Scilab Textbook Companion for Introduction To Nuclear And Particle Physics by V. K. Mittal, R. C. Verma And S. C. Gupta[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

The Nucleus

Scilab code Exa 1.3.1 de Broglie relation

```
1 // Scilab code Exa1.3.1 Momentum determination for a
    neutron using de-Broglie relation : Page 31
    (2011)
2 h = 6.626e-034;     // Planck's constant, Js
3 e = 1.602e-019;     // Charge on an electron, C
4 red_h = h/(2*%pi*e*1e+06);     // Reduced Planck's
    constant, MeV
5 lambda = 5.0e-015;     // de_Broglie wavelength of
    neutron, m
6 p = red_h/lambda;     // Momentum of the neutron, MeV
    -s/m
7 printf("\nThe momentum of the neutron from de-
    Broglie relation : %5.3e MeV-s/m", p);
8
9 // Result
10 // The momentum of the neutron from de-Broglie
    relation : 1.317e-007 MeV-s/m
```

Scilab code Exa 1.3.2 Isotopes Isotones and Isobars

```
// Scilab code Exa1.3.2 : Grouping the nuclides as isotopes, isotones and isobars : Page 32 (2011)
E = cell(3,3);    // Declare a cell array of empty matrices for nuclides information
E(1,1).entries = 'C';    // Assign element 'C' to (1,1) cell
E(2,1).entries = 'N';    // Assign element 'N' to (2,1) cell
E(3,1).entries = 'O';    // Assign element 'o' to (3,1) cell
E(1,2).entries = 6;    // Assign atomic No. 6 to (1,2) cell
E(2,2).entries = 7;    // Assign atomic No. 7 to (2,2) cell
E(3,2).entries = 8;    // Assign atomic No. 8 to (3,2) cell
E(1,3).entries = [12,13,14,16];    // Assign mass numbers for 'C' to (1,3) cell
E(2,3).entries = [14,15,16,17];    // Assign mass numbers for 'N' to (2,3) cell
E(3,3).entries = [14,15,16,17];    // Assign mass numbers for 'O' to (3,3) cell
// Isotopes
printf("\nIsotopes:");
printf("\n==========");
for i = 1:1:3    // Search for the three elements one-by-one
  printf("\n(Z = %d)\n",E(i,2).entries);
  for j= 1:1:4
     printf("\t%s(%d)",E(i,1).entries,E(i,3).
        entries(j));
  end
end
// Isotones
printf("\n\nIsotones:");
printf("\n==========");
for N = 6:1:9    // Search for the neutron numbers from 6 to 9
```

```
25      printf("\n(N = %d)\n",N);
26      for i = 1:1:3
27           for j= 1:1:4
28                if  E(i,3).entries(j)- E(i,2).entries
                     == N then // N = A-Z
29                   printf("\t%s(%d)",E(i,1).entries,E
                        (i,3).entries(j));
30                end
31           end
32      end
33 end
34 // Isobars
35 printf("\n\nIsobars:");
36 printf("\n=========");
37 for A = 14:1:17     // Search for the mass numbers
      from 14 to 17
38      printf("\n(A = %d)\n",A);
39      for i = 1:1:3
40           for j= 1:1:4
41                if  E(i,3).entries(j) == A then
42                   printf("\t%s(%d)",E(i,1).entries,E
                        (i,3).entries(j));
43                end
44           end
45      end
46 end
47 //
48 // Result
49 //
50 // Isotopes:
51 // ==========
52 // (Z = 6)
53 //   C(12)    C(13)    C(14)    C(16)
54 // (Z = 7)
55 //   N(14)    N(15)    N(16)    N(17)
56 // (Z = 8)
57 //  O(14)    O(15)    O(16)    O(17)
58 //
```

```
// Isotones:
// ========
// (N = 6)
//  C(12)     O(14)
// (N = 7)
//  C(13)     N(14)     O(15)
// (N = 8)
//  C(14)     N(15)     O(16)
// (N = 9)
//  N(16)     O(17)
//
// Isobars:
// =======
// (A = 14)
//  C(14)      N(14)     O(14)
// (A = 15)
//  N(15)     O(15)
// (A = 16)
//  C(16)      N(16)      O(16)
// (A = 17)
//  N(17)     O(17)
```

Scilab code Exa 1.4.1 Rest mass energy of electron

```
// Scilab code Exa1.4.1: To calculate the energy of
   electron at rest : Page 33 (2011)
m = 9.1e-031; // Mass of the electron, Kg
C = 3e+08; // Velocity of the light,m/s
E = m*C^2/1.6e-013; // Energy of the electron at
   rest, MeV
printf("\nEnergy of the electron at rest : %5.3f MeV
   ", E)

//   Result
//    Energy of the electron at rest : 0.512 MeV
```

Scilab code Exa 1.4.2 Nuclear radius

```
// Scilab code Exa1.4.2 : Estimation of the Nucleus
   type from its radius : Page 33 (2011)
r = 3.46e-015; // Radius of the nucleus, m
r0 = 1.2e-015; // Distance of closest approach of
   the nucleus, m
A = round((r/r0)^3); // Mass number of the nucleus
if A == 23 then
    element = "Na";
elseif A == 24 then
    element = "Mg";
elseif  A == 27 then
    element = "Al";
elseif  A == 28 then
    element = "Si";
end
printf("The mass number of the nucleus is %d and the
    nucleus is of %s", A, element);

//  Result
// The mass number of the nucleus is 24 and the
   nucleus is of Mg
```

Scilab code Exa 1.4.3 Nuclear density

```
// Scilab code Exa1.4.3 : Estimate the density of
   nuclear matter : Page 34 (2011)
m = 40*(1.66e-027); // Mass of the nucleus, kg
r0 = 1.2e-015; // Distance of the closest approach,
   m
```

```
A = 40; // Atomic mass of the nucleus
r = r0*A^(1/3); //Radius of the nucleus, m
V = 4/3*(%pi*r^3); // Volume of the nucleus, m^3
density = m/V; // Density of the nucleus, kg/m^3
printf("\nRadius of the nucleus: %3.1e m\nVolume of the nucleus: %5.3e m^3\nDensity of the nucleus: %3.1e kg/m^3",r,V,density);

// Result
// Radius of the nucleus: 4.1e-015 m
// Volume of the nucleus: 2.895e-043 m^3
// Density of the nucleus: 2.3e+017 kg/m^3
```

Scilab code Exa 1.4.4 Density of uranium 235

```
// Scilab code Exa1.4.4 : To determine the density of U-235 nucleus : Page 34 (2011)
m = 1.66e-027;     // Mass of a nucleon, kg
A = 235; // Atomic mass of U-235 nucleus
M = A*m;     //Mass of the U-235 nucleus, kg
r0 = 1.2e-015; // Distance of closest approach, m
r = r0*(A)^(1/3); // Radius of the U-235 nucleus
V = 4/3*(%pi*r^3); // Volume of the U-235 nucleus,m^3
d = M/V; // Density of the U-235 nucleus,kg/m^3
printf("\nThe density of U-235 nucleus : %4.2e kg per metre cube",d)

// Result
// The density of U-235 nucleus : 2.29e+017 kg per metre cube
```

Scilab code Exa 1.4.5 Variation of nuclear density with radius

```
1 // Scilab code Exa1.4.5 : To calculate densities of
    O and Pb whose radii are given: Page 35 (2011)
2 m_O = 2.7e-026; // Mass of O nucleus, kg
3 r_O = 3e-015; // Radius of O nucleus, m
4 V_O = 4/3*(%pi*(r0)^3); // Volume of O nucleus,
    metre cube
5 d_O = m_O/V_O; // Density of O nucleus, kg/metre
    cube
6 m_Pb = 3.4e-025; // Mass of Pb nucleus, kg
7 r_Pb = 7.0e-015; // Radius of Pb nucleus, m
8 V_Pb = 4/3*(%pi*(r_Pb)^3); // Volume of Pb nucleus,
    metre cube
9 d_Pb = m_Pb/V_Pb; //Density of Pb nucleus,kg/metre
    cube
10 printf("\nThe density of oxygen nucleus : %4.2e in
    kg/metre cube",d_O);
11 printf("\nThe density of Pb nucleus : %4.2e in kg/
    metre cube",d_Pb);
12
13 // Result
14 // The density of oxygen nucleus : 3.73e+018 in kg/
    metre cube
15 // The density of Pb nucleus : 2.37e+017 in kg/metre
     cube
```

Scilab code Exa 1.4.6 Distance of closest approach

```
1 // Scilab code Exa1.4.6 : Determination of distance
    of closest approach for alpha-particle : Page 35
    (2011)
2 E = 5.48*1.6e-013; // Energy of alpha particle, J
3 e = 1.6e-019; // Charge of an electron, C
4 Z = 79; // Mas number of Au nucleus,
5 epsilon_0 = 8.85e-012; // Permittivity of free space
    ,
```

```
6 D = (2*Z*e^2)/(4*%pi*epsilon_0*E); // Distance of
    closest approach, m
7 printf("\nThe distance of closest appproach of alpha
    particle : %4.2e m", D)
8
9 // Result
10 // The distance of closest appproach of alpha
    particle : 4.15e-014 m
```

Scilab code Exa 1.4.7 Radius of Pb 208

```
1 // Scilab code Exa1.4.7 : Determination of radius of
    Pb-208 : Page 36 (2011)
2 A = 208; // Mass number of Pb-208
3 r0 = 1.2e-015; // Distance of closest approach, m
4 r = r0*((A)^(1/3)); // Radius of Pb-208, m
5 printf("\nThe radius of Pb-208 : %4.2e m", r)
6
7 // Result
8 //    The radius of Pb-208 : 7.11e-015 m
```

Scilab code Exa 1.5.1 Binding energy of alpha particle

```
1 // Scilab code Exa1.5.1 : Calculation of binding
    energy of alpha particle and express in MeV and
    joule : Page 36 (2011)
2 amu = 931.49; // Atomic mass unit, MeV
3 M_p = 1.00758; // Mass of proton, amu
4 M_n = 1.00897;  // Mass of neutron, amu
5 M_He = 4.0028; // Mass of He nucleus, amu
6 Z = 2; // Atomic number
7 N = 2; // Number of neutron
8 M_defect = Z*M_p+N*M_n-M_He;     // Mass defect, amu
```

```
9  BE_MeV = M_defect*amu; // Binding energy, MeV
10 BE_J = M_defect*1.49239e-010;     // Binding energy,
     J
11 printf("\nThe binding energy (in MeV): %5.2f",
     BE_MeV)
12 printf("\nThe binding energy (in J): %4.2e", BE_J)
13
14 // Result
15 // The binding energy (in MeV): 28.22
16 // The binding energy (in J): 4.52e-012
```

Scilab code Exa 1.5.2 Dissociation energy of C12

```
1  // Scilab code Exa1.5.2 : Calculation of energy
     required to break C-12 into 3-alpha particle :
     Page 37 (2011)
2  amu = 1.49239e-010; // Atomic mass unit, J
3  M_C = 12; // Mass of C-12, amu
4  M_a = 4.0026;     // Mass of alpha particle, amu
5  M_3a = 3*M_a; // Mass of 3 alpha particle, amu
6  D = M_C-M_3a; // Difference in two masses, amu
7  E = D*amu; // Required energy,J
8  printf("\nThe energy required to break 3 alpha
     particles : %4.2e J",E)
9
10 // Result
11 // The energy required to break 3 alpha particles :
     -1.16e-012 J
```

Scilab code Exa 1.5.3 Dissociation energy of helium nucleus

```
1 // Scilab code Exa1.5.3 : Calculation of energy
     required to knock out nucleon from He nucleus :
     Page 37 (2011)
2 M_p = 1.007895; // Mass of proton, amu
3 M_n = 1.008665; // Mass of neutron, amu
4 M_He = 4.0026; // Mass of He-nucleus, amu
5 Z = 2; // Number of proton
6 N = 2; // Number of neutron
7 D_m = [(Z*M_p)+(N*M_n)-M_He]; // Mass defect, amu
8 amu = 931.49; // Atomic mass unit, MeV
9 E = D_m*amu; // Required energy, MeV
10 printf("\nThe energy required to knock out nucleons
     from the He nucleus = %5.2f MeV", E);
11
12 // Result
13 // The energy required to knock out nucleons from
     the He nucleus = 28.43 MeV
```

Scilab code Exa 1.5.4 Binding energy of Fe 56

```
1 // Scilab code Exa1.5.4 : To calculate binding
     energy of Fe-56 : Page 38 (2011)
2 M_Fe = 55.934939; // Mass of Fe-56, amu
3 M_p = 1.007825; // Mass of proton, amu
4 M_n = 1.008665; // Mass of neutron, amu
5 Z = 26; // Atomic number of Fe-56
6 N = 30; // Number of neutron in Fe-56
7 amu = 931.49; // Atomic mass unit, MeV
8 BE = [(Z*M_p)+(N*M_n)-M_Fe]*amu; // Binding energy
     of Fe-56, MeV
9 printf("\nThe binding energy of Fe-56 : %6.4f MeV",
     BE)
10
11 // Result
12 // The binding energy of Fe-56 : 492.2561 MeV
```

Scilab code Exa 1.5.5 Mass defect and packing fraction

```
1 // Scilab code Exa1.5.5 : Calculation of mass defect
      and packing fraction from given data Page : 38
     (2011)
2 amu = 931.49; // Atomic mass unit, MeV
3 M_p = 1.007825; // Mass of proton, amu
4 M_n = 1.008663;  // Mass of neutron, amu
5 A = 2;        // Mass number of deutron, amu
6 M_D = 2.014103;     // Mass of deuteron nucleus, amu
7 M_Defect = (M_p+M_n-M_D)*amu;      // Mass defect of
     the nucleus, MeV
8 P_fraction = (M_D - A)/A;      // Packing fraction of
      nucleus
9 printf("\n Mass defect       %4.2f MeV\n Packing
     fraction     %7.5f",M_Defect,P_fraction);
10
11 // Result
12 //    Mass defect       2.22 MeV
13 //    Packing fraction     0.00705
```

Scilab code Exa 1.5.6 Average binding energy

```
1 // Scilab code Exa1.5.6 : To calculate binding
     energy per nucleon of He-4 nucleus : Page 38
     (2011)
2 m_p = 1.007825; // Mass of proton, amu
3 m_n = 1.008665; // Mass of neutron, amu
4 m_He = 4.002634; // Mass of He-4 nucleus, amu
5 amu = 931.47; // Atomic mass unit, MeV
6 A = 4, // Mass number of He-4 nucleus
```

```
7 BE = [2*m_p+2*m_n-m_He]*amu; // Binding energy of He
    -4 nucleus, MeV
8 Av_BE = BE/A; // Average binding energy or binding
    energy per nucleon, MeV
9 printf("\nThe binding energy per nucleon : %4.2f MeV
    ", Av_BE);
10
11 // Result
12 // The binding energy per nucleon of He-4 is
13 // The binding energy per nucleon : 7.07 MeV
```

Scilab code Exa 1.6.1 Orbital angular momentum of coupled nucleons

```
1 // Scilab code Exa1.6.1 : Orbital angular momentum
    of coupled nucleons : Page 39 (2011)
2 l1 = 1;    // Orbital qunatum number for p-state
    nucleon
3 l2 = 2;    // Orbital qunatum number for d-state
    nucleon
4 // Display the value of L within the for loop
5 disp("The possible L values will be");
6 for i = abs(l1-l2):1:abs(l1+l2)        // Coupling
    of l-orbitals
7     printf("\t %1d",i);
8 end
9
10 // Result
11 // The possible L values will be
12 //  1     2     3
```

Scilab code Exa 1.6.2 Total angular momentum of proton

```
// Scilab code Exa1.6.2 : Total angular momentum of
   proton : Page 40  (2011)
// Get the l value from the user
l = 3;    // Orbital qunatum number for f-state
   proton
s = 1/2;    // Magnitude of spin quantum number
// Display the value of j within the for loop
disp("The j values will be between");
for i = abs(l-s):1:abs(l+s)          // l-s Coupling
    printf("\t %3.1f",i);
end

// Result
// The j values will be between
//  2.5     3.5
```

Scilab code Exa 1.11.1 Ion accelerated in a mass spectrograph

```
// Scilab code Exa1.11.1 : To find the speed, mass
   and mass number of the ion which is accelerated
   in a mass spectrograph : Page 40 (2011)
V = 1000; // Potential difference, volts
R = 0.122; // Radius of the circular path, m
B = 1500e-04; // Magnetic field, tesla
e = 1.602e-019; // Charge of the electron, C
amu = 1.673e-027; // Atomic mass unit, kg
v = (2*V)/(R*B); // Speed of the ion, m/s
M = 2*e*V/v^2; // Mass of the ion, kg
A = M/amu; // Mass number
printf("\n    Speed   >  %5.3e m/s  \n    Mass    >
    %5.3e kg  \n    Mass number   >  %5.2f ",v, M, A
   );

// Result
//
```

```
14 //     Speed    >  1.093e+005 m/s
15 //    Mass     >  2.682e-026 kg
16 //      Mass number   >  16.03
```

