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

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Book Description

Title: Concepts Of Modern Physics

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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.

Contents

List of R Codes

Chapter 1

Relativity

R code Exa 1.1 Time dilation

```
#(Pg no. 9)

proper_time_interval = 3600
relative_time_interval = 3601
c = 2.998 * 10 ^ 8

v = c * sqrt(1 - ((proper_time_interval ^ 2) / (
    relative_time_interval ^ 2)))
v = formatC(v, format = "e", digits = 1)

cat("V =", v, "m/s\n")
```

R code Exa 1.2 Longitudinal doppler effect in light

```
#(Pg no. 13)

v = 5.6e+14
v0 = 4.8e+14
```

```
c = 3.0e+8

vu = c * ((v ^ 2 - v0 ^ 2) / (v ^ 2 + v0 ^ 2))
vu = vu * 3.6
vu = formatC(vu, format = "e", digits = 2)

R = 1.0
l = 80.0

fine = as.numeric(vu) - l

cat("Fine = $", fine)
```

R code Exa 1.3 Doppler effect Hubbles law

```
#(Pg no. 14)

v = 6.12e+7
c = 3.0e+8
wl_0 = 500.0

wl = wl_0 * sqrt(((1 + (v / c)) / (1 - (v / c))))
wl_s = wl - wl_0

cat("Lambda =", round(wl_s), "nm\n")
```

R code Exa 1.4 Twin Paradox

```
#(Pg no.19)

StartAge = 20
c = 3e+8
v = 0.8 * c
```

```
t0 = 1

T1 = t0 * (sqrt((1 + v / c) / (1 - v / c)))
T2 = t0 * (sqrt((1 - v / c) / (1 + v / c)))

Dout = 15
Dret = 15
Dout_Signals = Dout / T1
Dret_Signals = Dret / T2
Total_DSignals = Dout_Signals + Dret_Signals
JaneAge = StartAge + Total_DSignals

L0 = 20
v0 = 0.8
Dout_acc_Jane = L0 / v0
Dret_acc_Jane = Total_DSignals - (Dout_acc_Jane + L0)
Dout_Signals_acc_Jane = (Dout_acc_Jane + L0) / T1
Dret_Signals_acc_Jane = Dret_acc_Jane / T2
Total_DSignals_acc_Jane = Dout_Signals_acc_Jane + Dret_Signals_acc_Jane
DickAge = StartAge + Total_DSignals_acc_Jane


cat("Age of Jan =", JaneAge, "y\n")
cat("Age of Dic =", DickAge, "y\n")
```

R code Exa 1.6 Mass and Energy of Stationary body

```
#(Pg no. 27)

m_frag = 1
c = 3e+8
v = 0.6 * c

```

```
E0 = 2 * ((m_frag * (c ^ 2)) / sqrt(1 - ((v / c) ^
    2)))
m = E0 / (c ^ 2)

cat("m =", m, "kg\n")
```

R code Exa 1.7 Mass and Energy of Sun

```
#(Pg no. 28)

rate = 1.4
R = 1.5e+11

P = (rate * (10 ^ 3)) * (4 * pi * (R ^ 2))

C = 3e+8
E = P

m = E / (C ^ 2)
m = formatC(m, format = "e", digits = 1)

cat("m =", m, "kg\n")
```

R code Exa 1.8 Energy and momentum of Electron and Photon

```
#(Pg no. 32)

c = 3e+8
me = 0.511 / (c ^ 2)
mp = 0
p = 2.000 / c

```

```
Ee = sqrt(((me ^ 2) * (c ^ 4)) + ((p ^ 2) * (c ^ 2)))
Ep = p * c

cat("E_e =", round(Ee, 3), "MeV\n")
cat("E_p =", Ep, "MeV\n")
```

R code Exa 1.11 Relativistic velocity transformation

```
#(Pg no. 44)

c = 3e+8
VaE = 0.90 * c
VbA = 0.50 * c

VbE = (VaE + VbA) / (1 + ((VaE * VbA) / (c ^ 2)))
VbE = VbE / c

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

```
#(Pg no. 61)

F_tf = 660
h = 6.63e-34

E_tf = h * F_tf
E_tf = formatC(E_tf, format = "e", digits = 2)

F_ao = 5.00e+14

E_ao = h * F_ao
E_ao_eV = E_ao / 1.60e-19

cat("hv_1 =", E_tf, "J\n")
cat("hv_2 =", E_ao, "J =", round(E_ao_eV, 3), "eV\n"
  )

