Fundamental physics:

- $c = 3 \times 10^8 \text{m/s} = 3 \times 10^{10} \text{cm/s}$
- $\hbar = 1.1 \times 10^{-34} \text{m}^2\text{kg/s}$
  $(h = 6.6 \times 10^{-34} \text{m}^2\text{kg/s})$
- $\hbar c = 200$ eV nm, $hc = 1200$ eV nm
- $G = 6.7 \times 10^{-11} \text{m}^3/\text{kg·s}$
- $e = 1.6 \times 10^{-19} \text{C}$
- $k_e e^2 = 2.3 \times 10^{-28} \text{m}^3\text{kg/s}^2 = 1.4 \text{eV} \cdot \text{nm}$
- $\alpha = \frac{k_e e^2}{\hbar c} = \frac{1}{137}$
- $m_e = 9.1 \times 10^{-31} \text{kg}$
  $m_p = 1.7 \times 10^{-27} \text{kg} = 1800 m_e$
- $\text{T} = \text{V·s/m}^2 = \text{N/A·m} = \text{Wb/m}^2 = \text{kg/C·s} = \text{kg/A·s}^2 = \text{N·s/C·m}$
  $\mu_0 = 1.3 \times 10^{-6} \text{T}^2\text{·m}^3\text{/J}$, $U_{\text{mag}} = \frac{B^2}{2\mu_0}$
- $\epsilon_0 = 8.9 \times 10^{-12} \text{J/m}^3\text{(V/m)}^2$, $U_{\text{elec}} = \frac{\epsilon_0 E^2}{2}$
- $\gamma = \frac{E}{mc^2} = \frac{1}{\sqrt{1-\beta^2}}$

Units:

- angstrom $= 10^{-10}\text{m} = \frac{1}{10}\text{nm}$
- eV $= 1.6 \times 10^{-19}$ J
- atm $= 10^5$ Pascal
- y = yocto $= 10^{-24}$, z = zepto $= 10^{-21}$
  a = atto $= 10^{-18}$, f = femto $= 10^{-15}$
  p = pico $= 10^{-12}$, n = nano $= 10^{-9}$
  μ = micro $= 10^{-6}$, m = milli $= 10^{-3}$
  k = kilo $= 10^3$, M = mega $= 10^6$
  G = giga $= 10^9$, T = tera $= 10^{12}$
  P = peta $= 10^{15}$, E = exa $= 10^{18}$
  Z = zetta $= 10^{21}$, Y = yotta $= 10^{24}$
- mile $= 1.6$km, inch $= 2.54$cm
  day $= 8.6 \times 10^4$s, year $= 3.2 \times 10^7$s
  lb $= 0.45$kg
- lightyear $= 9.5 \times 10^{15}$m
  parsec $= 3.1 \times 10^{16}$m
- mole $= 6.0 \times 10^{23} = \frac{1\text{g}}{m_p}$ (amu $= m_p$)
  molarity $= \frac{\text{mol}}{\text{L}} = (1.2\text{nm})^{-3}$
  $\text{g/cm}^3 = 1000\text{kg/m}^3$

Temperature & Radiation:

- 273 K = 0°C = 32°F, 100°C = 212°F
- $k_B = 1.4 \times 10^{-23} \text{J/K} = 8.6 \times 10^{-5} \text{eV/K}$
- room temperature: 300 K = 0.026 eV
- sun surface: 5800 K → 400 nm
  sun core: 16 million K
- Wien: $\lambda_{\max} = \frac{2.9 \times 10^{-3} \text{m·K}}{T} = \frac{250\text{nm·eV}}{k_B T}$

Atoms:

- 13.6eV $\to 10^7 \text{m}^{-1}$ $(\frac{m_e (Z k_e e^2)^2}{2\hbar^2})$
- $a_0 = \frac{\hbar}{\alpha m_e c} = 5.3 \times 10^{-11}\text{m}$

Solids:

- $\rho_{\text{wood}} \approx 0.5\text{g/cm}^3$, $\rho_{\text{steel}} = 7.8\text{g/cm}^3$, $\rho_{\text{rock}} \approx 2.8\text{g/cm}^3$
- Young's modulus: $E = \frac{\text{stress}}{\text{strain}} = \frac{F/A}{\Delta L/L}$
  - wood: 9GPa, steel: 200GPa

Fluids:

- $\rho_{\text{H}^2\text{O}} = 1.0\text{g/cm}^3$, $\rho_{\text{air}} = 1.2 \times 10^{-3}\text{g/cm}^3$
- Viscosity:
  - $\mu = \text{Pa} \cdot \text{s} = \text{kg/m·s}$, $\nu = \frac{\mu}{\rho} = \text{m}^2\text{/s}$
  - H_2O: $\mu = 1.0 \times 10^{-3}\text{kg/m·s}$,
    $\nu = 1.0 \times 10^{-6}\text{m}^2\text{/s}$ (↓ with T ↑)
  - air: $\mu = 2.0 \times 10^{-5}\text{kg/m·s}$,
    $\nu = 1.6 \times 10^{-5}\text{m}^2\text{/s}$
- Reynold's number:
  - $\text{Re} = \frac{\rho v R}{\mu} = \frac{vR}{\nu}$: ratio of inertial to viscous
  - high: large, fast (people, turbulence)
  - low: small, slow (bacteria, timeless)
- Drag:
  - DA gives $F_d = \rho R^2 v^2 f(\text{Re})$
  - $\text{Re} \ll 1$: $F_d \sim \rho R^2 v^2 \frac{1}{\text{Re}} = \nu \rho R v$ $(\times 6\pi)$
  - $\text{Re} \gg 1$: $F_d \sim \rho R^2 v^2$ $(\times \frac{1}{4})$
- Diffusion:
  - D is in $\text{m}^2\text{/s}$, so $L \propto \sqrt{Dt}$
  - Molecular: $D = \frac{k_B T}{6\pi\mu R}$
- Surface tension: $\sigma_{\text{H}^2\text{O}} = 0.07\text{N/m}$

