Scilab Textbook Companion for Fundamentals of Nuclear Science and Engineering by J. K. Shultis and R. E. Faw[1]

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Book Description

Title: Fundamentals of Nuclear Science and Engineering

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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

Fundamental Concepts

Scilab code Exa 1.1 Find Atomic weight of Boron

```
//Chapter 1, Example 1.1, Page 21
clc
clear
//Find Atomic weight of Boron
I10 = 0.199 // Isotopic abundance of B10 (Value used
    in question is wrong)
A10 = 10.012937 //Atomic weight of B10
I11 = 0.801 // Isotopic abundance of B11
A11 = 11.009306 //Atomic weight of B11
//Calculation
W = (I10*A10)+(I11*A11)
printf("The atomic weight of Boron = %f",W);

//Answers may vary due to round off error
```

Scilab code Exa 1.2 Number of 10B molecules in 5g of Boron

```
//Chapter 1, Example 1.2, Page 22
```

```
clc
clear
//Find number of 10B molecules in 5g of Boron
m = 5 //g
Na = 0.6022*10**24 //atoms/mol
AB = 10.811 //Atomic weight of 10B , g/mol
NB = (m*Na)/(AB)
printf("The number of Boron atoms = %e atoms",NB);

//Answers may vary due to round off error
```

Scilab code Exa 1.3 Estimate the mass on an atom of U 238

```
//Chapter 1, Example 1.3, Page 22
clc
clear
//Estimate the mass on an atom of U 238. From Eq. (1.3)
//Calculating the approximate weight
Mapprox = 238/(6.022*10**23)
//Calculating the precise weight
M = 238.050782/(6.022142*10**23)
printf("The approximate mass on an atom of U 238 = %e g/atom",Mapprox);
printf("\n The precise mass on an atom of U 238 = %e g/atom",M);
printf("Varies by a negligible error")
//Answers may vary due to round off error
```

Scilab code Exa 1.4 Density of Hydrogen atom in water

```
//Chapter 1, Example 1.4, Page 23
clc
```

```
clear
//Density of Hydrogen atom in water
p = 1 // density of water in g cm^-3
Na = 6.022*10^23 // molucules/mol
A = 18 // atomic weight of water in g/mol
N = (p*Na)/A
NH = 2*N
printf("The density of water = %e molecules/cm3",N);
printf("\n The density of hydrogen atoms = %e atoms/
    cm3",NH);
//Answers may vary due to round off error
```

Chapter 2

Modern Physics Concepts

Scilab code Exa 2.1 Find the inscrease in mass of the satellite

```
//Chapter 2, Example 2.1, Page 29
clc
clear
//Find the inscrease in mass of the Satellite
v = 7.5*10**3
c = 2.998*10**8
//Calculating the expression using the taylor series
FMI = (1/2)*(v**2/c**2)
printf("The fractional mass increase = %e",FMI);
//Answers may vary due to round off error
```

Scilab code Exa 2.2 Find the energy equivalent in MeV of the electron rest mass

```
//Chapter 2, Example 2.2, Page 33
clc
clear
//Find the energy equivalent in MeV of the electron
   rest mass
```

```
m1 = 9.109*10**-31 // kg
m2 = 5.486*10**-4 // atomic mass units
c1 = 2.998*10**8 // m/s
c2 = 931.49 // MeV/u
E1 = (m1*c1*c1)/(1.602*10**-13)
E2 = m2*c2
printf("E = %f MeV",E1);
printf("\n E measured in atomic mass unit and appropriate conversion factor= %f MeV",E2);

//Answers may vary due to round off error
```

Scilab code Exa 2.3 Maximum wavelength of light required to liberate photoelectron

```
//Chapter 2, Example 2.3, Page 37
clc
clear
//maximum wavelength of light required to liberate photoelectrons
A = 2.35 //eV
h = 4.136*10**-15 // eV/s^-1
c = 2.998*10**8 // m/s
v = A/h
w = c/v
printf("v-min = %e s^-1",v);
printf("\n Maximum wavelength = %f nm which corresponds to green",w*10**9);

//Answers may vary due to round off error
```