Scilab code Exa 1.11.2 Distance between isotopic Ar ions

```
1  // Scilab code Exa 1.11.2 : To determine distances
      between the isotopic Ar ions in Bainbridge mass
      spectrograph : Page 41 (2011)
2  amu = 1.673e-027; // Atomic mass unit, kg
3  E = 5e+04; // Electric field, V/m
4  B1 = 0.4; // Magnetic field, tesla
5  v = E/B1; // Velocity of ions, m/s
6  B = 0.8; // Magnetic field, tesla
7  e = 1.602e-019; //charge of electron,C
8  m_Ar = zeros(1,3);     // Array of masses of three Ar
       ions, amu
9  m_Ar(1,1) = 36,m_Ar(1,2) = 38,m_Ar(1,3) = 40; //
      Masses of three isoptopes of Ar, amu
10 r_Ar = zeros(1,3);     // Array of radii of three Ar
      ions, mm
11 for i = 1:1:3
12     r_Ar(1,i) = (m_Ar(1,i)*amu*v)/(B*e)*1e+03; //
          Radius of Ar ion orbit, mm
13     disp(r_Ar(1,i));
14 end
15 d1 = 2*(r_Ar(1,2)-r_Ar(1,1));     // Distance b/w
      first and second line, mm
16 d2 = 2*(r_Ar(1,3)-r_Ar(1,2));     // Distance b/w
      second and third line, mm
17 printf("\nThe distance between successive lines due
      to three different isotopes : %3.1f mm and %3.1f
      mm", d1,d2);
18
19 // Result
```

```
20 // The distance between successive lines due to
      three different isotopes : 6.5 mm and 6.5 mm
```

Chapter 2

Nuclear Models

Scilab code Exa 2.2.1 Binding energy and percentage discrepancy

```
1 // Scilab code Exa2.2.1 To calculate the binding
    energy of Ca(20,40) and %_age discrepancy : Page
    66 (2011)
2 // For Ca(20,40), actual binding energy is ......
3 m_p = 1.007825; // Mass of proton, amu
4 m_n = 1.008665; // Mass of neutron, amu
5 Z = 20; // Number of protons
6 N = 20;  // Number of neutrons
7 M_n = 39.962591; // Mass of the nucleus, amu
8 B_actual = (M_n-Z*m_p-N*m_n)*931.49; // Actual
    binding energy, MeV
9 // For Ca(20,40), Binding energ as per semiemperical
     mas formula ......
10 Z = 20; // Number of protons
11 a_v = 15.5; // Volume constant, MeV
12 a_s = 16.8; // Surface constant, MeV
13 a_a = 23.0; // Asymmetric constant, MeV
14 a_c = 0.7; // Coulomb constant, MeV
15 a_p = 34.0; // Paring constant, MeV
16 A = 40; // Mass number
17 B_semi = [a_v*A-(a_s*A^(2/3))-(a_c*Z*(Z-1)/A^(1/3))
```

```
    -(a_a*(A-2*Z)^2/A)-(a_p*A^(-3/4))]; // Binding
    energy as per semiemperical mass formula
18 // Percentage discrepancy between actual and
    semiemperical mass formula values are .......
19 Per_des = -(B_semi+B_actual)/B_actual*100; //
    Percentage discrepancy
20 printf("\nActual binding energy = %6.2f MeV\nBinding
     energy as per semiemperical mass formula = %6.2f
     MeV\nPercentage discrepancy = %3.1f percent",
    B_actual, B_semi, Per_des);
21
22 // Result
23 // Actual binding energy = -342.05 MeV
24 // Binding energy as per semiemperical mass formula
   = 343.59 MeV
25 // Percentage discrepancy = 0.4 percent
```

Scilab code Exa 2.2.2 Coulomb energies and nucelon masses of mirror nuclei

```
1 // Scilab code Exa2.2.2 To calculate the difference
    in coulomb energy and nucleons' mass difference
    for mirror nuclei and show in agreement with
    actual mass difference Page 67 (2011)
2  // Calculation of coulomb energy for mirror nuclei
     : N-7 and O-8
3  // For N-7 nucleus
4 a_c = 0.7; // Coulomb energy constant, MeV
5 Z_N = 7;  //  Atpmic no.
6 A = 15; // Atomic mass
7 E_C_N = a_c*Z_N*(Z_N-1)/(A^(1/3)); // Coulomb energy
     for N-7, MeV
8 // For O-8 nucleus
9 a_c = 0.7; // Coulomb energy constant, MeV
10 Z_O = 8;  //  Atpmic no.
```

```
A = 15; // Atomic mass
E_C_O = a_c*Z_O*(Z_O-1)/(A^(1/3)); // Coulomb energy for O-8, MeV
C_E_d = E_C_O-E_C_N; // Coulomb energy difference, MeV
m_p = 1.007276*931.49; // Mass of proton, MeV
m_n = 1.008665*931.49; // Mass of neutron, MeV
M_d = m_n-m_p; // Mass difference of nucleons, MeV
D_C_M = round(C_E_d-M_d); // Difference in coulomb energy and nucleon mass difference, MeV
M_O = 15.003070*931.49; // Mass of O-8, MeV
M_N = 15.000108*931.49; // Mass of N-7, MeV
D_A = round(M_O-M_N); // Actual mass difference, MeV
printf("\nDifference in Coulomb energy = %5.3f MeV\nNucleon mass difference  = %6.4f MeV\nDifference in Coulomb energy and nucleon mass difference = %5.3f MeV\nActual mass difference = %5.3f MeV", C_E_d, M_d ,D_C_M, D_A);
if D_A == D_C_M then printf("\nResult is verified")
end
// Result
// Difference in Coulomb energy = 3.974 MeV
// Nucleon mass difference  = 1.2938 MeV
// Difference in Coulomb energy and nucleon mass difference = 3.000 MeV
// Actual mass difference = 3.000 MeV
// Result is verified
```

Scilab code Exa 2.2.3 Neutron binding energy for isotopes of krypton

```
// Scilab code Exa2.2.3 To calculate the energy required to remove a neutron from Kr-81, Kr-82, Kr-83 : Page 68 (2011)
// For Kr-80,
m_p = 1.007825; // Mass of proton, amu
```

```
4  m_n = 1.008665; // Mass of neutron, amu
5  Z = 36; // Number of protons
6  N_80 = 44;  // Number of neutrons
7  M_n_80 = 79.91628; // Mass of Kr nucleus
8  BE_Kr_80 = (Z*m_p+N_80*m_n-M_n_80)*931.49; //
      Binding energy for Kr-80, MeV
9  // For Kr-81,
10 N_81 = 45; // Number of neutrons
11 M_n_81 = 80.91661; // Mass of Kr-81 nucleus
12 BE_Kr_81 = (Z*m_p+N_81*m_n-M_n_81)*931.49; //
      Binding energy for Kr-81 nucleus
13 // For Kr-82
14 N_82 = 46;  // Number of neutrons
15 M_n_82 = 81.913482; // Mass of Kr nucleus
16 BE_Kr_82 = (Z*m_p+N_82*m_n-M_n_82)*931.49;  //
      Binding energy for Kr-82,MeV
17 // For Kr-83
18 N_83 = 47; // Number of protons
19 M_n_83 = 82.914134; // Mass of Kr-83 nucleus
20 BE_Kr_83 = (Z*m_p+N_83*m_n-M_n_83)*931.49; //
      Binding energy for Kr-83, MeV
21 E_sep_81 = BE_Kr_81-BE_Kr_80; // Energy seperation
      of neutron for Kr-81, MeV
22 E_sep_82 = BE_Kr_82-BE_Kr_81; // Energy seperation
      of neutron for Kr-82, MeV
23 E_sep_83 = BE_Kr_83-BE_Kr_82; // Energy seperation
      of neutron for Kr-83, MeV
24 ,
25 printf("\nEnergy seperation of neutron for Kr-81 =
      %4.2f MeV\nEnergy seperation of neutron for Kr-82
       = %4.2f MeV\nEnergy seperation of  neutron for
      Kr-83 = %5.2f MeV", E_sep_81, E_sep_82, E_sep_83)
      ;
26
27 // Result
28 // Energy seperation of neutron for Kr-81 = 7.76 MeV
29 // Energy seperation of neutron for Kr-82 = 10.99
      MeV
```

```
30 // Energy seperation of  neutron for Kr-83 =  7.46
   MeV
```

Scilab code Exa 2.2.4 Isotopic stability

```
1 // Scilab code Exa2.2.4 To determine the most stable
    isotope of A = 75 : Page 68 (2011)
2 a_v = 15.5; // Volume energy coefficient , MeV
3 a_s = 16.8; // Surface energy coefficient MeV
4 a_c = 0.7; // Coulomb energy coefficient , MeV
5 a_a = 23.0; // Asymmetric energy coefficient , MeV
6 a_p = 34.0; // Pairing energy coefficient , MeV
7 A = 75; //  Given atomic mass
8 z = poly(0, 'z'); // z declares  a polynomial
9 B = -a_c*z*(z-1)/A^(1/3)-a_a*(A-2*z)^2/A ; //
   Binding energy as per liquid drop model
10 dB = derivat(B); // Differentiate B w.r.t. z
11 z = roots(dB); // Isotope of A = 75
12 z_i = round(z); // Most stable isotope of A = 75
13 printf("\nMost stable isotope of A = 75 corresponds
   to Z = %d ", z_i)
14
15 //   Result
16 //  Most stable isotope of A = 75 corresponds to Z =
    33
```

Scilab code Exa 2.2.5 Stable isotopes for different mass numbers

```
1 // Scilab code Exa2.2.5 To determine the most stable
    isotopes for A = 27, A = 118, A = 238 : Page 69
   (2011)
2 a_v = 15.5; // Volume energy , MeV
3 a_s = 16.8; // Surface energy , MeV
```

```
4  a_c = 0.7; // Coulomb energy, MeV
5  a_a = 23.0; // Asymmetric energy, MeV
6  a_p = 34.0; // Pairing energy, MeV
7  z = poly(0, 'z')
8  // For A = 27;
9  B_27 = -a_c*z*(z-1)/27^(1/3)-a_a*(27-2*z)^2/27 ; //
       Binding energy as per liquid drop model
10 dB_27 = derivat(B_27) // Differentiate B w.r.t. z
11 z_27 = roots(dB_27)   // Isotope of A = 27
12 z_i_27 = round(z_27)  // Most stable isotope of A =
       27
13 // For A = 118
14 B_118 = -a_c*z*(z-1)/118^(1/3)-a_a*(118-2*z)^2/118 ;
       // Binding energy as per liquid drop model
15 dB_118 = derivat(B_118)  // Differentiate B w.r.t. z
16 z_118 = roots(dB_118)    // Isotope of A = 118
17 z_i_118 = round(z_118)   // Most stable isotope of A
       = 118
18 // For A = 238
19 B_238 = -a_c*z*(z-1)/238^(1/3)-a_a*(238-2*z)^2/238 ;
       // Binding energy as per liquid drop model
20 dB_238 = derivat(B_238); // Differentiate B w.r.t. z
21 z_238 = roots(dB_238); // Isotope of A = 238
22 z_i_238 = round(z_238); // Most stable isotope of A
       = 238
23 printf("\nMost stable isotopes for A = 27, A = 118,
       A = 238 corresponds to z = %d, %d and %d
       respectively", z_i_27, z_i_118, z_i_238);
24
25 // Result
26 // Most stable isotopes for A = 27, A = 118, A = 238
       corresponds to z = 13, 50 and 92 respectively
```

Scilab code Exa 2.2.6 Coulomb energy coefficient of mirror nuclei

```
// Scilab code Exa2.2.6  : To calculate the coulomb coefficient and estimate nuclear radius for mirror nuclei: Page no. 69 (2011)
// Mirror nuclei : Na-11 and Mg-12
m_p = 1.007276; //  Mass of proton, amu
m_n = 1.008665; // Mass of neutron, amu
M_Mg  = 22.994124; //  Atomic mass of Mg-12, amu
M_Na = 22.989768; // Atomic mass of Na-11, amu
A = 23; // Mass number
Z_Mg = 12; // Atomic number of Mg-12
e = 1.6e-019; // Charge of the electron, C
K = 8.98e+09; // Coulomb force constant
a_c = A^(1/3)/(2*Z_Mg-1)*[(M_Mg-M_Na)+(m_n-m_p)]*931.47; // Coulomb coefficient, MeV
r_0 = 3/5*K*e^2/(a_c*1.6e-013); // Nuclear radius, m
printf("\nCoulomb coefficient = %4.2f MeV\nNuclear radius = %3.1e m", a_c, r_0)
//   Result
//   Coulomb coefficient = 0.66 MeV
//   Nuclear radius = 1.3e-015 m
```

Scilab code Exa 2.2.7 Coulomb and surface energies of uranium

```
// Scilab code Exa2.2.7 To calculate coulomb energy and surface energy for U(92,236) : Page 71 (2011)
Z = 92; // Atomic number of U-236
e = 1.6e-019; // Charge of an electron, C
A = 236; // Mass number of U-236
K = 8.98e+09; // Coulomb constant,
r_o = 1.2e-015; // Distance of closest approach, m
a_s = -16.8; // Surface constant
E_c = -(3*K*Z*(Z-1)*e^2)/(5*r_o*A^(1/3)*1.6e-013); // Coulomb energy, MeV
E_s = a_s*A^(2/3); // Surface energy, MeV
printf("\nCoulomb energy for U(92,236)  = %5.1f MeV
```

```
    \nSurface energy for U(92,236)    = %5.1f MeV  ",
    E_c, E_s)
11 //    Result
12 //  Coulomb energy for U(92,236)  = -973.3 MeV
13 //    Surface energy for U(92,236)    = -641.6 MeVS
```

Scilab code Exa 2.3.1 Mass of decayed radioactive material

```
1 // Scilab code Exa2.3.1 To calculate the mass of
    decayed radioactive material: Page 126 (2011)
2 t_prime =  1600; // Half life of radioactive
    material, years
3 t = 2000; // Total time, years
4 lambda = 0.6931/t_prime; // Decay constant, years
    ^(-1)
5 m0 = 1; // The mass of radioactive substance at t0,
    mg
6 m = m0* %e^(-(lambda*t)); // Ratio of total number
    of atoms and number of atoms disintegrat, mg
7 a = 1-m; // The amount of radioactive substance
    decayed, mg
8 printf("\nThe amount of radioactive substance
    decayed : %6.4f mg", a)
9
10 //    Result
11 //  The amount of radioactive substance decayed :
    0.5795 mg
```

Scilab code Exa 2.3.4 Magnetic moment of nuclei

```
1 // Scilab code Exa2.3.4 : To calculate the magnetic
    moment of given nuclei  : Page no. 74 : (2011)
2 // For Ne(10.19) nucleus
```

```
3  j_Ne_9 = 5/2; // Total angular momentum for Ne-19
       nucleus
4  u_Ne_9 = j_Ne_9+2.29; // Magnetic moment of Ne-19
       nucleus , nuclear magneton
5  // For Ne(10,20) nucleus
6  j_Ne_10 = 0;//  Total angular momentum for Ne-20
       nucleus
7  u_Ne_10 = j_Ne_10+2.29; // Magnetic moment of Ne-20
       nucleus , nuclear magneton
8  // For Ne(10,21) nucleus
9  j_Ne_11 = 5/2;//  Total angular momentum for Ne-21
       nucleus
10 u_Ne_11 = j_Ne_11+2.29; // Magnetic moment of Ne-21
       nucleus , nuclear magneton
11 printf("\nMagnetic moment of Ne-19 nucleus = %4.2f
       nuclear magneton\nMagnetic moment of Ne-20
       nucleus = %4.2f nuclear magneton\nMagnetic moment
        of Ne-21 nucleus = %4.2f nuclear magneton",
       u_Ne_9, u_Ne_10, u_Ne_11);
12 // Result
13 // Magnetic moment of Ne-19 nucleus = 4.79 nuclear
       magneton
14 // Magnetic moment of Ne-20 nucleus = 2.29 nuclear
       magneton
15 // Magnetic moment of Ne-21 nucleus = 4.79 nuclear
       magneton
```

Chapter 3

Radioactivity

Scilab code Exa 3.2.1 Curie becquerel relation

```
1 // Scilab code Exa3.2.1: To determine how many curie
      in 10^10 Bq : Page 124 (2011)
2 Bq = 1/3.7e+010; // Number of curie in one Bq, Ci
3 N = 10^10*Bq; // The number of curie in 10^10 Bq, Ci
4 printf("\nThe number of curie in 10^10 Bq : %4.2f Ci
     ", N)
5 //   Result
6 //  The number of curie in 10^10 Bq : 0.27 Ci
```

