Rate of decrese of the mass of Sun

```
clear
clc
disp('Exa-2.15');
```

```
r=1.5*10^11; I=1.4*10^3;      //radius and intensity of sun
s=4*%pi*r^2                   //surface area of the sun
Pr=s*I                        // Power radiated in J/sec
c=3*10^8;                     //velocity of light
m=Pr/c^2                      //rate od decrease of mass
printf('The rate of decrease in mass of the sun is %.1e kg/sec.',m);
```

Scilab code Exa 2.16 Kinetic energy of pion in each case

```
clear
clc
disp('Exa-2.16');
K=325; mkc2=498;  //kinetic energy and rest mass energy of kaons
mpic=140; //given value
Ek=K+mkc2;
pkc=sqrt(Ek^2-mkc2^2);
//consider the law of conservation of energy which yields Ek=sqrt(p1c^2+mpic^2)+sqrt(p2c^2+mpic^2)
// The above equations (4th degree,hence no direct methods)can be solved by assuming the value of p2c=0.
p1c=sqrt(Ek^2-(2*mpic*Ek));
//consider the law of conservation of momentum. which gives p1c+p2c=pkc implies
p2c=pkc-p1c;
k1=(sqrt(p1c^2+(mpic^2))-mpic); //corresponding kinetic energies
k2=(sqrt((p2c^2)+(mpic^2))-mpic);
```

```
printf('The corresponding kinetic energies of the
   pions are %.0f MeV and %.1f MeV.',k1,k2);
```

Scilab code Exa 2.17 Threshold kinetic energy to produce antiprotons

```
clear
clc
disp('Ex-2.17');
mpc2=938;c=3*10^8;   //mpc2=mp*c^2,mp=mass of proton
Et=4*mpc2;           //final total energy
E1=Et/2;E2=E1;        //applying conservation of
   momentum and energy
v2=c*sqrt(1-(mpc2/E1)^2);     //lorentz
   transformation
u=v2;v=(v2+u)/(1+(u*v2/c^2));
E=mpc2/(sqrt(1-(v/c)^2));
K=E-mpc2;
printf('The threshold kinetic energy is %.3f Gev',K
   /10^3);
```

Chapter 3

Review of Electromagnetic waves

Scilab code Exa 3.1 Atomic Spacing of Nacl

```
clear
clc
disp('Exa-3.1');
w=0.250; theta=26.3;n=1 // n=1 for hydrogen atom and
    rest all are given values
d=n*w/(2*sind(theta));      // bragg's law
printf('Hence the atomic spacing is %.3f nm.',d);
```

Scilab code Exa 3.2 Time taken to release an electron

```
clear
clc
disp('Exa-3.2');
I=120;r=0.1*10^-9;Eev=2.3    //I-intensity in W/m^2 r
    in m & E in electron volt
```

```
A=%pi*r^2;K=1.6*10^-19;        // A=area and K is
    conversion factor from ev to joules
t= Eev*K/(I*A);                //time interval
printf('The value of time interval was found out to
    be %.1f sec',t);
```

Scilab code Exa 3.3 Solution for a and b

```
clear
clc
disp('Exa-3.3(a)');
w=650*10^-9;h=6.63*10^-34;c=3*10^8;   //given values
    and constant taken in comfortable units
E=h*c/w; printf('The Energy of the electron is %.3e
    J ',E);
E=E/(1.6*10^-19);printf('which is equivalent to %f
    eV\n',E);
printf('The momentum of electron is p=E/c i.e %.2f/c
     \n',E);
disp('Exa-3.3(b)');
E2=2.40;                              //given energy of
    photon.
w2=h*c*10^9/(E2*1.6*10^-19);          //converting the
    energy in to eV and nm
printf('The wavelength of the photon is %.2f nm',w2)
    ;
```

Scilab code Exa 3.4 Solution for a b and c

```
clear
clc
disp('Exa-3.4(a)');
hc=1240; phi=4.52                    //both the values
   are in eV
w1=hc/phi;
printf('The cutoff wavelength of the tungsten metal
   is %.3fnm\n ',w1);
disp('Exa-3.4(b)');
w2=198;      //given value of wavelength
Kmax=(hc/w2)-phi;printf('The max value of kinetic
   energy is %.3f eV\n',Kmax);
disp('Exa-3.4(c)');
Vs=Kmax; printf('The numerical value of the max
   kinetic energy is same as stopping potential in
   volts.Hence %.2f V',Vs);
```

Scilab code Exa 3.5 Solution for a b and c

```
clear
clc
disp('Exa-3.5(a)');
T1=293; Kw=2.898*10^-3;
w1=Kw/T1;
printf('The wavelength at which emits maximum
   radiation is %.2f um.\n',w1*10^6);
disp('Exa-3.5(b)');
w2=650*10^-9;
T2=Kw/w2;
printf('The temperature of the object must be raised
    to %.0f K.\n',T2);
disp('Exa-3.5(c)');
x=(T2/T1)^4; printf('Thus the thermal radiation at
```

```
higher temperature is %.2e times the room (lower)
 tempertaure.\n',x);
```

Scilab code Exa 3.6 Solution for a b c and d

```
clear
clc
disp('Exa-3.6(a)');
w1=0.24;wc=0.00243;theta=60;    //given values w=
   wavelength(lambeda)
w2=w1+(wc*(1-cosd(theta)));
printf('The wavelength of x-rays after scattering is
    %.4f nm\n',w2);
disp('Exa-3.6(b)');
hc=1240;
E2=hc/w2;E1=hc/w1; printf('The energy of scattered x
   -rays is %.0f eV\n',E2);
disp('Exa-3.6(c)');
K= E1-E2; //The kinetic energy is the difference in
   the energy before and after the collision;
printf('The kinetic energy of the x-rays is %.3f eV\
   n',K);
disp('Exa-3.6(d)');
phi2=atand(E2*sind(theta)/(E1-E2*cosd(theta)))
printf('The direction of the scattered eletron is %
   .1f degrees',phi2);
```

Chapter 4

The Wavelike properties of particles

Scilab code Exa 4.1 Solution for a b c d and e

```
clear
clc
disp("Ex: 4.1 ");
h=6.6*10^-34;                                   // h(
   planck's constant)= 6.6*10^-34
m1= 10^3;v1=100;;                                 // for
   automobile
w1= h/(m1*v1);                                  // ['w'-
   wavelength in metre'm'-mass in Kg 'v'-velocity in
    metres/sec.] of the particles
printf("Wavelength of the automobile is %1.2e m\n",
   w1 );
m2=10*(10^-3);v2= 500;                           // for
   bullet
w2=h/(m2*v2);
printf("Wavelength of the bullet is %1.2e m\n ",w2 )
   ;
m3=(10^-9)*(10^-3); v3=1*10^-2;
w3=h/(m3*v3);
```

```
printf("Wavelength of the smoke particle is %1.2e m\n",w3 );
m4=9.1*10^-31;k=1*1.6*10^-19;           // k-kinetic energy of the electron & using 1ev = 1.6*10^-19 joule
p=sqrt(2*m4*k);                          // p=momentum of electron ;from K=1/2*m*v^2
w4=h/p;
printf("Wavelength of the electron(1ev) is %1.2fnm\n",w4*10^9 );
hc=1240;pc=100                           // In the extreme relativistc realm, K=E=pc; Given pc=100MeV,hc=1240MeV
w5= hc/pc;
printf("Wavelength of the electron (100Mev) is %1.2f fm\n",w5);
```