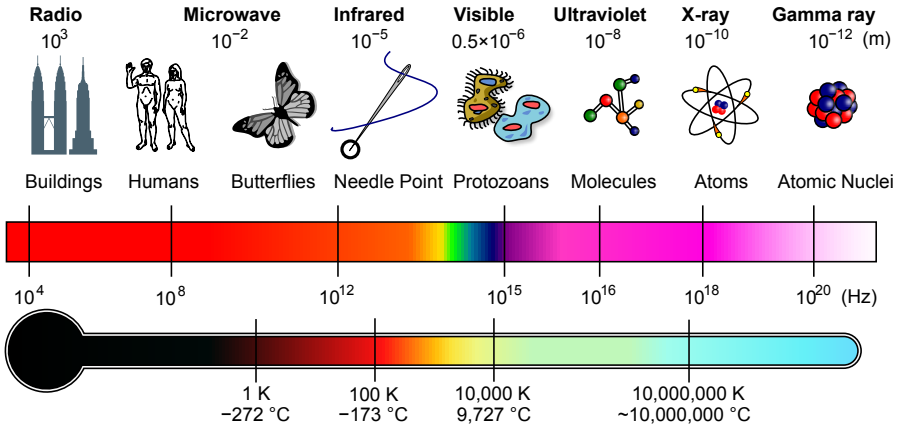
Waves:

	deep water	long waves
gravity	ocean	coast
surface	ponds	puddles

- $v_{\text{sound in air}} = 340\text{m/s}$
- long. mom. cons. $\to v\rho = \text{constant}$
- Dispersion! by wave type
  - Pressure: $\omega = vk$, $v_p = v_g = \sqrt{\frac{\text{Yo}}{\rho}}$
    $(v \sim \sqrt{\frac{k_B T}{m_{\text{part}}}})$
  - Gravity: $\omega = \sqrt{gk}$, $v_p = 2v_g = \sqrt{\frac{g}{k}}$
  - Cap.: $\omega^2 = \frac{\sigma}{\rho}k^3$, $v_p = \frac{2}{3}v_g = \sqrt{\frac{\sigma}{\rho}k}$

Optics:

- $\Delta\theta \sim \frac{\lambda}{D}$



Biology:

- I'm 70kg, 2m. got maybe 5×10^{13} cells
- E. coli census:
  - 1μm, 1fL, 1pg, 50%H_2O
  - dry: 55%prot, 20%RNA, %10lipid
  - 50% C $\to 10^{10}$ atoms
  - replicates in 50min
- diffusion: $D = 100\mu\text{m}^2\text{/s}$ for 5nm protein, $2000\mu\text{m}^2\text{/s}$ for ion
- ATP→ADP releases $30\text{kJ/mol} = \frac{1}{3}\text{eV} = 20 k_B T$

Earth:

- $r = 6000$km, $A = 5.1 \times 10^{14}\text{m}^2$, $V = 1.1 \times 10^{21}\text{m}^3$
- $m = 6.0 \times 10^{24}$kg, $\rho = 5.5\text{g/cm}^3$
- ocean: $d_{\text{avg}} = 3.8$km, $d_{\max} = 11$km
- atmosphere: ρ half-life = 5km

Solar System:

- Moon: 380km away, 7×10^{22}kg
- Sun:
  - $r = 7.0 \times 10^5$km
  - $1.5 \times 10^8\text{km}^3$ away
  - $2.0 \times 10^{30}\text{kg} = 333000 m_e$
- Sun & Moon subtend $\frac{1}{2}^\circ$ (d) from Earth

Universe:

- $1.4 \times 10^{10}\text{yr} = 4.3 \times 10^{17}\text{s}$ old
- $r = 14\text{b pc} = 46\text{b ly}$
- expanding: $v = (71\text{km/s/Mpc})d$

Computation:

- DVD is 7g, 5GB
- laptop uses 50W

Energy:

- worldwide consumption: 15TW
- Sun gives Earth 174PW (30% reflected)
  - 1.4kW/m^2

Nukes:

- fission of U-238 gives ~200MeV
- megaton TNT $= 4.2 \times 10^{15}$J (a bomb)
- D-T fusion: $^2\text{H} +^3 \text{H} \to^4 \text{He} +^1 \text{n} +$ 17.6MeV

Hints:

- Dimensional analysis!
- Circumvent missing knowledge w/guesswork
- Sanity check / intuity / reality