#The answer may slightly vary due to rounding off
  values
```

R code Exa 2.2 Photoelectric effect

```
#(Pg no. 66)

wl = 350
i = 1.00
wf = 2.2
wl = wl * (10 ^ -9)
Ep = 1.24e-6 / wl

KEmax = Ep - wf

A = 1.00
A = A * (10 ^ -4)
E = 5.68e-19

Np = i * A / E
Ne = (0.0050) * Np
Ne = formatC(Ne, format = "e", digits = 1)

cat("a) KE_max =", round(KEmax, 1), "eV\n")
cat("b) ne =", Ne, "photoelectrons/s\n")
```

R code Exa 2.3 X ray production

```
#(Pg no.72)

AP = 50000

wl_min = 1.24e-6 / AP
wl_min_nm = wl_min * (10 ^ 9)

```

```
Freq_max = 3e+8 / wl_min
Freq_max = formatC(Freq_max, format = "e", digits =
   2)

cat("Lambda_min =", wl_min_nm, "nm\n")
cat("V_max =", Freq_max, "Hz\n")
```

R code Exa 2.4 Compton Effect

```
#(Pg no. 78)

wl = 10.0
phi = 45.0
phi_rad = (45.0 * (22 / 7)) / 180
wlc = 2.426e-12
k = cos(phi_rad)
wlc = wlc * 10.0 ^ 12

wl2 = wl + wlc * (1.0 - k)

wl2_max = wl + (2 * wlc)
wl2_max = round(wl2_max, 1)

h = 6.63e-34
c = 3e+8
c = c * (10 ^ 12)
KEmax = (h * c) * ((1 / wl) - (1 / wl2_max))
KEmax_KeV = KEmax / 1.6022e-16
KEmax = formatC(KEmax, format = "e", digits = 2)

cat("a) Lambda\' =", round(wl2, 1), "pm\n")
cat("b) Lambda_max\' =", wl2_max, "pm\n")
cat("c) KE_max =", KEmax, "J =", round(KEmax_KeV,
   1), "keV\n")
```

R code Exa 2.6 Pair Production

```
#(Pg no. 82)

c = 3.0e+8
v = 0.5 * c
m = 0.511 / (c ^ 2)
y = 1 / sqrt(1 - (v / c) ^ 2)

p1_minus_p2 = (2 * y * m * v) * c

p1_plus_p2 = 2 * y * m * (c ^ 2)

p1 = (p1_minus_p2 + p1_plus_p2) / 2
p2 = p1_plus_p2 - p1
E1 = p1
E2 = p2

cat("E1 = ", round(E1, 3), "MeV\n")
cat("E2 = ", round(E2, 3), "MeV\n")
```

R code Exa 2.7 Photon Absorption and Radiation intensity

```
#(Pg no.85)

I = 2.0
mu = 4.9
x = 10.0
x = x / 100

I_rel_a = exp(-(mu * x))

```

```
I_rel_b = 0.01
I_rel_b_inv = 1 / I_rel_b

x2 = log(I_rel_b_inv) / mu

cat("a) I/Io =", round(I_rel_a, 2), "\n")
cat("b) x =", round(x2, 2), "m\n")
```

R code Exa 2.8 Energy of falling photon

```
#(Pg no. 86)

H = 22.5
vu = 7.3e+14
c = 3e+8
g = 9.8

Freq_change = (g * H / (c ^ 2)) * vu

cat("v\'-v =", round(Freq_change, 1), "Hz\n")
```

Chapter 3

Wave Properties of Particles

R code Exa 3.1 De Broglie wavelengths

```
#(Pg no. 94)

h = 6.63e-34
m1 = 46
m1 = m1 / 1000
v1 = 30
y1 = 1

wl1 = h / (y1 * m1 * v1)
wl1 = formatC(wl1, format =  "e", digits = 1)

m2 = 9.1e-31
v2 = 10 ^ 7
y2 = 1

wl2 = h / (y2 * m2 * v2)
wl2 = formatC(wl2, format = "e", digits = 1)

cat("a) Lambda =", wl1, "m\n")
cat("b) Lambda =", wl2, "m\n")
```

R code Exa 3.2 Kinetic Energy using De Broglie wavelengths

```
#(Pg no. 94)

wl = 1.0e-15
E0 = 0.938
h = 4.136e-15
c = 2.998e+8

pc = (h * c) / wl
pc = pc * (10 ^ -9)

E = sqrt((E0 ^ 2) + (pc ^ 2))
KE = E - E0
KE = KE * 1000

cat("KE =", round(KE), "MeV\n")
```

R code Exa 3.3 De Broglie phase and group velocities

