A1

a) 0.251 s
b) 1 Period. *Displacement* = 0,
Distance = 4 *X* =24cm
c) 2.90 cm
d) +131 cm/s
e) −1812 cm/s^2

A2

a) T ≅ 2.33 s (from graph),
f = 0.429 Hz
b) Depends on function you chose:
E.g. if you chose cos:

$$x(t) = X\cos(\omega t + \varphi) \;\Rightarrow\; \varphi = \frac{\pi}{2}, -\frac{3\pi}{2}, \ldots$$

c) Numerous ways of writing. One of them is:

$$x(t) = (2.4\text{ m})\cos\left(2.68\frac{\text{rad}}{\text{s}}t + \frac{\pi}{2}\right)$$

d) +6.98 m/s^2

A3

a) 0.431 m
b) 2.43 s
c) 1.11 m/s
d) no change of above answers. Phase constant would have changed, though.

A4

a) 88.8 N/m
b) 1.24 s
c) 0.152 m

A5

a) 2.00 s
b) 0.0792 J
c) 4.08 N
d) 0.248 m

B1

See Figure 1

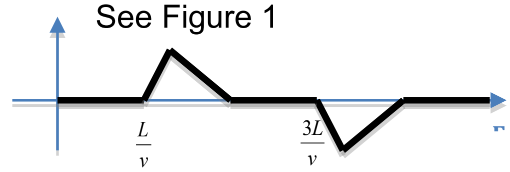


Figure 2: Answer for B1

B2

a) $A = 2.00 \times 10^{-3}\, m$, $\lambda = 1.60\, m$, $T = 5.56 \times 10^{-2}\, s$, $f = 18.0\, Hz$, $v = 28.9\, m/s$
b) $v_y(x = 3\text{m}, t = 4\text{s}) = 1.55\text{ m/s}$

B3

a) See Figure 2
b) See Figure 3
c) 9.88x10^{-4} kg/m

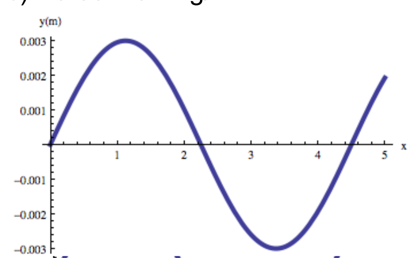


Figure 3 Answer for B3 part a)

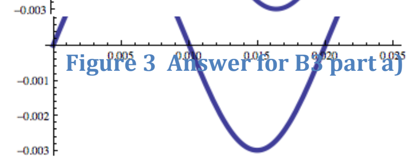


Figure 4: Answer for B3 part b)

C1

a) 146 N
b) 53.1 cm

C2

a) 1.67 m
b) 258.1 m/s
c) 155 Hz
d) (see equation below)

$$y(x,t) = (4.00\text{ mm})\sin[(3.77\text{ m}^{-1})x]\sin[977\text{s}^{-1}t]$$

e) 0.554 m, 1.66 m, 2.77 m

C3

2.96 kHz

SN3 Answers to Supplementary Problems

C4

a) 26.7 m/s
b) 1.11 m
c) (see equation below)

$y(x,t) = (2.5\text{ cm})\sin[(7.05\text{ m}^{-1})x]\sin[(188\text{ s}^{-1})t]$

d) A= 1.77 cm, $v_{y\text{-max}}$ = 0.666 m/s

C5

a) 342 m/s
b) 6.53 Hz

C6

875 Hz

D1

113 W

D2

3.00×10^4 m

D3

a) 25.2 m/s
b) 440 Hz

D4

546 Hz

E1

a) ±9.82°, ±30.8°, ±58.5°
b) 85.6 m
c) 363 m
d) 10.2 rad

E2

589.6 nm

E3

a) 102 nm
b) 306 nm

E4

658 nm

E5

0.0100°

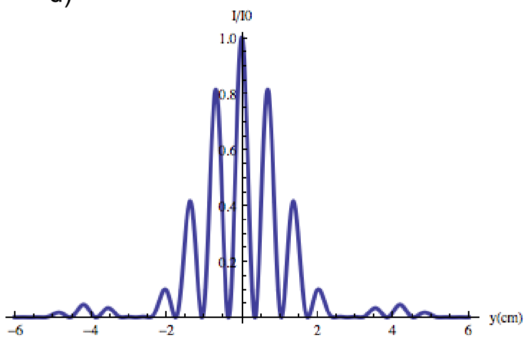
F1

a) 3.96 cm
b) 1.98 cm
c) 40.5%

F2

a) 420 nm

b) 4
c) 7
d)



F3

$0.25I_o$

G1

a) 2 complete orders are visible
b) 2nd and 3rd orders overlap

G2

a) 0.547 rad = 31.3˚
b) 0.708 rad = 40.5˚

H1

a) 0.604 V
b) 4.61×10^5 m/s
c) 1.91×10^{19} 1.91×10^{19}

H2

a) 4.29×10^{-15} Vs (approximately)
b) 2.07 eV (approximately)
c) 622 nm (using values from a and b)
d) Photons having a wavelength equal to the cutoff wavelength have just enough energy to excite an electron out of the photoelectric surface. Photons with longer wavelength (lower energy) are unable to produce photoelectrons via the photoelectric effect.

