R Textbook Companion for
Concepts Of Modern Physics
by Arthur Beiser[1]

Created by
Vipul Shrikant Brahmankar
Bachelor of Technology
Computer Science and Engineering
Shri Vile Parle Kelawani Mandals Institute of Technology, Dhule
Cross-Checked by
R TBC Team

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Book Description

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R 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)

For example, Exa 3.51 means solved example 3.51 of this book. Sec 2.3 means an R code whose theory is explained in Section 2.3 of the book.

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List of R Codes

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Chapter 1

Relativity

R code Exa 1.1 Time dilation

```
1  #(Pg no. 9)
2
3  proper_time_interval = 3600
4  relative_time_interval = 3601
5  c = 2.998 * 10 ^ 8
6
7  v = c * sqrt(1 - ((proper_time_interval ^ 2) / (
       relative_time_interval ^ 2)))
8  v = formatC(v, format = "e", digits = 1)
9
10 cat("V =", v, "m/s\n")
```

R code Exa 1.2 Longitudinal doppler effect in light

```
1  #(Pg no. 13)
2
3  v = 5.6e+14
4  v0 = 4.8e+14
```

```
5  c = 3.0e+8
6
7  vu = c * ((v ^ 2 - v0 ^ 2) / (v ^ 2 + v0 ^ 2))
8  vu = vu * 3.6
9  vu = formatC(vu, format = "e", digits = 2)
10
11 R = 1.0
12 l = 80.0
13
14 fine = as.numeric(vu) - l
15
16 cat("Fine = $", fine)
```

R code Exa 1.3 Doppler effect Hubbles law

```
1  #(Pg no. 14)
2
3  v = 6.12e+7
4  c = 3.0e+8
5  wl_0 = 500.0
6
7  wl = wl_0 * sqrt(((1 + (v / c)) / (1 - (v / c))))
8  wl_s = wl - wl_0
9
10 cat("Lambda =", round(wl_s), "nm\n")
```

R code Exa 1.4 Twin Paradox

```
1  #(Pg no.19)
2
3  StartAge = 20
4  c = 3e+8
5  v = 0.8 * c
```

```
6  t0 = 1
7
8  T1 = t0 * (sqrt((1 + v / c) / (1 - v / c)))
9  T2 = t0 * (sqrt((1 - v / c) / (1 + v / c)))
10
11 Dout = 15
12 Dret = 15
13 Dout_Signals = Dout / T1
14 Dret_Signals = Dret / T2
15 Total_DSignals = Dout_Signals + Dret_Signals
16 JaneAge = StartAge + Total_DSignals
17
18 L0 = 20
19 v0 = 0.8
20 Dout_acc_Jane = L0 / v0
21 Dret_acc_Jane = Total_DSignals - (Dout_acc_Jane + L0
       )
22 Dout_Signals_acc_Jane = (Dout_acc_Jane + L0) / T1
23 Dret_Signals_acc_Jane = Dret_acc_Jane / T2
24 Total_DSignals_acc_Jane = Dout_Signals_acc_Jane +
       Dret_Signals_acc_Jane
25 DickAge = StartAge + Total_DSignals_acc_Jane
26
27
28 cat("Age of Jan =", JaneAge, "y\n")
29 cat("Age of Dic =", DickAge, "y\n")
```

R code Exa 1.6 Mass and Energy of Stationary body

```
1 #(Pg no. 27)
2
3 m_frag = 1
4 c = 3e+8
5 v = 0.6 * c
6
```

```
7  E0 = 2 * ((m_frag * (c ^ 2)) / sqrt(1 - ((v / c) ^
      2)))
8  m = E0 / (c ^ 2)
9
10 cat("m =", m, "kg\n")
```

R code Exa 1.7 Mass and Energy of Sun

```
1  #(Pg no. 28)
2
3  rate = 1.4
4  R = 1.5e+11
5
6  P = (rate * (10 ^ 3)) * (4 * pi * (R ^ 2))
7
8  C = 3e+8
9  E = P
10
11 m = E / (C ^ 2)
12 m = formatC(m, format = "e", digits = 1)
13
14 cat("m =", m, "kg\n")
```

R code Exa 1.8 Energy and momentum of Electron and Photon

```
1  #(Pg no. 32)
2
3  c = 3e+8
4  me = 0.511 / (c ^ 2)
5  mp = 0
6  p = 2.000 / c
7
```

```
8  Ee = sqrt(((me ^ 2) * (c ^ 4)) + ((p ^ 2) * (c ^ 2))
      )
9  Ep = p * c
10
11 cat("E_e =", round(Ee, 3), "MeV\n")
12 cat("E_p =", Ep, "MeV\n")
```

R code Exa 1.11 Relativistic velocity transformation

```
1  #(Pg no. 44)
2
3  c = 3e+8
4  VaE = 0.90 * c
5  VbA = 0.50 * c
6
7  VbE = (VaE + VbA) / (1 + ((VaE * VbA) / (c ^ 2)))
8  VbE = VbE / c
9
10 cat("V_x =", round(VbE, 2), "c\n")
```

Chapter 2

Particle Properties of Waves

R code Exa 2.1 Energy of tuning fork and atomic oscillator

```
1  #(Pg no. 61)
2
3  F_tf = 660
4  h = 6.63e-34
5
6  E_tf = h * F_tf
7  E_tf = formatC(E_tf, format = "e", digits = 2)
8
9  F_ao = 5.00e+14
10
11 E_ao = h * F_ao
12 E_ao_eV = E_ao / 1.60e-19
13
14 cat("hv_1 =", E_tf, "J\n")
15 cat("hv_2 =", E_ao, "J =", round(E_ao_eV, 3), "eV\n"
       )
16
17 #The answer may slightly vary due to rounding off
       values
```