Scilab code Exa 3.2.2 Activity of thorium

```
1 // Scilab code Exa3.2.2: To calculate the activity
     of 10g of Th-232 : Page 125 (2011)
2 lambda_232 = 1.58e-018; // Decay constant, s^-1
3 N = 2.596e+022; // Number of atoms in 10g Th-232
4 A = N*lambda_232; // The activity of 10g of Th-232,
     dps
5 printf("\nThe activty of 10g of Th-232 : %5.3e dps",
      A)
```

```
6 //    Result
7 //    The activty of 10g of Th-232 : 4.102e+004 dps
```

Scilab code Exa 3.2.3 Mass of radiactive sample

```
1 // Scilab code Exa3.2.3: Calculation of mass of 1 Ci
      sample of radioactive sample : Page 125 (2011)
2 A = 3.7e+010; // Activity of 1Ci sample, dps
3 t = 1608; // Half life of radioactive substance, s
4 N = 6.023e+023/214; // Number of atoms in 1g of
    substance having atomic mass 214
5 lambda = 0.6931/t; // Decay constant, s^-1
6 m = A/(lambda*N); // The mass of radoiactive
    substance, g
7 printf("\nThe mass of radioactive substance : %4.2e
    g", m)
8 //    Result
9 //      The mass of radioactive substance : 3.05e-008
      g
```

Scilab code Exa 3.2.4 Activity of 1 kg of uranium

```
1 // Scilab code Exa3.2.4: To calculate the activity
    of 1kg of U-238: Page 125 (2011)
2 t =  1.419e+017; // Half life of U-238, s
3 N = 6.023e+023/238; // Number of atoms in 1g of U
    -238
4 lambda = 0.6931/t; // Decay constant, s^-1
5 A = (lambda*N)*1000/(3.7e+010); // The activity of 1
    kg of U-238, Ci
6 printf("\nThe activity of 1kg of U-238 : %4.2e Ci",
    A)
7 //    Result
```

```
8 //      The activity of 1kg of U-238 : 3.34e-004 Ci
```

Scilab code Exa 3.2.6 Half life of radioactive material

```
1 // Scilab code Exa3.2.6 Determination of half life
    of radioactive material Page 127 (2011)
2 t =  10; // Total period of radioactive material,
    days
3 lambda = log(6.6667)/10; //Decay constant, day^-1
4 t_h = 0.6931/(lambda); // Half life of radioactive
    substance, days
5 printf("\nThe half life of radioactive substance  :
    %4.2f days", t_h)
6 //   Result
7 //     The half life of radioactive substance  :
    3.65 days
```

Scilab code Exa 3.2.7 Mass of Ra 226

```
1 // Scilab code Exa3.2.7 : To calculate the mass of
    Ra-226 :Page no. 127 (2011)
2 t_h  = 1620*31536000; // Half life of Ra-226, S
3 D = 0.6931/t_h; // Decay constant, S^-1
4 A_Ci = 3.7e+010; // Activity, Ci
5 N_Ci = A_Ci/D; // Number of atoms decayed
6 m = 0.226; // Mass of 6.023e+023 atoms, kg
7 M_Ci = m*N_Ci/6.023e+023; // Mass of 1-Ci sample of
    Ra-226, kg
8 A_rf = 10^6; // Activity, Rf
9 N_rf = A_rf/D; // Number of atoms decayed
10 M_rf = m*N_rf/6.023e+023; // Mass of 1-Rf sample of
    Ra-226, kg
```

```
11 printf("\n Mass of 1-Ci sample of Ra-226   = %5.3e
     kg and \n Mass of 1-Rf sample of Ra-226  =  %4.2e
     kg ",M_Ci, M_rf )
12 //   Result
13 // Mass of 1-Ci sample of Ra-226   = 1.023e-003 kg
     and
14 // Mass of 1-Rf sample of Ra-226  =  2.77e-008 kg
```

Scilab code Exa 3.2.8 Activity and weight of radiactive material

```
1 // Scilab code Exa3.2.8 To calculate the activity
     and weight of radioactive material : Page 128
     (2011)
2 N_o = 7.721e+018; // Number of atoms in 3 mg of U
     -234
3 t_h = 2.5e+05; // Half life of U-234, years
4 T = 150000; // Total time, years
5 lambda = 0.6931/t_h; // Decay constant, year^-1
6 N = N_o*(%e^-(lambda*T)); // Number of atoms left
     after T years
7 m = 234000; // Mass of 6.023e+023 atoms of U-234, mg
8 M = m*N/(6.023e+023); // Weight of sample left after
     t years,
9 L = 8.8e-014; // Given decay constant, S^-1
10 A = N*L*10^6/(3.7e+010); // Activity, micro Ci
11 printf("\nThe weight of sample  =  %5.3f mg  \n
     Activity   =  %5.2f micro Ci ", M, A)
12 //   Result
13 //     The weight of sample  =  1.979 mg
14 //      Activity   =  12.12 micro Ci
```

Scilab code Exa 3.2.9 Activity of K 40

```
1 // Scilab code Exa3.2.9 : To calculate the activity
    of K-40 : Page no. 129 (2011)
2 N = 6.324e+020; // Number of atoms in 4.2e-05 kg of
    K-40
3 t_h = 1.31e+09*31536000; // Half life of K-40, s
4 D = 0.693/t_h; // Decay constant, s^-1
5 A = N*D/(3.7e+010)*10^6; // Activity of K-40,
    microCi
6 printf("\nThe activity of K-40 : %5.3f micro Ci", A
    )
7 //   Result
8 //    The activity of K-40 : 0.287 micro Ci
```

Scilab code Exa 3.2.10 Power in radioactive decay

```
1 // Scilab code Exa3.2.10 : To calculate the power
    produced by 10 mg of Po-210  : Page no. 130
    (2011)
2 N = 2.87e+019; // Number of atoms in 10e-10kg of Po
    -210
3 t_h = 138*24*3600; // Half life of Po-210, s
4 D = 0.693/t_h; // Decay constant, s^-1
5 A = N*D; // Activity of K-40, dps
6 E = 5.3*1.6e-013; // Power produce by one dps, MeV
7 P = A*E; // Power produced by 1.667e+012 dps, W
8 printf("\nThe Power produced by 1.667e+012 dps : %3
    .1f W", P)
9 //   Result
10 //   The Power produced by 1.667e+012 dps : 1.4 W
```

Scilab code Exa 3.3.1 Emitted particles during nuclear disintegration

```
1  // Scilab code Exa 3.3.1 : Finding particles in the
       given reactions : page no. 131 (2011)
2  // Declare three cells (for three reactions)
3  R1 = cell(4,3);
4  R2 = cell(4,3);
5  R3 = cell(3,3);
6
7  // Enter data for first cell (Reaction)
8  R1(1,1).entries = "Pb";
9  R1(1,2).entries = 82;
10 R1(1,3).entries = 211;
11 R1(2,1).entries = 'Bi';
12 R1(2,2).entries = 83;
13 R1(2,3).entries = 211;
14 R1(3,1).entries = 'Tl';
15 R1(3,2).entries = 81;
16 R1(3,3).entries = 207;
17 R1(4,1).entries = 'Pb';
18 R1(4,2).entries = 82;
19 R1(4,3).entries = 207;
20
21 // Enter data for second cell (Reaction)
22 R2(1,1).entries = "U";
23 R2(1,2).entries = 92;
24 R2(1,3).entries = 238;
25 R2(2,1).entries = 'Th';
26 R2(2,2).entries = 90;
27 R2(2,3).entries = 234;
28 R2(3,1).entries = 'Pa';
29 R2(3,2).entries = 91;
30 R2(3,3).entries = 234;
31 R2(4,1).entries = 'U';
32 R2(4,2).entries = 92;
33 R2(4,3).entries = 234;
34
35 // Enter data for third cell (Reaction)
36 R3(1,1).entries = "Bi";
37 R3(1,2).entries = 83;
```

```
38 R3(1,3).entries = 211;
39 R3(2,1).entries = 'Pa';
40 R3(2,2).entries = 84;
41 R3(2,3).entries = 211;
42 R3(3,1).entries = 'Pb';
43 R3(3,2).entries = 82;
44 R3(3,3).entries = 207;
45
46 // Declare a function returning the type of particle
       emitted
47 function particle = identify_particle(d_Z, d_A)
48       if d_Z == 2 & d_A == 4 then
49        particle = "Alpha";
50    elseif d_Z == -1 & d_A == 0 then
51        particle = "Beta minus";
52    elseif d_Z == 1 & d_A == 0 then
53        particle = "Beta plus";
54       end
55 endfunction
56
57 // Display emitted particles for first reaction
58 printf("\n\n\nReaction-I:");
59 for i = 1:1:3
60         dZ = R1(i,2).entries-R1(i+1,2).entries;
61         dA = R1(i,3).entries-R1(i+1,3).entries;
62         p = identify_particle(dZ,dA);
63         printf("\n%s(%d) - (%s) --> %s(%d)", R1(i,1)
              .entries, R1(i,2).entries, p, R1(i+1,1).
              entries, R1(i+1,2).entries);
64 end
65
66 // Display emitted particles for second reaction
67 printf("\n\n\nReaction-II:");
68 for i = 1:1:3
69         dZ = R2(i,2).entries-R2(i+1,2).entries;
70         dA = R2(i,3).entries-R2(i+1,3).entries;
71         p = identify_particle(dZ,dA);
72         printf("\n%s(%d) - (%s) --> %s(%d)", R2(i,1)
```

```
            .entries, R2(i,2).entries, p, R2(i+1,1).
            entries, R2(i+1,2).entries);
end

// Display emitted particles for third reaction
printf("\n\n\nReaction-III:");
for i = 1:1:2
        dZ = R3(i,2).entries-R3(i+1,2).entries;
        dA = R3(i,3).entries-R3(i+1,3).entries;
        p = identify_particle(dZ,dA);
        printf("\n%s(%d) - (%s) --> %s(%d)", R3(i,1)
            .entries, R3(i,2).entries, p, R3(i+1,1).
            entries, R3(i+1,2).entries);
end

// Result
//
// Reaction-I:
// Pb(82) - (Beta minus) --> Bi(83)
// Bi(83) - (Alpha) --> Tl(81)
// Tl(81) - (Beta minus) --> Pb(82)


// Reaction-II:
// U(92) - (Alpha) --> Th(90)
// Th(90) - (Beta minus) --> Pa(91)
// Pa(91) - (Beta minus) --> U(92)


// Reaction-III:
// Bi(83) - (Beta minus) --> Pa(84)
// Pa(84) - (Alpha) --> Pb(82)
```

Scilab code Exa 3.3.2 Energy of Pb decay

```
// Scilab code Exa 3.3.2 To calculate mass number of
    Pb isotope and energy emitted : Page no : 132
    (2011)
M_U = 238.050786; // Atomic mass of U-238, amu
M_Pb = 205.9744550; // Atomic mass of Pb-205, amu
M_He = 4.002603; // Atomic mass of He-4, amu
M_e = 5.486e-04; // Atomic mass of electron , amu
M = M_Pb+(8*M_He)+(6*M_e); // Total mass of products
    , amu
D = M_U-M; // Decrease in mass, amu
E = D*931.47; // Energy evolved, MeV
printf("\nTotal mass of products  = %1.7f amu \n
    Decrease in mass   =  %9.7f amu and \n Energy
    evolved   = %4.1f MeV", M, D,  E)
// Result
//     Total mass of products  = 237.9985706 amu
//  Decrease in mass   =  0.0522154 amu and
//   Energy evolved   = 48.6 MeV
```

Scilab code Exa 3.4.1 Atomic and mass numbers of daughter nuclei

```
// Finding atomic No. and mass No. of daughter
    nuclei in the given reactions : Page No.
    133(2011)
// Declare  cell (for given reaction)
R1 = cell(5,4);
// Enter data for cell (Reaction-I)
R1(1,1).entries = "A";
R1(1,2).entries = 90;
R1(1,3).entries = 238;
R1(1,4).entries = "Alpha";
R1(2,1).entries = 'B';
R1(2,4).entries = "Beta minus";
R1(3,1).entries = 'C';
R1(3,4).entries = "Alpha";
```

```
13 R1(4,1).entries = 'D';
14 R1(4,4).entries = "Beta minus";
15 R1(5,1).entries = 'E';
16
17 // Declare a function returning the type of particle
       emitted
18 function [Z, A] = daughter_nucleus(particle_emitted)
19       if particle_emitted == "Alpha" then
20           Z = 2, A = 4;
21    elseif particle_emitted == "Beta minus" then
22           Z = -1, A = 0;
23    elseif particle_emitted == "Beta plus" then
24           Z = 1, A = 0;
25       end
26 endfunction
27
28 // Display emitted particles for first reaction
29 printf("\n\n\nReaction-I:");
30 for i = 1:1:4
31         [Z, A] = daughter_nucleus(R1(i,4).entries);
32         R1(i+1,2).entries = R1(i,2).entries-Z;
33         R1(i+1,3).entries = R1(i,3).entries-A;
34         printf("\n%s(%d,%d) - (%s) --> %s(%d,%d)",
              R1(i,1).entries, R1(i,2).entries, R1(i,3)
              .entries, R1(i,4).entries, R1(i+1,1).
              entries, R1(i+1,2).entries, R1(i+1,3).
              entries)
35         ;
36 end
37 // Result
38 //
39 // Reaction-I:
40 // A(90,238) - (Alpha) --> B(88,234)
41 // B(88,234) - (Beta minus) --> C(89,234)
42 // (89,234) - (Alpha) --> D(87,230)
43 // D(87,230) - (Beta minus) --> E(88,230)
```

Scilab code Exa 3.4.2 Number of half lives of Rn 222

```
1 // Scilab code Exa 3.4.2 : To determine the number
    of Rn-222 half lives elapsed when it reaches 99%
    of its equilibrium concentration : Page no. 133 :
     (2011)
2  D = log(2); // Decay constant, s^-1
3  t = log(100); // Half life, s
4  n = t/D; // Number of half-lives
5 printf("\n Number of half-lives : %4.2f ", n)
6 // Result
7 //       Number of half-lives : 6.64
```

Scilab code Exa 3.4.3 Decay constant for alpha and beta decays

```
1 // Scilab code Exa 3.4.3 : To calculate the  decay
    constant for alpha and beta decays : Page no. 133
     : (2011)
2  H_t = 60.5*60; // Total half life period, s
3  T_d = 0.693/H_t; // Total decay constant, s^-1
4  A_d = 34/100*T_d; // Decay constant for alpha
     decays, s^-1
5  B_d = 66/100*T_d; // Decay constant for beta decay,
      s^-1
6 printf("\n Alpha decay   =  %4.2e s^-1    \n Beta
    decay    = %4.2e s^-1", A_d, B_d)
7 // Result
8 //       Alpha decay   =  6.49e-005 s^-1
9 //       Beta decay    = 1.26e-004 s^-1
```

Scilab code Exa 3.4.4 Half life of uranium 234

```
1 // Scilab code Exa 3.4.4 : To calculate the half
    life of U(92,234): Page no. 134 : (2011)
2 A_r = 1.8e+04; // Atomic ratio of U(92,238) and U
    (92,234)
3 T_238  = 2.5e+05; // Half life of U(92,238), years
4 T_234 = A_r*T_238; // Half life of U(92,234), years
5 printf("\n Half life of U(92,234): %3.1e years",
    T_234)
6 // Result
7 //         Half life of U(92,234): 4.5e+009 years
```

Scilab code Exa 3.4.5 Decayed amount of radioactive matter

```
1 // Scilab code Exa3.2.5 To calculate the mass of
    decayed radioactive material: Page 126 (2011)
2 t_h =  1600; // Half life of radioactive material,
    years
3 t = 2000; // Totaltime, years
4 lambda = 0.6931/t_h; // Decay constant, years^-1
5 m0 = 1; // The mass of radioactive substance at t0,
    mg
6 m = m0* %e^(-(lambda*t)); // Ratio of total number
    of atoms and number of atoms disintegrat, mg
7 A = 1-m; // The amount of radioactive substance
    decayed, mg
8 printf("\nThe amount of radioactive substance
    decayed : %6.4f mg",A)
9 //   Result
10 //     The amount of radioactive substance decayed :
     0.5795 mg
```

Scilab code Exa 3.5.2 Kinetic energy of alpha particle

```
1 // Scilab code Exa 3.5.2 : To calculate the K.E. of
    alpha particle in following decay  Pu-239 to U
    -235+He-4
2 M_239 = 239.052158; // Atomic mass of Pu-239, amu
3 M_235 = 235.043925; // Atomic mass of U-235, amu
4 M_4 = 4.002603; // Atomic mass of He-4, amu
5 Q = (M_239-M_235-M_4)*931.47; // Difference in
    masses, MeV
6 A = 241; // Mass number
7 K_alpha = Q*(A-4)/A; // Kinetic energy of alpha
    particle, MeV
8 printf("\nKinetic energy of alpha particle %5.2f MeV
    ", K_alpha)
9 // Result
10 //        Kinetic energy of alpha particle  5.16 MeV
```