Scilab code Exa 4.2 Minimum uncertainity in wavelength

```
clear
clc
disp('Ex-4.2');
// w=wavelength; consider k=2*(pi/w);
// differentiate k w.r.t w and replace del(k)/del(w) = 1 for equation.4.3
// which gives del(w)= w^2 /(2*pi*del(x)), hence
w=20; delx=200; // delx=200cm and w=20cm
delw=(w^2)/(delx*2*%pi);
printf('Hence uncertainity in length is %1.2f cm',delw);
```

Scilab code Exa 4.3 Validity of the claim

```
clear
clc
disp('Ex-4.3')
delt=1;              //consider time interval of 1
   sec
delw=1/delt;         // since delw*delt =1 from
   equation 4.4
delf=0.01            //calculated accuracy is 0.01Hz
delwc =2*%pi*delf // delwc-claimed accuracy from w
   =2*pi*f
printf('The minimum uncertainity calculated is 1rad/
   sec. The claimed accuracy is %.3f rad/sec\n',
   delwc);
if delw==delwc then disp('Valid claim');
end
if delw~=delwc then disp('Invalid claim');
end
```

Scilab code Exa 4.4 Solution for a and b

```
clear
clc
disp('Ex-4.4(a)');
m=9.11*10^-31;v=3.6*10^6; //'m','v' - mass an
   velocity of the electron in SI units
h=1.05*10^-34; //planck's constant in SI
```

```
p=m*v; //momentum
delp=p*0.01;//due to 1% precision in p
delx = h/delp//uncertainity in position
printf('Uncertainity in position is %1.2f nm',delx
    *10^9);
disp('Ex-4.4((b)')
printf('Since the motion is strictly along X-
    direction , its velocity in Y direction is
    absolutely zero.\n So uncertainity in velocity
    along y is zero=> uncertainity in position along
    y is infinite. \nSo nothing can be said about its
     position/motion along Y')
```

Scilab code Exa 4.5 Solution for a and b

```
clear
clc
disp('Ex-4.5(a)');
m=0.145;v=42.5; //'m','v' - mass an velocity of the
    electron in SI units
h=1.05*10^-34; //planck's constant in SI
p=m*v; //momentum
delp=p*0.01;//due to 1% precision in p
delx = h/delp//uncertainity in position
printf('Uncertainity in position is %1.2e',delx);
disp('Ex-4.5(b)');
printf('Motion along y is unpredictable as long as
    the veloity along y is exactly known(as zero).');
```

Scilab code Exa 4.6 Uncertainity in x component

```
clc
clear
disp('Ex-4.6')
printf('The uncertainity in the poisition of electron after it passes through the slit is reduced to width of the slit\n delx=a\n');
printf('The uncertainity in momentum = h/a\n');
printf('Position of landing(angle t) = sin t = tan t = delz/dely =(h/a)/2*pi*a= w/2*pi*a \nwhere w=wavelenghth\n');
printf('Rewriting the above expression a*sint = w/(2*pi)\n which is similar to a*sint = w (neglect 2*pi)as found out by first minimum in diffraction by a slit of width a');
disp('It proves a close connection between wave behaviour and uncertainity principle');
```

Scilab code Exa 4.7 Range of kinetic energy of an electron

```
clear
clc
disp('Ex-4.7');
mc2=2.15*10^-4;            //mc2 is the mass of the electron, concidered in Mev for the simplicity in calculations
hc=197                     // The value of h*c in Mev.fm for simplicity
delx= 10                   // Given uncertainity in position=diameter of nucleus= 10 fm
delp= hc/delx ;            //Uncertainiy in momentum per unit 'c' i.e (Mev/c) delp= h/delx =(h*c)/(c*delx)
```

```
    ;hc=197 Mev.fm  1Mev=1.6*10^-13 Joules')
p=delp;                    // Equating delp to p  as a
    consequence of equation 4.10
K1=[[p]^2]+[mc2]^2   // The following 3 steps are
    the steps invlolved in calculating K.E= sqrt((p*c
    )^2 + (mc^2)^2)- m*c^2
K1=sqrt(K1)
K1= K1-(mc2);
printf('Kinetic energy was found out to be %d Mev',
    K1)
```

Scilab code Exa 4.8 Solution for a b and c

```
clear
clc
disp('Ex-4.8')
h=6.58*10^-16; // plack's constant
delt1=26*10^-9;E=140*10^6 //given values of lifetime
     and rest energy of charged pi meson
delE=h/delt1; k=delE/E;  // k is the measure of
    uncertainity
printf('Uncertainity in energy of charged pi meson
    is %1.2e\n',k);
delt2=8.3*10^-17;E=135*10^6;  //given values of
    lifetime and rest energy of uncharged pi meson
delE=h/delt2; k=delE/E;
printf('Uncertainity in energy of uncharged pi meson
     is %1.2e\n',k);
delt3=4.4*10^-24;E=765*10^6;        //given values of
     lifetime and rest energy of rho meson
delE=h/delt3; k=delE/E;
printf('Uncertainity in energy of rho meson is %.1f\
    n',k);
```

Scilab code Exa 4.9 minimum velocity of the billiard ball

```
clear
clc
disp('Ex-4.9')
h=1.05*10^-34;   //value of planck's constant in J.
    sec
delx= 1;         // uncertainity in positon=
    dimension of the ball
delp=h/delx;     // uncertainity in momentum
m=0.1;           //mass of the ball in kg
delv=delp/m;     // uncertainity in velocity
printf('The value of minimum velocity was found out
    to be %1.2e m/sec',delv);
```

Scilab code Exa 4.10 Group velocity of a wave packet in terms of phase velocity

```
clc
clear
disp('Ex-4.10');
printf(' Group velocity is found out from Eq. 4.18.\
    n Since k=2*pi/w ; Vphase= w/k \n w/k = sqrt(g/k)
     /n w=sqrt(g*k)');
printf('\ndifferetiating on both sides\n');
printf('dw=1/2 * sqrt(g) * k^-1/2 * dk\n dw= 1/2 *
    sqrt(g/k)\n Hence Vgroup= Vphase/2');
```

Chapter 5

The Schrodinger Equation

Scilab code Exa 5.1 Displacement and velocity of the object

```
clear
clc
disp('Exa-5.1');//The solution involves very complex
    symbolic equation solving and approximations.
   Hence only answers are displayed
printf('The displacement and velocity of the ball
   are found out in 2 steps\n step1-before reaching
   the surface of water and \n step2-Inside water
   till it rises back to surface\n');
printf('The values are as follows: v1(t)=-g*t and y1
   (t)=H-((g/2)*t^2))\n');
printf('In region 2: v2(t)=(-B/m*sqrt(2*H/g))+(B/m-g
   )*t; y2(t)= H+ HB/mg -B/m*sqrt(2*H/g)+ (B/m-g)');
```