R code Exa 2.2 Photoelectric effect

```
1  #(Pg no. 66)
2
3  wl = 350
4  i = 1.00
5  wf = 2.2
6  wl = wl * (10 ^ -9)
7  Ep = 1.24e-6 / wl
8
9  KEmax = Ep - wf
10
11 A = 1.00
12 A = A * (10 ^ -4)
13 E = 5.68e-19
14
15 Np = i * A / E
16 Ne = (0.0050) * Np
17 Ne = formatC(Ne, format = "e", digits = 1)
18
19 cat("a) KE_max =", round(KEmax, 1), "eV\n")
20 cat("b) ne =", Ne, "photoelectrons/s\n")
```

R code Exa 2.3 X ray production

```
1  #(Pg no.72)
2
3  AP = 50000
4
5  wl_min = 1.24e-6 / AP
6  wl_min_nm = wl_min * (10 ^ 9)
7
```

```
8  Freq_max = 3e+8 / wl_min
9  Freq_max = formatC(Freq_max, format = "e", digits =
      2)
10
11 cat("Lambda_min =", wl_min_nm, "nm\n")
12 cat("V_max =", Freq_max, "Hz\n")
```

R code Exa 2.4 Compton Effect

```
1  #(Pg no. 78)
2
3  wl = 10.0
4  phi = 45.0
5  phi_rad = (45.0 * (22 / 7)) / 180
6  wlc = 2.426e-12
7  k = cos(phi_rad)
8  wlc = wlc * 10.0 ^ 12
9
10 wl2 = wl + wlc * (1.0 - k)
11
12 wl2_max = wl + (2 * wlc)
13 wl2_max = round(wl2_max, 1)
14
15 h = 6.63e-34
16 c = 3e+8
17 c = c * (10 ^ 12)
18 KEmax = (h * c) * ((1 / wl) - (1 / wl2_max))
19 KEmax_KeV = KEmax / 1.6022e-16
20 KEmax = formatC(KEmax, format = "e", digits = 2)
21
22 cat("a) Lambda\' =", round(wl2, 1), "pm\n")
23 cat("b) Lambda_max\' =", wl2_max, "pm\n")
24 cat("c) KE_max =", KEmax, "J  =", round(KEmax_KeV,
      1), "keV\n")
```

R code Exa 2.6 Pair Production

```
1  #(Pg no. 82)
2
3  c = 3.0e+8
4  v = 0.5 * c
5  m = 0.511 / (c ^ 2)
6  y = 1 / sqrt(1 - (v / c) ^ 2)
7
8  p1_minus_p2 = (2 * y * m * v) * c
9
10 p1_plus_p2 = 2 * y * m * (c ^ 2)
11
12 p1 = (p1_minus_p2 + p1_plus_p2) / 2
13 p2 = p1_plus_p2 - p1
14 E1 = p1
15 E2 = p2
16
17 cat("E1 = ", round(E1, 3), "MeV\n")
18 cat("E2 = ", round(E2, 3), "MeV\n")
```

R code Exa 2.7 Photon Absorption and Radiation intensity

```
1  #(Pg no.85)
2
3  I = 2.0
4  mu = 4.9
5  x = 10.0
6  x = x / 100
7
8  I_rel_a = exp(-(mu * x))
9
```

```
10  I_rel_b = 0.01
11  I_rel_b_inv = 1 / I_rel_b
12
13  x2 = log(I_rel_b_inv) / mu
14
15  cat("a) I/Io =", round(I_rel_a, 2), "\n")
16  cat("b) x =", round(x2, 2), "m\n")
```

R code Exa 2.8 Energy of falling photon

```
1  #(Pg no. 86)
2
3  H = 22.5
4  vu = 7.3e+14
5  c = 3e+8
6  g = 9.8
7
8  Freq_change = (g * H / (c ^ 2)) * vu
9
10  cat("v\'-v =", round(Freq_change, 1), "Hz\n")
```

Chapter 3

Wave Properties of Particles

R code Exa 3.1 De Broglie wavelengths

```
1  #(Pg no. 94)
2
3  h = 6.63e-34
4  m1 = 46
5  m1 = m1 / 1000
6  v1 = 30
7  y1 = 1
8
9  wl1 = h / (y1 * m1 * v1)
10 wl1 = formatC(wl1, format =  "e", digits = 1)
11
12 m2 = 9.1e-31
13 v2 = 10 ^ 7
14 y2 = 1
15
16 wl2 = h / (y2 * m2 * v2)
17 wl2 = formatC(wl2, format = "e", digits = 1)
18
19 cat("a) Lambda =", wl1, "m\n")
20 cat("b) Lambda =", wl2, "m\n")
```

R code Exa 3.2 Kinetic Energy using De Broglie wavelengths

```
1  #(Pg no. 94)
2
3  wl = 1.0e-15
4  E0 = 0.938
5  h = 4.136e-15
6  c = 2.998e+8
7
8  pc = (h * c) / wl
9  pc = pc * (10 ^ -9)
10
11 E = sqrt((E0 ^ 2) + (pc ^ 2))
12 KE = E - E0
13 KE = KE * 1000
14
15 cat("KE =", round(KE), "MeV\n")
```