Scilab code Exa 2.4 Recoil Kinetic Energy

```
//Chapter 2, Example 2.4, Page 39
```

```
clc
clear
//Recoil Kinetic Energy
m1 = 9.109*10**-31 // kg
c1 = 2.998*10**8 // m/s
E = 3 //Mev
mc2 = (m1*c1*c1)/(1.602*10**-13) // converting to MeV
E1 = 1/((1/E)+(1/mc2)*(1-cos(%pi/4)))
printf("\n Recoil kinetic energy = %f MeV",E1);

//Answers may vary due to round off error
```

Chapter 3

Atomic and Nuclear Models

Scilab code Exa 3.1 Energy required to remove electron in the ground state

```
//Chapter 3, Example 3.1, Page 66
clc
clear
//Energy required to remove electron in the ground
   state
//Obtaining values from table 1.5
h = 6.626*10**-34 // J s
m = 9.109*10**-31 // kg
e = 1.6022*10**-19 // C
E0 = 8.854*10**-12 // F m^-1
E1 = -(m*(2*e**2)**2)/(8*E0**2*h**2)
EJ = E1/(1.6022*10**-19) // converting to eV
printf("\n E1 in Joules = %e J",E1);
printf("\n E1 in eV = %f EV",EJ);

//Answer may vary due to round off error
```

Scilab code Exa 3.2 Estimate the mass of Ga

```
//Chapter 3, Example 3.2, Page 79
clc
clear
// Estimate the mass of Ga
//Based on equation 3.16
av = 15.835 // MeV
as = 18.33 // MeV
ac = 0.714 // MeV
aa = 23.30 // MeV
ap = 11.2 // MeV
A = 70
c2 = (1/931.5)
mn = 1.0072765
mp = 1.0086649
me = 0.00054858
a = av*A
b = as*A**(2/3)
c = ac*(31**2/A**(1/3))
d = aa*((A-62)**2/A)
c = ap/sqrt(A)
BE = (a-b-c-d)*c2 // BE/C^2
M = 31*mn+39*mp-BE+31*me
printf("\n Nuclear binding energy = %f u",BE); //
    answer provided in the textbook is wrong
printf("\n Atomic mass = %f u",M);

//Answer may vary due to round off error
```

Chapter 4

Nuclear Energetics

Scilab code Exa 4.1 Binding energy

```
//Chapter 4, Example 4.1, Page 86
clc
clear
//Binding energy
mn = 1.0078250
mp = 1.0086649
M = 4.0026032 // mass of He
MD = 2*mn+2*mp-M //Mass defect
BE = MD*931.5
printf("\n Mass defect = %f u",MD);
printf("\n Nuclear binding energy = %f MeV",BE); //
    answer provided in the textbook is wrong
//Answer may vary due to round off error
```

Scilab code Exa 4.2 Binding energy

```
//Chapter 4, Example 4.2, Page 89
clc
```

```
clear
//Binding energy
O15 = 15.0030654 // atomic mass of O15 isotope
mn = 1.00866492
O16 = 15.9949146 // atomic mass of O16 isotope
c2 = 931.5 // C^2 in MeV
S = (O15+mn-O16)*c2
printf("\n Binding energy = %f MeV",S);
//Answer may vary due to round off error
```

Scilab code Exa 4.3 Endothermic and exothermic reaction

```
//Chapter 4, Example 4.3, Page 94
clc
clear
// Q value of an endothermic and exothermic reaction
//Exothermic reaction
Be = 9.012182 //Reactants
He = 4.002603 //Reactants
C12 = 12 //Product
n = 1.008664 //Product
C2 = 931.5 // C^2 in MeV
Exo1 = Be+He
Exo2 = C12+n
Dif1 = Exo1-Exo2
Q1 = Dif1*C2
printf("\n Q of the exothermic reaction = %f MeV",Q1);
//Endothermic reaction
O = 15.994915 //Reactants
n = 1.008664 //Reactant
C13 = 13.003354 //Product
He = 4.002603 //product
End1 = O+n
End2 = C13+He
```

```
Dif2 = End1-End2
Q2 = Dif2*C2
printf("\n Q of the exothermic reaction = %f MeV",Q2
    );
//Answer may vary due to round off error
```

Scilab code Exa 4.4 Q value in a reaction

```
//Chapter 4, Example 4.4, Page 95
clc
clear
// Q value in a reaction
MH = 1.00782503
MD = 2.01410178
me = 0.00054858
C2 = 931.5
Q = (2*MH-MD-2*me)*C2
printf("\n Q of the reaction = %f MeV",Q);// Answer
    provided in the text is wrong
//Answer may vary due to round off error
```