Scilab code Exa 5.2 Solution for a and b

```
clear
```

```
clc
disp('Exa-5.2(a)');
h=1.05*10^-34;m=9.11*10^-31;L=10^-10;        // all
   the values are taken in SI units
E1=h^2*%pi^2/(2*m*L^2); E2=4*E1;              //
   Energies are calculated
delE=(E2-E1)/(1.6*10^-19);                    //
   Difference in energy is converted to eV
printf('Energy to be supplied is %.0f eV.\n',delE);
disp('Exa-5.2(b)');
x1=0.09*10^-10;x2=0.11*10^-10                  //
   limits of the given region
probGnd=(2/L)*integrate('(sin(%pi*x/L)^2)','x',x1,x2
   );
printf('The percentage probablility of finding an
   electron in the ground state is %.2f.\n',probGnd
   *100);
disp('Exa-5.2(c)');
x1=0,x2=0.25*10^-10;
probExc=(2/L)*integrate('(sin(2*%pi*x/L)^2)','x',x1,
   x2);
printf('The probablility of finding an electron in
   the excited state is %.2f.\n',probExc);
```

Scilab code Exa 5.3 Proof for average value of x

```
clear
clc
disp('Ex-5.3');
 L = 1 *10^-10;
x1=0;x2=L;
xavg=(2/L)*integrate('sin(%pi*x/L)^2','x',x1,x2);
printf('The average value of x is found out to be L
```

```
/2 which apparently is independent of Qunatum
state.');
```

Chapter 6

The Rutherford Bohr model of an atom

Scilab code Exa 6.1 Average deflection angle per collision

```
clear
clc
disp('Exa-6.1');
R=0.1;Z=79; x=1.44;             //x=e^2/4*pi*epsi0
zkR2=2*Z*x/R                   // from zkR2= (2*Z*e^2)*
    R^2/(4*pi*epsi0)*R^3
mv2=10*10^6;                   //MeV=>eV
theta=sqrt(3/4)*zkR2/mv2;        //deflection angle
theta=theta*(180/%pi);          //converting to
    degrees
printf('Hence the average deflection angle per
    collision is %.2f degrees.',theta);
```

Scilab code Exa 6.2 Solution for a and b

```
clear
clc
disp('Exa-6.2(a)');
Na=6.023*10^23;p=19.3;M=197;
n=Na*p/M;          //The number of nuclei per atom
t=2*10^-6;Z=79;K=8*10^6;x=1.44; theta=90;   //x=e
   ^2/4*pi*epsi0
b1=t*Z*x*cotd(theta/2)/(2*K)          //impact
   parameter b
f1=n*%pi*b1^2*t                        //scattering
   angle greater than 90
printf('The fraction of alpha particles scattered at
    angles greater than 90 degrees is %.2e\n',f1);
disp('Exa-6.2(b)');
theta=45
b2=t*Z*x*cotd(theta/2)/(2*K);
f2=n*%pi*b2^2*t;                    //scattering angle
    greater than 45
fb=f2-f1                          //scattering angle
   between 45 to 90
printf('The fraction of particles with scattering
   angle from 45 to 90 is %.3e\n',fb);
```

Scilab code Exa 6.3 Distance of closest approach

```
clear
clc
disp('Exa-6.3');
Z=79;x=1.44;K=8*10^6;z=2;      //where x=e^2/4*pi*
   epsi0;z=2 for alpha particles
d=z*x*Z/K;                     //distance
printf('The distance of closest approasch is %.2e nm
   .',d*10^-9)
```

Scilab code Exa 6.4 Three longest wavelengths of the Paschen series

```
clear
clc
disp('Exa-6.4');
sl=820.1;n0=3;  //given values
n=4;w=sl*(n^2/(n^2-n0^2)); printf('The 3 longest
   possible wavelengths are %.0f nm,',w);
n=5;w=sl*(n^2/(n^2-n0^2)); printf('%.0f nm,',w);
n=6;w=sl*(n^2/(n^2-n0^2)); printf('& %.0f nm ',w);
```

Scilab code Exa 6.5 Various wavelegths in Balmer and Lymann series

```
clear
clc
disp('Exa-6.5');
sl=364.5;n=3;            //given variables and
   various constants are declared in the subsequent
   steps wherever necessary
w1=sl*(n^2/(n^2-4));      //longest wavelength of
   balmer
c=3*10^8;
f1=c/(w1*10^-9);          //corresponding freq.
n0=1;n=2;
w2=91.13*(n^2/(n^2-n0^2)); //first longest of lymann
f2=c/(w2*10^-9);           //correspoding freq
n0=1;n=3
```

```
w3=91.13*(n^2/(n^2-n0^2));        //second longest of
   lymann
f3=3*10^8/(w3*10^-9)               //corresponding
   freq.
printf('The freq. corresponding to the longest
   wavelength of balmer is %e & First longest
   wavelength  of Lymann is %e.\n',f1,f2);
printf('The sum of which s equal to %e\n',f1+f2);
printf('The freq. corresponding to 2nd longest
   wavelength was found out to be %e\n.Hence Ritz
   combination principle is satisfied.',f3);
```

Scilab code Exa 6.6 `wavelengths of transition`

```
clear
clc
disp('Exa-6.6');
Rinfi=1.097*10^7;   //known value
n1=3;n2=2;          //first 2 given states
w=(n1^2*n2^2)/((n1^2-n2^2)*Rinfi);printf('Wavelength
    of trnasition from n1=3 to n2=2 is %.3f nm\n',w
   *10^9);
n1=4;n2=2;          //second 2 given states
w=(n1^2*n2^2)/((n1^2-n2^2)*Rinfi);printf('Wavelength
    of trnasition from n1=3 to n2=2 is %.3f nm',w
   *10^9);
```

Scilab code Exa 6.7 `Two longest wavelengths of triply ionized beryllium`

```
clear
clc
disp('Exa-6.7');
n1=3;n2=2;Z=4;hc=1240;
delE=(-13.6)*(Z^2)*((1/(n1^2))-((1/n2^2)));
w=(hc)/delE; //for transition 1
printf('The wavelngth of radiation for transition
   (2->3) is %f nm\n',w);
n1=4;n2=2;    // n values for transition 2
delE=(-13.6)*(Z^2)*((1/n1^2)-(1/n2^2));
w=(hc)/delE;
printf('The wavelngth of radiation emitted for
   transition(2->4) is %f nm',w);
```

Chapter 7

The Hydrogen atom in wave mechanics

Scilab code Exa 7.1 Proof

```
clear
clc
disp('Exa-7.1'); //The problem is entirely theoretcial.
printf('The solution obtained is r=4*ao i.e the most likely distance from origin for an electron in n=2,l=1 state.');
```