R code Exa 3.3 De Broglie phase and group velocities

```
1  #(Pg no. 103)
2
3  wl = 2.0e-12
4  h = 4.136e-15
5  c = 2.998e+8
6
7  pc = (h * c) / wl
8  pc = pc / 1000
9
10 E0 = 511
11
12 E = sqrt((E0 ^ 2) + (pc ^ 2))
```

```
13  KE = E - E0
14
15  v = c * sqrt(1 - (E0 ^ 2 / E ^ 2))
16  vp = (c ^ 2 / v) / c
17  vg = v / c
18
19  cat("a) KE = ", round(KE), "keV\n")
20  cat("b) vp = ", round(vp, 2), "c\n")
21  cat("    vg = ", round(vg, 4), "c\n")
```

R code Exa 3.4 Permitted Energies of a Particle in a Box

```
 1  #(Pg no. 107)
 2
 3  library(RColorBrewer)
 4
 5  rm(list = ls())
 6
 7  m = 9.1e-31
 8  L = 1.0e-10
 9  h = 6.63e-34
10  n0 = 1
11
12  En = (h ^ 2) / (8 * m * (L ^ 2))
13  En = formatC(En, format = "e", digits = 2)
14  En_eV = round(as.numeric(En) * 6.242e+18)
15
16  cat("En   =", En, "n^2 J  =", En_eV, "n^2 eV\n")
17  E = c()
18
19  c = colors()
20  c = brewer.pal(4, "Set1")
21  plot(
22      E,
23      type = "l",
```

19

```
24    xaxt = 'n',
25    xlim = c(0, 10),
26    xlab = "",
27    ylab = "En,   eV",
28    yaxs = "i",
29    ylim = c(0, 700),
30    yaxp = c(0, 1000, 10)
31 )
32
33 labels = c("n=1", "n=2", "n=3", "n=4")
34
35 for (n in seq(1, 4))
36 {
37    E[n] = En_eV * (n ^ 2)
38    cat("\tn=", n, ":\tEn= ", E[n], "eV\n")
39    abline(h = E[n], col = c[n], lwd = 4)
40    text(5, E[n], labels[n], pos = 3, offset = 0.2)
41 }
```

R code Exa 3.5 Permitted Energies of a Marble in a Box

```
1 #(Pg no. 107)
2
3 m = 10.0
4 m = m / 1000
5 L = 10
6 L = L / 100
7 h = 6.63e-34
8
9 En = (h ^ 2) / (8 * m * (L ^ 2))
10 En = formatC(En, format = "e", digits = 1)
11
12 cat("\tEn =", En, "n^2 J\n")
13
14 E = c()
```

```
15  for (n in seq(1, 4))
16  {
17    E[n] = as.numeric(En) * (n ^ 2)
18    cat("\tn=", n, ":\tEn= ", E[n], "J\n")
19  }
```

R code Exa 3.6 Uncertainty in protons position

```
1  #(Pg no. 112)
2
3  X0 = 1.00e-11
4  h_bar = 1.054e-34
5  t1 = 1.00
6  m = 1.672e-27
7
8  x1 = (h_bar * t1) / (2 * m * X0)
9  x1 = formatC(x1, format = "e", digits = 2)
10
11  cat("Delta_x >=", x1, "m\n")
```

R code Exa 3.7 Energy of Nuclear electron by Uncertainty Principle

```
1  #(Pg no. 114)
2
3  r = 5.00e-15
4  del_x = r
5  h_b = 1.054e-34
6
7  del_p = h_b / (2 * del_x)
8  del_p = formatC(del_p, format = "e", digits = 1)
9
10  p = as.numeric(del_p)
11  c = 3e+8
```

```
12
13  KE = p * c
14  KE_eV = KE / 1.602e-19
15  KE_eV = KE_eV / 10 ^ 6
16
17  cat("KE_min =", KE, "J  =", KE_eV, "MeV\n")
```

R code Exa 3.8 Energy of Hydrogen electron by Uncertainty Principle

```
1  #(Pg no.  115)
2
3  r = 5.3e-11
4  del_x = r
5  h_bar = 1.054e-34
6
7  del_p = h_bar / (2 * del_x)
8
9  p = del_p
10  m = 9.1e-31
11
12  KE = (p ^ 2) / (2 * m)
13  KE = formatC(KE, format = "e", digits = 1)
14  KE_eV = as.numeric(KE) / 1.602e-19
15
16  cat("KE_min =", KE, "J  =", round(KE_eV, 1), "eV\n")
```

R code Exa 3.9 Uncertainty in Time and Energy

```
1  #(Pg no.  116)
2
3  del_t = 1e-8
4  h_b = 1.054e-34
5
```

```r
 6  del_E = h_b / (2 * del_t)
 7  del_E = formatC(del_E, format = "e", digits = 1)
 8
 9  h = 6.626e-34
10
11  del_nu = as.numeric(del_E) / h
12  del_nu = formatC(del_nu, format = "e", digits = 1)
13
14  cat("Delta_E >=", del_E, "J\n")
15  cat("Delta_nu >=", del_nu, "Hz\n")
```

Chapter 4

Atomic Structure

R code Exa 4.1 Electron orbits of Hydrogen atom

```
1  #(Pg no.  125)
2
3  E = -13.6
4  e = 1.6e-19
5  E = E * e
6  E0 = 8.85e-12
7  pi = 22 / 7
8
9  r = -(e ^ 2 / (8 * pi * E0 * E))
10 r = as.numeric(formatC(r, format = "e", digits = 1))
11
12 m = 9.1e-31
13
14 v = e / sqrt(4 * pi * E0 * m * r)
15 v = formatC(v, format = "e", digits = 1)
16
17 cat("r =", r, "m\n")
18 cat("v =", v, "m/s\n")
```