Scilab code Exa 4.5 Q value of the reaction

```
//Chapter 4, Example 4.5, Page 96
clc
clear
// Q value of the reaction
mn = 1.0086649
MB = 10.0129370
MHe = 4.0026032
MLi = 7.0160040
C2 = 931.5
Q = (mn+MB-MHe-MLi)*C2 -0.48
```

```
printf("\n Q of the reaction = %f MeV",Q);
//Answer may vary due to round off error
```

Chapter 5

Radioactivity

Scilab code Exa 5.1 `Initial Kinetic energy`

```
//Chapter 5, Example 5.1, Page 103
clc
clear
// Initial Kinetic energy
MRa = 226.025402
MRn = 222.017571
MHe = 4.00260325
C2 = 931.5
Ad = 222
Aa = 4
Q = (MRa-MRn-MHe)*C2
E = Q*(Ad/(Ad+Aa))
R = Q-E
printf("\n Q of the reaction = %f MeV",Q);
printf("\n Kinetic Enerfy of the reaction = %f MeV",
    E);
printf("\n The reminder of Q is the kinetic energy
    of the product nucleus,Rn = %f MeV",R);
// Answer may vary due to round off error
```

Scilab code Exa 5.2 Probablility of decay by positron emission

```
//Chapter 5, Example 5.2, Page 117
clc
clear
//Probablility of decay by positron emission
//3 decay modes
LBp = 0.009497
LBm = 0.02129
LEC = 0.02381
L = LBp+LBm+LEC
P = LBp/L
printf("\n Probability of decay = %f ",P);
//Answer may vary due to round off error
```

Scilab code Exa 5.4 Time takes for the activity

```
//Chapter 5, Example 5.4, Page 127
clc
clear
//Time takes for the activity of daughter is within
   5% of that of parent
t = -log(1-0.95)/(1.083*10^-2)
printf("\n Time = %f h ",t);
printf("\n Time = %f d ",t/24);
//Answer may vary due to round off error
```

Scilab code Exa 5.6 Age of the wood

```
//Chapter 5, Example 5.6, Page 129
clc
clear
// Age of the wood
//based on eq 5.74
t = -(5730/log(2))*log(1.2/6.4)
printf("\n Time = %f y ",t);
//Answer may vary due to round off error
```

Scilab code Exa 5.7 Calculate the time

```
//Chapter 5, Example 5.7, Page 129
clc
clear
// Calculate the time
//based on eq 5.74
t = (14.05*10**9/log(2))*log(1+(0.31232/1.37208))
printf("\n Time = %e y ",t);
//Answer may vary due to round off error
```

Scilab code Exa 5.8 Calculate the time

```
//Chapter 5, Example 5.8, Page 130
clc
clear
// Calculate the time
//based on eq 5.74
t = (4.88*10**10/log(2))*log(1+((0.80-0.710)
   /1.37208))
printf("\n Time = %e y ",t);
//Answer may vary due to round off error
```

Chapter 6

Binary Nuclear Reactions

Scilab code Exa 6.1 Minimum Kinetic energy

```
//Chapter 6, Example 6.1, Page 142
clc
clear
// Minimum Kinetic energy
Q = [1.311 -0.6259 -0.1582] //Q in MeV of all the
    reactions
Ex = [1.994 2.11 0.1695]
KE = Q+Ex
printf("Kinetic Energy for 13C(d,t)12C = %f \n",KE
    (1))
printf(" Kinetic Energy for 14C(p,n)14N = %f \n",KE
    (2))
printf(" Kinetic Energy for 14C(n,a)11B = %f",KE(3))
```

Scilab code Exa 6.2 Maximum Energy loss

```
//Chapter 6, Example 6.2, Page 145
clc
```

```
clear
// Maximum Energy loss
me = 0.0005486
M = 4.003
EM = 4
Emax = 4*(me/M)*EM
printf("Emax = %f keV",Emax*10^3)
//Answers may vary due to round off error
```