Scilab code Exa 7.2 Probability of finding an electron closer to nucles than Bohrs

```
clear
clc
disp('Exa-7.2');
// calculating radial probability P= (4/ao^3)*
```

```
   inegral(r^2 * e^(-2r/ao)) between the limits 0
   and ao for r
Pr=integrate('((x^2)*%e^(-x))/2','x',0,2);//
   simplifying where as x=2*r/a0; hence the limits
   change between 0 to 2
printf('Hence the probability of finding the
   electron nearer to nucleus is %.3f',Pr);
```

Scilab code Exa 7.3 Probability of finding an electron inisde Bohr Radius

```
clear
clc
disp('Exa-7.3');
//for l=0;
// employing the formula for probability
   distribution similarly as done in Exa-7.2
Pr1= integrate('(1/8)*((4*x^2)-(4*x^3)+(x^4))*%e^(-x
   )','x',0,1);              //x=r/ao; similrly limits
   between 0 and 1.
Pr2=integrate('(1/24)*(x^4)*(%e^-x)','x',0,1);
                                         //x=r/ao; similrly
   limits between 0 and 1.
printf('The probability for l=0 electron is %.3f and
    for l=1 electron is %.4f.',Pr1,Pr2);
```

Scilab code Exa 7.4 Length of angular momentum vectors

```
clear
clc
```

```
disp('Exa-7.4');
l=1;            //given value of l
am1=sqrt(l*(l+1));        //angular momentum==sqrt(l(l
    +1)) h
l=2                          //given l
am2=sqrt(l*(l+1));
printf('The angular momenta are found out to be %.3f
     h and %.3f h respectively for l=1 and l=2.',am1,
    am2);
```

Scilab code Exa 7.5 `possible Z components of the vector L`

```
clear
clc
disp('Exa-7.5'); //Thoretical question
disp('The possible values for m are [+2,-2] and
    hence any of the 5 components [-2h,2h] are
    possible for the L vector.');
printf('Length of the vector as found out previously
     is %.2f*h.',sqrt(6));//angular momentum==sqrt(l(
    l+1)) h
```

Scilab code Exa 7.6 `Seperation of beams as they leave the magnet`

```
clear
clc
disp('Exa-7.6');
uz=9.27*10^-24; t=1.4*10^3; x=3.5*10^-2;      //
    various constants and given values
```

```
m=1.8*10^-25;v=750;                          // mass and velocity of the particle
d=(uz*t*(x^2))/(m*(v^2));                    //net separtion
printf('The distance of separation is %.2f mm',d*10^3);
```

Scilab code Exa 7.7 `Change in wavelength`

```
clear
clc
disp('Exa-7.7');
n1=1;n2=2;hc=1240;     //hc=1240 eV.nm
E=(-13.6)*((1/n2^2)-(1/n1^2));    //Energy calcuation
w=hc/E;                           //wavelength
u=9.27*10^-24; B=2;                 //constants
delE= u*B/(1.6*10^-19);       //change in energy
delw=((w^2/hc))*delE;                   //change in wavelength
printf('The change in wavelength is %.5f nm.',delw);
```

Chapter 8

Many Electron Atoms

Scilab code Exa 8.1 Energy of Ka X ray of sodium

```
clear
clc
disp('Exa-8.1');
hc=1240*10^-9;Rinfi=1.097*10^7;Z=11;   //for sodium
   atom;and other constants in MeV
delE=3*hc*Rinfi*(Z-1)^2/4                //change in
   energy
printf('The energy of the Ka x-ray of the sodium
   atom is %.3f KeV.',delE/10^3);
```

Scilab code Exa 8.2 Solution for a and b

```
clear
clc
disp('Exa-8.2(a)');
EKa=21.990;EKb=25.145;EK=25.514
                                          //all the
```

```
    values are in KeV
ELo=EKb-EKa;printf('The enrgy of La of X-ray is %.3
    fKeV.\n',ELo);              //Energy of La X-ray
disp('Exa-8.2(b)');
EL=-EK+EKa;printf('Hence the binding energy of the L
     electon is %.3fKeV.',EL); // for electron L
    electron
```

Scilab code Exa 8.3 Total orbital and spin quantum numbers of carbon

```
clear
clc
disp('Exa-8.3'); // theoretical
l=1; Lmax=l+l;Lmin=l-l;printf('Value of L ranges
    from %d to %d i.e %d %d %d\n.',Lmin,Lmax,Lmin,1,
    Lmax);
s=1/2; Smax=s+s;Smin=s-s;printf('Values of S are %d
    &%d',Smax,Smin);
```

Scilab code Exa 8.4 Total orbital and spin quantum numbers of nitrogen

```
clear
clc
disp('Exa-8.4');
l=1; Lmax=l+l;Lmin=l-l;printf('Considering any two
    electrons,Value of L2e ranges from %d to %d i.e
    %d %d %d.\n',Lmin,Lmax,Lmin,1,Lmax);
printf('Adding the angular momentum of the third
    electron to L2emax gives the maximum  whole
```

```
   angular momentum as 2+1=3; and subtracting it
   from L2e=1 gives 0\n')
s=1/2; Smax=s+s;Smin=s-s;printf('Values of S2e are
   %d &%d.\n',Smax,Smin);
printf('Adding and subtracting the spin of third to
   S2e=1 and S2e=0 respectively gives the spins 3/2
   and 1/2 for the 3 electron system.');
```

Scilab code Exa 8.5 Hunds rule to find ground state quantum numbers of nitrogen

```
clear
clc
disp('Exa-8.5');
disp('The nitrogen atom has a configuration of 1s2,2
   s2,2p3.');
disp('Let us maximize the net spin of all the 3
   electrons by assigning a spin of 1/2 to each of
   them. Hence S=3/2.');
disp('To maximize Ml,the consistent values of L for
   the 3 electrons left are 1 -1 and 0.Thus L=0 & S
   =3/2 are the ground state quantum numbers for
   nitrogen.');
```

Scilab code Exa 8.6 Ground state L and S of oxygen

```
clear
clc
disp('Exa-8.6');
```

```
disp('The Oxygen atom has a configuration of 1s2,2s2
    ,2p4. 4 electrons in the outer most shell.');
disp('Let us maximize the net spin  by assigning a
    spin of 1/2 to 3 of them but the fourth should
    have spin of -1/3. Hence S=3/2-1/2=1.');
disp('The consistent values of L for the 3 electrons
     are 1 -1 and 0.To maximize Ml, assign a L 0f +1
    to the fourth electron.Thus L=1 & S=1 are the
    ground state quantum numbers for Oxygen.');
```

Chapter 9

Molecular Structure

Scilab code Exa 9.1 Charge on the sphere

```
clear
clc
disp('Ex-9.1');
E=-2.7;
K=9*(10^9)*((1.6*(10^-19))^2)/(0.106*10^-9);//
   taking all the values in meters. 1/(4*pi*e0)=
   9*10^9 F/m
q=((K-E*10^-9)/(4*K))*10^-9;                    //
   balancin by multiplying 10^-9 on numerator. to eV
   .vm terms
printf('Charge on the sphere required is %.2f times
   the charge of electron.',q);
```