Scilab code Exa 3.5.3 Height of barrier faced by alpha particle

```
1 // Scilab code Exa 3.5.3 : To calculate the height
    of barrier faced by alpha particle of Ra-226 :
    Page no. : 136 (2011)
2 Z = 88; // Atomic number of Ra-226 nucleus,
3 A = 226; // Atomic mass of Ra-226 nucleus
4 R_0 = 1.3e-015; // Distance of closest approach, m
5 E_0 = 8.854e-012; // Permittivity of free space, C
    ^2/Nm^2
6 e = 1.6e-019; // Charge of an electron, C
7 B = 2/(1.6e-013)*(Z-2)*e^2/(4*%pi*E_0*R_0*A^(1/3));
    // The barrier height faced by alpha particle,
    MeV
8 printf("\nThe barrier height faced by alpha particle
    : %4.1f MeV", B)
9 // Result
```

```
10 //          The barrier height faced by alpha
       particle : 31.2 MeV
```

Scilab code Exa 3.5.4 Height of coulomb barrier

```
1 // Scilab code Exa 3.5.4 : To calculate the height
       of coulomb barrier faced by alpha particle  :
       Page no. : 136 (2011)
2 Z_1 = 2; //Atomic number of He-4,
3 Z_2 = 7; // Atomic number of N-14,
4 A_1 = 4; // Atomis mass of He-4 nucleus
5 A_2 = 14; // Atomic mass of N-14 nucleus
6 R_0 = 1.5e-015; // Distance of closest approach, m
7 E_0 = 8.854e-012; // Permittivity of free space, C
       ^2/Nm^2
8 e = 1.6e-019; // Charge of an electron, C
9 B = Z_1/(1.6e-013)*Z_2*e^2/(4*%pi*E_0*R_0*(A_1^(1/3)
       +A_2^(1/3))); // The coulomb barrier  faced by
       alpha particle, MeV
10 printf("\nThe coulomb barrier  faced by alpha
       particle : %4.2f MeV", B)
11 // Result
12 //    The coulomb barrier  faced by alpha particle :
        3.36 MeV
```

Scilab code Exa 3.5.5 KE of a proton to penetrate the barrier

```
1 // Scilab code Exa 3.5.5 : To calculate the K.E. of
       a proton to penetrate the barrier of H nucleus  :
        Page no. : 137 (2011)
2 R_0 = 1.2; // Distance of closest approach, m
3 E_b = 197/(R_0*137); // The K.E. of proton to
       penetrate the berrier of H nucleus, Mev
```

```
4 printf("\nThe K.E. of proton to penetrate the
    berrier of H nucleus : %3.1f MeV", E_b)
5 // Result
6 //         The K.E. of proton to penetrate the
    berrier of H nucleus : 1.2 MeV
```

Scilab code Exa 3.6.1 Mass of daughter nucleus

```
1 // Scilab code Exa 3.6.1 : To determine the mass of
    daughter nucleus for given reaction : Page no.
    138 : (2011)
2  M_C = 14.007685; // Mass of C-14 nucleus, amu
3  E_e = 0.156/931.47; // Kinetic energy of emitted
     electron, amu
4  M_N = M_C-E_e; // Mass of N-14 nucleus, amu
5 printf("\n Mass of N-14 nucleus : %9.6f amu", M_N)
6 // Result
7 //      Mass of N-14 nucleus : 14.007518 amu
```

Scilab code Exa 3.6.3 Number of proton decayed per year from water

```
1 // Scilab code Exa. 3.6.3 : To determine the number
    of proton decayed  per year from H2O in a
    reservior : Page no. 139 : (2011)
2 N_p = 6.70e+033;// Number of protons
3 T_p = 10^32; // Mean life of proton, years
4 D_p = N_p/T_p*0.5; // Number of proton decays per
    year, decays/year
5 printf("\n Number of proton decays per year,: %4.1f
    decays/year", D_p)
6 // Result
7 //      Number of proton decayed per year: 33.5
    decays/year
```

Scilab code Exa 3.7.1 Energy of gamma photons from excited Ni 60

```
1 // Scilab code Exa. 3.7.1 : To determine the
    energies of two gamma rays emitted during de-
    excitation of Ni-60: Page no. 141 : (2011)
2 E_2 = 2505; // Second excited state of Ni-60, KeV
3 E_1 = 1332; // First excited state of Ni-60, KeV
4 E_0 = 0; // Ground state of Ni-60 , KeV
5 E_G_2 = E_2-E_1; // Energy of gamma rays emitted
    when transition from 2 to 1, KeV
6 E_G_1 = E_1-E_0; // Energy of gamma rays emitted
    when transition from 1 to 0, KeV
7 printf("\n Energies of two gamma rays emitted : %d
    KeV and %d KeV", E_G_2, E_G_1)
8 // Result
9 //     Energy of two gamma rays emitted : 1173 KeV
    and 1332 KeV
```

Scilab code Exa 3.7.2 Conversion energies for K and L shell electrons

```
1 // Scilab code Exa. 3.7.2 : To determine the
    energies conversion for K and L-shell electrons
    for reaction Cs(55,137) = Ba(56,137)+e(-1,0):
    Page no. 141 : (2011)
2 E = 662; // Energy available with the nucleus, KeV
3 I_b_K = 37.4; // Binding energy for K-shell, KeV
4 I_b_L = 6.0; // Binding energy for L-shell, KeV
5 E_c_K = E-I_b_K; // Energy conversion for K-shell,
    KeV
6 E_c_L = E-I_b_L; // Energy conversion for L-shell,
    KeV
```

```
7 printf("\n Energies conversion for K and L-shell
    electrons : %5.1f KeV and %d KeV", E_c_K, E_c_L)
8 // Result
9 //      Energies conversion for K and L-shell
    electrons : 624.6 KeV and 656 KeV
```

Scilab code Exa 3.9.1 Age of uranium mineral

```
1 // Scilab code Exa. 3.9.1 : To calculate the age of
    uranium mineral: Page no. 143 : (2011)
2 t_h = 4.5e+09; // Half life of mineral, years
3 D_c = 0.6931/t_h; // Decay constant of minerals,
    years^-1
4 N_1 = 6.023e+023/238; // Number of nuclei in 1g of
    Uranium
5 N = 6.023e+023*0.093/206; // Number of nuclei in
    0.093g of lead
6 t = log(1+N/N_1)/D_c; // Age of the mineral, years
7 printf("\n Age of the mineral : %6.4e years ", t)
8 // Result
9 //          Age of the mineral : 6.6261e+008 years
```

Scilab code Exa 3.9.2 Age of boat from its half life

```
1 // Scilab code Exa. 3.9.2 : To determine the age of
    boat whose half life is given : Page no. 145 :
    (2011)
2 t_h = 5760; // Half life of boat, years
3 D_c = 0.6931/t_h; // Decay constant of boat, years
    ^-1
4 N_1 = 16; // Number of atoms decay per min. per gram
     initially
```

```
5 N = 5; // Number of atoms decay per min per gram
    presently
6 t = log(N_1/N)*1/D_c; // Age of the boat, years
7 printf("\n Age of the boat : %d years ", t)
8 // Result
9 //          Age of the boat : 9666 years
```

Scilab code Exa 3.9.4 radioactive disintegration of Pu 239

```
1 // Scilab code Exa. 3.9.4 : To calculate the number
    of nuclei at t = 0, initial activity and age of
    Pu-239 which emit alpha particle : Page no. 145 :
    (2011)
2 t_h = 24000*365*24*3600; // Half life of Pu-239, s
3 D_c = 0.6931/t_h; // Decay constant of Pu-239, s^-1
4 N = 6.023e+023*10/239; // Number of nuclei at t = 0,
    nuclei
5 A_0 = D_c*N; // Initial activity, disintegrations/
    sec
6 A = 0.1; // Activity after time t, disintegrations/
    sec
7 t = log(A_0/A)*1/D_c; // Age of the Pu-239, years
8 printf("\nThe number of nuclei at t = 0,  = %4.2e
    nuclei \nInitial activity  = %4.2e
    disintegrations/s and \nAge  of Pu-239  = %4.2e
    years ", N, A_0, t)
9 // Result
10 //   The number of nuclei at t = 0,  = 2.52e+022
    nuclei
11 // Initial activity  = 2.31e+010 disintegrations/s
    and
12 //  Age of Pu-239  = 2.86e+013 years
```

Chapter 4

Nuclear Reactions

Scilab code Exa 4.3.1 Cross section of lithium

```
1 // Scilab code Exa4.3.1: To calculate the cross
     section of Li(3,7) : Page 179(2011)
2 t = 10^-5; // Thickness of Li(3,7), m
3 d = 500; // Density, Kg/m^3
4 N = 6.023e+026; // Number of  nuclei in 7-Kg of Li-7
5 M = 7 ; // Molar mass of Li
6 n = d*N*t/M; // Number of Li(3,7) nuclei/area
7 N_p = 10^8; // Number of neutron produced/s
8 N_0 = 10^13; // Number of incident particle striking
     /unit area of target
9 C_s = N_p/(N_0*n*10^(-028)); //  Cross section, b
10 printf("\n Cross section : %5.3f b", C_s)
11  // Result
12 //  Cross section : 0.232 b
```

Scilab code Exa 4.3.2 Neutron absorption ratio

```
1 // Scilab code Exa4.3.2: To calculate the fraction
```

```
    of neutron absorbed by Cd sheet of given
    thickness : Page 180 (2011)
t = 0.2e-03; // Thickness of Cd sheet, m
d = 8.64e+03; // Density, Kg/m^3
N = 6.023e+026; // Number of  nuclei in 7-Kg of Li-7
M = 112 ; // Atomic mass of Cd-113, amu
C_s = 20000e-028; //  Cross section of neutron for
    Cd-113, m^2
n = 0.12*d*N/M; // Number of Cd atoms/volume, atoms/
    m^3
F_inc_absorb = [1-%e^(-n*C_s*t)]*100; // Fraction of
     neutron absorbed
printf("\n Fraction of neutron absorbed by Cd sheet
    : %4.2f percent",F_inc_absorb )
// Result
//   Fraction of neutron absorbed by Cd sheet :
    89.25 percent
```

Scilab code Exa 4.4.1 Nuclear reactions

```
// Scilab code Exa test : Checking the possibility
    of occurence of reactions : page no. 181 (2011)
// Declare three cells (for three reactions)
R1 = cell(4,4);
R2 = cell(5,4);
R3 = cell(4,4);
// Enter data for first cell (Reaction)
R1(1,1).entries = 'Al'; // Element
R1(1,2).entries = 13;   // Atomic number
R1(1,3).entries = 27;    // Mass number
R1(1,4).entries = 0;    // Lepton number
R1(2,1).entries = 'He';
R1(2,2).entries = 2;
R1(2,3).entries = 4;
R1(2,4).entries = 0;
```

```
15 R1(3,1).entries = 'Si';
16 R1(3,2).entries = 14;
17 R1(3,3).entries = 30;
18 R1(2,4).entries = 0;
19 R1(4,1).entries = 'n';
20 R1(4,2).entries = 0;
21 R1(4,3).entries = 1;
22 R1(2,4).entries = 0;
23 // Enter data for second cell (Reaction)
24 R2(1,1).entries = "U";
25 R2(1,2).entries = 92;
26 R2(1,3).entries = 235;
27 R2(1,4).entries = 0;
28 R2(2,1).entries = 'n';
29 R2(2,2).entries = 0;
30 R2(2,3).entries = 1;
31 R2(2,4).entries = 0;
32 R2(3,1).entries = 'Ba';
33 R2(3,2).entries = 56;
34 R2(3,3).entries = 143;
35 R2(3,4).entries = 0;
36 R2(4,1).entries = 'Kr';
37 R2(4,2).entries = 36;
38 R2(4,3).entries = 90;
39 R2(4,4).entries = 0;
40 R2(5,1).entries = '2n';
41 R2(5,2).entries = 0;
42 R2(5,3).entries = 1;
43 R1(5,4).entries = 0;
44 // Enter data for third cell (Reaction)
45 R3(1,1).entries = 'P';
46 R3(1,2).entries = 15;
47 R3(1,3).entries = 32;
48 R3(1,4).entries = 0;
49 R3(2,1).entries = 'S';
50 R3(2,2).entries = 16;
51 R3(2,3).entries = 32;
52 R3(2,4).entries = 0;
```

```
53 R3(3,1).entries = 'e';
54 R3(3,2).entries = -1;
55 R3(3,3).entries = 0;
56 R3(3,4).entries = 0;
57 R3(4,1).entries = 'v_e';
58 R3(4,2).entries = 0;
59 R3(4,3).entries = 0;
60 R3(4,4).entries = 0;
61 // Declare a function returning equality status of
     nucleon number
62 function f = check_nucleon(nr_sum,np_sum)
63         if nr_sum == np_sum then
64             f = 1;
65         else
66             f = 0;
67         end
68 endfunction
69
70 // Declare a function returning equality status of
     proton number
71 function f = check_proton(pr_sum,pp_sum)
72         if pr_sum == pp_sum then
73             f = 1;
74         else
75             f = 0;
76         end
77 endfunction
78
79 // Declare a function returning equality status of
     lepton number
80 function f = check_lepton(lr_sum,lp_sum)
81         if lr_sum == lp_sum then
82             f = 1;
83         else
84             f = 0;
85         end
86 endfunction
87
```

```
88  // Reaction-I
89  printf("\n\n\nReaction-I:\n\n");
90          pr_sum = R1(1,2).entries+R1(2,2).entries;
91          pp_sum = R1(3,2).entries+R1(4,2).entries;
92          nr_sum = R1(1,3).entries+R1(2,3).entries;
93          np_sum = R1(3,3).entries+R1(4,3).entries;
94          lr_sum = R1(1,4).entries+R1(2,4).entries;
95          lp_sum = R1(3,4).entries+R1(4,4).entries;
96          if (check_nucleon(nr_sum,np_sum)&
               check_proton(pr_sum,pp_sum)&check_lepton(
               lr_sum,lp_sum) == 1) then
97              printf("The Reaction\n")
98              printf("\t%s(%d) + %s(%d) --> %s(%d)+%s(
                   %d)\nis possible", R1(1,1).entries,
                   R1(1,3).entries, R1(2,1).entries, R1
                   (2,3).entries, R1(3,1).entries, R1
                   (3,3).entries, R1(4,1).entries, R1
                   (4,3).entries);
99          elseif (check_proton(pr_sum,pp_sum) == 0)
               then
100             printf("The Reaction\n")
101             printf("\t%s(%d) + %s(%d) --> %s(%d)+%s(
                   %d)\nis impossible", R1(1,1).entries,
                    R1(1,3).entries, R1(2,1).entries, R1
                   (2,3).entries, R1(3,1).entries, R1
                   (3,3).entries, R1(4,1).entries, R1
                   (4,3).entries);
102             R1(4,1).entries = 'H'; R1(4,3).entries =
                    1;
103             printf("\nThe correct reaction is:\n")
104             printf("\t%s(%d) + %s(%d) --> %s(%d)+%s(
                   %d)\n", R1(1,1).entries, R1(1,3).
                   entries, R1(2,1).entries, R1(2,3).
                   entries, R1(3,1).entries, R1(3,3).
                   entries, R1(4,1).entries, R1(4,3).
                   entries);
105         end
106 //  Display for reaction-II
```

```
107     printf("\n\n\nReaction-II:\n\n");
108           pr_sum = R2(1,2).entries+R2(2,2).entries;
109           pp_sum = R2(3,2).entries+R2(4,2).entries+R2
                 (5,2).entries;
110           nr_sum = R2(1,3).entries+R2(2,3).entries;
111           np_sum = R2(3,3).entries+R2(4,3).entries+R2
                 (5,3).entries;
112           lr_sum = R2(1,4).entries+R2(2,4).entries;
113           lp_sum = R2(3,4).entries+R2(4,4).entries+R2
                 (5,4).entries;
114           if (check_nucleon(nr_sum,np_sum)&
                 check_proton(pr_sum,pp_sum)&check_lepton(
                 lr_sum,lp_sum) == 1) then
115              printf("The Reaction\n")
116              printf("\t%s(%d) + %s(%d) --> %s(%d)+%s(
                    %d)+%s(%d)\nis possible", R2(1,1).
                    entries, R2(1,3).entries, R2(2,1).
                    entries, R2(2,3).entries, R2(3,1).
                    entries, R2(3,3).entries, R2(4,1).
                    entries, R2(4,3).entries, R2(5,1).
                    entries, R2(5,3).entries);
117           elseif (check_nucleon(nr_sum,np_sum) == 0)
                 then
118              printf("The Reaction\n")
119              printf("\t%s(%d) + %s(%d) --> %s(%d)+%s(
                    %d)+%s(%d)\nis impossible", R2(1,1).
                    entries, R2(1,3).entries, R2(2,1).
                    entries, R2(2,3).entries, R2(3,1).
                    entries, R2(3,3).entries, R2(4,1).
                    entries, R2(4,3).entries, R2(5,1).
                    entries, R2(5,3).entries);
120               R2(5,1).entries = '3n';
121              printf("\nThe correct reaction is:\n")
122              printf("\t%s(%d) + %s(%d) --> %s(%d)+%s(
                    %d)+%s(%d)\n", R2(1,1).entries, R2
                    (1,3).entries, R2(2,1).entries, R2
                    (2,3).entries, R2(3,1).entries, R2
                    (3,3).entries, R2(4,1).entries, R2
```

```
                (4,3).entries, R2(5,1).entries, R2
                (5,3).entries);
123          end
124  //      Reaction-III
125              printf("\n\n\nReaction-III:\n\n");
126          pr_sum = R3(1,2).entries+R3(2,2).entries;
127          pp_sum = R3(3,2).entries+R3(4,2).entries;
128          nr_sum = R3(1,3).entries+R3(2,3).entries;
129          np_sum = R3(3,3).entries+R3(4,3).entries;
130          lr_sum = R3(1,4).entries+R3(2,4).entries;
131          lp_sum = R3(3,4).entries+R3(4,4).entries;
132          if (check_nucleon(nr_sum,np_sum)&
                check_proton(pr_sum,pp_sum)&check_lepton(
                lr_sum,lp_sum) == 1) then
133              printf("The Reaction\n")
134              printf("\t%s(%d) + %s(%d) --> %s(%d)+%s(
                    %d)\nis possible", R3(1,1).entries,
                    R3(1,3).entries, R3(2,1).entries, R3
                    (2,3).entries, R3(3,1).entries, R3
                    (3,3).entries, R3(4,1).entries, R2
                    (4,3).entries);
135          elseif (check_lepton(nr_sum,np_sum) == 0)
                then
136              printf("The Reaction\n")
137              printf("\t%s(%d) + %s(%d) --> %s(%d)+%s(
                    %d)\nis impossible", R3(1,1).entries,
                     R3(1,3).entries, R3(2,1).entries, R3
                    (2,3).entries, R3(3,1).entries, R3
                    (3,3).entries, R3(4,1).entries, R3
                    (4,3).entries);
138               R3(4,1).entries = 'v_e_a'
139              printf("\nThe correct reaction is:\n")
140              printf("\t%s(%d) + %s(%d) --> %s(%d)+%s(
                    %d)\n", R3(1,1).entries, R3(1,3).
                    entries, R3(2,1).entries, R3(2,3).
                    entries, R3(3,1).entries, R3(3,3).
                    entries, R3(4,1).entries, R3(4,3).
                    entries);
```

```
141         end
142
143 // Reaction-I:
144
145 // The Reaction
146 //  Al(27) + He(4) --> Si(30)+n(1)
147 // is impossible
148 // The correct reaction is:
149 //  Al(27) + He(4) --> Si(30)+H(1)
150
151
152
153 // Reaction-II:
154
155 // The Reaction
156 //  U(235) + n(1) --> Ba(143)+Kr(90)+2n(1)
157 // is impossible
158 // The correct reaction is:
159 //  U(235) + n(1) --> Ba(143)+Kr(90)+3n(1)
160
161
162
163 // Reaction-III:
164
165 // The Reaction
166 //  P(32) + S(32) --> e(0)+v_e(0)
167 // is impossible
168 // The correct reaction is:
169 //  P(32) + S(32) --> e(0)+v_e_a(0)
```

