Physics - Chapter 3 ⇒ Elastic Properties of Material

Rules:

Stress

$\sigma = \frac{F}{A}$ N/m^2

Strain

$\varepsilon = \frac{\Delta L}{L}$ m

Hooke's Law

$F = -K \Delta L$ N

Spring Constant

$K = Y \frac{A}{L}$ N/m^{-1}

Young's Modulas

$Y = \frac{\sigma}{\varepsilon}$

$= \frac{F/A}{\Delta L / L}$ N/m^2

$\therefore F = \frac{YA}{L} \Delta L$ N

Elastic Strain Energy

$\mathcal{E} = \frac{1}{2} F \Delta L$ J

$\mathcal{E} = \frac{YA}{2L} \Delta L^2$ J

Bone Fracture : Energy Considerations

$\Delta L = \frac{\sigma_B L}{Y}$

$\mathcal{E} = \frac{YA}{2L} \left(\frac{\sigma_B L}{Y}\right)^2$

$\therefore \mathcal{E} = \frac{AL\sigma_B^2}{2Y}$

Energy gained by jumping

$\mathcal{E} = mgh$

Shear Modulus

$S = \frac{\sigma_s}{\varepsilon_s} = \frac{F/A}{\Delta x / h}$

Δx = horizontal distance
h = height of the object

Bulk Modulus

$B = \frac{\text{volume stress}}{\text{volume strain}}$

$= -\frac{F/A}{\Delta V / V_i} = \frac{\Delta P}{\Delta V / V_i}$

Physics ⇒ Chapter 4
Thermal Properties of Matter

∘ Conversions

$T_F = \frac{9}{5} T_C + 32°$

$T_C = \frac{5}{9}(T_F - 32)$

$\Delta T_F = \frac{9}{5}\Delta T_C$

$\Delta T_C = \frac{5}{9}\Delta T_F$

$\Delta T = \Delta T_C$

$T = T_C = 237.15K$

∘ Boyle's Law

$P_1 V_1 = P_2 V_2$

∘ Charles' Law

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

∘ Gay - Lussac's Law

$\frac{P_1}{T_1} = \frac{P_2}{T_2}$

∘ Ideal Gas Law

$\underbrace{P}_{\text{pressure (Pa/atm/N/m}^2)} \underbrace{V}_{\text{volume (L)}} = \underbrace{n}_{\text{moles}} \overset{J/K}{R} \underbrace{T}_{\text{Temp (k)}}$

$R = 8.314\ J/K\ mol$

$1\ atm = 1.013 \times 10^5\ Pa$

$PV = \underbrace{N}_{\text{molecules/atoms}} \overset{J/K}{K_B} T$

$K_B = \frac{R}{N_A} = \frac{8.314}{6.022 \times 10^{23}}$

$K_B = 1.38 \times 10^{-23}\ J/K$

$PV = \frac{2}{3} N K_{av}$

∘ Average Kinetic Energy

$\underbrace{K_{av}}_{m/s} = \frac{1}{2} \underbrace{m_0}_{\text{mass of molecule}} \underbrace{V^2}_{\text{speed } m/s}$

mass of molecule $\Rightarrow \frac{M_w}{N_A}$

$K_{av} = \frac{3}{2} K_B T$

∘ Root Mean Square

$V_{rms} = \sqrt{\frac{3RT}{M_w}}$

$\sqrt{V^2} = rms$

∘ Density

$\rho = \frac{P M_w}{RT}$

∘ Linear Expansion of solids [1D]

$\Delta L = \underbrace{\alpha}_{\text{Thermal coefficient of linear expansion } K^{-1}} L_0 \underbrace{\Delta T}_{(T_f - T_i)}$

$\underbrace{L}_{\text{final length after temp. change}} = L_0(1 + \alpha \Delta T)$

$\frac{\Delta L}{L_0} = \alpha \Delta T$

∘ Area Expansion of solids [2D]

$\Delta A = \underbrace{\beta}_{\text{Thermal coeff. of Area expansion}} A_0 \Delta T$

$\Delta A \approx (2\alpha) A_0 \Delta T$ → for isotropic solids

$\frac{\Delta A}{A_0} = \beta \Delta T$

$\underbrace{A \approx A_0(1 + 2\alpha + \Delta T)}_{\text{final area after temp. change}}$

∘ Volumetric Expansion of Solids [3D]

$\Delta V = \underbrace{\gamma}_{\text{Thermal coeff. of volumetric expansion}} V_0 \Delta T$

$\Delta V \approx (3\alpha) V_0 \Delta T$ → for isotropics

$\frac{\Delta V}{V_0} = \gamma \Delta T$

$\Delta T = \frac{\Delta L}{L_0} / \alpha + T_i$

$\underbrace{V \approx V_0(1 + 3\alpha + \Delta T)}_{\text{final volume after temp. change}}$