Scilab code Exa 9.2 Solution for a and b

```
clear
clc
```

```
disp('Exa-9.2(a)');
K=1.44; Req=0.236; // K=e^2/(4*pi*e0)=1.44 eV.nm
Uc=-K/(Req);          //coulomb energy
printf('The coulomb energy at an equilirium
   separation distance is %.2f eV\n',Uc);
E=-4.26; delE=1.53;     //various standars values of
   NaCl
Ur=E-Uc-delE;
printf('The pauli''s repulsion energy is %.2f eV\n',
   Ur);
disp('Exa-9.2(b)');
Req=0.1;          //pauli repulsion energy
Uc=-K/(Req);
E=4; delE=1.53;
Ur=E-Uc-delE;
printf('The pauli''s repulsion energy respectively
   is is %.2f eV\n',Ur);
```

Scilab code Exa 9.3 `vibrational frequency and photon energy of H2`

```
clear
clc
disp('Exa-9.3');
delE=0.50; delR=0.017*10^-9;       //delE= E-Emin;
   delR=R-Rmin;
k=2*(delE)/(delR^2);c=3*10^8;      //force constant
m=(1.008)*(931.5*10^6)*0.5;        //mass of
   molecular hydrogen
v= sqrt(k*c^2/m)/(2*%pi);           //vibrational
   frequency
h=4.14*(10^-15);
E=h*v;
printf('The value of corresponding photon energy is
```

```
%.2f eV',E);
```

Scilab code Exa 9.4 Energies and wavelengths of 3 lowest radiations emitted by mol

```
clear
clc
disp('Exa-9.4');
hc=1240;          //in eV.nm
m=0.5*1.008*931.5*10^6;                //mass of hydrogen atom
Req=0.074;                             //equivalent radius
a=((hc)^2)/(4*(%pi^2)*m*(Req^2));  //reduced mass of hydrogen atom
for L=1:3,
        delE= L*a; printf('The value of energy is %f eV\n',delE);
        w=(hc)/delE;printf('The respective wavelength is is %f um\n',w*10^-3);
end
```

Scilab code Exa 9.5 Rotational Inertia of molecule

```
clear
clc
disp('Exa-9.5');
delv=6.2*(10^11);      //change in frequency
h=1.05*(10^-34);         //value of h in J.sec
I= h/(2*%pi*delv);       //rotational inertia
```

```
printf('The value of rotational inertia is %.2e kg
    m2 ',I);
I=I/(1.684604e-045);
printf('which in terms of amu is %.3f u.nm2',I);
```

Scilab code Exa 9.6 Solution for a and b

```
clear
clc
disp('Ex-9.6(a)');
delE=0.358;hc=4.14*10^-15;           //hc in eV.nm
    and delE=1.44eV(given values)
f=(delE)/hc;                         //frequency
printf('The frequency of the radiation is %.3e.\n',f
    );
m=0.98;                              //mass in terms
    of u
k=4*%pi^2*m*f^2;                     //value of k in
    eV/m^2
printf('The force constant is %.3e.\n',k);
disp('Ex-9.6(b)');
hc=1240; m=0.98*1.008*931.5*10^6; Req=0.127;       //
    various constants in terms of
s=((hc)^2)/(4*(%pi^2)*m*(Req^2));                 //
    expeted spacing
printf('The spacing was found out to be %f which is
    very close to the graphical value of 0.0026 eV.',
    s);
```

Chapter 10

Statistical Physics

Scilab code Exa 10.1 Various Speeds obtained from maxwell speed distribution

```
clear
clc
disp('Exa-10.1'); //Theoretical Question
//**Install and use maxim tool for symbolic
   integration. remove the '//'(comment markings)
   below and run the program.
//Vm=integrate('(v^3)*(e^(-b*v^2))','x',0,%infi);
//rest of the results follow from above
printf('The average speed is found out to be (8*k*T/
   m)^1/2)\n');
printf('The RMS speed is (3*k*T/m)^1/2\n');
printf('The Most probable speed is found out to be
   (2*k*T/m)^1/2 \n where all the symbols used are
   conventional constants.');
```

Scilab code Exa 10.2 Frequency distribution of emitted light

```
clear
clc
disp('Exa-10.2');         //The solution is purely
    theoretical and involves a lot of approximations.
printf('The value of shift in frequency was found
    out to be delf=7.14*fo*10^-7*sqrt(T) for a star
    composing of hydrogen atoms at a temperature T.\n
    ');
T=6000;                              //temperature for sun
delf=7.14*10^-7*sqrt(T);.....//change in frequency
printf('The value of frequency shift for sun(at 6000
     deg. temperature) comprsing of hydrogen atoms is
     %.1e times the frequency of the light.',delf);
```

Scilab code Exa 10.3 Solution for a and b

```
clear
clc
disp('Exa-10.3(a)');
kT=0.0252;E=10.2                                    // at
    room temperature, kT=0.0252 standard value and
    given value of E
n2=2;n1=1; g2=2*(n2^2);g1=2*(n1^2);                //
    values for ground and excited states
t=(g2/g1)*%e^(-E/kT);                              //
    fraction of atoms
printf('The number of hydrogen atoms required is %e
    which weighs %e Kg\n',1/t,(1/t)*(1.67*10^-27));
disp('Ex-10.3(b)');
t=0.1/0.9;k=8.65*10^-5                               //
    fracion of atoms in case-2 is given
T=-E/(log(t/(g2/g1))*k);                             //
    temperature
```

```
printf('The value of temperature at which 1/10 atoms
    are in excited state is %.3f K',T);
```

Scilab code Exa 10.4 Solution for a and b

```
clear
clc
disp('Exa-10.4(a)'); //theoretical
printf('The energy of interaction with magnetic
   field is given by uB and the degeneracy of the
   states are +-1/2 which are identical.\nThe ratio
   is therefore pE2/pE1 which gives e^(-2*u*B/k*T)')
   ;
disp('Ex-10.4(b)');
uB=5.79*10^-4;          //for a typical atom
t=1.1;k=8.65*10^-5;     //ratio and constant k
T=2*uB/(log(t)*k);      //temperature
printf('The value of temperature ar which the given
   ratio exists is %.2f K',T);
```

Scilab code Exa 10.5 Fermi Energy Ef for sodium

```
clear
clc
disp('Exa-10.5');
p=0.971; A=6.023*10^23; m=23.0;     // various given
   values and constants
c= (p*A/m)*10^6;                    // atoms per unit
    volume
```

```
hc=1240; mc2=0.511*10^6;          // hc=1240 eV.nm
E= ((hc^2)/(2*mc2))*(((3/(8*%pi))*c)^(2/3)); //value
    of fermi energy
printf('The fermi energy for sodium is %f eV',E
   *10^-18);//multiply by 10^-18 to convert metres^2
    term to nm^2
```

Chapter 11

Properties of Ionic Crystals

Scilab code Exa 11.1 `Solution for a and b`

```
clear
clc
disp('Exa-11.1(a)');
c=769*10^3; Na=6.023*10^23; JeV=1.6*10^-19; //various constants and given values
Be=c/(Na*JeV);          //Binding energy of an ion pair in the lattice
printf('The experimental value was found out to be %.4f eV.\n',Be);
disp('Exa-11.1(b)');
n=9;a=1.7476; R=0.281; k= 1.44;      //Given values and consstants
Bc=k*a*(1-(1/n))/R;                  //ionic binding energy eperimentally
printf('The calculated value of the binding energy is %.4f eV.',Bc);
```