H3

a) 485 nm
b) −1.51 eV
c) λ = 1.01 μm

H4

5800 K

Section H continued on next page

SN3 Answers to Supplementary Problems

H5

$$0.39\frac{MW}{m^2}$$

H6

a) 9.98 pm
b) 3.98×10^4 m/s

H7

a) See figures 4 and 5 below
b) 206 MeV, 1850 MeV
c) 7.56×10^{-16} m γ-rays

H8

1.05×10^3 m/s

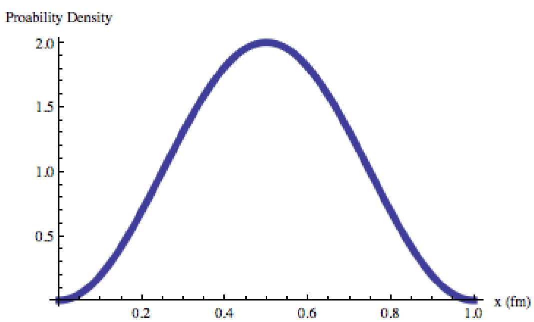
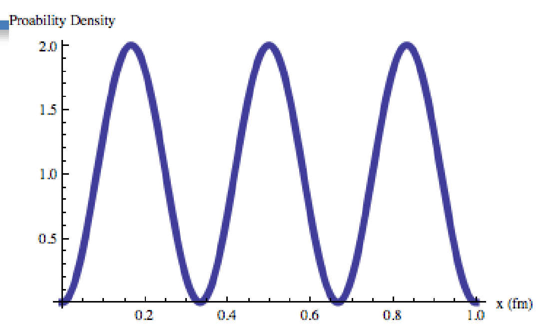


Figure 6:

Figure 5: Probability Distribution for n=1

Probability Distribution for n=3



I1

9315 MeV

I2

Number of atoms in 500g of potassium:

$$N = \frac{500g \cdot 6.02 \cdot 10^{23}\,\frac{atoms}{mol}}{39.10\,\frac{g}{mol}} = 7.70 \times 10^{24}$$

Number of ${}^{40}_{19}K$ atoms:

$${}^{40}_{19}K = 7.70 \cdot 10^{24} \cdot 0.0001 = 7.70 \cdot 10^{20}$$

Activity constant of ${}^{40}_{19}K$

$$\lambda = \frac{ln2}{T_{1/2}}$$

$$\lambda = \frac{ln2}{1.28 \cdot 10^{9} yr \cdot 365\,\frac{days}{yr} \cdot 24\,\frac{hr}{day} \cdot 3600\,\frac{s}{hr}}$$

$$\lambda = 1.72 \cdot 10^{-17} s^{-1}$$

$$A = -\frac{dN}{dt} = -\left(-\lambda N_0 e^{-\lambda t}\right) = \lambda N$$

$$A = 1.72 \cdot 10^{-17} \cdot 7.70 \cdot 10^{20} = 1.32 \cdot 10^{4}\,\text{Bq}$$

I3

(a) d=2r=2 $\left(1.2 \times 10^{-15} \times 60^{\frac{1}{3}}\right)$

$d = 9.40 \times 10^{-15\,m}$

(b)

$m({}^{58}_{28}Ni)$=	57.935 346 u
$28 \cdot m({}^{1}_{1}H) + 30 \cdot m({}^{1}_{0}n)$=	58.479 050 u
Mass defect	0.543 704 u

$$BEN = \frac{E_b}{A} = \frac{\left(0.543704u \cdot 931.494\,\frac{MeV/c^2}{u}\right) \cdot c^2}{58}$$

BEN=8.73 MeV

$m({}^{107}_{47}Ag)$=	106.905 091 u
$47 \cdot m({}^{1}_{1}H) + 60 \cdot m({}^{1}_{0}n)$=	107.887 675 u
Mass defect	0.982 584 u

$$BEN = \frac{E_b}{A} = \frac{\left(0.982584u \cdot 931.494\,\frac{MeV/c^2}{u}\right) \cdot c^2}{107}$$

BEN=8.55 MeV

I4

a) ${}^{227}_{89}Ac \rightarrow {}^{223}_{87}Fr + {}^{4}_{2}He$

b)

$m({}^{227}_{89}Ac)$=	227.027 749 u
$m({}^{223}_{87}Fr)$ =	223.019 733 u
$m({}^{4}_{2}He)$ =	4.002 602 u
$m({}^{223}_{87}Fr + {}^{4}_{2}He)$=	227.022 335 u

$$\Delta m = m({}^{227}_{89}Ac) - m({}^{223}_{87}Fr + {}^{4}_{2}He)$$
$$= 0.005\,414\,u$$

$$E = \Delta mc^2$$

$$E = \left(0.005\,414\,u \cdot 931.494\,\frac{MeV/_{c^2}}{u}\right) \cdot c^2$$

E =5.04 MeV

I5

a) ${}^{15}_{8}O \rightarrow {}^{15}_{7}N + v$

b) (optional, but fun)

