Problem (2.1)

(a) *How many atoms are there in a yoctomole?*
1 mole = 6.022×10^{23} atoms.
1 yoctomole = 10^{-24} moles → $6.022 \times 10^{23} \times 10^{-24} = 0.6022$ atoms.

(b) *How many seconds are there in a nanocentury?*
1 century ≈ 3.154×10^{9} s →
1 nanocentury = 3.154 s.

Problem (2.2)

A large data system has 1 EB (10^{18} bytes). Each DVD ~4.7 GB (4.7×10^{9} bytes). Find height of stacked DVDs and compare to "space" (~100 km).

- Number of DVDs ≈ $(10^{18}) / (4.7 \times 10^{9}) \approx 2.13 \times 10^{8}$.
- DVD thickness ≈ 1.2 mm → total height = $2.13 \times 10^{8} \times 1.2 \times 10^{-3}$ m ≈ 2.56×10^{5} m = 256 km.
  This is about 2.5 times higher than the Kármán line (~100 km).

Problem (2.3)

If every atom in the observable universe (~10^{80} atoms) encodes one bit, what is the decimal value of that binary number?

$2^{(10^{80})} = 10^{[(10^{80}) \log_{10}(2)]} \approx 10^{(3.01 \times 10^{79})}$.

Problem (2.4)

Compare gravitational acceleration at Earth's surface (9.8 m/s²) to that from a 1 kg mass at 1 m. Express ratio in dB.

- Small-mass acceleration = $G(1\ \text{kg})/(1\ \text{m})^2 = 6.67 \times 10^{-11}$ m/s².
- Ratio $R = 9.8 / (6.67 \times 10^{-11}) \approx 1.47 \times 10^{11}$.
- In dB: $20 \log_{10}(R) \approx 223$ dB.

Problem (2.5)

(a) *Chemical energy in 1 ton of TNT* ≈ 4 × 10^9 J.
(b) *Energy in 10 000 tons of TNT* = 4 × 10^9 × 10^4 = 4 × 10^13 J. Fission of ^{235}U releases ~200 MeV ≈ 3.2 × 10^(–11) J per atom. → Need ~1.25 × 10^24 fissions, about 0.5 kg of ^{235}U.
(c) *Rest-mass energy of 0.5 kg* is (0.5 kg) c^2 ≈ 4.5 × 10^16 J, which is ~1000 times larger than 4 × 10^13 J.

Problem (2.6)

(a) *Baseball (m=0.145 kg, v=30 m/s)*
p ≈ 4.35 kg·m/s → λ = h/p ≈ 1.5 × 10^(–34) m.

(b) *N_2 molecule* (m ≈ 4.65 × 10^(–26) kg, v ~500 m/s)
p ~ 2.33 × 10^(–23) → λ ≈ 2.8 × 10^(–11) m.

(c) *Distance between N_2 molecules* at STP ≈ 3.3 nm.

(d) *T where λ ~ 3.3 nm* is extremely low (< 10^(–20) K), so quantum overlaps are negligible at room T.

Problem (2.7)

(a) *Escape velocity* $v_e = \sqrt{2GM/r}$.
(b) *Schwarzschild radius* $R_s = 2GM/c^2$.
(c) *Photon from mass M* has λ = h/(Mc).
(d, e) *Setting $\lambda = R_s$* defines the Planck mass (~2.18 × 10^(–8) kg) and Planck length (~1.6 × 10^(–35) m).
(f) *Planck energy* ~2 × 10^9 J.
(g) *Planck time* ~10^(–43) s.

Problem (2.8) (a) Consider a pyramid of height H and a square base of side length L. A sphere is placed so that its center is at the center of the square at the base, and so that it is tangent to all of the edges of the pyramid (intersecting each edge at just one point). How high is the pyramid in terms of L?
(b) What is the volume of the space common to the sphere and the pyramid?