R code Exa 4.2 Energy level of Electron Hydrogen collision

```
1  #(Pg no. 135)
2
3  ni = 1
4  nf = 3
5  E1 = -13.6
6
7  del_E = E1 * ((1 / nf ^ 2) - (1 / ni ^ 2))
8
9  cat("Delta_E =", round(del_E, 1), "eV\n")
```

R code Exa 4.3 Energy level of Rydberg atoms

```
1  #(Pg no. 135)
2
3  rn = 1.00e-5
4  a0 = 5.29e-11
5
6  n = sqrt(rn / a0)
7
8  E1 = -13.6
9  En = E1 / n ^ 2
10 En = formatC(En, format = "e", digits = 2)
11
12 cat("a) n =", round(n), "\n")
13 cat("b) En =", En, "eV")
```

R code Exa 4.4 Balmer series of Hydrogen Spectrum

```
1  #(Pg no. 138)
2
3  ni = 3.0
```

```
4  nf = 2.0
5  R = 1.097e+7
6
7  freq = (1 / nf ^ 2) - (1 / ni ^ 2)
8  wl = 1 / (freq * R)
9  wl = wl * (10 ^ 9)
10
11 cat("Lamda =", round(wl), "nm\n")
```

R code Exa 4.5 Frequency of revolution

```
1  #(Pg no. 139)
2
3  ni = 1
4  nf = 2
5  E1 = -2.18e-18
6  h = 6.63e-34
7
8  foR1 = (-E1 / h) * (2 / ni ^ 3)
9  foR2 = (-E1 / h) * (2 / nf ^ 3)
10 foR1 = formatC(foR1, format = "e", digits = 2)
11 foR2 = formatC(foR2, format = "e", digits = 2)
12
13 ni = 2
14 nf = 1
15
16 v = (-E1 / h) * ((1 / (nf ^ 3)) - (1 / ni ^ 3))
17 v = formatC(v, format = "e", digits = 2)
18
19 f = as.numeric(foR2)
20 del_t = 1.00e-8
21
22 N = f * del_t
23 N = formatC(N, format = "e", digits = 2)
24
```

```
25  cat(" a)  f1 =",  foR1,  " rev/s\n")
26  cat("     f2 =",  foR2,  " rev/s\n")
27  cat(" b)  v =",  v,  " Hz\n")
28  cat(" c)  N =",  N,  " rev\n")
29
30  #The answer may slightly vary due to rounding off
        values
```

R code Exa 4.7 Reduced Mass of Moun

```
1  #(Pg no. 142)
2
3  me = 9.1095e-31
4  m = 207 * me
5  M = 1836 * me
6
7  M_red = (m * M) / (m + M)
8
9  a0 = 5.29e-11
10  r1 = a0
11
12  r1_red = (me / (M_red)) * r1
13  r1_red = formatC(r1_red, format = "e", digits = 3)
14
15  n = 1
16  E1 = -13.6
17
18  E1_red = (M_red / me) * (E1 / n ^ 2)
19  E1_red = E1_red / (10 ^ 3)
20
21  cat(" a)  r1\' =",  r1_red,  " m\n")
22  cat(" b)  E1\' =",  round(E1_red, 2),  " KeV\n")
```

R code Exa 4.8 Rutherford Scattering Formula

```
1  #(Pg no. 156)
2
3  I = 7.7
4  D_gold = 1.93e+4
5  u = 1.66e-27
6  M_gold = 197 * u
7
8  n = D_gold / M_gold
9  n = as.numeric(formatC(n, format = "e", digits = 2))
10
11 Z_gold = 79
12 e = 1.6e-19
13 KE = (I * e) / (10 ^ -6)
14 Theta = 45
15 Theta = 45 * (pi / 180)
16 p = 1 / tan(Theta / 2)
17 E0 = 8.85e-12
18 t = 3e-7
19
20 f = pi * n * t * (((Z_gold * (e ^ 2)) / (4 * pi * E0
       * KE)) ^ 2) * (p ^ 2)
21 f = as.numeric(formatC(f, format = "e", digits = 0))
22
23 cat("f =", f, "\n")
24 cat("Fraction =", f * 100, "%\n")
```

Chapter 5

Quantum Mechanics

R code Exa 5.4 Wave function of Particle in a Box

```
1  #(Pg no. 180)
2
3  L = 1
4  x1 = 0.45
5  x2 = 0.55
6
7  f = function(x)
8  {
9    y = sin(n * pi * x) ^ 2
10   return(y)
11 }
12
13 n = 1
14 I1 = integrate(f, x1, x2)
15 P1 = (2 / L * as.numeric(I1[1]))
16 P1 = round(P1, 3)
17
18 n = 2
19 I2 = integrate(f, x1, x2)
20 P2 = (2 / L * as.numeric(I2[1]))
21 P2 = round(P2, 4)
```

```
22
23  cat("P_g =", P1, "=", P1 * 100, "percent\n")
24  cat("P_1e =", P2, "=",  P2 * 100, "percent\n")
```