```
#(Pg no. 103)

wl = 2.0e-12
h = 4.136e-15
c = 2.998e+8

pc = (h * c) / wl
pc = pc / 1000

E0 = 511

E = sqrt((E0 ^ 2) + (pc ^ 2))
```

```
KE = E - E0

v = c * sqrt(1 - (E0 ^ 2 / E ^ 2))
vp = (c ^ 2 / v) / c
vg = v / c

cat("a) KE = ", round(KE), "keV\n")
cat("b) vp = ", round(vp, 2), "c\n")
cat("    vg = ", round(vg, 4), "c\n")
```

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

```
#(Pg no. 107)

library(RColorBrewer)

rm(list = ls())

m = 9.1e-31
L = 1.0e-10
h = 6.63e-34
n0 = 1

En = (h ^ 2) / (8 * m * (L ^ 2))
En = formatC(En, format = "e", digits = 2)
En_eV = round(as.numeric(En) * 6.242e+18)

cat("En   =", En, "n^2 J   =", En_eV, "n^2 eV\n")
E = c()

c = colors()
c = brewer.pal(4, "Set1")
plot(
  E,
  type = "l",
```

```
  xaxt = 'n',
  xlim = c(0, 10),
  xlab = "",
  ylab = "En,  eV",
  yaxs = "i",
  ylim = c(0, 700),
  yaxp = c(0, 1000, 10)
)

labels = c("n=1", "n=2", "n=3", "n=4")

for (n in seq(1, 4))
{
  E[n] = En_eV * (n ^ 2)
  cat("\tn=", n, ":\tEn= ", E[n], "eV\n")
  abline(h = E[n], col = c[n], lwd = 4)
  text(5, E[n], labels[n], pos = 3, offset = 0.2)
}
```

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

```
#(Pg no. 107)

m = 10.0
m = m / 1000
L = 10
L = L / 100
h = 6.63e-34

En = (h ^ 2) / (8 * m * (L ^ 2))
En = formatC(En, format = "e", digits = 1)

cat("\tEn =", En, "n^2 J\n")

E = c()
```

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

R code Exa 3.6 Uncertainty in protons position

```
#(Pg no. 112)

X0 = 1.00e-11
h_bar = 1.054e-34
t1 = 1.00
m = 1.672e-27

x1 = (h_bar * t1) / (2 * m * X0)
x1 = formatC(x1, format = "e", digits = 2)

cat("Delta_x >=", x1, "m\n")
```

R code Exa 3.7 Energy of Nuclear electron by Uncertainty Principle

```
#(Pg no. 114)

r = 5.00e-15
del_x = r
h_b = 1.054e-34

del_p = h_b / (2 * del_x)
del_p = formatC(del_p, format = "e", digits = 1)

p = as.numeric(del_p)
c = 3e+8
```

```
KE = p * c
KE_eV = KE / 1.602e-19
KE_eV = KE_eV / 10 ^ 6

cat("KE_min =", KE, "J  =", KE_eV, "MeV\n")
```

R code Exa 3.8 Energy of Hydrogen electron by Uncertainty Principle

```
#(Pg no. 115)

r = 5.3e-11
del_x = r
h_bar = 1.054e-34

del_p = h_bar / (2 * del_x)

p = del_p
m = 9.1e-31

KE = (p ^ 2) / (2 * m)
KE = formatC(KE, format = "e", digits = 1)
KE_eV = as.numeric(KE) / 1.602e-19

cat("KE_min =", KE, "J  =", round(KE_eV, 1), "eV\n")
```

R code Exa 3.9 Uncertainty in Time and Energy

```
#(Pg no. 116)

del_t = 1e-8
h_b = 1.054e-34

```

```
del_E = h_b / (2 * del_t)
del_E = formatC(del_E, format = "e", digits = 1)

h = 6.626e-34

del_nu = as.numeric(del_E) / h
del_nu = formatC(del_nu, format = "e", digits = 1)

cat("Delta_E >=", del_E, "J\n")
cat("Delta_nu >=", del_nu, "Hz\n")
```

Chapter 4

Atomic Structure

R code Exa 4.1 Electron orbits of Hydrogen atom

```r
#(Pg no. 125)

E = -13.6
e = 1.6e-19
E = E * e
E0 = 8.85e-12
pi = 22 / 7

r = -(e ^ 2 / (8 * pi * E0 * E))
r = as.numeric(formatC(r, format = "e", digits = 1))

m = 9.1e-31

v = e / sqrt(4 * pi * E0 * m * r)
v = formatC(v, format = "e", digits = 1)

cat("r =", r, "m\n")
cat("v =", v, "m/s\n")
```

R code Exa 4.2 Energy level of Electron Hydrogen collision

