2.1 a) $\frac{1 \text{ ymol}}{1} \cdot \frac{1 \text{ mol}}{10^{24} \text{ ymol}} \cdot \frac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = \boxed{0.602 \text{ atoms}}$

b) $\frac{1 \text{ nanocentury}}{1} \cdot \frac{1 \text{ century}}{10^{9} \text{ nanocentury}} \cdot \frac{100 \text{ years}}{1 \text{ century}} \cdot \frac{365 \text{ days}}{1 \text{ year}} \cdot \frac{24 \text{ hours}}{1 \text{ day}}$

$\cdot \frac{60 \text{ min}}{1 \text{ hour}} \cdot \frac{60 \text{ sec}}{1 \text{ min}} = \boxed{0.302 \text{ seconds}}$

↳ near constant?

2.2 DVD capacity = 4.7 GB, thickness = 1.2 mm (Wikipedia)

$\frac{1 \text{ EB}}{1} \cdot \frac{10^9 \text{ GB}}{1 \text{ EB}} \cdot \frac{1.2 \text{mm}}{4.7 \text{GB}} \cdot \frac{1 \text{ km}}{10^6 \text{ mm}} = \boxed{255 \text{ km}}$

Distance to space ≈ 100 km → ≈ $\boxed{2.5 \times \text{ dist. to space}}$

2.3 Atoms in universe = 10^{80}

10^{80} bit # where all bits are 1 → $\boxed{2^{(10^{80})} - 1}$

↳ simplify?

2.4 Gravitational acc. at Earth surface → $g = 9.81 \text{ m/s}^2$

1 kg mass @ 1 m → $g = \frac{GM}{r^2} = \frac{6.67 \times 10^{-11} \frac{\text{m}^3}{\text{kg} \cdot \text{s}^2} \cdot 1 \text{ kg}}{1 \text{ m}^2} = 6.67 \times 10^{-11} \text{ m/s}^2$

Ratio $= 20 \log_{10}\left(\frac{9.81}{6.67 \times 10^{-11}}\right) = \boxed{223 \text{ dB}}$

2.5 a) Assume energy stored in 1 ton of N_2 bonds

Energy in N_2 bond = 945 kJ/mol

Molar mass of N_2 = 28 g/mol

$\frac{1 \text{ ton}}{1} \cdot \frac{1000 \text{ kg}}{1 \text{ ton}} \cdot \frac{1000 \text{ g}}{1 \text{ kg}} \cdot \frac{1 \text{ mol } N_2}{28 \text{ g}} \cdot \frac{945 \text{ kJ}}{1 \text{ mol } N_2} \cdot \frac{1 \text{ GJ}}{10^6 \text{ kJ}} = \boxed{33.8 \text{ GJ per ton}}$

b) Nuclear fission of Uranium-235 releases 2-3 neutrons per atom; assume 2.5 on average

According to Wikipedia, nuclear energy binding a neutron to a Uranium-235 nucleus = 7.6 MeV

Nuclear energy released by a gram of U-235:

$$\frac{1\text{ g U-235}}{1} \cdot \frac{1\text{ mol}}{235\text{ g}} \cdot \frac{6.02\times10^{23}\text{ atoms}}{1\text{ mol}} \cdot \frac{2.5\times 7.6\text{ MeV}}{1\text{ atom}} \cdot \frac{1.60\times10^{-19}\text{ MJ}}{1\text{ MeV}}$$

$= 7788\text{ MJ} = 7.79\text{ GJ}$ per gram U-235

Energy in 10,000 tons TNT = 338 TJ

$$\frac{338\text{ TJ}}{1} \cdot \frac{1000\text{ GJ}}{1\text{ TJ}} \cdot \frac{1\text{ g U-235}}{7.79\text{ GJ}} \cdot \frac{1\text{ kg}}{1000\text{ g}} = \boxed{43.4\text{ kg U-235}}$$

c) $E = mc^2 = 43.4\text{ kg} \cdot (3\times10^8\text{ m/s})^2 = 3.91\times10^{18}\text{ J} = \boxed{3.91\text{ EJ}}$

Nuclear rxn releases $\frac{338\text{ TJ}}{3.91\text{ EJ}} = \frac{338}{3.91\times10^6} = \boxed{0.0086\%\text{ of energy}}$