R code Exa 5.6 Tunnel effect transmission probability

```
 1  #(Pg no. 186)
 2
 3  rm(list = ls())
 4
 5  E1 = 1.0
 6  E2 = 2.0
 7  U = 10.0
 8  L1 = 0.50
 9  L1  = L1 * 10 ^ -9
10  h_bar = 1.054e-34
11  Me = 9.1e-31
12  e = 1.6e-19
13
14  k2 = sqrt(2 * Me * (U - E1) * e) / h_bar
15  k1 = sqrt(2 * Me * (U - E2) * e) / h_bar
16
17  T1 = exp(-2 * k2 * L1)
18  T1 = formatC(T1, format = "e", digits = 1)
19  T2 = exp(-2 * k1 * L1)
20  T2 = formatC(T2, format = "e", digits = 1)
21
22
23  L2 = L1 * 2
24  T11 = exp(-2 * k2 * L2)
25  T11 = formatC(T11, format = "e", digits = 1)
26  T22 = exp(-2 * k1 * L2)
27  T22 = formatC(T22, format = "e", digits = 1)
28
29
```

```
30  cat (" a )  T1 =" ,  T1 ,  " \n" )
31  cat ("    T2 =" ,  T2 ,  " \n" )
32  cat (" b )  T1 \ ' =" ,  T11 ,  " \n" )
33  cat ("    T2 \ ' =" ,  T22 ,  " \n" )
34
35  #The  answer  may  slightly  vary  due  to  rounding  off
        values .
```

Chapter 6

Quantum Theory of the Hydrogen Atom

R code Exa 6.3 Probability of Finding Electron

```
1 #(Pg no. 215)
2
3 max_prob = 1
4
5 Pro_Ratio = 4 * exp(-1)
6 Prezense_precent = (Pro_Ratio - max_prob) * 100
7
8 cat("Prez_perce =", round(Prezense_precent))
```

R code Exa 6.4 Normal Zeeman Effect

```
1 #(Pg no. 226)
2
3 B = 0.300
4 wl = 450
5 wl = wl * (10 ^ -9)
```

```r
 6  e = 1.6e-19
 7  m = 9.1e-31
 8  c = 3e+8
 9
10  del_wl = (e * B * (wl ^ 2)) / (4 * pi * m * c)
11  del_wl = del_wl * (10 ^ 9)
12  del_wl = round(del_wl, 5)
13
14  cat("Delta_Lamda =", del_wl, "nm\n")
```

Chapter 7

Many Electron Atoms

R code Exa 7.1 Equatorial velocity of an electron

```
1  #(Pg no.  230)
2
3  r = 5.00e-17
4  m = 9.1e-31
5  h_bar = 1.055e-34
6
7  v = ((5 * sqrt(3)) / 4) * (h_bar / (m * r))
8
9  c = 3e+8
10
11 v = v / c
12 v = formatC(v, format = "e", digits = 2)
13
14 cat("v =", v, "c\n")
```

R code Exa 7.2 Effective charge on electron of lithium atom

```
1  #(Pg no.  241)
```

```
 2
 3  n = 2
 4  E2 = -5.39
 5  E1 = -13.6
 6
 7  Z = n * (sqrt(E2 / E1))
 8  Z = round(Z, 2)
 9
10  e = 1.6e-19
11
12  C_effective = Z * e
13  C_effective = formatC(C_effective, format = "e",
      digits = 3)
14
15  cat("En =", Z, "e  =", C_effective, "C\n")
```

R code Exa 7.3 Magnetic energy for an electron

```
 1  #(Pg no.  248)
 2
 3  n = 2
 4  Ao = 5.29e-11
 5  r = (n ^ 2) * Ao
 6  f = 8.4e+14
 7  Mu_0 = 4 * pi * (10 ^ -7)
 8  e = 1.6e-19
 9
10  B = (Mu_0 * f * e) / (2 * r)
11
12  Mu_b = 9.27e-24
13
14  Um = Mu_b * B
15  Um = Um / e
16  Um = as.numeric(formatC(Um, format = "e", digits =
      1))
```

```
17
18  cat (" Um =", Um, "eV\n")
19  cat (" 2 x Um =", (2 * Um), "eV\n")
```

R code Exa 7.8 K alpha X rays

```
1  #(Pg no. 257)
2
3  wl = 0.180
4  wl = wl * (10 ^ -9)
5  c = 3e+8
6
7  f = c / wl
8
9  R = 1.097e+7
10
11  Z = 1 + (sqrt((4 * f) / (3 * c * R)))
12
13  cat ("Z =", round(Z), "\n")
```

Chapter 8

Molecules

R code Exa 8.1 Energy and angular velocity of the CO

```
1  #(Pg no. 283)
2
3  R = 0.113
4  Mc = 1.99e-26
5  Mo = 2.66e-26
6
7  Mco_red = (Mc * Mo) / (Mc + Mo)
8  I = Mco_red * ((R * (10 ^ -9)) ^ 2)
9  J = 1
10 h_bar = 1.054e-34
11 E_J1 = (J * (J + 1) * (h_bar ^ 2)) / (2 * I)
12 e = 1.6e-19
13 E_J1_eV = E_J1 / e
14 E_J1_eV = formatC(E_J1_eV, format = "e", digits = 2)
15
16 W_J1 = sqrt(2 * E_J1 / I)
17 W_J1 = formatC(W_J1, format = "e", digits = 2)
18
19 cat("a) E_J1 = ", E_J1_eV, "eV\n")
20 cat("b) W_J1 = ", W_J1, "rad/sec\n")
21
```

```
22  #The answer provided in the textbook is wrong
```