```
#(Pg no. 135)

ni = 1
nf = 3
E1 = -13.6

del_E = E1 * ((1 / nf ^ 2) - (1 / ni ^ 2))

cat("Delta_E =", round(del_E, 1), "eV\n")
```

R code Exa 4.3 Energy level of Rydberg atoms

```
#(Pg no. 135)

rn = 1.00e-5
a0 = 5.29e-11

n = sqrt(rn / a0)

E1 = -13.6
En = E1 / n ^ 2
En = formatC(En, format = "e", digits = 2)

cat("a) n =", round(n), "\n")
cat("b) En =", En, "eV")
```

R code Exa 4.4 Balmer series of Hydrogen Spectrum

```
#(Pg no. 138)

ni = 3.0
```

```
nf = 2.0
R = 1.097e+7

freq = (1 / nf ^ 2) - (1 / ni ^ 2)
wl = 1 / (freq * R)
wl = wl * (10 ^ 9)

cat("Lamda =", round(wl), "nm\n")
```

R code Exa 4.5 Frequency of revolution

```
#(Pg no. 139)

ni = 1
nf = 2
E1 = -2.18e-18
h = 6.63e-34

foR1 = (-E1 / h) * (2 / ni ^ 3)
foR2 = (-E1 / h) * (2 / nf ^ 3)
foR1 = formatC(foR1, format = "e", digits = 2)
foR2 = formatC(foR2, format = "e", digits = 2)

ni = 2
nf = 1

v = (-E1 / h) * ((1 / (nf ^ 3)) - (1 / ni ^ 3))
v = formatC(v, format = "e", digits = 2)

f = as.numeric(foR2)
del_t = 1.00e-8

N = f * del_t
N = formatC(N, format = "e", digits = 2)

```

```
cat("a) f1 =", foR1, "rev/s\n")
cat("   f2 =", foR2, "rev/s\n")
cat("b) v =", v, "Hz\n")
cat("c) N =", N, "rev\n")

#The answer may slightly vary due to rounding off
    values
```

R code Exa 4.7 Reduced Mass of Moun

```
#(Pg no. 142)

me = 9.1095e-31
m = 207 * me
M = 1836 * me

M_red = (m * M) / (m + M)

a0 = 5.29e-11
r1 = a0

r1_red = (me / (M_red)) * r1
r1_red = formatC(r1_red, format = "e", digits = 3)

n = 1
E1 = -13.6

E1_red = (M_red / me) * (E1 / n ^ 2)
E1_red = E1_red / (10 ^ 3)

cat("a) r1\' =", r1_red, "m\n")
cat("b) E1\' =", round(E1_red, 2), "KeV\n")
```

R code Exa 4.8 Rutherford Scattering Formula

```
#(Pg no. 156)

I = 7.7
D_gold = 1.93e+4
u = 1.66e-27
M_gold = 197 * u

n = D_gold / M_gold
n = as.numeric(formatC(n, format = "e", digits = 2))

Z_gold = 79
e = 1.6e-19
KE = (I * e) / (10 ^ -6)
Theta = 45
Theta = 45 * (pi / 180)
p = 1 / tan(Theta / 2)
E0 = 8.85e-12
t = 3e-7

f = pi * n * t * (((Z_gold * (e ^ 2)) / (4 * pi * E0
    * KE)) ^ 2) * (p ^ 2)
f = as.numeric(formatC(f, format = "e", digits = 0))

cat("f =", f, "\n")
cat("Fraction =", f * 100, "%\n")
```

Chapter 5

Quantum Mechanics

R code Exa 5.4 Wave function of Particle in a Box

```
#(Pg no. 180)

L = 1
x1 = 0.45
x2 = 0.55

f = function(x)
{
  y = sin(n * pi * x) ^ 2
  return(y)
}

n = 1
I1 = integrate(f, x1, x2)
P1 = (2 / L * as.numeric(I1[1]))
P1 = round(P1, 3)

n = 2
I2 = integrate(f, x1, x2)
P2 = (2 / L * as.numeric(I2[1]))
P2 = round(P2, 4)
```

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

R code Exa 5.6 Tunnel effect transmission probability

```
#(Pg no. 186)

rm(list = ls())