Scilab code Exa 4.5.1 Q value for reaction

```
1 // Scilab code Exa4.5.1: To calculate Q-value for
    given reaction  : Page 182 (2011)
2 M_n = 1.00866501; // Mass of neutron, amu
```

```
3 M_Hp = 2.014102; // Mass of proton, amu
4 M_Hd = 3.016049; // Mass of deutron, amu
5 M_He = 4.002603; // Mass of alpha particle, amu
6 Q = [M_Hp+M_Hd-M_He-M_n]*931.49; // Q-value, MeV
7 printf("\nThe Q-value for the reaction : %4.1f MeV",
      Q)
8 // Result
9 //    The Q-value for the reaction : 17.6 MeV
```

Scilab code Exa 4.5.2 Energy emitted in nuclear reaction

```
1 // Scilab code Exa4.5.2: To calculate Q-value for
     the reaction : Page 183 (2011)
2 M_Cf = 252.081621; // Mass of califronium, amu
3 M_Cm = 248.072343; // Mass of curium, amu
4 M_He = 4.002603; // Mass of alpha particle, amu
5 Q = [M_Cf-M_Cm-M_He]*931.49; // Q-value, MeV
6 printf("\nThe Q-value for the reaction : %4.2f MeV",
      Q)
7 // Result
8 // The Q-value for the reaction : 6.22 MeV
```

Scilab code Exa 4.5.3 Threshold energy and Q value for nuclear reaction

```
1 // Scilab code Exa4.5.3: To calculate Q-value and
     threshold energy for the given reaction : Page
     183 (2011)
2 // Pb_208(Fe_56, Fe_54)Pb_210
3 M_Pb_208 = 207.976641; // Mass of Pb-208, amu
4 M_Fe_56 = 55.934939; // Mass of Fe-56, amu
5 M_Pb_210 = 209.984178; // Mass of Pb-210, amu
6 M_Fe_54 = 53.939612; // Mass of Fe-54, amu
```

```
7 Q = [M_Pb_208+M_Fe_56-M_Pb_210-M_Fe_54]*931.49; // Q
    -value , MeV
8 E_th = -Q*(M_Fe_56+M_Pb_208)/M_Pb_208; // Threshold
    energy , MeV
9 printf("\nThe Q-value for the reaction   = %5.2f
    MeV \n Threshold energy   = %5.2f MeV ", Q,E_th)
10 // Result
11 //  The Q-value for the reaction   =  -11.37 MeV
12 //  Threshold energy   = 14.43 MeV
```

Scilab code Exa 4.5.4 Mass of neutron from nuclear reaction

```
1 // Scilab code Exa4.5.4: To calculate  the mass of
    neutron for  given reaction : P.No. 184 (2011)
2 // H(1,1)+n(0,1) = H(1,2)+G is the reaction
3 M_H_2 = 2.014735; // Mass of H-2, amu
4 M_H_1 = 1.008142 ; // Mass of H-1, amu
5 E_g = 2.230; // Energy of gamma rays , MeV
6 M_n_1 = [(M_H_2*931.47+E_g)-(M_H_1*931.47)]/931.47;
    //Mass of neutron , amu
7 printf("\nThe  mass of the neutron  : %8.6f MeV ",
    M_n_1)
8 // Result
9 //      The mass of the neutron  : 1.008987 MeV
```

Scilab code Exa 4.5.5 Q value sign for nuclear reaction

```
1 // Scilab code Exa 4.5.5 : Checking given reaction
    condition : page no. 184 (2011)
2 // Li-6 + n-1     > He-4 + H-3 is the given reaction
3 M_Li = 6.0151234; // Atomic mass of Li , amu
4 M_n = 1.0086654; //  Atomic mass of neutron , amu
5 M_He = 4.0026034; //  Atomic mass of He, amu
```

```
6  M_H = 3.0160294; //  Atomic mass of H, amu
7  r_sum = M_Li+M_n; //  Sum of reactant , amu
8  p_sum = M_He+M_H; //  Sum of product , amu
9  // Declare a function returning equality status of
       nucleon number
10 function Q = check_Qvalue(r_sum,p_sum)
11         if r_sum >= p_sum then
12             Q = 1;
13         else
14             Q = 0;
15         end
16 endfunction
17
18 // Reaction
19         if (check_Qvalue(r_sum,p_sum)  == 1) then
20             printf("\n Reaction : \n\n\t Li(6)+n(1)
                   ----> He(4)+H(3)")
21             printf("\n\n\t\tThis reaction is
                   exoergic")
22         elseif (check_Qvalue(r_sum,p_sum) == 0) then
23             printf("\n Reaction : \n\n\t Li(6)+n(1)
                   ----> He(4)+H(3)")
24             printf("\n\n\t\tThis reaction is
                   endoergic")
25           end
26 // Reaction :
27
28 //  Li(6)+n(1) ----> He(4)+H(3)
29
30    //  This reaction is exoergic
```

Scilab code Exa 4.5.6 Spontaneity of Q value for nulclear reaciton

```
1 // Scilab code Exa 4.5.5 : Checking whether the
      reaction  is spontaneous or exoergic : page no.
```

```
   185 (2011)
// Cf-252    > Zr-98 +Ce-145 + 9*n-1 is the given
   reaction
M_Cf = 252.081621; // Atomic mass of Cf, amu
M_Zr = 97.912735; //  Atomic mass of Zr, amu
M_Ce = 144.917230; //  Atomic mass of Ce, amu
M_n = 3.0160294; //  Atomic mass of neutron, amu
r_sum = M_Cf+M_Zr; //  Sum of reactant, amu
p_sum = M_Ce+M_n; //  Sum of product, amu
// Declare the function which check the Q-value
function Q = check_Qvalue(r_sum,p_sum)
        if r_sum >= p_sum then
            Q = 1;
        else
            Q = 0;
        end
endfunction

// Reaction
        if (check_Qvalue(r_sum,p_sum)  == 1) then
            printf("\n Reaction : \n\n\t Cf(256)
               ----> Zr(98)+Ce(145)+9*n(1)")
            printf("\n\n\t\tThis reaction is
               spontaneous")
        elseif (check_Qvalue(r_sum,p_sum) == 0) then
            printf("\n Reaction : \n\n\t Cf(256)
               ----> Zr(98)+Ce(145)+9*n(1)")
            printf("\n\n\t\tThis reaction is not
               spontaneous")
          end
 // Reaction :
   //  Cf(256) ----> Zr(98)+Ce(145)+9*n(1)

    //  This reaction is spontaneous
```

Scilab code Exa 4.5.7 Nuclear reaction Q value

```
1 // Scilab code Exa4.5.7: To calculate Q-value for
    given reaction : Page 185 (2011)
2 // O(8,16)      > N(7,15)+ H(1,1) is the given
    reaction
3 M_N_15 = 15.000108; // Mass of N-15, amu
4 M_O_16 = 16; // Mass of O-16, amu
5 M_H_1 = 1.007825; // Mass of H-1, amu
6 Q = [M_O_16-M_N_15-M_H_1]*931.49; // Q-value, MeV
7 printf("\nThe Q-value for the reaction  : %3.1f MeV
    ", Q)
8 // Result
9 //The Q-value for the reaction  : -7.4 MeV
```

Scilab code Exa 4.5.8 Threshold energy for given reaction

```
1 // Scilab code Exa4.5.8: To determine the threshold
    energy for given reaction : P.no. 185 (2011)
2 // Na(11,23)+ n    >   F(9,20)+ He(2,4) is the
    reaction
3 M_Na_23 = 22.99097; // Mass of Na-23, amu
4 M_n_1 =1.00866 ; // Mass of n-1, amu
5 Q = -5.4; // Q-value, MeV
6 E_th = -Q*(M_Na_23+M_n_1)/M_Na_23; // Threshold
    energy, MeV
7 printf("\nThe threshold energy for the reaction  :
    %4.2f MeV ", E_th)
8 // Result
9 //   The threshold energy for the reaction  : 5.64
    MeV
```

Scilab code Exa 4.5.9 Q value of nuclear reaction

```
1 // Scilab code Exa4.5.9: To calculate Q-value for
    the reaction : Page 187 (2011)
2 // He(2,4)+ N(7,14) = O(8,17)+ H(1,1)is the given
    reaction
3 M_N_14 = 14.00755; // Mass of N-14, amu
4 M_He_4 = 4.00388; // Mass of He-4, amu
5 M_O_17 = 17.00452; // Mass of O-17, amu
6 M_H_1 = 1.00815; // Mass of H-1, amu
7 Q = [M_N_14+M_He_4-M_O_17-M_H_1]*931.49; // Q-value,
    MeV
8 printf("\nThe Q-value for the reaction  : %4.2f MeV
    ", Q)
9 // Result
10 //The Q-value for the reaction  : -1.16 MeV
```

Scilab code Exa 4.5.10 Energy of gamma rays

```
1 // Scilab code Exa4.5.10: To determine the energy of
    gamma ray for reaction :: P.no. 186 (2011)
2 //    H(1,2)+G = H(1,1)+ n(0,1) is the given
    reaction
3 M_H_2 = 2.014735; // Mass of H-2, amu
4 M_H_1 = 1.008142 ; // Mass of H-1, amu
5 M_n_1 = 1.008987; // Mass of M_n_1, amu
6 Q = -5.4; // Q-value, MeV
7 E_g = (M_H_1*931.47+M_n_1*931.47)-(M_H_2*931.47); //
    Energy of the gama rays, MeV
8 printf("\nThe energy of the gama rays  : %6.4f MeV
    ", E_g)
9 // Result
10 //   The energy of the gama rays  : 2.2299 MeV
```

Scilab code Exa 4.7.1 Energy and power released during fission of U 235

```
1 // Scilab code Exa4.7.1: To calculate the energy
    and power released during fission of U-235 : Page
     189 (2011)
2 m = 0.001; // Mass of U-235 lost during fission, Kg
3 c = 3e+08; // Velocity of light, m/s
4 E = m*c^2; // Energy released during fission, J
5 E_t = E/(4e+09*1000); // Energy requires TNT, Kt
6 printf("\n Energy released during fission     = %1.0e
    J  \n Destructive power of bomb    =  %4.1f Kt
    of TNT", E, E_t)
7 // Result
8   //     Energy released during fission     = 9e+013
     J
9 //  Destructive power of bomb    =  22.5 Kt of TNT
```

Scilab code Exa 4.7.2 Fission rate induced in the uranium foil by neutron

```
1 // Scilab code Exa4.7.2: To determine the fission
    rate induced in the foil by neutron  : Page 190
    (2011)
2 t = 0.15; // Thickness of the foil, Kg
3 N = 6.023e+026; // Number of nuclei in 1Kg of U-235,
     nuclei
4 N_1 = N/235*t; // Number of nuclei in 0.15Kg of U
    -235, nuclei
5 A = 2e-026; // Area present in each nucleus, m^2
6 I = 10^6; // Intensity ,s^-1
7 F_r = N_1*A; // Rate of fissions induced in the foil
     by the neutrons, s^-1
8 printf("\n Rate of fissions induced in the foil by
    the neutrons: %5.3e per sec", F_r)
9 // Result
10 //      Rate of fissions induced in the foil by the
    neutrons: 7.689e-003 per sec
```

Scilab code Exa 4.7.3 Power in fission process

```
1 // Scilab code Exa4.7.3: To determine the fission
    power produced by one microgram of Fm-256 : Page
    190 (2011)
2 N = 6.023e+023/256*10^-6; // Number of nuclei in 1ug
    of Fm-256
3 t_h = 158*60; // Half life of Fm-256, s
4 D_c = log(2)/t_h; // Decay constant, s^-1
5 F_r = N*D_c; // Fission rate, fissions/s
6 E = 220*1.6e-013; // Energy released during fission
    of one nucleus, J
7 P = E*F_r; // Power released in fission of 1
    microgram of Fm-256, W
8 printf("\n Power released in fission of 1 microgram
    of Fm-256 = %d W", P)
9 // Result
10 //          Power released in fission of 1 microgram
    of Fm-256 = 6 W
```

Scilab code Exa 4.7.4 Power released in fission

```
1 // Scilab code Exa4.7.4: To determine the power
    produced by 100 milligram of Cf-252 : Page 191
    (2011)
2 N = 6.023e+023/252*0.1; // Number of nuclei in 100mg
    of Cf-252
3 t_h = 2.62*365*24*3600; // Half life of Cf-252, s
4 D_c = log(2)/t_h; // Decay constant, s^-1
5 F_r = N*D_c; // Fission rate, fissions/s
6 E = 210*1.6e-013; // Energy released during fission
    of one nucleus, J
```

```
7 P = E*F_r; // Power released in fission of 100
    milligram of Cf-252, W
8 printf("\n Power released in fission of 100
    milligram of Cf-252: %4.1f W", P)
9 // Result
10 //          Power released in fission of 100
    milligram of Cf-252: 67.4 W
```