2.6 a) Baseball weighs 145 g, thrown at 80 mph = 35.8 m/s

$$\lambda = \frac{h}{mv} = \frac{6.63\times10^{-34}\text{ m}^2\cdot\text{kg/s}}{0.145\text{ kg}\cdot 35.8\text{ m/s}} = \boxed{1.28\times10^{-34}\text{ m}}$$

b) Kinetic energy $= \frac{1}{2}kT = \frac{1}{2}\cdot 1.38\times10^{-23}\ \frac{\text{J}}{\text{K}} \cdot 300\text{K} = 2.07\times10^{-21}\text{ J}$

Mass of $N_2 = \frac{28\text{ g}}{6.02\times10^{23}} = 4.65\times10^{-23}\text{ g} = 4.65\times10^{-26}\text{ kg}$

Set $\frac{1}{2}kT = \frac{1}{2}mv^2 \rightarrow 2.07\times10^{-21}\text{ J} = \frac{1}{2}\cdot 4.65\times10^{-26}\text{ kg}\cdot v^2$

↳ $v = 298\text{ m/s}$

$$\lambda = \frac{h}{mv} = \frac{6.63\times10^{-34}\text{ m}^2\cdot\text{kg/s}}{4.65\times10^{-26}\text{ kg}\cdot 298\text{ m/s}} = 4.79\times10^{-11}\text{ m} = \boxed{47.9\text{ pm}}$$

c) $PV = nRT$

Pressure = 1 atm = 101325 Pa

Temp = 300K

$101\text{ kPa}\cdot V = 1\text{ mol}\cdot 8.31\ \frac{\text{L}\cdot\text{kPa}}{\text{mol}\cdot\text{K}}\cdot 300\text{K}$

$V = 24.7\text{ L} = 0.0247\text{ m}^3$ per mole N_2

$\hookrightarrow \frac{0.0247\ m^3}{1\ mol} \cdot \frac{1\ mol}{6.02\times10^{23}\ molecules} = 4.10\times10^{-26}\ m^3/molecule$

Sphere volume $= \frac{4}{3}\pi r^3 = 4.10\times10^{-26}\ m^3 \rightarrow r = 2.14\times10^{-9}\ m$

Spacing $= 2\cdot r = \boxed{4.28\ nm}$

d) $v = \sqrt{\frac{kT}{m}}$

$\lambda = \frac{h}{m}\cdot\sqrt{\frac{m}{kT}} = h\sqrt{\frac{1}{m\cdot kT}} = 4.28\times10^{-9}\ m$

$\frac{h^2}{m\cdot kT} = 1.83\times10^{-17}\ m^2$

$T = \frac{h^2}{m\cdot k\cdot 1.83\times10^{-17}\ m^2} = \frac{(6.63\times10^{-34}\ m^2\cdot kg/s)^2}{4.65\times10^{-26}\ kg\cdot 1.38\times10^{-23}\ \frac{J}{K}\cdot 1.83\times10^{-17}\ m^2}$

$= 0.0387\ K = \boxed{38.7\ mK}$

2.7 a) $KE = -PE$

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

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

b) $c = \sqrt{\frac{2GM}{r}}$

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

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

c) $E = Mc^2 = \frac{hc}{\lambda}$

$\lambda = \frac{h}{Mc}$

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

$M^2 = \frac{hc}{2G}$

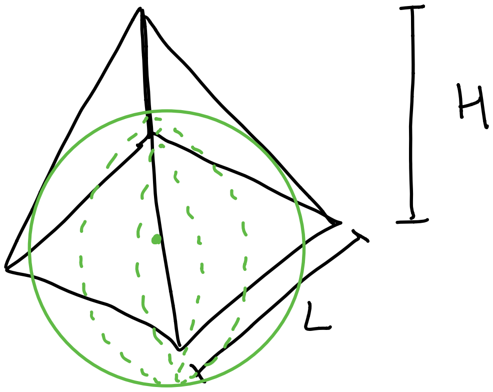
$M = \sqrt{\frac{hc}{2G}}$

e) $r = \frac{2GM}{c^2} = \frac{2G}{c^2}\sqrt{\frac{hc}{2G}} = \sqrt{\frac{4G^2}{c^4}\cdot\frac{hc}{2G}} = \sqrt{\frac{2Gh}{c^3}}$

f) $E = Mc^2 = \sqrt{\frac{hc}{2G}}\,c^2 = \sqrt{\frac{hc^5}{2G}}$

g) $f = \frac{E}{h} \rightarrow T = \frac{h}{E} = h\sqrt{\frac{2G}{hc^5}} = \sqrt{\frac{2Gh}{c^5}}$

2.8



a) Sphere radius $= \frac{L}{2}$