E1 = 1.0
E2 = 2.0
U = 10.0
L1 = 0.50
L1  = L1 * 10 ^ -9
h_bar = 1.054e-34
Me = 9.1e-31
e = 1.6e-19

k2 = sqrt(2 * Me * (U - E1) * e) / h_bar
k1 = sqrt(2 * Me * (U - E2) * e) / h_bar

T1 = exp(-2 * k2 * L1)
T1 = formatC(T1, format = "e", digits = 1)
T2 = exp(-2 * k1 * L1)
T2 = formatC(T2, format = "e", digits = 1)


L2 = L1 * 2
T11 = exp(-2 * k2 * L2)
T11 = formatC(T11, format = "e", digits = 1)
T22 = exp(-2 * k1 * L2)
T22 = formatC(T22, format = "e", digits = 1)
```

```
cat("a) T1 =", T1, "\n")
cat("   T2 =", T2, "\n")
cat("b) T1\' =", T11, "\n")
cat("   T2\' =", T22, "\n")

#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

```
#(Pg no. 215)

max_prob = 1

Pro_Ratio = 4 * exp(-1)
Prezense_precent = (Pro_Ratio - max_prob) * 100

cat("Prez_perce =", round(Prezense_precent))
```

R code Exa 6.4 Normal Zeeman Effect

```
#(Pg no. 226)

B = 0.300
wl = 450
wl = wl * (10 ^ -9)
```

```
e = 1.6e-19
m = 9.1e-31
c = 3e+8

del_wl = (e * B * (wl ^ 2)) / (4 * pi * m * c)
del_wl = del_wl * (10 ^ 9)
del_wl = round(del_wl, 5)

cat("Delta_Lamda =", del_wl, "nm\n")
```

Chapter 7

Many Electron Atoms

R code Exa 7.1 Equatorial velocity of an electron

```
#(Pg no. 230)

r = 5.00e-17
m = 9.1e-31
h_bar = 1.055e-34

v = ((5 * sqrt(3)) / 4) * (h_bar / (m * r))

c = 3e+8

v = v / c
v = formatC(v, format = "e", digits = 2)

cat("v =", v, "c\n")
```

R code Exa 7.2 Effective charge on electron of lithium atom

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

```
n = 2
E2 = -5.39
E1 = -13.6

Z = n * (sqrt(E2 / E1))
Z = round(Z, 2)

e = 1.6e-19

C_effective = Z * e
C_effective = formatC(C_effective, format = "e",
    digits = 3)

cat("En =", Z, "e  =", C_effective, "C\n")
```

R code Exa 7.3 Magnetic energy for an electron

```
#(Pg no. 248)

n = 2
Ao = 5.29e-11
r = (n ^ 2) * Ao
f = 8.4e+14
Mu_0 = 4 * pi * (10 ^ -7)
e = 1.6e-19

B = (Mu_0 * f * e) / (2 * r)

Mu_b = 9.27e-24

Um = Mu_b * B
Um = Um / e
Um = as.numeric(formatC(Um, format = "e", digits =
    1))
```

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

R code Exa 7.8 K alpha X rays

```
#(Pg no. 257)

wl = 0.180
wl = wl * (10 ^ -9)
c = 3e+8

f = c / wl

R = 1.097e+7

Z = 1 + (sqrt((4 * f) / (3 * c * R)))

cat("Z =", round(Z), "\n")
```

Chapter 8

Molecules

R code Exa 8.1 Energy and angular velocity of the CO

```r
#(Pg no. 283)

R = 0.113
Mc = 1.99e-26
Mo = 2.66e-26

Mco_red = (Mc * Mo) / (Mc + Mo)
I = Mco_red * ((R * (10 ^ -9)) ^ 2)
J = 1
h_bar = 1.054e-34
E_J1 = (J * (J + 1) * (h_bar ^ 2)) / (2 * I)
e = 1.6e-19
E_J1_eV = E_J1 / e
E_J1_eV = formatC(E_J1_eV, format = "e", digits = 2)

W_J1 = sqrt(2 * E_J1 / I)
W_J1 = formatC(W_J1, format = "e", digits = 2)

cat("a) E_J1 = ", E_J1_eV, "eV\n")
cat("b) W_J1 = ", W_J1, "rad/sec\n")
```

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

R code Exa 8.2 Bond length of CO molecule

```
#(Pg no. 285)

Ji = 0
Jf = 1
v = 1.15e+11
h_bar = 1.054e-34

Ico = (h_bar / (2 * pi * v)) * (Ji + 1)

Mco_red = 1.14e-26

r = sqrt(Ico / Mco_red)
r = r * (10 ^ 9)

cat("R_co =", round(r, 3), "nm\n")
```