R code Exa 8.2 Bond length of CO molecule

```
1  #(Pg no. 285)
2
3  Ji = 0
4  Jf = 1
5  v = 1.15e+11
6  h_bar = 1.054e-34
7
8  Ico = (h_bar / (2 * pi * v)) * (Ji + 1)
9
10 Mco_red = 1.14e-26
11
12 r = sqrt(Ico / Mco_red)
13 r = r * (10 ^ 9)
14
15 cat("R_co =", round(r, 3), "nm\n")
```

R code Exa 8.3 Force constant and vibrational levels in CO

```
1  #(Pg no. 288)
2
3  Vo = 6.42e+13
4  Mco_red = 1.14e-26
5  h = 6.63e-34
6  pi=22/7
7
8  k = 4 * (pi ^ 2) * (Vo ^ 2) * Mco_red
9  k = formatC(k, format = "e", digits = 2)
10
11 del_E = h * Vo
```

38

```
12  del_E = del_E * 6.24e+18
13
14  cat("a) k =", k, "N/m\n")
15  cat("b) Delta_E =", round(del_E, 3), "eV\n")
```

Chapter 9

Statistical Mechanics

R code Exa 9.1 Maxwell Boltzmann distribution function

```
1  #(Pg no. 299)
2
3  E1 = -13.6
4  E2 = -3.4
5  g1 = 2
6  g2 = 8
7  k = 8.617e-5
8
9  T0 = 0
10 T0 = T0 + 273
11
12 x0 = (E2 - E1) / (k * T0)
13 x0 = round(x0)
14
15 n_ratio1 = (g2 / g1) * exp(-x0)
16 n_ratio1 = formatC(n_ratio1, format = "e", digits =
       1)
17
18 T1 = 10000
19 T1 = T1 + 273
20
```

```
21  x1 = (E2 - E1) / (k * T1)
22  x1 = round(x1, 1)
23
24  n_ratio2 = (g2 / g1) * exp(-x1)
25  n_ratio2 = formatC(n_ratio2, format = "e", digits =
       2)
26
27  cat("a)  ratio_0 =", n_ratio1, "\n")
28  cat("b)  ratio_10,000 =", n_ratio2, "\n")
```

R code Exa 9.4 Root mean square speed of oxygen molecule

```
1  #(Pg no.  305)
2
3  M_o = 16.0
4  M_o2 = M_o * 2
5  u = 1.66e-27
6  m = M_o2 * u
7  T = 273
8  k = 1.38e-23
9
10  Vrms = sqrt(3 * k * T / m)
11  Vrms_miles = (Vrms / 1609.34) * 3600
12
13  cat("Vrms =", round(Vrms), "m/s  =", round(Vrms_
       miles), "mi/h\n")
```

R code Exa 9.5 Planck Radiation Law

```
1  #(Pg no.  314)
2
3  V = 1.00
4  V = V * 10 ^ -6
```

```
5  dI = 2.404
6  k = 8.617e-5
7  h = 4.135e-15
8  T = 1000
9  c = 3e+8
10
11 N = 8 * pi * V * (((k * T) / (h * c)) ^ 3) * dI
12 N = formatC(N, format = "e", digits = 2)
13
14 Sigma = 5.670e-8
15 e = 6.24e+18
16
17 E_photon = (Sigma * (c ^ 2) * (h ^ 3) * T) / (2.405
      * (2 * pi * (k ^ 3)))
18 E_photon_eV = E_photon * e
19 E_photon = formatC(E_photon, format = "e", digits =
      2)
20
21 cat("a) N =", N, "photons\n")
22 cat("b) E\' =", E_photon, "J  =", round(E_photon_eV,
      3), "eV\n")
```

R code Exa 9.6 Wiens displacement law

```
1 #(Pg no. 317)
2
3 T = 2.7
4
5 wl_max = 2.898e-3 / T
6 wl_max = wl_max * 10 ^ 3
7
8 cat("Lambda_max =", round(wl_max, 1), "mm\n")
```

R code Exa 9.7 Surface temperature of the Sun

```
1  #(Pg no. 317)
2
3  R_earth = 1.5e+11
4  rate = 1.4
5  rate = 1.4 * 10 ^ 3
6
7  P = rate * (4 * pi * (R_earth ^ 2))
8
9  R_sun = 7e+8
10
11 R = P / (4 * pi * (R_sun ^ 2))
12
13 e = 1
14 Sig = 5.670e-8
15
16 T = (R / (e * Sig)) ^ (1 / 4)
17 T = formatC(T, format = "e", digits = 1)
18
19 cat("T =", T, "K\n")
```

R code Exa 9.8 Fermi energy in Copper

```
1  #(Pg no. 325)
2
3  u = 1.66e-27
4  Den_c = 8.94e+3
5  M_c = 63.5
6
7  Den_e = Den_c / (M_c * u)
8
9  h = 6.63e-34
10 M_e = 9.1e-31
11 e = 6.23e+18
```

```
12
13  E_fermi = (h ^ 2 / (2 * M_e)) * ((3 * Den_e) / (8 *
        pi)) ^ (2.0 / 3.0)
14  E_fermi_eV = E_fermi * e
15  E_fermi = formatC(E_fermi, format = "e", digits = 2)
16
17  cat("e_F =", E_fermi, "J  =", round(E_fermi_eV, 2),
        "eV\n")
```