Scilab code Exa 4.7.5 Fission counts and mass reduction of fissile material

```
1 // Scilab code Exa4.7.5: To determine the number of
    nuclear fission and decrease in mass during
    explosion at hiroshima : Page 191 (2011)
2 E = 200*1.6e-013; // Energy released during fission
    of one nucleus, J
3 E_t = 20000*4.18e+09; // Energy released in
    detonation of 20000 tons of TNT, J
4 N_f = E_t/E; // Number of fission occured during
    eplosion, fissions
5 c = 3e+08; // Velocity of light, m/s
6 m = E_t/(c)^2*10^6; // Decrease in mass during
    explosion, mg
7 m_r = round(m)
8 printf("\n Number of fissions occured during
    explosion    = %4.2e fissions \n Decrease in mass
     during explosion    = %d mg ", N_f, m_r)
9 // Result
10 //          Number of fissions occured during
    explosion    = 2.61e+024 fissions
11 //          Decrease in mass during explosion    =
    929 mg
```

Scilab code Exa 4.8.1 Energy liberated in fusion reaction

```
1 // Scilab code Exa4.8.1: To calculate the energy
     liberated during fusion reaction: Page 194 (2011)
2 //  5*H(1,2)= He(2,3)+He(2,4)+H(1,2)+2*n(0,1)+25MeV
     is the given reaction
3 N = 6.023e+026/2*10; // Number of atoms in 10Kg of H
     -2, atoms
4 E = 25/5*1.6e-013; // Energy liberate during fusion
     of 1 atom of H-2, J
5 E_l = E*N; // Energy liberate during fusion of 10 Kg
      of H-2, J
6 printf("\n Energy liberated during fusion of 10 Kg
     of H-2 = %4.2e J", E_l)
7 // Result
8 //   Energy liberated during fusion of 10 Kg  of H-2
     = 2.41e+015 J
```

Scilab code Exa 4.8.2 Energy produced by helium carbon fusion

```
1 // Scilab code Exa4.8.2: To calculate the energy
     produced by the fusion reaction He(2,4)+C(6,12)=
     O(8,16) : Page 194 (2011)
2 M_r = 16.002603; // Mass of the reactant, amu
3 M_p = 15.994915; // Mass of reactant, amu
4 M_d = 7.688e-03; // Difference in masses, amu
5 E_p = M_d*931.49; // Energy produced, MeV
6 printf("\n Energy produced by the fusion reaction :
     %4.2f MeV", E_p)
7 // Result
8 // Energy produced by the fusion reaction :7.16 MeV
```

Scilab code Exa 4.8.3 Energy released and temperature required for fusion of gases

```
1 // Scilab code Exa4.8.3: To calculate the energy
    released and temperature required for fusion of
    given gases : Page 194 (2011)
2 // Firstly calculate for B-10
3 Z_B = 5; // Atomic number of B-10
4 r_B = 5.17; //  Seperation of two nuclei, fm
5 K = 1.38e-023; // Boltzmann's constant
6 F = 1/137; // Fine structure constant
7 E = 197.5*1.6e-013; // Energy, J
8 V_c_B = F*Z_B^2*E/r_B; // Coulomb barrier for B-10,
    J
9 T_B = 2/3*V_c_B/K; // Temperature required to
    overcome the barrier for B-10, K
10 // Now calculate for Mg-24
11 Z_Mg = 12; // Atomic number of Mg-24
12 r_Mg = 6.92; //  Seperation of two nuclei, fm
13 K = 1.38e-023; // Boltzmann's constant
14 F = 1/137; // Fine structure constant
15 E = 197.5*1.6e-013; // Energy, J
16 V_c_Mg = F*Z_Mg^2*E/r_Mg; // Coulomb barrier for Mg
    -24, J
17 T_Mg = 2/3*V_c_Mg/K; // Temperature required to
    overcome the barrier for Mg-24, K
18 printf("\nFor B-10 \n Energy released    = %4.2e J \n
     Temperature required    = %4.1e K    \nFor Mg-24
    \n Energy released     = %4.2e J \n Temperature
    required  =  %4.2e K", V_c_B,T_B, V_c_Mg,  T_Mg)
19 // Result
20  //       For B-10
21  // Energy released    = 1.12e-012 J
22  // Temperature required    = 5.4e+010 K
23 // For Mg-24
24 //  Energy released     = 4.80e-012 J
25 //  Temperature required  =  2.32e+011 K
```

Scilab code Exa 4.8.4 Life time of sun

```
1 // Scilab code Exa4.8.4: To calculate the life time
    of sun for given reaction : Page 196 (2011)
2 // 4*H(1,1)= He(2,4)+2*e(1,0)+2*v+G is the reaction
3 E_r = 3.9e+026; // Energy releasd in 1s, J
4 N = 1.2e+057; // Number of hydrogen atoms in the sun
    , atoms
5 M_d = 0.027599;// Mass difference, amu
6 E = M_d*931.47; // In terms of energy, MeV
7 E_t = N/4*E*1.6e-013; // Total energy available in
    the sun, J
8 t = E_t/(E_r*365*24*3600*10^9); // Life time of the
    sun, billion years
9 printf("\n Life time of the sun : %5.1f billion
    years", t)
10 // Result
11 //        Life time of the sun : 100.3 billion years
```

Scilab code Exa 4.8.5 Particle identification in the nuclear reaction

```
1 // Scilab code Exa 4.8.5 : Identifying the nucleus
    and energy released in the given reaction : page
    no. 197 (2011)
2 // Declare three cells (for three reactions)
3 R = cell(4,3);
4 // Enter data for first cell (Reaction)
5 R(1,1).entries = 'H'; // Element
6 R(1,2).entries = 1;   // Atomic number
7 R(1,3).entries = 2;    // Mass number
8 R(2,1).entries = 'H';
9 R(2,2).entries = 1;
```

```
10 R(2,3).entries = 3;
11 R(3,1).entries = 'n'
12 R(3,2).entries = 0;
13 R(3,3).entries = 1;
14 R(4,1).entries = 'He'
15 R(4,2).entries = 2;
16 R(4,3).entries = 3;
17 // Declare a function returning equality status of
   nucleon number
18
19         p_sum = R(1,2).entries+R(2,2).entries;
20                 if (p_sum == 2) then
21
22             printf("\n The particle is : %s(%d,%d) "
                  ,R(4,1).entries,R(4,2).entries,R(4,3)
                  .entries )
23              end
24 //  Calculate the energy released
25 m_n = 1.008665; // Mass of neutron, amu
26 m_d = 2.014102; // Mass of deutron, amu
27 m_He = 3.0160293; // Mass of He-3, amu
28 E = [2*m_d-(m_n+m_He)]*931.47; // Energy released in
    this reaction, MeV
29 printf("\n The energy released in this reaction : %4
   .2f MeV", E )
30 // Result
31 //          The particle is : He(2,3)
32  //       The energy released in this reaction : 3.27
     MeV
```

Scilab code Exa 4.8.6 Mass defect and q value for fusion reaction

```
1 // Scilab code Exa4.8.6: To calculate the mass
   defect and Q-value for the fusion reactions :
   Page 197 (2011)
```

```
2  //  Reaction-1 = H(1,2)+H(1,2)= He(2,3)+n(0,1)
3  m_p = 1.007825; // Mass of proton, amu
4  m_n = 1.008665; // Mass of neutron, amu
5  m_H = 2.014102; // Mass of H(1,2), amu
6  m_He = 3.016029; // Mass of He(2,3), amu
7  m_d_1 = 2*m_H-m_He-m_n; // Mass defect for reaction
       first, amu
8  Q_1 = m_d_1*931.47; // Q-value for reaction first,
       MeV
9  // Reaction-2 = H(1,2)+H(1,2)= H(1,3)+p(1,1)
10 m_p = 1.007825; // Mass of proton, amu
11 m_n = 1.008665; // Mass of neutron, amu
12 m_H = 2.014102; // Mass of H(1,2), amu
13 m_H_3 = 3.016049; // Mass of H(1,3), amu
14 m_d_2 = 2*m_H-m_H_3-m_p; // Mass defect for reaction
       second, amu
15 Q_2 = m_d_2*931.47; // Q-value for reaction second,
       MeV
16 printf("\nFor first reaction \n Mass defect    = %7
       .5f amu \n Q-value    =   %7.5f amu   \nFor
       second reaction \n Mass defect   =  %7.5f MeV \n
       Q-value    = %4.2f MeV ", m_d_1,Q_1, m_d_2,  Q_2)
17 // Result
18 //   For first reaction
19 //  Mass defect    = 0.00351 amu
20 //  Q-value    =   3.26946 amu
21 // For second reaction
22 //  Mass defect   =  0.00433 MeV
23 //  Q-value    = 4.03 MeV
```

Chapter 5

Interaction of Radiations with Matter

Scilab code Exa 5.2.1 Energy lost during collision

```
1 // Scilab code Exa5.2.1: To calculate the energy and
    no. of collision required to stop collision : P.
    no. 223 (2011)
2 m = 511; // Mass of electron , KeV
3 M = 938*10^3; // Mass of incident charged particle ,
    KeV
4 E = 10*10^3; // Energy of proton , KeV
5 E_l = 4*m*E/M; // Energy lost during collison , KeV
6 n = E/E_l; // Number of collisions ,
7 N = round(n)
8 printf("\n The energy lost during collision  = %5.2f
    KeV \n Number of collision required  = %d
    collisions",E_l, N )
9 // Result
10 //     The energy lost during collision  = 21.79 KeV
11 //  Number of collision required  = 459 collisions
```

Scilab code Exa 5.5.1 Half value thickness of aluminium

```
1 // Scilab code Exa5.5.1: To calculate the half value
      thickness of Al for given radiation : P.no. 225
     (2011)
2 x = 0.2; // Thickness of Al material , m
3 I_r = 3/100; // Intensity ratios ,
4 x_h = log(2)*x/log(1/I_r); // Half value thickness
    of Al, m
5 printf("\n  Half value thickness of Al : %6.4f m",
    x_h )
6 // Result
7 //       Half value thickness of Al : 0.0395 m
```

Scilab code Exa 5.5.2 Thickness of lead

```
1 // Scilab code Exa5.5.2: To calculate the thickness
    of Pb: P.no. 226 (2011)
2 u = 0.75; // Absorption coefficient , cm^-1
3 I_r = 1/100; // Intensity ratios ,
4 x = log(1/I_r)*u; // Thckness of Pb, cm
5 printf("\n Thickness of Pb : %5.3f cm",x )
6 // Result
7 //       Thickness of Pb : 6.140 m
```

Scilab code Exa 5.5.3 Percentage loss of intensity of gamma rays

```
1 // Scilab code Exa5.5.3: To calculate the percentage
     loss of intensity of gamma rays  : P.no. 226
    (2011)
2 x_h = 5; // Half thickness of an absorber , mm
3 u = log(2)/x_h; // Absorption coefficient , mm^-1
4 x = 20; // Thickness of an absorber , mm
```

```
5 I_r = %e^(-u*x); // Intensity ratios,
6 P_loss = I_r*100; // Percentage loss in intensity,
    percent
7 printf("\n Percentage loss in intensity : %4.2f
    percent",P_loss )
8 // Result
9 //        Percentage loss in intensity : 6.25
    percent
```

Scilab code Exa 5.6.1 Velocity of ejected photoelectron

```
1 // Scilab code Exa5.6.1: To calculate the velocity
    of ejected photoelectron : P.no. 230 (2011)
2  C = 3e+08; // Speed of light, m/s
3  h = 6.626e-034; // Planck's constant, Js
4  lambda = 2500e-010; //   wavelength of light, m
5 e = 1.602e-019; // Charge of electron, C
6  w = 1.9; // Work function, J
7 m = 9.1e-031; // Mass of the electron, kg
8 E_c = h*C/(lambda*e); // Calculated energy, J
9 E_e = E_c-w; // Energy of photoelectron, J
10 v = sqrt((2*E_e*e)/m); // Velocity of photoelectron,
    m/s
11 printf("\nThe velocity of photoelectron : %4.2e m/s
    ", v )
12 // Result
13 //      The velocity of photoelectron : 1.04e+006 m/
    s
```

Scilab code Exa 5.6.2 Rate of photoelectron emission

```
1 // Scilab code Exa5.6.2: To calculate the kinetic
     energy of photoelectron and rate at which
     photoelectron emitted : P.no. 231 (2011)
2  C = 3e+08; // Speed of light, m/s
3  h = 6.626e-034; // Planck's constant, Js
4  lambda = 250e-09; // Wavelength of light, m
5  w = 2.30; // Work function, eV
6 A = 2e-04; // Area of the surface, m^2
7 I = 2; // Intensity of light, W/m^2
8 e = 1.6e-019; // Charge of the electron, C
9 E_p = h*C/(lambda*e); // Energy of photoelectron, eV
10 E_max = E_p-w; // Maximum kinetic energy of
     photoelectron, eV
11 n_p = I*A/(E_p*e); // Number of photons reaching the
     surface per second, photons/s
12 R_p = 0.2/100*n_p; // Rate at which photoelectrons
     are emitted, photoelectrons/s
13 printf("\n The maximum kinetic energy    = %4.2f eV
     \n The rate at which photoelectrons are emitted
       =  %4.2e photoelectrons/s ", E_max, R_p)
14 // Result
15 //         The maximum kinetic energy    = 2.67 eV
16  // The rate at which photoelectrons are emitted
     =  1.01e+012 photoelectrons/s
```

Scilab code Exa 5.6.3 Kinetic energy of photoelectron

```
1 // Scilab code Exa5.6.3: To calculate the wavelength
     of light whose kinetic energy is given : P. No.
     232 (2011)
2  C = 3e+08; // Speed of light, m/s
3  h = 6.626e-034; // Planck's constant, Js
4  T_lambda = 190e-09; // Threhold wavelength of light
     , m
5 e = 1.6e-019; // Charge of the electron, C
```

```
E_max = 1.1; // Maximum kinetic energy of
   photoelectron , eV
w = h*C/(T_lambda*e); // Work function , eV
E_t = E_max+w; // threshold energy , eV
lambda = h*C/(E_t*e); // Wavelength of light used , m
printf("\nThe wavelength of light used  : %5.3e m",
   lambda)
// Result
//     The wavelength of light used  : 1.626e-007 m
```

Scilab code Exa 5.7.1 Compton shift

```
// Scilab code Exa5.7.1: To calculate the Compton
   shift : P.no. 233 (2011)
h = 6.62e-034; // Value of Planck's constant , J
m_e = 9.11e-031; // Mass of the electron ,Kg
c = 3e+08; // Velocity of light , m/s
A = 65; // Angle between scattered radiation and
   incident radiation , degree
C_s =  h/(m_e*c)*(1-cosd(A)); // Compton shift , m
printf("\nCompton shift  : %4.2e m",C_s )
// Result
//      Compton shift  : 1.40e-012 m
```

Scilab code Exa 5.7.2 Wavelength of the scattered gamma rays

```
// Scilab code Exa5.7.2: To calculate the
   wavelength of the scattered gamma rays: P.no. 233
    (2011)
h = 6.626e-034; // Value of Planck's constant , J
m_e = 9.11e-031; // Mass of the electron ,Kg
c = 3e-04; // Velocity of light , m/s
```

```
5 A = 135; // Angle between scattered radiation and
    incident radiation, degree
6 W_i = 1.87; // Wavelength of incident radiation, pm
7 W_s = W_i + [h*(1-cosd(A))]/(m_e*c); // Wavelength
    of scattered radiation, pm
8 printf("\nWavelength of scattered radiation    : %4.2
    f pm",W_s )
9 // Result
10 //        Wavelength of scattered radiation    : 6.01
    pm
```

Scilab code Exa 5.7.3 Wavelength of the incident beam of X rays

```
1 // Scilab code Exa5.7.3: To calculate the
    wavelength of the incident beam of X-rays : P.no.
     234 (2011)
2 h = 6.626e-034; // Value of Planck's constant, J
3 m_e = 9.11e-031; // Mass of the electron,Kg
4 c = 3e-04; // Velocity of light, pm/s
5 A = 90; // Angle between scattered radiation and
    incident radiation, degree
6 W_s = 3.8; // Wavelength of scattered radiation, pm
7 W_i = [W_s - h/(m_e*c)*(1-cosd(A))]; // Wavelength
    of incident beam of Xrays, pm
8 printf("\nWavelength of incident beam of X-rays : %4
    .2f pm", W_i )
9 // Result
10 //        Wavelength of incident beam of X-rays :
    1.38 pm
```

Scilab code Exa 5.7.4 Frequency of the scattered photon

```
1 // Scilab code Exa 5.7.4 : To calculate the
    frequency of the scattered photon  Page.no. 234
    (2011)
2 h = 6.626e-034; // Value of Planck's constant, J
3 m_e = 9.11e-031; // Mass of the electron,Kg
4 c = 3e+08; // Velocity of light, pm/s
5 A = 60; // Angle between scattered radiation and
    incident radiation, degree
6 v_0 = 3.2e+019; // Frequency of the incident photon,
     Hz
7 V = 1/v_0 + h/(m_e*c^2)*(1-cosd(A));
8 v =(1/V); // Frequency of the scattered photon, Hz
9 printf("\n Frequency of the scattered photon: %4.2e
    Hz", v )
10 // Result
11 //       Frequency of the scattered photon: 2.83e
    +019 Hz
```