R code Exa 8.3 Force constant and vibrational levels in CO

```
#(Pg no. 288)

Vo = 6.42e+13
Mco_red = 1.14e-26
h = 6.63e-34
pi=22/7

k = 4 * (pi ^ 2) * (Vo ^ 2) * Mco_red
k = formatC(k, format = "e", digits = 2)

del_E = h * Vo
```

```
del_E = del_E * 6.24e+18

cat("a) k =", k, "N/m\n")
cat("b) Delta_E =", round(del_E, 3), "eV\n")
```

Chapter 9

Statistical Mechanics

R code Exa 9.1 Maxwell Boltzmann distribution function

```
#(Pg no. 299)

E1 = -13.6
E2 = -3.4
g1 = 2
g2 = 8
k = 8.617e-5

T0 = 0
T0 = T0 + 273

x0 = (E2 - E1) / (k * T0)
x0 = round(x0)

n_ratio1 = (g2 / g1) * exp(-x0)
n_ratio1 = formatC(n_ratio1, format = "e", digits =
   1)

T1 = 10000
T1 = T1 + 273

```

```
x1 = (E2 - E1) / (k * T1)
x1 = round(x1, 1)

n_ratio2 = (g2 / g1) * exp(-x1)
n_ratio2 = formatC(n_ratio2, format = "e", digits =
    2)

cat("a) ratio_0 =", n_ratio1, "\n")
cat("b) ratio_10,000 =", n_ratio2, "\n")
```

R code Exa 9.4 Root mean square speed of oxygen molecule

```
#(Pg no. 305)

M_o = 16.0
M_o2 = M_o * 2
u = 1.66e-27
m = M_o2 * u
T = 273
k = 1.38e-23

Vrms = sqrt(3 * k * T / m)
Vrms_miles = (Vrms / 1609.34) * 3600

cat("Vrms =", round(Vrms), "m/s  =", round(Vrms_
    miles), "mi/h\n")
```

R code Exa 9.5 Planck Radiation Law

```
#(Pg no. 314)

V = 1.00
V = V * 10 ^ -6
```

```
dI = 2.404
k = 8.617e-5
h = 4.135e-15
T = 1000
c = 3e+8

N = 8 * pi * V * (((k * T) / (h * c)) ^ 3) * dI
N = formatC(N, format = "e", digits = 2)

Sigma = 5.670e-8
e = 6.24e+18

E_photon = (Sigma * (c ^ 2) * (h ^ 3) * T) / (2.405 * (2 * pi * (k ^ 3)))
E_photon_eV = E_photon * e
E_photon = formatC(E_photon, format = "e", digits = 2)

cat("a) N =", N, "photons\n")
cat("b) E\' =", E_photon, "J =", round(E_photon_eV, 3), "eV\n")
```

R code Exa 9.6 Wiens displacement law

```
#(Pg no. 317)

T = 2.7

wl_max = 2.898e-3 / T
wl_max = wl_max * 10 ^ 3

cat("Lambda_max =", round(wl_max, 1), "mm\n")
```

R code Exa 9.7 Surface temperature of the Sun

```
#(Pg no. 317)

R_earth = 1.5e+11
rate = 1.4
rate = 1.4 * 10 ^ 3

P = rate * (4 * pi * (R_earth ^ 2))

R_sun = 7e+8

R = P / (4 * pi * (R_sun ^ 2))

e = 1
Sig = 5.670e-8

T = (R / (e * Sig)) ^ (1 / 4)
T = formatC(T, format = "e", digits = 1)

cat("T =", T, "K\n")
```

R code Exa 9.8 Fermi energy in Copper

```
#(Pg no. 325)

u = 1.66e-27
Den_c = 8.94e+3
M_c = 63.5

Den_e = Den_c / (M_c * u)

h = 6.63e-34
M_e = 9.1e-31
e = 6.23e+18
```

```
E_fermi = (h ^ 2 / (2 * M_e)) * ((3 * Den_e) / (8 * pi)) ^ (2.0 / 3.0)
E_fermi_eV = E_fermi * e
E_fermi = formatC(E_fermi, format = "e", digits = 2)

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

```
#(Pg no. 342)

r0 = 2.81e-10
a = 1.748
n = 9
e = 1.6e-19
e0 = 8.85e-12

U0 = -(a * (e ^ 2) / (4 * pi * e0 * r0)) * (1 - (1 /
    n))
U0 = U0 / e
U0 = U0 / 2

