2.1.a

Yoctomole = 6.022E(23-24) = .6 atoms

2.1.b

Nanocentury to seconds = 3.154E7(+2 (century) -9 (nano)) = 3.154E0 is almost pi

2.2

A CD is half a gigabyte and a millimeter thick. A petabyte is 2E6 CDs, 2km tall. This is more than twice as tall as our tallest buildings.

2.3

2^(10^80) atoms in universe) = (2^10)^80 = 1E(3*80) = 1E240

Or 2^(10^80) = 10^ (80/log10(2)) = 10^265.

2.4

6.673E-11 (m^3/kg s^2) * 1 kg / (1m)^2 = 6.6E-11 m/s^2 vs 9.8m/s^2

6.8e-12 → 10*(-12 + log(6.8)) dB= (-120 +10*.83)dB= -111.7 dB

2.5a

Assume TNT is pure Nitrogen with 3 bonds, each storing 1eV, shared with another atom.

(907,000 g/Ton) / (14 grams per mole) * (6.022e23 atoms per mole) * (1.5eV per atom) * (1.6E-19 J/eV)

+6 -1.1 +23.8 +.1 -18.8

10^(10) Joules per Ton tnt

Overestimated by roughly 10x.

2.5b

10,000 tons of TNT is 10^(10+4) Joules

Assume Uranium is 10^6 eV per atom, and 237 grams per enriched mole.

(10^(14) Joules) /(1.6E-19 J/eV) / (1E6 eV per atom) / (6.022e23 atoms per mole) * (237 g per mole)

+14 +18.8 -6 -23.8 +2.3

10^(5.3) grams of Uranium, or 200kg. Correcting for my TNT mis-estimation brings its to 10^(4.3) grams, or 20kg

Little Boy was 4,400 kg and yielded 15 kilotons, but only contained 64 kg uranium. This is 4.3 kilotons per kilogram, compared to my half kiloton per kilogram.

2.5c.

1kg * (3E8 m/s)^2 = 9E16 Joules per kilogram for total conversion.

1E13 Joules / 20kg = 5E11 Joules per kilogram as a nuclear bomb. Only one part in 180,000 is used.

2.6

h = 6.26E-34 Joule Seconds → -33.2

Assume baseball is 100 grams and 50m/s

6.26E-34 Js / (.100 kg * 50m/s)

-33.2 +1 -1.7

10^(-33.9) meters = 1.25E-34 meters

2.6b

Each degree of freedom of a molecule has on average 3/2 kT kinetic energy, and weighs 28AMU

3/2* (300 Kelvin) * (1.38E-23 J/K) = 6.2E-21 Joules per molecule

V = sqrt(2 * E / m) = sqrt(2 * 6.2E-21 J / (28 AMU * 1.66E-24 grams per AMU) = 520m/s

2.6c

$$PV = nRT$$

At STP, 1 mole is 22.4L.

1 mole * 6.022E23 / 22.4L = 2.69E25 per m^3.

$$\sqrt[3]{\frac{m^3}{2.69E25}} \approx 3nm$$

2.6d

Distance remains constant at 3nm with falling temperature

$$\lambda = h/p$$

$p = \sqrt{2mKE} = \sqrt{2m\left(\frac{3}{2}kT\right)}$

$\sqrt{3mkT} = h/\lambda$

$T = \left(\frac{h}{\lambda}\right)^2 \frac{1}{3mk} = \left(\frac{6.626Js}{3nm}\right)^2 \frac{1}{3(28*1.66E-24\ g)(1.38E-23\ J/K)}$ = .025 Kelvin

2.7a

$\frac{1}{2}mv^2 = GMm/r$

$v = \sqrt{2GM/r}$

2.7b

$r = \frac{2GM}{v^2} \rightarrow \frac{2GM}{c^2}$

2.7c

$\lambda = \frac{hc}{E} = \frac{hc}{Mc^2} = h/Mc$

2.7d

$\lambda = r$

$\frac{h}{Mc} = \frac{2GM}{c^2}$

$h = \frac{2GM^2}{c}$

$M = \sqrt{hc/2G} = 38.6\mu g$

2.7e

$\frac{2GM}{c^2} = 38.6\mu g\ * \frac{2G}{c^2}$ = 5.73E-35meters

2.7f

$E = \frac{hc}{\lambda} = h\frac{c^3}{2GM} = 3.46E9J$

2.7g

Period = $\frac{\lambda}{c}$= 1.79E-43 seconds

2.8A

Radius of Sphere is $L/2$

Construct triangle through edges (45 degrees off vertical).

Base is $\sqrt{2}L$

Dashed line is sphere radius $\frac{L}{2}$

Triangles are similar (see labeling)

A = $\sqrt{B^2 - C^2}$ A'= $\sqrt{1/2}L$

B = A' = $\sqrt{1/2}L$ B'=

C = $\frac{1}{2}L$ C'= H

A = $L\sqrt{1/2 - 1/4} = L/2$

$\frac{C'}{C} = \frac{A'}{A}$

$C' = \frac{(L/\sqrt{2})(L/2)}{(L/2)} = \boldsymbol{L/\sqrt{2}} = \boldsymbol{H}$

$B' = \frac{A'}{A}B = \frac{(L/\sqrt{2})(L/\sqrt{2})}{(L/2)} = L$

2.8B

Construct as hemisphere missing 4 partial spheres

$\left(\frac{1}{2}\right)\left(\frac{4}{3}\right)\pi r^3 - 4\left(\frac{\pi h}{6}\right)\left(3r'^2 + h^2\right)$, r= big sphere radius, r'=radius of base of partial sphere, h=extension above face

r is known to be $L/2$

The face is an equilateral triangle, L on each side (see calculation of B' above).

$r' = \frac{1}{2}L\tan^{-1}60 = L/\sqrt{12}$

Type equation here.

The height of the sphere cap is the major radius minus the distance to the face d

$d = L\sqrt{\frac{1}{2}^2 - \frac{1}{12}} = L/\sqrt{6}$

$h = r - d = L/2 - L/\sqrt{6}$

All together

$$\left(\frac{1}{2}\right)\left(\frac{4}{3}\right)\pi r^3 - 4\left(\frac{\pi h}{6}\right)\left(3{r'}^2 + h^2\right)$$

$$\left(\frac{1}{2}\right)\left(\frac{4}{3}\right)\pi (L/2)^3 - 4\left(\frac{\pi\left(L/2 - L/\sqrt{6}\right)}{6}\right)\left(3\left(\frac{L}{\sqrt{12}}\right)^2 + \left(L/2 - L/\sqrt{6}\right)^2\right)$$

$$\approx 0.2124L^3$$