Scilab code Exa 6.4 Initail fragment of KE

```
//Chapter 6, Example 6.4, Page 155
clc
clear
// Initail fragment of KE
MU = 235.043923
mn = 1.008665
MXE = 138.918787
MSr = 94.919358
Ep = abs(MU+mn-MXE-MSr-(2*mn*931.5))
printf("Ep = %f keV",Ep)// Answer provided in the
    textbook is wrong
//Answers may vary due to round off error
```

Scilab code Exa 6.5 Energy released

```
//Chapter 6, Example 6.5, Page 158
clc
clear
// Energy released
MLa = 138.906348
MMo = 94.905842
MXE = 138.918787
```

```
MSr = 94.919358
Ep = (MXE+MSr-MLa-MMo)*(931.5)
printf("Ep = %f MeV",Ep)
//Answers may vary due to round off error
```

Chapter 7

Radiation Interactions with Matter

Scilab code Exa 7.1 Thickness of shield

```
//Chapter 7, Example 7.1, Page 177
clc
clear
// Thickness of shield
Wmu = 0.07066 // meu of water
Lmu = 0.7721 // meu of lead
Wx= log(10)*(1/Wmu)
Lx= log(10)*(1/Lmu)
printf("Thickness of water shield = %f cm\n",Wx)
printf(" Thickness of lead shield = %f cm",Lx)
//Answers may vary due to round off error
```

Scilab code Exa 7.2 Total interaction coefficient

```
//Chapter 7, Example 7.2, Page 179
clc
```

```
clear
// Total interaction coefficient
Femu = 0.05951 // meu/p of iron
Pbmu = 0.06803 // meu/p of lead
w = 0.5
mew= (w*Femu)+(w*Pbmu)
Pmix = 2*(1/((1/7.784)+(1/11.35)))
mmix = mew*Pmix
printf("(mew/p)^mix = %f cm^2/g\n",mew)
printf(" (mew)^mix = %f cm^-1",mmix)
//Answers may vary due to round off error
```

Scilab code Exa 7.3 Absorption coefficient

```
//Chapter 7, Example 7.3, Page 180
clc
clear
// Absorption coefficient
AbsC = 0.03343*((2*0.99985*0.333)
    +(2*0.00015*0.000506)+(0.99756*0.000190)
    +(0.00039*0.239)+(0.000160*0.00205))
printf(" Absorption coefficient = %f cm^-1",AbsC)
//Answers may vary due to round off error
```

Scilab code Exa 7.4 Flux density

```
//Chapter 7, Example 7.4, Page 186
clc
clear
// Flux density
Sp = 1.295*10**13
r = 100
mew = 0.3222
```

```
phimax = 2*10**3
phi = Sp*10^-2/(4*%pi*r**2)
t = -(1/mew)*log(phimax/phi)
printf("phi = %e cm^-2/s^-1\n",phi)
printf(" t = %f cm^-1",t)
//Answers may vary due to round off error
```

Scilab code Exa 7.5 Activity of the sample

```
//Chapter 7, Example 7.5, Page 199
clc
clear
// Activity of the sample
lambda = 7.466*10**-5
m = 2
Na = 0.6022*10**24
A = 55
sigma  = 13.3*10**-24
delta = 10**13
t = 120
Activity= lambda*(m*Na/A)*sigma*delta*t
printf("Activity = %e Bq\n",Activity)

//Answers may vary due to round off error
```

Scilab code Exa 7.6 Energy required

```
//Chapter 7, Example 7.6, Page 206
clc
clear
// Energy required
Z = 79
E = 700/Z
```

```
printf("E = %f MeV\n",E)

//Answers may vary due to round off error
```

Scilab code Exa 7.7 Range in water

```
//Chapter 7, Example 7.7, Page 209
clc
clear
// Range in water
x = poly([-2.5839, 1.3767, 0.20954],'x','c')
r = log10(2)
pow = horner(x,r)
Rp = 10**pow
RT = 3*Rp
printf("Rp = %f cm\n",Rp)
printf("RT = %f cm\n",RT)
//Answers may vary due to round off error
```