Scilab code Exa 5.7.5 Energy of scattered photon and recoil electron

```
1 // Scilab code Exa 5.7.5 : To calculate the  energy
    of the scattered photon and the energy of recoil
    electron : P.no. 235 (2011)
2 h = 6.626e-034; // Value of Planck's constant, J
3 m_e = 9.11e-031; // Mass of the electron,Kg
4 c = 3e+08; // Velocity of light, pm/s
5 A = 180; // Angle between scattered radiation and
    incident radiation, degree
6 E_i = 1836; // Energy of the incident electron, KeV
7 E = 1/E_i + 1/511*(1-cosd(A));
8 E_s = round(1/E); // Energy of the sscattered photon
    , KeV
9 E_r = E_i-E_s; // Energy of the recoil electron, KeV
10 printf("\n Energy of the scattered photon     = %d
    KeV  \n Energy of the recoil electron     = %d KeV
```

```
    ", E_s, E_r )
// Result
//         Energy of the scattered photon    = 224
    KeV
 //         Energy of the recoil electron    = 1612
     KeV
```

Scilab code Exa 5.7.6 Scattering angle of X rays

```
// Scilab code Exa 5.7.6 : To calculate the
   scattering angle of X-rays  Page.no. 235 (2011)
E_s = 180; // Energy of the scattered X-rays, KeV
E_i = 200; // Energy of the incident X-rays, KeV
a = acosd(1-[{1/E_s-1/E_i}*511]); //
A = round(a); // Scattering angle of X-rays, degree
printf("\n Scattering angle of X-rays: %d degree", A
    )
// Result
//          Scattering angle of X-rays: 44 degree
```

Scilab code Exa 5.8.1 Kinetic energy of electron and positron

```
// Scilab code Exa5.8.1: To calculate the kinetic
   energy of electron and positron :P.no. 236 (2011)
 M_e = 0.511; // Rest mass of electron, MeV
 M_p = 0.511; // Rest mass of positron, MeV
 E_c = M_e+M_p; // Energy consumed, Mev
 E_g = 5.0; // Given energy, MeV
 E_l = E_g-E_c; // Energy left, Mev
 E_k = E_l/2; // Kinetic energy of electron and
    positron, MeV
 printf("\n The kinetic energy of electron and
    positron  : %5.3f Mev", E_k)
```

```
9  // Result
10 //          The kinetic energy of electron and
       positron   : 1.989 Mev
```

Chapter 6

Particle Accelerators

Scilab code Exa 6.2.1 Kinetic energy of protons

```
1 // Scilab code Exa6.2.1 : To calculate the kinetic
     energy of protons : Page 264 (2011)
2 q = 1;  //   Number of proton,
3 V = 800;    //  Voltage applied to the dome, kV
4 E = q*V; // The kinetic energy of proton,keV
5 printf("\nThe kinetic energy of proton : %d keV", E)
     ;
6 // Result
7 // The kinetic energy of proton : 800 keV
```

Scilab code Exa 6.3.1 Protons in Van de Graff accelerator

```
1 // Scilab code Exa6.3.1 : To calculate the kinetic
     energy of protons in Van de Graff accelerator:
     Page 265 (2011)
2 q = 1;  //   Number of proton,
3 V = 7;    //  Voltage applied to the dome, MV
4 E = q*V; // The kinetic energy of proton,MeV
```

```
5 printf("\nThe kinetic energy of proton : %d MeV", E)
    ;
6 // Result
7 //     The kinetic energy of proton : 7 MeV
```

Scilab code Exa 6.3.2 Reactions at different particle energies

```
1 // Scilab code Exa6.3.2 : To calculate the kinetic
    energy of protons and no. of  possibile reactions
    :  Page 265 (2011)
2 V = 5; // Voltage of accelerator, MV
3 // Declare three cells (for three reactions): Page
    no. : 133(2011)
4  R1 = cell(3,2)
5  R2 = cell(10,2)
6 // Enter data for first cell (Reaction)
7 R1(1,1).entries = "p";
8 R1(1,2).entries = 1;
9 R1(2,1).entries = 'd';
10 R1(2,2).entries = 1;
11 R1(3,1).entries = 'He';
12 R1(3,2).entries = 2;
13 E_p =  (R1(1,2).entries)*V
14 E_d =  (R1(2,2).entries)*V
15 E_He =  (R1(3,2).entries)*V
16  // Enter data for second cell (Reaction)
17  R2(1,1).entries = "p"
18  R2(1,2).entries = 1
19  R2(2,1).entries = "N"
20  R2(2,2).entries = 14
21  R2(3,1).entries = "O"
22  R2(3,2).entries = 15
23  R2(4,1).entries = "y"
24  R2(4,2).entries = 0
25  R2(5,1).entries = "d"
```

```
26  R2(5,2).entries = 1
27  R2(6,1).entries = "n"
28  R2(6,2).entries = 0
29  R2(7,1).entries = "He"
30  R2(7,2).entries = 3
31  R2(8,1).entries = "C"
32  R2(8,2).entries = 13
33  R2(9,1).entries = "He"
34  R2(9,2).entries = 4
35  R2(10,1).entries = "C"
36  R2(10,2).entries = 12
37  printf("\nProtons energy   = -%d MeV \n Deuterons
       energy   = -%d MeV  \n Double charged He-3  = -
       %d MeV", E_p, E_d, E_He)
38  printf("\n Possible reaction at these energies are"
       )
39  printf("\n %s + %s(%d) --->   %s(%d)+ %s", R2(1,1).
       entries,R2(2,1).entries,R2(2,2).entries,R2(3,1).
       entries,R2(3,2).entries,R2(4,1).entries)
40 printf("\n %s + %s(%d) --->   %s(%d) + %s ", R2(5,1)
     .entries,R2(2,1).entries,R2(2,2).entries,R2(3,1).
     entries,R2(3,2).entries,R2(6,1).entries)
41 printf("\n %s(%d) +%s(%d)  --->   %s(%d)+ %s", R2
     (7,1).entries,R2(7,2).entries,R2(8,1).entries,R2
     (8,2).entries,R2(3,1).entries,R2(3,2).entries,R2
     (6,1).entries)
42  printf("\n %s(%d) + %s(%d)  --->  %s(%d) +%s", R2
       (9,1).entries,R2(9,2).entries,R2(10,1).entries,
       R2(10,2).entries,R2(3,1).entries,R2(3,2).entries
       ,R2(6,1).entries)
43
44 // Result
45 // Protons energy   = -5 MeV
46 // Deuterons energy   = -5 MeV
47 // Double charged He-3  = -10 MeV
48 // Possible reaction at these energies are
49 // p + N(14) --->   O(15)+ y
50 // d + N(14) --->   O(15) + n
```

```
51 // He(3) +C(13)  --->   O(15)+ n
52 // He(4) + C(12)  --->  O(15) +n
```

Scilab code Exa 6.4.1 Protons passing through the carbon stripper foil

```
1 // Scilab code Exa6.4.1 : To calculate the kinetic
     energy of protons passing through the carbon
     stripper foil : Page 266 (2011)
2 q = 2;  //   Number of proton,
3 V = 15;    //  Voltage applied to the dome, MV
4 E = q*V; // The kinetic energy of proton,MeV
5 printf("\nThe kinetic energy of proton : %d MeV", E)
     ;
6 // Result
7 //    The kinetic energy of proton : 30 MeV
```

Scilab code Exa 6.5.1 Electron at relativistic energy

```
1 // Scilab code Exa6.5.1 : To calculate the
     difference between the electron's speed and speed
      of light. Page 265 (2011)
2 v = 2.999999997e+08;  //  Velocity of the electron,
     m/s
3 c = 3e+08;  // Velocity of light,m/s
4 D = c-v; // difference between electron's speed and
     speed of light,m/s
5 printf("\nThe difference between electron speed and
     speed of light : %3.1f m/s", D);
6 // Result
7 //  The difference between electron speed and speed
     of light : 0.3 m/s
```

Scilab code Exa 6.5.2 Protons accelerating through drift tubes

```
1 // Scilab code Exa6.5.2 : To calculate the length of
     the first and last drift tubes which accelerate
    the protons whose frequency and energies are
    given. Page 268 (2011)
2 f = 200e+06;  //  Frequency of applied the voltage,
    Hz
3 V_0 = 750e+03;  // Applied potential difference, V
4 q = 1.6e-019; // Charge of proton, C
5 m = 1.67e-027; // Mass of proton, Kg
6 n_1 = 1; // For first tube
7 L_1 = sqrt(2*n_1*q*V_0/m)/(2*f);   // Length of the
    first tube, m
8 n_n = 128; //  For last tube
9 L_n = 1/(2*f)*sqrt(2*n_n*q*V_0/m); // Length of the
    last tube,m
10 printf("\n Length of the first tube = %4.2f m \n
    Length of the last tube = %4.2f m ", L_1,L_n);
11 // Result
12 //    Length of the first tube = 0.03 m
13 //    Length of the last tube = 0.34 m
```

Scilab code Exa 6.5.3 Electron speed at relativistic energies

```
1 // Scilab code Exa6.5.3 : To calculate the velocity
    of the electrons using relativistic
    considerations . Page 269 (2011)
2 K_E = 1.17; // Kinetic energy of the electron, MeV
3 E_r = 0.511; // Rest mass energy of the electron,
    MeV
```

```
4 v = [1-1/(K_E/E_r+1)^2]; // Velocity of the electron
    , m/s
5 printf("\nVelocity of the electron : %4.2fc", v)
6 // Result
7 //    Velocity of the electron : 0.91c
```

Scilab code Exa 6.7.1 Proton accelerating in a cyclotron

```
1 // Scilab code Exa6.7.1 : To calculate the maximum
    energy, oscillator frequency and number of
    revolutions of proton accelerated in a cyclotron.
     Page 270(2011)
2 V = 20e+03; // Potential difference across the dees,
    V
3 r = 0.28; // Radius of the dees, m
4 B = 1.1; // Magnetic field, tesla
5 q = 1.6e-019; // Charge of the proton, C
6 m = 1.67e-027; // Mass of the proton, Kg
7 E_max = B^2*q^2*r^2/(2*m*1.6e-013); // Maximnum
    energy acquired by protons,MeV
8 f = B*q/(2*%pi*m*10^06); // Frequecy of the
    oscillator,MHz
9 N = E_max*1.6e-013/(q*V); // Number of revolutions,
10 disp(N)
11 printf("\n Maximum energy acquired by proton  = %4
    .2f MeV \n Frequency of the oscillator  = %4.2f
    MHz \n Number of revolutions  = %d revolutions
     ", E_max,f,N)
12 // Result
13 //    Maximum energy acquired by proton  =  4.54
    MeV
14 //  Frequency of the oscillator  = 16.77 MHz
15 //  Number of revolutions  =  227 revolutions
```

Scilab code Exa 6.7.2 Frequency of deutron accelerated in a cyclotron

```
1 // Scilab code Exa6.7.2 : To calculate the frequency
     of deutron accelerated in a cyclotron. Page
    271(2011)
2 B= 2.475; // Magnetic field, tesla
3 q = 1.6e-019; // Charge of the deutron, C
4 m = 2*1.67e-027; // Mass of the deutron, Kg
5 f = B*q/(2*%pi*m*10^06); // Frequency of the deutron
    ,MHz
6 printf("\nFrequency of the deutron:  %4.2f MHz ", f)
7 // Result
8 //   Frequency of the deutron:  18.87 MHz
```

Scilab code Exa 6.7.3 Relation between magnetic field and cyclotron frequency

```
1 // Scilab code Exa6.7.3 : To calculate the magnetic
    field applied to cyclotron whose frequency is
    given. Page 271(2011)
2 q = 1.6e-019; // Charge of the proton, C
3 r = 0.60; // radius of the dees, m
4 m = 1.67e-027; // Mass of the proton, Kg
5 f = 10^6; // Frequecy of the proton,Hz
6 B = 2*%pi*m*f/q; // Magnetic field applied to
    cyclotron, tesla
7 printf("\nMagnetic field applied to cyclotron :  %6
    .4f tesla ", B)
8 // Result
9 //    Magnetic field applied to cyclotron :  0.0656
    tesla
```

Scilab code Exa 6.7.4 Frequency of alternating field

```
1 // Scilab code Exa6.7.4 : To calculate the frequency
     of alternating field applied to dees. Page
    272(2011)
2 q = 1.6e-019; // Charge of the proton, C
3 m = 1.67e-027; // Mass of the proton, Kg
4 B = 1.4; // Magnetic field , tesla
5 f = B*q/(2*%pi*m*10^06); // Frequency of the applied
     field, tesla
6 printf("\n Frequency of the applied field : %4.2f
    MHz", f)
7 // Result
8 //     Frequency of the applied field :  21.35 MHz
```

Scilab code Exa 6.8.1 Energy gained by an electron in the magnetic field

```
1 // Scilab code Exa6.8.1. : To calculate the energy
    gained per turn of an electron present in given
    magnetic field. Page 273(2011)
2 e = 1.6e-019 ; // Charge of an electron, C
3 f = 60; // Frequency of variation magnetic field, Hz
4 B_0 = 1; // Magnetic field , tesla
5 r_0 = 1; // Radius of doughnut, m
6 E = 4*e*2*%pi*f*r_0^2/(1.6e-019); // Energy gained
    by electron per turn, eV
7 E_g = round(E)
8 printf("\n Energy gained by electron per turn:  %d
    eV", E_g)
9 // Result
10 //      Energy gained by electron per turn:  1508 eV
```

Scilab code Exa 6.9.1 Ratio of highest to the lowest frequency of accelerating proton

```
1 // Scilab code Exa6.9.1 : To determine the ratio of
    highest to the lowest frequency of cyclotron
    accelerating protons whose energy is given. Page
    273(2011)
2 K = 500; // Kinetic energy of the proton, MeV
3 E_r = 938; // Rest mass energy of the proton, MeV
4 R_f = E_r/(K+E_r); // The ratio of highest to the
    lowest frequency,
5 printf("\nThe ratio of highest to the lowest
    frequency : %4.2f ", R_f)
6 // Result
7 //    The ratio of highest to the lowest frequency :
     0.65
```

Scilab code Exa 6.9.2 W B ration of completely stripped nitrogen

```
1 // Scilab code Exa6.9.2 : To calculate the w/B ratio
     for a completely stripped nitrogen to move in a
    stable orbit : Page 274(2011)
2 E_k = 1200; // Kinetic energy of the proton, MeV
3 q = 7; // Number of proton in nitrogen
4 E_r = 13040 //  Rest mass energy of the electron,
    MeV
5 E = (E_k+E_r)*1.6e-013; // Total energy,j
6 c = 3e+08; // Velocity of light, m/s
7 R_w_B = q*1.6e-019*c^2/E; // Ratio of w/B, m^2/W
8 printf("\nThe ratio of w/B : %4.2e m^2/W ", R_w_B)
9 // Result
10 //      The ratio of w/B :  4.42e+007 m^2/W
```

Scilab code Exa 6.10.1 Magnetic field of the electron

```
1 // Scilab code Exa6.10.1 : To calculate the value of
     magnetic field of the electron whose energy is
    given   Page 274(2011)
2 q = 1.602e-019; // Charge of an electron , C
3 r = 0.28; // Radius of stable orbit ,m
4 E = 70*1.6e-013;  //  Energy of the electron , j
5 c = 3e+08; // Velocity of light , m/s
6 B = E/(e*r*c); // Magnetic field , T
7 printf("\nThe magnetic field of the electron :  %4.2
    f T", B)
8 // Result
9 //   The magnetic field of the electron :  0.83 T
```

Scilab code Exa 6.10.2 Radius of proton orbit in synchrotron

```
1 // Scilab code Exa6.10.2 : To calculate the radius
    of proton orbit in synchrotron of given energy
    Page 275(2011)
2 c= 3e+08; // Speed of light in vacuum, m/s
3 q = 1.602e-019; // Charge on proton , coulomb
4 amu = 931;     // Energy equivalent of 1 amu, MeV
5 m = 938;  //  Rest mass of a proton , MeV
6 KE = 12e+03;     // Kinetic energy of proton , MeV
7 B = 1.9; // Magnetic field , T
8 E = m + KE;     // Total energy of proton , MeV
9 // As E = m*amu, solving for m, the mass of proton
10 m = E/amu*1.672e-027;     // Proton mass in motion,
    kg
11 v = 0.9973*c; // Velocity of the proton , m/s
```

```
12 r = m*v/(B*q); // Radius of the proton, m
13 printf("\nRadius of the proton orbit :  %4.2f m", r)
14 // Result
15 //          Radius of the proton orbit:  22.84 m
```