∘ Heat Energy

$\overset{J}{Q} = \underbrace{\overset{J/kg°C}{C}}_{\text{specific heat energy}} \underbrace{m}_{\text{mass}} \Delta T$

∘ Conservation Energy
(when two substances are mixed)

$Q_{gain} + Q_{lost} = 0$

∘ Heat Transfer

$\overset{watt}{H} = \underbrace{K}_{\text{Thermal conductivity W/mK}} \underbrace{\overset{m^2}{A}}_{\text{Area surface}} \frac{(T_{hot} - T_{cold})}{\underbrace{L}_{\text{Seperation distance } m}}$

∘ Stefan - Boltzmann Law

$\underbrace{P}_{\text{Power watt}} = \underbrace{e}_{\text{emissivity}} \sigma \overset{\text{Area Surface}}{A} (T^4 - T_s^4)$

$\sigma = 5.67 \times 10^{-8}\ watt/m^2K^4$

∘ Wien Displacement Law

$\underbrace{\lambda}_{\text{wave length } m} = \frac{B}{T}$

$B = 2.898 \times 10^{-3}\ mK$

∘ Heat Energy lost

$Q = P_{net} \cdot \Delta t$

∘ Bulk modulus

$B = -V_1 \frac{\Delta P}{\Delta V} = -V_1\left(-\frac{P_2}{V_1}\right)$

∘ Specific Heat Capacity
(when two substances are mixed)

$C_x = \frac{m_w C_w (T_f - T_w)}{m_x (T_x - T_f)}$

Physics ⇒ Chapter 5

Fluid Mechanics

$$KE = \frac{1}{2}\Delta m v^2 = \frac{1}{2}\rho \Delta V v^2$$

$$KE_{density} = \frac{1}{2}\rho v^2$$

$$PE_{density} = \rho g h$$

- **Continuity Equation**

$$Q_{in} = Q_{out}$$

flow rate

$$Q = \frac{\Delta V}{\Delta t} = A\bar{v}$$

A: Cross sectional area

$$= \text{Constant}$$

- **Bernoulli's Equation**

$$P + \frac{1}{2}\rho \bar{v}^2 + \rho g h = \text{Constant}$$

↳ ① Static consequence

$KE = 0$

$$P + \rho g h = \text{Constant}$$

↳ ② horizontal flow consequence

$PE = 0$

$$P + \frac{1}{2}\rho \bar{v}^2 = \text{Constant}$$

↳ ③ Venturi tube

$$P_1 - P_2 = \frac{1}{2}\rho(\bar{v}_2^2 - \bar{v}_1^2)$$

$$v_1 = \sqrt{\frac{2(P_1 - P_2)}{\rho\left(\left(\frac{A_1}{A_2}\right)^2 - 1\right)}}$$

- **Blood Circulation**

↳ Reclinig

$$P_B = P_H = P_F$$

↳ Standing

$$P_F = P_H + \rho g h_H = P_B + \rho g h_B$$

$$P_B = P_H + \rho g(h_H - h_B)$$

↳ Upwards acceleration

$$P_B = P_H + \rho(g+a)\underbrace{(h_H - h_B)}_{\text{usually -ive}}$$

↳ Downwards acceleration

$$P_B = P_H + \rho(g-a)(h_H - h_B)$$

- **Viscous Fluid Flow**

$$F = \eta A \frac{\Delta V}{\Delta y}$$

η: viscousity Coeff. (Pa·s)

A: Surface area

ΔV: Speed

Δy: Seperation distance

$$F = (P_1 - P_2)\pi r^2$$

Laminar Flow in a tube

πr^2: Cross sectional area

$$\bar{v}_{max} = \frac{\Delta P r^2}{4\eta L} \quad m\cdot s^{-1}$$

$$\bar{v} = \frac{\Delta P r^2}{8\eta L} = \frac{1}{2}V_{max}$$

$$Q = \frac{\pi \Delta P r^4}{8\eta L} = \frac{1}{2}AV_{max}$$

Q: Flow rate m^3/s

- **Poiseuille Law**

- **Power Dissiption**

W

$$\mathcal{P} = \Delta P A\bar{V} = \Delta P Q = \cancel{Q^2 R_f} = \frac{\Delta P^2}{R_f}$$