Chapter 10

The Solid State

R code Exa 10.1 Cohesive energy in NaCl

```
1  #(Pg no. 342)
2
3  r0 = 2.81e-10
4  a = 1.748
5  n = 9
6  e = 1.6e-19
7  e0 = 8.85e-12
8
9  U0 = -(a * (e ^ 2) / (4 * pi * e0 * r0)) * (1 - (1 /
       n))
10 U0 = U0 / e
11 U0 = U0 / 2
12
13 E1 = 5.14
14 E2 = -3.61
15 E = E1 + E2
16 E = E / 2
17 Ecohesive = (U0 + E)
18
19 cat("E_cohesive =", round(Ecohesive, 2), "eV\n")
```

R code Exa 10.2 Drift velocity of free electrons in Copper

```
1  #(Pg no. 350)
2
3  A = 1.0
4  A = A * (10 ^ -6)
5  I = 1.0
6  n = 8.5e+28
7  e = 1.6e-19
8
9  Vdrift = I / (n * A * e)
10 Vdrift = formatC(Vdrift, format = "e", digits = 1)
11
12 cat("V_drift =", Vdrift, "m/s\n")
13
14 #The answer provided in the textbook is wrong
```

R code Exa 10.3 Mean free path of free electrons in Copper

```
1  #(Pg no. 353)
2
3  n = 8.48e+28
4  V_fermi = 1.57e+6
5  rho = 1.72e-8
6  e = 1.6e-19
7  M_e = 9.1e-31
8
9  lamda = (M_e * V_fermi) / (n * (e ^ 2) * rho)
10 lamda = lamda * (10 ^ 9)
11
12 cat("Lambda =", round(lamda, 1), "nm\n")
```

Chapter 11

Nuclear Structure

R code Exa 11.1 Density of C12 Nucleus

```
1  #(Pg no. 393)
2
3  u = 1.66e-27
4  M_c = 12 * u
5  R = 2.7e-15
6
7  Den_cn = M_c / ((4 / 3) * pi * (R ^ 3))
8  Den_cn = formatC(Den_cn, format = "e", digits = 1)
9
10 cat("rho =", Den_cn, "kg/m^3\n")
```

R code Exa 11.2 Repulsive electric force on proton

```
1  #(Pg no. 393)
2
3  r = 2.4
4  r = r * (10 ^ -15)
5  e = 1.6e-19
```

```
6  Po = 8.85e-12
7
8  F = (1 / (4 * pi * Po)) * ((e ^ 2) / (r ^ 2))
9
10 cat("F =", round(F), "N\n")
```

R code Exa 11.3 Magnetic energy and Larmor frequency of proton

```
1  #(Pg no. 395)
2
3  B = 1.000
4  Mu_n = 3.152e-8
5  Mu_p = 2.793 * Mu_n
6
7  del_E = 2 * Mu_p * B
8  del_E = formatC(del_E, format = "e", digits = 3)
9
10 h = 4.136e-15
11
12 F_larmor = as.numeric(del_E) / h
13 F_larmor = F_larmor / (10 ^ 6)
14
15 cat("a) Delta_E =", del_E, "eV\n")
16 cat("b) V_L =", round(F_larmor, 2), "MHz\n")
```

R code Exa 11.4 Binding energy of Neon isotope

```
1  #(Pg no. 401)
2
3  Z = 10
4  N = 10
5  E_b = 160.647
6  Mh = 1.007825
```

```
7 Mn = 1.008665
8
9 M_neon = ((Z * Mh) + (N * Mn)) - (E_b / 931.49)
10
11 cat("M_Ne10 =", round(M_neon, 3), "u\n")
```

R code Exa 11.5 Binding energy of Calcium isotope

```
1 #(Pg no. 402)
2
3 M_Ca42 = 41.958622
4
5 M_neutron = 1.008665
6 M_Ca41 = 40.962278
7
8 M_proton = 1.007276
9 K_19 = 40.96237
10
11 M_neutron_plus_Ca41 = M_neutron + M_Ca41
12 M_proton_plus_K_19 = K_19 + M_proton
13
14 Eb_neutron =  (M_neutron_plus_Ca41 - M_Ca42) *
       931.49
15 Eb_proton = (M_proton_plus_K_19 - M_Ca42) * 931.49
16
17 cat("a) Eb_neutron =", round(Eb_neutron, 2), "MeV\n"
       )
18 cat("b) Eb_proton  =", round(Eb_proton, 2), "MeV\n")
```

R code Exa 11.6 Binding energy of Zinc isotope

```
1 #(Pg no. 407)
2
```

```
3  Z = 30
4  N = 34
5
6  Mh = 1.007825
7  Mn = 1.008665
8  M_zinc = 63.929
9
10 E_b1 = ((Z * Mh) + (N * Mn) - M_zinc) * 931.49
11
12 a1 = 14.1
13 a2 = 13.0
14 a3 = 0.595
15 a4 = 19.0
16 a5 = 33.5
17 A = Z + N
18
19 E_b2 = ((a1 * A) - (a2 * (A ^ (2 / 3))) - (a3 * Z *
       (Z - 1) / (A ^ (1 / 3))) -
20             (a4 * ((A - 2 * Z) ^ 2) / A) + (a5 / (A ^
                 (3 / 4))))
21
22 cat("E_b =", round(E_b1, 1), "MeV\n")
23 cat("E_b_sb =", round(E_b2, 1), "MeV\n")
```

R code Exa 11.7 Most stable isobar of given atomic number

```
1  #(Pg no.  408)
2
3  A = 25
4
5  Z = (0.595 * A ^ (-1 / 3) + 76) / (1.19 * A ^ (-1 /
       3) + (152 * A ^ -1))
6
7  cat("A = 25,    Z =", round(Z, 2), "=", round(Z), "\n
       ")
```