Chapter 9

Radiation Doses and Hazard Assessment

Scilab code Exa 9.1 Iron kerma and absorbed dose rates

```
//Chapter 9, Example 9.1, Page 241
clc
clear
// Iron kerma and absorbed dose rates
Sp = 10**14
r = 100
mew = 0.03031
mtr = 0.02112 // mew/pro
men = 0.01983 // mew/pro
p0 = 10**-6*Sp*exp(-mew*r)/(4*%pi*r**2)
K0 = 1.602*10**-10*mtr*p0
D0 = 1.602*10**-10*men*p0
printf("p0 = %f cm^-2s^-1\n",p0)
printf(" K0 = %e Gy/s\n",K0)
printf(" D0 = %e Gy/s\n",D0)
// Answers may vary due to round off error
```

Scilab code Exa 9.2 Kerma rate

```
//Chapter 9, Example 9.2, Page 242
clc
clear
// kerma rate
fsMs = (0.6022/18)*((2*12.8*0.5)+(3.5*0.1107))
K = 1.602*10**-10*fsMs*10**10*0.1
printf("fsUs/p = %f cm^2/g\n",fsMs)
printf(" K = %f Gy/s\n",K)
// Answers may vary due to round off error
```

Scilab code Exa 9.3 Find fluence and H

```
//Chapter 9, Example 9.3, Page 245
clc
clear
//Find fluence and H
Sp = 10**9
dt = 600
r = 1500
E = 0.03103
phi = Sp*dt/(4*%pi*r**2)
H = 1.602*10**-10*E*phi
printf("fluence = %e cm^2\n",phi)
printf(" H = %f microSv\n",H*10**8)
// Answer may vary due to round off error
```

Chapter 10

Principles of Nuclear Reactors

Scilab code Exa 10.1 `Thermal utilization factor`

```
//Chapter 10, Example 10.1, Page 280
clc
clear
// Thermal utilization factor
Summation = ((0.0055*103.4)+(0.720*687)+(99.2745*2.73))/100
sigma = 0.0034
f = 7.662/(7.662+(sigma*450))
printf("Total thermal macroscopic = %f N^U cm^1\n",Summation)
printf(" f = %f \n",f)
// Answer may vary due to round off error
```

Scilab code Exa 10.2 `Thermal fission factor`

```
//Chapter 10, Example 10.2, Page 280
clc
clear
```

```
// Thermal fission factor
neeta = (2.42*587)/(687 +(2.73*0.98/0.02))
printf(" Thermal fission factor = %f \n",neeta)
// Answer may vary due to round off error
```

Scilab code Exa 10.3 Find the probability

```
//Chapter 10, Example 10.3, Page 282
clc
clear
// Find the probability
P = exp(-6.85*10**-4*368)
Pnl = 1/(1+(578*6.85*10**-4))
printf("Fast−neutron nonleakage probability = %f \n"
    ,P)
printf(" Thermal−neutron nonleakage probability = %f
    \n",Pnl)
// Answer may vary due to round off error
```

Scilab code Exa 10.4 Find the value of K

```
//Chapter 10, Example 10.4, Page 283
clc
clear
// k of a homogeneous
f = 687/(687 +(0.0034*40000))
k = 2.07*f
printf("f = %f \n",f)
printf(" k = %f \n",k)
//Answer may vary due to round off error
```

Scilab code Exa 10.5 Calculate radius R

```
//Chapter 10, Example 10.5, Page 284
clc
clear
//Calculate radius R
L = 578
T = 368
Bc = 6.358*10**-4
R = sqrt(%pi^2/Bc)
printf(" R = %f cm \n",R)
//Answer may vary due to round off error
```

Scilab code Exa 10.6 mass of U235

```
//Chapter 10, Example 10.6, Page 285
clc
clear
// mass of U235
m = (((4/3)*%pi*125**3*1.60)*235)/(40000*12)
printf(" m = %f kg \n",m*10**-3)
//Answer may vary due to round off error
```

Scilab code Exa 10.7 Value of Keff

```
//Chapter 10, Example 10.7, Page 285
clc
clear
// Keff
Keff = 1/(1-0.0065*0.1)
printf(" Keff = %f \n",Keff)
//Answer may vary due to round off error
```

Scilab code Exa 10.8 `Resulting reactor period`

```
//Chapter 10, Example 10.8, Page 293
clc
clear
//Resulting reactor period
bt = 0.0065
dt = 0.00065
T = (bt*12.8)/dt
Pt = 10000
P0 = 10
t = T*log(Pt/P0)
printf(" Resulting reactor period = %f sec \n",T)
printf(" t = %f sec\n",t)
//Answer may vary due to round off error
```