E1 = 5.14
E2 = -3.61
E = E1 + E2
E = E / 2
Ecohesive = (U0 + E)

cat("E_cohesive =", round(Ecohesive, 2), "eV\n")
```

R code Exa 10.2 Drift velocity of free electrons in Copper

```
#(Pg no. 350)

A = 1.0
A = A * (10 ^ -6)
I = 1.0
n = 8.5e+28
e = 1.6e-19

Vdrift = I / (n * A * e)
Vdrift = formatC(Vdrift, format = "e", digits = 1)

cat("V_drift =", Vdrift, "m/s\n")

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

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

```
#(Pg no. 353)

n = 8.48e+28
V_fermi = 1.57e+6
rho = 1.72e-8
e = 1.6e-19
M_e = 9.1e-31

lamda = (M_e * V_fermi) / (n * (e ^ 2) * rho)
lamda = lamda * (10 ^ 9)

cat("Lambda =", round(lamda, 1), "nm\n")
```

Chapter 11

Nuclear Structure

R code Exa 11.1 Density of C12 Nucleus

```
#(Pg no. 393)

u = 1.66e-27
M_c = 12 * u
R = 2.7e-15

Den_cn = M_c / ((4 / 3) * pi * (R ^ 3))
Den_cn = formatC(Den_cn, format = "e", digits = 1)

cat("rho =", Den_cn, "kg/m^3\n")
```

R code Exa 11.2 Repulsive electric force on proton

```
#(Pg no. 393)

r = 2.4
r = r * (10 ^ -15)
e = 1.6e-19
```

```
Po = 8.85e-12

F = (1 / (4 * pi * Po)) * ((e ^ 2) / (r ^ 2))

cat("F =", round(F), "N\n")
```

R code Exa 11.3 Magnetic energy and Larmor frequency of proton

```
#(Pg no. 395)

B = 1.000
Mu_n = 3.152e-8
Mu_p = 2.793 * Mu_n

del_E = 2 * Mu_p * B
del_E = formatC(del_E, format = "e", digits = 3)

h = 4.136e-15

F_larmor = as.numeric(del_E) / h
F_larmor = F_larmor / (10 ^ 6)

cat("a) Delta_E =", del_E, "eV\n")
cat("b) V_L =", round(F_larmor, 2), "MHz\n")
```

R code Exa 11.4 Binding energy of Neon isotope

```
#(Pg no. 401)

Z = 10
N = 10
E_b = 160.647
Mh = 1.007825
```

```
Mn = 1.008665

M_neon = ((Z * Mh) + (N * Mn)) - (E_b / 931.49)

cat("M_Ne10 =", round(M_neon, 3), "u\n")
```

R code Exa 11.5 Binding energy of Calcium isotope

```
#(Pg no. 402)

M_Ca42 = 41.958622

M_neutron = 1.008665
M_Ca41 = 40.962278

M_proton = 1.007276
K_19 = 40.96237

M_neutron_plus_Ca41 = M_neutron + M_Ca41
M_proton_plus_K_19 = K_19 + M_proton

Eb_neutron =  (M_neutron_plus_Ca41 - M_Ca42) *
    931.49
Eb_proton = (M_proton_plus_K_19 - M_Ca42) * 931.49

cat("a) Eb_neutron =", round(Eb_neutron, 2), "MeV\n"
    )
cat("b) Eb_proton  =", round(Eb_proton, 2), "MeV\n")
```

R code Exa 11.6 Binding energy of Zinc isotope

```
#(Pg no. 407)

```

```
Z = 30
N = 34

Mh = 1.007825
Mn = 1.008665
M_zinc = 63.929

E_b1 = ((Z * Mh) + (N * Mn) - M_zinc) * 931.49

a1 = 14.1
a2 = 13.0
a3 = 0.595
a4 = 19.0
a5 = 33.5
A = Z + N

E_b2 = ((a1 * A) - (a2 * (A ^ (2 / 3))) - (a3 * Z * (Z - 1) / (A ^ (1 / 3))) -
           (a4 * ((A - 2 * Z) ^ 2) / A) + (a5 / (A ^ (3 / 4))))

cat("E_b =", round(E_b1, 1), "MeV\n")
cat("E_b_sb =", round(E_b2, 1), "MeV\n")
```

R code Exa 11.7 Most stable isobar of given atomic number

```
#(Pg no. 408)

A = 25

Z = (0.595 * A ^ (-1 / 3) + 76) / (1.19 * A ^ (-1 / 3) + (152 * A ^ -1))

cat("A = 25,    Z =", round(Z, 2), "=", round(Z), "\n")
```