$m({}^{15}_{8}O)$ = 15.003 065 u

$m({}^{15}_{7}N)$ = 15.000 108 u

$$\Delta m = \left(m({}^{15}_{8}O) - m({}^{15}_{7}N)\right) = 0.002957\,\text{u}$$

$$E = \Delta mc^2$$

$$= \left(0.002957\,\text{u} \cdot 931.494\,\frac{MeV/_{c^2}}{u}\right) \cdot c^2$$

E=2.75 MeV

I6

a) $A = \lambda N \rightarrow N = \frac{A}{\lambda} = \frac{A}{ln2/_{T_{1/2}}} = \frac{A \cdot T_{1/2}}{ln2}$

$$N = \frac{10^{-6}Ci \cdot 3.7 \cdot 10^{10}\,{}^{Bq}/_{Ci} \cdot 5730 \cdot yr \cdot 365\,{}^{days}/_{yr} \cdot 24\,{}^{hrs}/_{day} \cdot 3600\,{}^{s}/_{hr}}{ln2}$$

N=9.65·10^15 atoms

$$m = \frac{9.65 \times 10^{15}\,\text{atoms} \cdot 14.003242\,\frac{g}{mol}}{6.02 \cdot 10^{23}\,\frac{atoms}{mol}}$$

m=0.224µg

b) ${}^{14}_{6}C \rightarrow {}^{14}_{7}N + e^{-} + \bar{v}$

c) 1/3 of ${}^{14}_{6}C$ decays means that 2/3 remains

$$\frac{2}{3}N_0 = N_o e^{-\lambda t} \rightarrow ln\left(\frac{2}{3}\right) = -\lambda t$$

$$t = \frac{-ln\left(\frac{2}{3}\right)}{\lambda} \rightarrow \frac{-ln\left(\frac{2}{3}\right)}{\frac{\ln(2)}{5790yr}}$$

$t = 3390\ yr$

d) if we started out with pure ${}^{14}_{6}C$, there is still no ${}^{12}_{6}C$ in the sample after 3390yrs because ${}^{14}_{6}C$ does not decay into ${}^{12}_{6}C$ and ${}^{14}_{7}N$ is stable.

e) Activity of the sample

$$A = \lambda N = \lambda \frac{2}{3} N_0 = \frac{2}{3} \lambda N_0 = \frac{2}{3} A_0$$

$$A = \frac{2}{3} \mu Ci$$

Mass of sample

If we assume that high-energy electrons were simply ejected from the sample during thecay, the sample is now $\frac{1}{3}\, {}^{14}_{7}N$ and $\frac{2}{3}\, {}^{14}_{6}C$

N=9.65·10[15] atoms

$$\frac{\frac{1}{3} \cdot 9.65 \cdot 10^{15} atoms \cdot 14.003\ 074 \frac{g}{mol}}{6.02 \cdot 10^{23} \frac{atoms}{mol}} + \frac{\frac{2}{3} \cdot 9.65 \cdot 10^{15} atoms \cdot 14.003\ 242 \frac{g}{mol}}{6.02 \cdot 10^{23} \frac{atoms}{mol}}$$

m=0.224 μC

the sample mass decreases a tiny bit,but does not change significantly during beta decay

I7

a) ${}^{224}_{88}Ra \rightarrow {}^{210}_{82}Pb + {}^{14}_{6}C + energy$

b) m(${}^{210}_{82}Pb$)= 209.984 163 u

$m({}^{14}_{6}C)$= 14.003 242 u

$sum =$ 223.987 405

m(${}^{224}_{88}Ra$)= 224.020 187 u

Δm= 0.032782 u

energy $= \Delta \text{m}c^2 =$ 30.5 MeV

I8

Missing product has Z=92-36=56 (barium)

Missing product has mass number A=1+235-95-3=138

Missing product is ${}^{138}_{56}Ba$

m(${}^{235}_{92}U$)= 235.043 324 u

m · (${}^{1}_{0}n$)= 1.0086652 u

sum 1= 236.052 589 u

m(${}^{95}_{36}Kr$)= 94.939 711 u

m(${}^{138}_{56}Ba$)= 137.905 236 u

m 3 · (${}^{1}_{0}n$)= 3·(1.008665) u

sum 2= 235.870 942 u

Δm=sum 1-sum 2 0.181647 u

energy $= \Delta \text{m}c^2 =$ 169 MeV

(this is a LOT of energy)

I9

$${}^{12}_{6}C + 4 \cdot {}^{1}_{1}H \rightarrow {}^{12}_{6}C + {}^{4}_{2}He + 2 \cdot e^{+} + 2 \cdot \upsilon + 3 \cdot \gamma$$

(1) fusion
(2) β+ decay
(3) fusion
(4) fusion
(5) β+ decay
(6) fusion

Sanity check: the 2 β+ decays turned 2 protons into neutons