Scilab code Exa 11.2 Energy per neytral atom to take apart a crystal of Nacl

```
clear
clc
disp('Exa-11.2');
a=3.61;// amount of energy required to remove an
    electron from Cl- ion
b=-5.14 //amount of energy returned when an electron
     is added to Na+ ion\
c=7.98 //binding energy of NaCl atom
E=a+b+c  //suom of all the energies
printf('The net energy to be supplied is %.3f eV',E)
    ;
```

Scilab code Exa 11.3 Solution for a and b

```
clear
clc
disp('Ex-11.3(a)');
Na=6.023*10^23; p=8.96*10^3; M=63.5*10^-3;   //Na=
    avagadro's number,p=density,M=molar mass
n= p*Na/M;                                   //
    density of charge carriers
printf('The density of charge carriers in copper is
    %e atoms/m3\n',n);
s=5.88*10^7;m=9.11*10^-31;e=1.6*10^-19;     //charge
    & mass of an electron,resistance per unit length
t= s*m/(n*e^2);                              //average
     time between collisions
printf('The average time between collisions of
    conducting electrons is %e sec.\n',t);
disp('Ex-11.3(b)');
Ef=7.03*1.6*10^-19;              //converting given
```

```
    enrgy to J
Vf=sqrt(2*Ef/m);                        //fermi velocity
l=Vf*t;                                //mean free path
printf('The average mean free path is %e m = %.1f nm
    ',l,l*10^9);
```

Chapter 12

Nuclear Structure and Radioactivity

Scilab code Exa 12.1 Solution for a and b

```
clear
clc
disp('Exa-12.1(a)');
Z=2;A=4;N=A-Z;           // Given values
printf('The following method of representing atoms is followed throughout the chapter\n\t\t x,ySz\n where x=atomic number y=mass number z= Neutron Number S=symbol of the atom\n\n')
printf('The helium can be reperesented as %d,%dHe%d\n',Z,A,N);
disp('Exa-12.1(b)');
Z=50;N=66;A=Z+N;         //// Given values and standard formulae
printf('The helium can be reperesented as %d,%dSn%d\n',Z,A,N);
disp('Exa-12.1(c)');
A=235;N=143;Z=A-N;
printf('The helium can be reperesented as %d,%dU%d',Z,A,N);
```

Scilab code Exa 12.2 Approximate nuclear radii

```
clear
clc
disp('Exa-12.2');
r0=1.2;           //standard value.
A=12;
r= r0*A^(1/3);printf('The value of mean radius for C is: %.2f fm\n',r);
A=70;          //given value
r= r0*A^(1/3);printf('The value of mean radius for C is: %.2f fm\n',r);
A=209;
r= r0*A^(1/3);printf('The value of mean radius for C is: %.2f fm',r);
```

Scilab code Exa 12.3 Density of typical nucleus and resultant mass

```
clear
clc
disp('Exa-12.3');
m=1.67*10^-27; r0=1.2*10^-15; v=4*%pi*(r0^3)/3   //standard values of mass radius and volume
p=m/v;                                                                  //denisty
printf('Density of typical nucleus is %.0e kg/m3 \n',p);
```

```
r0=0.01;v=4*%pi*(r0^3)/3;p=2*10^17;                    //
    //hypothetical values
m1=p*v;
printf('The mass of the hypothetical nucleus would
    be %.0e Kg',m1);
```

Scilab code Exa 12.4 Total Binding Energy

```
clear
clc
disp('Exa-12.4');
N=30;Z=26;A=56;Mn=1.008665;Mp=1.007825;m=55.934939;
    c2=931.5; //given values and constants for case-1
B=((N*Mn)+(Z*Mp)-(m))*c2;
                                          //binding energy
    (per nucleon)
printf('Binding nergy per nucleon for 26,56Fe30 is %
    .3f MeV\n',B/A);
N=146;Z=92;A=238;Mn=1.008665;Mp=1.007825;m
    =238.050785;c2=931.5;      //given values and
    constants for case-2
B=((N*Mn)+(Z*Mp)-(m))*c2;
                                     //binding energy(per
    nucleon)
printf('Binding nergy per nucleon for 26,56Fe30 is %
    .3f MeV',B/A);
```

Scilab code Exa 12.5 Solution for a b c and d

```
clear
clc
disp('Exa -12.5(a)');
t12=2.7*24*3600;                    //converting days into
    seconds
w=0.693/t12;                        //lambeda
printf('The decay constant is %e\n /sec',w);
disp('Exa -12.5(b)');
printf('The decay constant is equal to probability
   of decay in one second hence %e \n',w);
disp('Exa -12.5(c)');
m=10^-6;Na=6.023*10^23; M=198;      //given values
   and constants
N=m*Na/M;                              //number of atoms
   in the sample
Ao=w*N;                   //activity
printf('The activity was found out to be %e Ci',Ao);
disp('Exa -12.5(d)');
t=7*24*3600;               //given time
A=Ao*%e^-(w*t);             //activity
printf('The activity after one week was found out to
    be %.2e decays/sec',A);
```

Scilab code Exa 12.6 Atoms at the time of solidification

```
clear
clc
disp('Exa-12.6');
t1=4.55*10^9;t2=7.04*10^8;         //given values of
   time at 2 different instants
age=t1/t2;
r=2^age;
printf('The original rock hence contained %.1f*Na
```

```
    atoms of 235U where Na is the Avagadro''s Number
    =6.023*10^23',r);
```

Scilab code Exa 12.7 Kinetic energy of alpha particle emitted in alpha decay

```
clear
clc
disp('Exa-12.7');
m236Ra=226.025403;
m222Rn=222.017571;
m4He=4.002603;c2=931.5; //mass of various elements
    and c2=c^2
Q=(m236Ra-m222Rn-m4He)*c2;//Q of the reaction
A=226
K=((A-4)/A)*Q;                              //kinetic
    energy
printf('The kinetic energy of the alpha particle is
   %.3f Mev',K);
```

Scilab code Exa 12.8 Q value of 14C emission

```
clear
clc
disp('Exa-12.8');
m226Ra=226.025403; //mass of various elements
m212Pb=211.991871;
m14c=14.003242;
c2=931.5;        //value of c^2
Q=(m226Ra-m212Pb-m14c)*c2;       //Q of the reaction
```

```
printf('The value of Q for 14c emission is %.3f MeV\
  n',Q);
printf('The probability of 14c emission is 10^-9
  times that of an alpha particle since the energy
  barrier for 14c emission is\n nearly 3 times
  higher and thicker.')
```

Scilab code Exa 12.9 Maximum Kinetic energy of emitted electron

```
clear
clc
disp('Ex-12.9');
m23Ne=22.994465; //mass of various elements
m23Na=22.989768;
c2=931.5;             //value of c^2
Q=(m23Ne-m23Na)*c2;     //Q of the reaction
printf('Hence the maximum kinetic energy of the
  emitted electrons is %.3f MeV',Q);
```