Chapter 12

Nuclear Transformations

R code Exa 12.2 Radioactive decay of Radon

```
#(Pg no. 425)

T_half = 3.82
Lambda = 0.693 / T_half

p = 0.6
N = (1 - p)

t = (1 / Lambda) * (log(1 / N))

cat("t =", round(t, 2), "d\n")
```

R code Exa 12.3 Activity of Radon

```
#(Pg no. 427)

T_half = 3.8
Lambda = 0.693 / (T_half * 86400)
```

```
W_radon = 1
M_Radon = 222

N = (W_radon * (10 ^ -6)) / (M_Radon * (1.66e-27))
N = formatC(N, format = "e", digits = 2)

R = Lambda * as.numeric(N)
R = formatC(R, format = "e", digits = 2)

R_TBq = round(as.numeric(R) / 10 ^ 12, 2)
R_Ci = R_TBq * 27.15

cat("R =", R, "decays/sec  =", R_TBq, "TBq  =",
   round(R_Ci), "Ci\n")
```

R code Exa 12.4 Activity of Radon one week later

```
#(Pg no. 427)

R0 = 155
Lambda = 2.11e-6
t = 7
t = t * 86400

Lambda_t = Lambda * t
R = R0 * exp(-Lambda_t)

cat("R =", round(R), "Ci\n")
```

R code Exa 12.5 Death date of tree by Radiometric Dating

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

```
R = 13
R0 = 16
T_half = 5760

Lambda = 0.693 / T_half
t = (1 / Lambda) * (log(R0 / R))
t = formatC(t, format = "e", digits = 1)

cat("t =", t, "y\n")
```

R code Exa 12.6 Radioactive equilibrium for half life of U238

```
#(Pg no. 432)

Thalf_U234 = 2.5e+5
Atomic_ratio = 1.8e+4

Thalf_U238 = Atomic_ratio * Thalf_U234
Thalf_U238 = formatC(Thalf_U238, format = "e", digits = 1)

cat("Thalf_U238 =", Thalf_U238, "y\n")
```

R code Exa 12.7 Alpha Decay in polonium isotope

```
#(Pg no. 433)

Z_Po = 84
Z_He = 2
Z_nuc = Z_Po - Z_He

A_Po = 210
```

```
A_He = 4
A_nuc = A_Po - A_He

M_Po = 209.9829
M_He = 4.0026
E_He = 5.3

Q = (A_Po / A_nuc) * E_He
M_Q = Q / 931
M_nuc = M_Po - M_He - M_Q

cat("a) Z =", Z_nuc, "\n")
cat("   A =", A_nuc, "\n")
cat("b) M =", round(M_nuc, 4), "u\n")
```

R code Exa 12.8 Cross Section of Cadmium

```
#(Pg no. 444)

X_sec = 2e+4
X_sec = X_sec * (10 ^ -28)
M_cad = 112
density = 8.64e+3
x = 0.1
x = x * (10 ^ -3)
p = 12
u = 1.66e-27

n = (p / 100.0) * density / (M_cad * u)
Frac_absr = 1 - exp(-n * X_sec * x)

x2 = (-log(0.01)) / (n * X_sec)
x2 = x2 * 10 ^ 3

cat("a) f =", round(Frac_absr, 2), "\n")
```

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

R code Exa 12.9 Mean free path in Cadmium

```
#(Pg no. 445)

n_sigma = 1.12e+4
Lambda = 1 / n_sigma
Lambda = Lambda * (10 ^ 3)

cat("Lambda =", round(Lambda, 4), "mm\n")
```

R code Exa 12.10 Cross Section of Gold

```
#(Pg no. 446)

T_half = 2.69
Lambda = 0.693 / (T_half * 86400)

R = 200.0
R = R * (10 ^ -6)

del_N = (R * 3.70e+10) / Lambda

W_gold = 10
u = 1.66e-27
M_gold = 197

n2 = (W_gold * (10 ^ -6)) / (M_gold * u)

flux = 2e+16
X_sec = 99e-28
N = del_N
```

```
del_T = del_N / (flux * n2 * X_sec)
del_T = floor(del_T)

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

```
#(Pg no. 450)

mB = 14.00307
mA = 4.00260
mC = 1.00783
mD = 16.99913

Q = (mB + mA - mC - mD) * 931.5
KE_cm = -Q
KE_lab = ((mA + mB) / mB) * KE_cm

cat("KE_lab =", round(KE_lab, 3), "MeV\n")
```