Chapter 7

Radiation Detectors

Scilab code Exa 7.2.1 Energy of alpha particle

```
1 // Scilab code Exa7.2.1: To calculate the energy of
      alpha particle :P.no. 308 (2011)
2   E_p = 30; // Energy required for one pair, eV
3   n = 150000; // Number of pairs
4  E_a = n*E_p/10^6; // Energy of alpha particle, Mev
5   printf("\n The energy of alpha particle  : %3.1f
      Mev", E_a)
6 // Result
7 //     The energy of alpha particle  : 4.5 Mev
```

Scilab code Exa 7.3.1 Pulse height of ionising particle

```
1 // Scilab code Exa7.3.1: To calculate the pulse
     height of ionising particle :P.no. 308 (2011)
2   E = 5.48e+06; // Energy of alpha particle, eV
3   C = 50e-012; // Capacitance of the chamber, F
4   R = 10^6; // Resistance, ohm
5   E_p = 35; // Energy required to produced an ion
      pair, eV
```

```
6   n = E/E_p; // Number of ion pair produced
7     e = 1.6e-019; // Charge of an electron, C
8   V =( n*e)/C; // Pulse height, V
9     I = V/R; // current produced, A
10  printf("\n The pulse height  =  %4.3e V \n Current
      produced  = %5.3e A", V,I)
11 // Result
12 // The pulse height    =  5.010e-004 V
13  //Current produced   = 5.010e-010 A
```

Scilab code Exa 7.3.2 Charge deposited on detector plate

```
1 // Scilab code Exa7.3.2: To calculate the  kinetic
    energy and amount of charge collected on plate :P
    .no. 309 (2011)
2  E_p = 35; // Energy required to produced an ion
     pair, eV
3   n = 10^5; // Number of ion pair produced
4     e = 1.6e-019; // Charge of an electron, C
5  E_k = E_p*n/10^6; // Kinetic energy of the proton,
     MeV
6   A = n*e; // The amount of charge collected on each
       plate, C
7  printf("\n The kinetic energy of the proton    = %3
     .1f MeV  \n The amount of charge collected on
     each plate     =  %3.1e C ", E_k, A)
8 // Result
9  //   The kinetic energy of the proton = 3.5 MeV
10 //    The amount of charge collected on each plate
    =  1.6e-014 C
```

Scilab code Exa 7.4.1 Height of voltage pulses

```
// Scilab code Exa7.4.1: To calculate the charge flow in a counter and height of voltage pulses :P.no. 310 (2011)
E_p = 30; // Energy required to produced an ion pair, eV
M = 1000; // Multiplication factor
e = 1.6e-019; // Charge of an electron, C
t = 10^-3; // Time, s
R = 10^5; // Resistance, ohm
E_k = 20*10^6; // Kinetic energy of the proton, eV
n = E_k/E_p; // Number of ion pairs produced
n_a = n*M; // Number of ion-pair after multiplication
Q = n_a*e; // Charge carried by these ion, C
I = Q/t; // The current through 100-ohm resistance, A
A = I*R; // ,The amplitude of voltage pulse, V
printf("\n The current through 100-ohm resistance = %6.4e A \n The amplitude of voltage pulse = %6.4e V ", I, A)
// Result
// The current through 100-ohm resistance = 1.0667e-007 A
// The amplitude of voltage pulse = 1.0667e-002 V
```

Scilab code Exa 7.4.2 Electric field at the surface of wire

```
// Scilab code Exa7.4.2: To calculate the electric field at the surface of wire :P.no. 310 (2011)
V = 1500; // Potential difference, V
a = 0.0001; // Radius of the wire, m
b = 0.02; // Radius of the cylinderical tube, m
r = 0.0001; // Distance of electric field from the surface, m
E_r = V/(r*log(b/a)); // the electric field at the
```

```
    surface , V/m
7  printf("\n The electric field at the surface : %4.2
    e V/m", E_r)
8 // Result
9 //    The electric field at the surface : 2.83e+006
    V/m
```

Scilab code Exa 7.5.1 Electric filed in G M counter

```
1 // Scilab code Exa7.5.1: To calculate the electric
    field at the surface of wire of G.M. counter :P.
    no. 311 (2011)
2  V = 2000; // Potential difference , V
3  a = 0.01; // Radius of the wire , cm
4  b = 2; // Radius of the cylinderical tube , cm
5  r = 0.01; // Radius of the wire , m
6  E_r = V/(r*log(b/a)); // the electric field at the
    surface , V/m
7  printf("\n The electric field at the surface : %d V
    /cm", E_r)
8 // Result
9 //    The electric field at the surface : 37747 V/cm
```

Scilab code Exa 7.5.2 Life of G M counter

```
1 // Scilab code Exa7.5.2: To calculate the life of G.
    M. counter :P.no. 312 (2011)
2  n_t = 10^9; // Total number of counts
3  n_d = 2000*3*60; // Count recorded per day
4  n_y = n_d*365; // Counts recorded in 365-days
5  t = n_t/n_y; // The life of G.M. counter , year
6 printf("\nThe life of G.M. counter : %4.2f year", t)
7 // Result
```

```
8 //     The life of G.M. counter : 7.61 year
9  //
```

Scilab code Exa 7.5.3 Amplitude of voltage pulses in G M counter

```
1 // Scilab code Exa7.5.3: To calculate the voltage
     pulse of G.M. counter :P.no. 312 (2011)
2  E_p = 30; // Energy required for one electron pair,
       eV
3  E = 10e+06 ; // Energy lost by alpha particle, eV
4  n = E/E_p; // Number of ion-pairs produced
5  M = 5000; // Multiplication factor
6  C = 50e-012; // Capacitance, F
7  n_M = n*M; // Number of ion-pairs after
     multiplication
8  e = 1.6e-019; // Charge of an electron, C
9  Q = n_M*e; // Charge present in each ion
10 A = Q/C; // Amplitude of voltage pulse, V
11 printf("\n Amplitude of voltage pulse : %3.1f V", A
     )
12 // Result
13  //     Amplitude of voltage pulse : 5.3 V
```

Scilab code Exa 7.5.4 Estimating true count rate of G M counter

```
1 // Scilab code Exa7.5.4: To estimate the true count
     rate of G.M. counter :P.no. 312 (2011)
2  n = 30000; // Count per minute
3  n_o = n/60; // Observed count rate, count/s
4  t = 2e-04; // Dead time, s
5  n_t = round(n_o/(1-n_o*t)); // The true count rate,
       count/s
6  printf("\n The true count rate : %d counts/s", n_t)
```

```
7 // Result
8  //   The true count rate : 556 counts/s
```

Scilab code Exa 7.6.1 Energy resolution of gamma rays

```
1 // Scilab code Exa7.6.1: To calculate the energy
     resolution of gamma rays emitted by Na-22 for
     channel first and second :P.no. 313 (2011)
2 // For 511 KeV gamma rays (for channel first)
3 F_W_H_M_1 = 97; //  Frequency width at half maximum
     for channel first
4 P_pos_1 = 1202; // Peak position for channel first
5 Res_KeV_1 = F_W_H_M_1/P_pos_1*511; // Resolution in
    KeV for channel first
6 // For 1275 KeV gamma rays (for channel second)
7 F_W_H_M_2 = 82; // Frequency width at half maximum
     for channel second
8 P_pos_2 =  1202; // Peak position for channel second
9 Res_KeV_2 = round(F_W_H_M_2/P_pos_2*1275); //
     Resolution in KeV for channel second
10   printf("\n Resolution  for channel first  = %d KeV
         \n Resolution  for channel second  = %d KeV "
       ,Res_KeV_1, Res_KeV_2)
11   // Result
12 //   Resolution  for channel first = 41 KeV
13 //   Resolution  for channel second = 87 KeV
```

Scilab code Exa 7.6.2 Amplitude of output voltage pulse

```
1 // Scilab code Exa7.6.2 : To calculate the amplitude
     of output voltage pulse for NaI(Tl) :P.no. 314
     (2011)
2 e = 1.6e-019; // Charge of an electron, C
```

```
3 n = 4.2e+08; // Number of photoelectrons
4 C = 200e-012; // Capacitance, F
5 A = n*e/C; // Amplitude of output voltage pulse, V
6 printf("\n Amplitude of output voltage pulse : %4.2f
    V ",A)
7 // Result
8 //            Amplitude of output voltage pulse :
    0.34 V
```

Scilab code Exa 7.6.3 Resolution of scintillation detector

```
1 // Scilab code Exa7.6.3 : To calculate the %-
    resolution and resolution in KeV for
    scintillation detector for Cs-137 :P.no. 315
    (2011)
2 F_W_H_M = 0.72; // Full width at half maximum, V
3 P_p = 6.0; // Peak position, V
4 E = 662; // Energy of photopeak, KeV
5 %_resolution = F_W_H_M/P_p*100; // Percentage
    resolution in percent
6 Res_KeV = %_resolution/100*E; // Resolution in KeV
    for Cs-137
7 printf("\n The percentage resolution   = %d percent
     \n Resolution in KeV  = %4.1f KeV  ",
    %_resolution, Res_KeV)
8 // Result
9 //       The percentage resolution   = 12 percent
10 //        Resolution in KeV  = 79.4 KeV
```

Scilab code Exa 7.7.1 Silicon pulse detector

```
// Scilab code Exa7.7.1 : To calculate the thickness
    of depletion layer of silicon detector and
   amplitude of voltage pulse :P.no. 316 (2011)
E_r = 12; // Relative permittivity
E_o = 8.85e-012; // Permittivity of free space
E = E_r*E_o; // Absolute dielectric constant
C = 100e-012; // Capacitance of the dielectric , F
A = 1.6e-04; // Area of the detector , m^2
e = 1.602e-019; // Charge of an electrin , C
E_p = 3.2; // Energy required to create an ion pair ,
    eV
E_s = 12e+06; // Energy required to stopped ion pair
   , eV
n = E_s/E_p; // Number of ion-pair produced
Q = n*e; // Charge of these ion pair , C
d = A*E/(C*10^-6); // The thickness of the depletion
    layer , micron
A = Q/C*1000; // The amplitude of voltage pulse , mV
printf("\n The thickness of the depletion layer    =
    %d micron \n  The amplitude of voltage pulse:
      = %6.4f mV  ", d, A)
// Result
//      The thickness of the depletion layer    =
   169 micron
//      The amplitude of voltage pulse:    = 6.0075
   mV
```

Scilab code Exa 7.7.2 Detector characteristics

```
// Scilab code Exa7.7.2 : To calculate the
   capacitance and the amplitude of voltage pulse
   across the detector :Page 316 (2011)
E_r = 12; // Relative permittivity
E_o = 8.85e-012; // Permittivity of free space
E = E_r*E_o; // Absolute dielectric constant
```

```
A = 2e-04; // Area of the detector, m^2
e = 1.602e-019; // Charge of an electron, C
d = 100e-06; // The thickness of the depletion layer, m
C = E*A/d; // The capacitance of the dielectric, F
E_p = 3.0; // Energy required to create an ion pair, eV
E_s = 5.48e+06; // Energy required to stopped ion pair, eV
n = E_s/E_p; // Number of ion-pair produced
Q = n*e; // Charge of these ion pair, C
A = Q/C*1000; // The amplitude of voltage pulse, mV
printf("\n The capacitance of dielectric   = %5.3e F \n The amplitude of voltage pulse   = %5.3f mV ", C, A)
// Result
//    The capacitance of dielectric   = 2.124e-010 F
//   The amplitude of voltage pulse   = 1.378 mV
```

Chapter 8

Particle Physics

Scilab code Exa 8.5.1 Average kinetic energy of pion

```
1 // Scilab code Exa8.5.1: To calculate the average
    kinetic energy of each pion:P.No.360 (2011)
2 // Proton and antiproton annihilate to produced
    three pions
3 E_p = 938; // Energy of proton, MeV
4 E_pi = 139.5; // Energy of pions, MeV
5 E_pi_0 = 134.9; // Energy of pi_0_ion, MeV
6 E_KE = [2*E_p-(2*E_pi+E_pi_0)]/3; // The average
    kinetic energy of each pions, MeV
7 printf("\n The average kinetic energy of each pions
     : %5.1f MeV", E_KE)
8 // Result
9 // The average kinetic energy of each pions : 487.4
    MeV
```

Scilab code Exa 8.5.2 Inherent uncertainity in mass of the particle

```
1 // Scilab code Exa8.5.2: To calculate the inherent
```

```
    uncertainity in mass of the given particle : P.no
    . 360 (2011)
// Here r_1 and r_2 are two decay rates are given
// Declare the cell
R1 = cell(1,2)
R1(1,1).entries = 'r_1'
R1(1,2).entries = 'r_2'
    printf("\n The inherent uncertainity in mass of
       particle = h(%s + %s) ", R1(1,1).entries, R1
       (1,2).entries)
// Result
//   The inherent uncertainity in mass of particle =
    h(r_1 + r_2)
```

Scilab code Exa 8.7.3 Sub nuclear reactions

```
// Scilab code Exa8.7.3: Determine the possibility
   of the given reaction:P.no. 362 (2011)
// Declare cell for the given reaction
R1 = cell(7,5)
// Enter data for the cell
R1(1,1).entries = 'p'
R1(1,2).entries = 1
R1(1,3).entries = 1
R1(1,4).entries = 0
R1(1,5).entries = 1/2
R1(2,1).entries = 'K_+'
R1(2,2).entries = 1
R1(2,3).entries = 0
R1(2,4).entries = 1
R1(2,5).entries = 1/2
R1(3,1).entries = 'S_+'
R1(3,2).entries = 1
R1(3,3).entries = 1
R1(3,4).entries = -1
```

```
R1(3,5).entries = 1
R1(4,1).entries = 'pi_-'
R1(4,2).entries = -1
R1(4,3).entries = 0
R1(4,4).entries = 0
R1(4,5).entries = 1
R1(5,1).entries = 'S_0'
R1(5,2).entries = 0
R1(5,3).entries = 1
R1(5,4).entries = -1
R1(5,5).entries = 0
R1(6,1).entries = 'p_-'
R1(6,2).entries = -1
R1(6,3).entries = -1
R1(6,4).entries = 0
R1(6,5).entries = 1/2
R1(7,1).entries = 'n_0'
R1(7,2).entries = 0
R1(7,3).entries = 0
R1(7,4).entries = 0
R1(7,5).entries = 0

function f = check_Isotopic_no(Ir_sum,Ip_sum)
        if Ir_sum == Ip_sum then
            f = 1;
        else
            f = 0;
        end
endfunction
1
// Declare a function returning equality status of
   proton number
function f = check_strangeness(sr_sum,sp_sum)
        if sr_sum == sp_sum then
            f = 1;
        else
            f = 0;
        end
```

```
56 endfunction
57 function f = check_charge(cr_sum,cp_sum)
58         if cr_sum == cp_sum then
59             f = 1;
60         else
61             f = 0;
62         end
63 endfunction
64 // Declare a function returning equality status of
      lepton number
65
66 //      Reaction-I
67 printf("\n\n\nReaction-I:\n\n");
68          Ir_sum = R1(1,5).entries+R1(1,5).entries;
69          Ip_sum = R1(2,5).entries+R1(3,5).entries;
70         if (check_Isotopic_no(Ir_sum,Ip_sum) == 0)
             then
71             printf("The Reaction\n")
72             printf("\t%s + %s --> %s + %s \nis  not
                  possible", R1(1,1).entries,  R1(1,1).
                  entries, R1(2,1).entries, R1(3,1).
                  entries)
73 //      Reaction-II
74             printf("\n\n\nReaction-II")
75          sr_sum = R1(1,4).entries+R1(4,4).entries;
76          sp_sum = R1(5,4).entries+R1(7,4).entries;
77            if (check_strangeness(sr_sum,sp_sum)== 0)
                then
78             printf("\n\nThe Reaction\n")
79             printf("\t%s + %s --> %s + %s \nis not
                  possible", R1(1,1).entries, R1(4,1).
                  entries, R1(5,1).entries, R1(7,1).
                  entries)
80 //      Reaction-III
81             printf("\n\n\nReaction-III:\n\n");
82          cr_sum = R1(1,2).entries+R1(1,2).entries;
83          cp_sum = R1(1,2).entries+R1(1,2).entries+R1
              (1,2).entries+R1(6,2).entries;
```

```
84                  if (check_charge(cr_sum,cp_sum) == 1)
                        then
85                printf("The Reaction\n")
86                printf("\t%s + %s --> %s + %s + %s \nis
                     possible", R1(1,1).entries, R1(1,1).
                     entries, R1(1,1).entries, R1(1,1).
                     entries, R1(6,1).entries)
87          end
88           // Reaction-I:
89
90  // The Reaction
91  //  p + p --> K_+ + S_+
92  // is  not possible
93
94
95  // Reaction-II
96
97  // The Reaction
98  //  p + pi_- --> S_0 + n_0
99  // is not possible
100
101
102 // Reaction-III:
103
104 // The Reaction
105 //  p + p --> p + p + p_-
106 // is possible
```