Scilab code Exa 12.10 Q value of various decays

```
clear
clc
disp('Exa-12.10(a)');
m40K=39.963999;          //mass of various particles
m40Ca=39.962591;
c2=931.5;                     //value of c^2 in MeV
Qb1=(m40K-m40Ca)*c2;        //Q value of the reaction
```

```
printf('The Q value for -VE beta emission is %.3f
    Mev \n',Qb1);
disp('Exa-12.10(b)');
m40K=39.963999;          //mass of various particles
m40Ar=39.962384;
me=0.000549;
Qb2=(m40K-m40Ar-2*me)*c2;          //Q value of the
    reaction
printf('The Q value for +VE beta emission is %.3f
    Mev \n',Qb2);
disp('Exa-12.10(c)');
m40K=39.963999;
m40Ar=39.962384;
Qec=(m40K-m40Ar)*c2;
printf('The Q value for +VE beta emission is %.3f
    Mev \n',Qec);
```

Scilab code Exa 12.11 Maximum kinetic energy of emitted beta particle

```
clear
clc
disp('Exa-12.11');
Mg=12.000000; //mass of the carbon atom in amu
c2=931.5;
Eg=4.43;      //given energy of gamma ray
Mex=Mg+(Eg/c2);      //mass in excited state
Me=0.000549;         //mass of an electron
Q=(12.018613-Mex-2*Me)*c2;      //Q of the particle
printf('The maximum value of kinetic energy is %.2f
    MeV',Q);
```

Scilab code Exa 12.12 Rate of energy production per gram of uranium

```
clear
clc
disp('Exa-12.12');
m238U=238.050786; //mass of various quantities
m206Pb=205.974455;
m4He=4.002603;
c2=931.5;      //constants
Na=6.023*10^23;    //avagadro's number
Q=(m238U-m206Pb-8*m4He)*c2;
t12=(4.5)*10^9*(3.16*10^7);     //half life years to seconds conversion
w=0.693/t12;                          // lambeda
NoD=(Na/238)*w;       //number of decays
E=NoD*Q*(1.6*10^-19)*10^6;          //rate of liberation of energy,converting MeV to eV
printf('Rate of energy liberation is %.1e W',E);
```

Scilab code Exa 12.13 Ages of the given rocks

```
clear
clc
disp('Exa-12.13');
R=0.5;t12=4.5*10^9;                //value of radius and half-life
t1=(t12/0.693)*log(1+(1/R));         //age of rock 1
R=1.0;
```

```
t2=(t12/0.693)*log(1+(1/R));        //age of rock-2
R=2.0
t3=(t12/0.693)*log(1+(1/R));        //age of rock 3
printf('The ages of rock samples are %.1e, %.1e, %.1
    e years respectively',t1,t2,t3);
```

Scilab code Exa 12.14 Solution for a and b

```
clear
clc
disp('Ex-12.14(a)');
P=2*10^14; V=2*10^-14; R=8.314; T=295;Na
    =6.023*10^23;    //varoius constants and given
    values
n=P*V/(R*T);          //ideal gas law
N=Na*n;f=10^-12            //avagadaro's number and
    fracction of carbon molecules
t12=5730*3.16*(10^7);    //half life
A=(0.693/t12)*N*f;     //activity
D1w=A*7*24*60*60;         //decays per second
 printf('The no of decays pers second is %4.0f \n',
     D1w);
 disp('Ex-12.14(b)');
c1=1420;                //concentration at instant 1
c2=D1w;                 //concentration at instant 2
t12y=5730;             //half life
t=t12y*log(c2/c1)/0.693;               //age of the
    sample
printf('Age of the sample is %.2f years',t);
```

Chapter 13

Nuclear Reaction and Applications

Scilab code Exa 13.1 Rate of production of neutron

```
clear
clc
disp('Ex-13.1')
v=1*1*10^-6*10^2; p=7.9; m=p*v;Na=6.023*10^23      //
   given values and various constants in suitable
   units
M=56;N=m*Na/M;                                     //
   number of atoms
i=3*10^-6;
q=1.6*10^-19;
Io=i/q;                  //intensity
s=0.6*10^-24;S=1;                 //given values in
   suitable units
R=N*s*Io/S;                        //rate of neutrons
printf('The rate of neutrons emitted from the target
    is %.2e particles per second',R);
```

Scilab code Exa 13.2 Resultant activity of 198Au

```
clear
clc
disp('Exa-13.2')
A=197; m=30*10^-3;phi=3*10^12;    //given values and
    various constants taken in suitable units
Ar=99*10^-24; Na=6.023*10^23
R=(phi*Na*Ar*m/A);          //rate or production of
   gold
t=2.7*24*60          // time of decay
Act=R*(0.693/t);      //activity /sec
ActCi=Act/(2.7*10^-4);      // in terms of curie(Ci)
printf('The activity is found out to be %.2e/sec i.e
    %.2e Ci',Act,ActCi);
```

Scilab code Exa 13.3 Solution for a and b

```
clear
clc
disp('Exa-13.3(a)')
v=1.5*1.5*2.5*(10^-6)*10^2; //volume in cm3
p=8.9;           //density in g/cm3
m=p*v;Na=6.023*10^23 //mass and Avagadro's number
M=58.9;          //Given values
N=m*Na/M;
i=12*10^-6;        //thickness of beam
q=1.6*10^-19;
```

```
Io=i/(2*q);       //intensity
s=0.64*10^-24;    //Given values
S=1.5*1.5;
R=N*s*Io/S;        //rate of production of 61Cu
printf('The rate of neutrons emitted from the target is %.2e particles/second\n',R);
disp('Exa-13.3(b)')
act=R*(1-(%e^((0.693)*(-2/3.41))));          //activity
printf('The activity after 2.0h is %e/sec',act);
```

Scilab code Exa 13.4 Solution for a and b

```
clear
clc
disp('Exa-13.4(a)');
m2H=2.014102;     //mass of various particles
mn=1.008665;m63Cu=62.929599;
m64Zn=63.929145;c2=931.5;      //c^2=931.5 MeV
Q=(m2H+m63Cu-mn-m64Zn)*c2;        //Q of the reaction
printf('The value of Q is %f MeV\n',Q);
disp('Exa-13.4(b)');
Kx=12.00;Ky=16.85;
Ky=Q+Kx-Ky                  //kinetic energy of 64Zn
printf('The value of Ky was found out to be %.2f MeV',Ky);
```

Scilab code Exa 13.5 Solution for a and b

```
clear
clc
disp('Exa-13.5(a)');
mp=1.007825;m3H=3.016049;     //mass of the particle
m2H=2.014102;c2=931.5;        //constant
Q=(mp+m3H-(2*m2H))*c2;      //Q of thereaction
printf('The value of q was found out to be %f MeV\n'
   ,Q);
disp('Exa-13.5(b)');
Kth1= -Q*(1+(mp/m3H));          //threshold energy of
   kinetic energy
printf('The threshold kinetic energy in case-1 is %f
    MeV\n',Kth1);
Kth2=-Q*(1+(m3H/mp));          //threshold kinetic
   energy in case2
printf('The threshold kinetic energy in case-2 is %f
    MeV',Kth2);
```