Chapter 12

Nuclear Transformations

R code Exa 12.2 Radioactive decay of Radon

```
1  #(Pg no. 425)
2
3  T_half = 3.82
4  Lambda = 0.693 / T_half
5
6  p = 0.6
7  N = (1 - p)
8
9  t = (1 / Lambda) * (log(1 / N))
10
11  cat("t =", round(t, 2), "d\n")
```

R code Exa 12.3 Activity of Radon

```
1  #(Pg no. 427)
2
3  T_half = 3.8
4  Lambda = 0.693 / (T_half * 86400)
```

```
5
6  W_radon = 1
7  M_Radon = 222
8
9  N = (W_radon * (10 ^ -6)) / (M_Radon * (1.66e-27))
10 N = formatC(N, format = "e", digits = 2)
11
12 R = Lambda * as.numeric(N)
13 R = formatC(R, format = "e", digits = 2)
14
15 R_TBq = round(as.numeric(R) / 10 ^ 12, 2)
16 R_Ci = R_TBq * 27.15
17
18 cat("R =", R, "decays/sec  =", R_TBq, "TBq  =",
       round(R_Ci), "Ci\n")
```

R code Exa 12.4 Activity of Radon one week later

```
1  #(Pg no. 427)
2
3  R0 = 155
4  Lambda = 2.11e-6
5  t = 7
6  t = t * 86400
7
8  Lambda_t = Lambda * t
9  R = R0 * exp(-Lambda_t)
10
11 cat("R =", round(R), "Ci\n")
```

R code Exa 12.5 Death date of tree by Radiometric Dating

```
1  #(Pg no. 428)
```

```
 2
 3  R = 13
 4  R0 = 16
 5  T_half = 5760
 6
 7  Lambda = 0.693 / T_half
 8  t = (1 / Lambda) * (log(R0 / R))
 9  t = formatC(t, format = "e", digits = 1)
10
11  cat("t =", t, "y\n")
```

R code Exa 12.6 Radioactive equilibrium for half life of U238

```
1  #(Pg no. 432)
2
3  Thalf_U234 = 2.5e+5
4  Atomic_ratio = 1.8e+4
5
6  Thalf_U238 = Atomic_ratio * Thalf_U234
7  Thalf_U238 = formatC(Thalf_U238, format = "e",
       digits = 1)
8
9  cat("Thalf_U238 =", Thalf_U238, "y\n")
```

R code Exa 12.7 Alpha Decay in polonium isotope

```
1  #(Pg no. 433)
2
3  Z_Po = 84
4  Z_He = 2
5  Z_nuc = Z_Po - Z_He
6
7  A_Po = 210
```

```
 8  A_He = 4
 9  A_nuc = A_Po - A_He
10
11  M_Po = 209.9829
12  M_He = 4.0026
13  E_He = 5.3
14
15  Q = (A_Po / A_nuc) * E_He
16  M_Q = Q / 931
17  M_nuc = M_Po - M_He - M_Q
18
19  cat("a) Z =", Z_nuc, "\n")
20  cat("   A =", A_nuc, "\n")
21  cat("b) M =", round(M_nuc, 4), "u\n")
```

R code Exa 12.8 Cross Section of Cadmium

```
 1  #(Pg no. 444)
 2
 3  X_sec = 2e+4
 4  X_sec = X_sec * (10 ^ -28)
 5  M_cad = 112
 6  density = 8.64e+3
 7  x = 0.1
 8  x = x * (10 ^ -3)
 9  p = 12
10  u = 1.66e-27
11
12  n = (p / 100.0) * density / (M_cad * u)
13  Frac_absr = 1 - exp(-n * X_sec * x)
14
15  x2 = (-log(0.01)) / (n * X_sec)
16  x2 = x2 * 10 ^ 3
17
18  cat("a) f =", round(Frac_absr, 2), "\n")
```

```
19  cat("b) x =", round(x2, 2), "mm\n")
```

R code Exa 12.9 Mean free path in Cadmium

```
1  #(Pg no. 445)
2
3  n_sigma = 1.12e+4
4  Lambda = 1 / n_sigma
5  Lambda = Lambda * (10 ^ 3)
6
7  cat("Lambda =", round(Lambda, 4), "mm\n")
```

R code Exa 12.10 Cross Section of Gold

```
1   #(Pg no. 446)
2
3   T_half = 2.69
4   Lambda = 0.693 / (T_half * 86400)
5
6   R = 200.0
7   R = R * (10 ^ -6)
8
9   del_N = (R * 3.70e+10) / Lambda
10
11  W_gold = 10
12  u = 1.66e-27
13  M_gold = 197
14
15  n2 = (W_gold * (10 ^ -6)) / (M_gold * u)
16
17  flux = 2e+16
18  X_sec = 99e-28
19  N = del_N
```

```
20
21  del_T = del_N / (flux * n2 * X_sec)
22  del_T = floor(del_T)
23
24  cat("Delta_t =", del_T, "s  =", del_T %/% 60, "min",
        del_T %% 60, "s\n")
```

R code Exa 12.11 Kinetic energies and Q value of Nuclear Reactions

```
1  #(Pg no. 450)
2
3  mB = 14.00307
4  mA = 4.00260
5  mC = 1.00783
6  mD = 16.99913
7
8  Q = (mB + mA - mC - mD) * 931.5
9  KE_cm = -Q
10 KE_lab = ((mA + mB) / mB) * KE_cm
11
12 cat("KE_lab =", round(KE_lab, 3), "MeV\n")
```