- **Flow Resistance** Pa.s/m³

$$R_f = \frac{\Delta P}{Q} = \frac{8\eta L}{\pi r^4}$$

- **Turbulent Flow**

$$N_R = \frac{2\rho \bar{v} r}{\eta}$$

N_R: Reynold's

$N_R < 2000$ ⇒ Laminar flow

$N_R > 3000$ ⇒ Turbulent flow

$2000 < N_R < 3000$ ⇒ unstable flow

$P_H = 13300$ Pa

$\rho_{blood} = 1060$

$\rho_{water} = 1000$

1 atm = 1.013×10^5

1 poise = 10^{-1} Pa·s

$$\eta = ML^{-1}T^{-1}$$

Physics → Chapter 6

Bioelectricity

$I = \frac{Q}{t}$

Current (A); Q → Charge (C); t → time (s)

$V = \frac{I}{n \cdot e \cdot A}$

drift velocity (m/s); e → 1.6×10^{-19}; A → Cross Sectional area

$J = \frac{I}{A}$

J → Current density; A → cross sectional area

$V = IR$

V → Voltage (V); R → resistance (Ω)

$R_T = R_0 (1 + \alpha(T - T_0))$

$\rho_T = \rho_0 (1 + \alpha(T - T_0))$

$R = \rho \frac{L}{A}$

ρ → resistivity (Ω·m); L → length; A → Cross Sectional area

$P = IV$ (Power in load resistor)

P → Power (W)

$P = I^2 r$ (Power in internal resistor)

$P = \frac{V^2}{R}$ (Load resistor)

$\mathcal{E} = V_R + V_r$

ℰ → emf/battery (V)

$I = \frac{\mathcal{E}}{R + r}$

$V = \mathcal{E} - Ir$

∘ Circuits

① Series

$R_{eq} = R_1 + R_2 + R_3$

I is Constant

② Parallel

$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

V is constant

∘ Capacitors

$C = \frac{Q}{\Delta V}$

C → capacitance (F)

$C = \frac{\varepsilon_0 A}{d}$

ε_0 → epsilon; A → surface area; d → distance

$\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$

$\lambda = \sqrt{\frac{\rho_m r}{2 \rho_a}}$

λ → Space Parameter

∘ Charging Capacitor

$Q_0 = C\mathcal{E}$

→ max charge

$I_0 = \frac{\mathcal{E}}{R}$

→ max current

$\tau = RC$

→ time Constant

$V_c(t) = \mathcal{E}(1 - e^{-t/RC})$

$I_c(t) = I_0 e^{-t/RC}$

$Q_{c(t)} = Q_0 (1 - e^{-t/RC})$

→ when asked for t:

$t = -RC \ln\left(\frac{V}{\mathcal{E}} - 1\right)$

$= -RC \ln\left(\frac{I}{I_0}\right)$

→ when asked for RC:

$RC = \frac{-t}{\ln\left(\frac{V}{\mathcal{E}} - 1\right)}$

....

∘ Discharging Capacitor

$Q_{d(t)} = Q_0 e^{-t/RC}$

$\cancel{I_0 = \frac{Q}{RC}}$

$I_{d(t)} = -I_0 e^{-t/RC}$

$V_d(t) = V_0 e^{-t/RC}$

∘ Nerve Coduction

$R_a = \rho \frac{L}{\pi r^2}$

→ axon resistance

$R_m = \frac{\rho_m}{2\pi r L}$

R_m → membrane resistance; ρ_m → membrane resistivity

$C_m = \frac{C}{A} = \frac{\mathcal{E}}{d}$

or C_{um}; E → dielectric constant; d → thickness

$$V = \pm 61.4 \times 10^{-3} \log\left(\frac{C_o}{C_i}\right)$$

C_o → concentration outside

C_i → Con. inside

V → Potential difference across the membrane

$$E = \frac{V}{d}$$

V ← Voltage

d ← distance

E → electric field strength (v/m)

Propagation speed → v

$$v = \frac{r}{2 C_m \rho_a x} = \frac{r}{2(5\times10^{-5})(2)(x)}$$

r ← radius

x → length

or

$$v = \frac{\lambda^2}{C_m \rho_m x} = \frac{\lambda^2}{(5\times10^{-5})(40)\, x}$$

λ^2 → space Parameter

$$N_e = \frac{\Delta Q}{q_e}$$

ΔQ → Charge

q_e → charge of electron 1.6×10^{-19}

N_e → number of electrons

Constants

Unmyelinated Axon	Myelinated Axon	
$\rho_a = 2\ \Omega\cdot m$	$\rho_a = 2\ \Omega\cdot m$	← axoplasm resistivity
$\rho_u = 0.2\ \Omega\cdot m^2$	$\rho_m = 40\ \Omega\cdot m^2$	← wall resistivity
$C = 10^{-2}\ F/m^2$	$C = 5\times10^{-5}\ F/m^2$	← wall Capacitance