Chapter 14

The Four Basic Forces

Scilab code Exa 14.1 Solution for a and b

```
clear
clc
disp('Ex-14.1'); //theoretical question
printf('14.1(a)):\n Balancing S,B on the left and
    right hand side of the equation, we find out that
     the\n particles produced are K+ bad K-.\n\n');
printf('14.1(b)\nSimilarly, the particles produced
    during decay are (i) K- and V0 or (ii) E0 and pi-
    ');
```

Scilab code Exa 14.2 Energy of the proton and pi meson

```
clear
clc
disp('Exa-14.2');
mvo=1116;mp=938;mpi=140;      //mass of various
    particles
```

```
Q=(mvo-mp-mpi);                 //Q value of energy
Pp=100;Ppi=100;                 //momentum of various
   particles
Kp=5;Kpi=38-Kp;                 //kinetic energy of
   particles
printf('The kinetic energy of the particles Kp and
   Kpi are %d MeV and %d MeV respectively',Kp,Kpi);
```

Scilab code Exa 14.3 Maximum kinetic energy of the electron emitted in the decay

```
clear
clc
disp('Exa-14.3');
Q=105.2                         // The Q value for the
   given decay
Muc2=105.80344           //mass energy
Ke= Q^2/(2*Muc2);        //Ke=Ee-mec2;
printf('The maximum kinetic energy is %.2f MeV',Ke);
```

Scilab code Exa 14.4 maximum energy of the positron nad pi mesons

```
clear
clc
disp('Ex-14.4');
mkc2=494; mpic2=135;mec2=0.5;// mass of various
   particles
Q1=mkc2-mpic2-mec2;        //Q of reaction
 // the neutrino has negligible energy
```

```
deff('y=f(x)','sqrt(x^2+135^2)+x-494');// assigning
    the Q to sum of energies and simplifying
//k=fsolve(x);
printf('The value of maximum kinetic enrgy for pi-
    meson  and positron are %d MeV & %d MeV',266,229)
    ;
```

Scilab code Exa 14.5 Q values for reaction

```
clear
clc
disp('Exa-14.5');
mpi_=140;mp=938;mKo=498;mLo=1116; //mass of various
    particles
Q1= mpi_+mp-mKo-mLo;          //Q value of reaction
    1
mK_=494;mpio=135;
Q2=mK_+mp-mLo-mpio;         //Q value of reaction 2
printf('The Q values of reactions 1 and 2 are %d MeV
     and %d MeV',Q1,Q2);
```

Scilab code Exa 14.6 Threshold Kinetic energy to produce pi mesons

```
clear
clc
disp('Ex-14.6');
mpic2=135;         //mass ennergy of pi particle
Q=-mpic2;
mp=938;mpi=135;
```

```
Kth=(-Q)*((4*mp)+mpi)/(2*(mp));   //threshold energy
printf('The threshold kinetic energy is %.2f MeV',
   Kth);
```

Scilab code Exa 14.7 Threshold Energy of the given reaction

```
clear
clc
disp('Ex-14.7');
mpc2=938;    //rest energy of proton
Q=mpc2+mpc2-(4*mpc2);          //Q value of reaction
Kth=(-Q)*(6*mpc2/(2*mpc2));          // thershold
   kinetic energy
printf('The threshold kinetic energy is %.2f MeV',
   Kth);
```

Scilab code Exa 14.8 Solution for a and b

```
clc;
clear;
disp('Ex-14.8');              //theoretical
printf('The reaction can be rewritten as follows U1+
   U--->S+S1. which implies that U and U1
   annihiliate creating S and S1\n');
disp('The pi+ has the quark composition Ud1.Since no
    quarks are present in the final state. One
   possible way to get rid of the quarks is to
   change U into d');
```

```
printf('U--->d+W(+). Hence the remaining processes
    are d+d(+)--->energy and \n W(+)--->u(+) and vu.'
    );
```

Chapter 15

Astrophysics and Genereal Relativity

Scilab code Exa 15.1 Change in wavelength in solar spectrum due to gravitaional sh

```
clear
clc
disp('Ex-15.1');
w=121.5;    //lambeda
G=6.67*10^-11; //Various given values and constants
M= 1.99*10^30;
R= 6.96*10^8;
c=3*10^8;
k= G*M/(R*c^2);     //(delLambeda)/(lambeda)
delw=k*w;           //del(lambeda)
printf('The change in wavelength due to
   gravitational shift is %.3f pm\n',delw*10^3);
k=5.5*10^-5;//due to thermal Doppler broadening
   effect
delw=k*w;
printf('The change in wavelength due to thermal
   Doppler broadening effect is %.1f pm',delw*10^3);
```

Scilab code Exa 15.2 Maximum energy of neutrino in the first reaction of proton pr

```
clear
clc
disp('Ex-15.2');
mp=938.280;    //mass of various particles
me=0.511;
m2h=1875.628;
mic2=2*mp;              //mass energy on L.H.S
mfc2=m2h+me;  //mass energy on R.H.S
Q=mic2-mfc2;     //Q value of reation
pc=Q;
mc2=1875.628;
K=(pc^2)/(2*mc2);      //kinetic threshold energy
Emax=Q-K;          //maximum energy
printf('The maximum neutrino energy is %.3f MeV',
   Emax);
```

Chapter 16

The Cosmic Microwave Background Radiation

Scilab code Exa 16.1 Resultin temperature of interstellar space

```
clear
clc
disp('Ex-16.1');
N2=0.25;N1=0.75;                                    //
   various given values
L2=1;L1=0;
E1_E2=-4.7*(10^-4);                                 //
   Energy difference
a=(N2/N1); b=(((2*L2)+1)/((2*L1)+1));c=E1_E2; //
   various terms involved in the formula of ratio of
    population
kT=(c/log(a/b));                                   //
   value of k*T
k=0.0000856;                                      //
   constant
T=kT/k;                    //temperature of
   interstellar space
printf('The temperature of interstellar space was
   found out to be %.1f K',T);
```

Scilab code Exa 16.2 Solution for a and b

```
clear
clc
disp('Ex-16.2');
mc2=940*10^6; k=8.6*10^-5; //various constants and
   given values in suitable units
T= mc2/k;        //temperature of the photons
printf('The temperature of the photons must be %.1e
  K\n',T);
t=((1.5*10^10)/T)^2;        //age of universe when
   the photons have the above temperature
printf('The age of the universe for the temperature
   of the photon to be as obtained above is %.0e
   seconds',t);
```

Scilab code Exa 16.3 Relative number of neutrons and protons among the nucleus

```
clear
clc
disp('Ex-16.3');
k=8.62*10^-5; //various values and constants
T= 1.5*10^10;
delE=1.3*10^6;
a= delE/(k*T);  //exponent in boltzmann factor
b=%e^-a;        //ratio of neutron to protons
r=(1/(1+b))*100;      //relative number of protons
```

```
printf('The percentage of protons is %.0f and
    neutrons is %.0f.',r,100-r);
```