2.1.a
Yoctomole = \(6.022 \times 10^{-23}\) = .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
\(6.673 \times 10^{-11} \text{ m}^3/\text{kg s}^2\) * 1 kg / (1m)^2 = 6.6E-11 m/s^2 vs 9.8m/s^2

6.8e-12 \(\rightarrow\) 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.

\[
\frac{(907,000 \text{ g/Ton})}{(14 \text{ grams per mole})} \times (6.022e23 \text{ atoms per mole}) \times (1.5eV \text{ per atom}) \times (1.6E-19 \text{ J/eV})
\]
\[
+6 -1.1 +23.8 +.1 -18.8
\]

10^10 Joules per Ton tnt
Overestimated by roughly 10x.

2.5b
10,000 tons of TNT is 10^10(10+4) Joules

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

\[
\frac{(10^{14} \text{ Joules})}{(1.6E-19 \text{ J/eV})} \times (1E6 \text{ eV per atom}) \times (6.022e23 \text{ atoms per mole}) \times (237 \text{ g per mole})
\]
\[
+14 +18.8 -6 -23.8 +2.3
\]

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

\[ \frac{6.26 \times 10^{-34} \text{Js}}{0.100 \text{kg} \times 50 \text{m/s}} = 12.5 \times 10^{-34} \text{meters} \]

2.6b

Each degree of freedom of a molecule has on average \( \frac{3}{2} kT \) kinetic energy, and weighs 28AMU

\[ \frac{3}{2} \times (300 \text{ Kelvin}) \times (1.38 \times 10^{-23} \text{ J/K}) = 6.2 \times 10^{-21} \text{ Joules per molecule} \]

\[ V = \sqrt{\frac{2 \times E}{m}} = \sqrt{\frac{2 \times 6.2 \times 10^{-21} \text{ J}}{28 \text{ AMU} \times 1.66 \times 10^{-24} \text{ grams per AMU}} = 520 \text{m/s} \]

2.6c

\[ PV = nRT \]

At STP, 1 mole is 22.4L.

\[ 1 \text{ mole} \times 6.022 \times 10^{23} / 22.4 \text{L} = 2.69 \times 10^{25} \text{ per m}^3. \]

\[ \sqrt[3]{ \frac{m^3}{2.69 \times 10^{25}} } \approx 3 \text{nm} \]

2.6d

Distance remains constant at 3nm with falling temperature

\[ \lambda = \frac{h}{p} \]
\[ p = \sqrt{2mKE} = \sqrt{2m \left( \frac{3}{2} kT \right)} \]

\[ \sqrt{3mkT} = \frac{h}{\lambda} \]

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

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

\[ \frac{2GM}{c^2} = 38.6\mu g \quad \frac{2G}{c^2} = 5.73\text{E-35meters} \]

2.7f

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

2.7g

Period = \[ \frac{\lambda}{c} = 1.79\text{E-43 seconds} \]
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)

\[ A = \sqrt{B^2 - C^2} \quad A' = \sqrt{\frac{1}{2}L} \]

\[ B = A' = \sqrt{\frac{1}{2}L} \quad B' = \]

\[ C = \frac{1}{2}L \quad C' = H \]

\[ A = L\sqrt{\frac{1}{2} - \frac{1}{4}} = L/2 \]

\[ \frac{C'}{C} = \frac{A'}{A} \]

\[ C' = \frac{(L/\sqrt{2})(L/2)}{(L/2)} = L/\sqrt{2} = H \]

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

2.8B

Construct as hemisphere missing 4 partial spheres

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

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
\[ d = L \sqrt{\frac{1}{2^2}} - \frac{1}{42} = L/\sqrt{6} \]

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

All together

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

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

\[ \approx 0.2124L^3 \]