

PHYSICS FORMULA LIST

0.1: Physical Constants

Speed of light	c	3×10^8 m/s
Planck constant	h	6.63×10^{-34} J s
Gravitation constant	hc	1242 eV-nm
Boltzmann constant	G	6.67×10^{-11} m ³ kg ⁻¹ s ⁻²
Molar gas constant	k	1.38×10^{-23} J/K
Avogadro's number	R	8.314 J/(mol K)
Charge of electron	N_A	6.023×10^{23} mol ⁻¹
Permeability of vacuum	e	1.602×10^{-19} C
Permitivity of vacuum	μ_0	$4\pi \times 10^{-7}$ N/A ²
Coulomb constant	ϵ_0	8.85×10^{-12} F/m
Faraday constant	$\frac{1}{4\pi\epsilon_0}$	9×10^9 N m ² /C ²
Mass of electron	F	96485 C/mol
Mass of proton	m_e	9.1×10^{-31} kg
Mass of neutron	m_p	1.6726×10^{-27} kg
Atomic mass unit	m_n	1.6749×10^{-27} kg
Atomic mass unit	u	1.66×10^{-27} kg
Stefan-Boltzmann constant	u	931.49 MeV/c ²
Rydberg constant	σ	5.67×10^{-8} W/(m ² K ⁴)
Bohr magneton	R_∞	1.097×10^7 m ⁻¹
Bohr radius	μ_B	9.27×10^{-24} J/T
Standard atmosphere	a_0	0.529×10^{-10} m
Wien displacement constant	atm	1.01325×10^5 Pa
	b	2.9×10^{-3} m K

MECHANICS

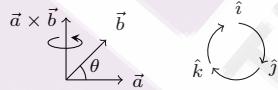
1.1: Vectors

Notation: $\vec{a} = a_x \hat{i} + a_y \hat{j} + a_z \hat{k}$

Magnitude: $a = |\vec{a}| = \sqrt{a_x^2 + a_y^2 + a_z^2}$

Dot product: $\vec{a} \cdot \vec{b} = a_x b_x + a_y b_y + a_z b_z = ab \cos \theta$

Cross product:



$$\vec{a} \times \vec{b} = (a_y b_z - a_z b_y) \hat{i} + (a_z b_x - a_x b_z) \hat{j} + (a_x b_y - a_y b_x) \hat{k}$$

$$|\vec{a} \times \vec{b}| = ab \sin \theta$$

1.2: Kinematics

Average and Instantaneous Vel. and Accel.:

$$\begin{aligned}\vec{v}_{\text{av}} &= \Delta \vec{r} / \Delta t, \\ \vec{a}_{\text{av}} &= \Delta \vec{v} / \Delta t\end{aligned}$$

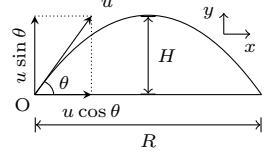
$$\begin{aligned}\vec{v}_{\text{inst}} &= d\vec{r} / dt \\ \vec{a}_{\text{inst}} &= d\vec{v} / dt\end{aligned}$$

Motion in a straight line with constant a :

$$v = u + at, \quad s = ut + \frac{1}{2}at^2, \quad v^2 - u^2 = 2as$$

Relative Velocity: $\vec{v}_{A/B} = \vec{v}_A - \vec{v}_B$

Projectile Motion:



$$\begin{aligned}x &= ut \cos \theta, \quad y = ut \sin \theta - \frac{1}{2}gt^2 \\ y &= x \tan \theta - \frac{g}{2u^2 \cos^2 \theta} x^2 \\ T &= \frac{2u \sin \theta}{g}, \quad R = \frac{u^2 \sin 2\theta}{g}, \quad H = \frac{u^2 \sin^2 \theta}{2g}\end{aligned}$$

1.3: Newton's Laws and Friction

Linear momentum: $\vec{p} = m\vec{v}$

Newton's first law: inertial frame.

Newton's second law: $\vec{F} = \frac{d\vec{p}}{dt}, \quad \vec{F} = m\vec{a}$

Newton's third law: $\vec{F}_{AB} = -\vec{F}_{BA}$

Frictional force: $f_{\text{static, max}} = \mu_s N, \quad f_{\text{kinetic}} = \mu_k N$

Banking angle: $\frac{v^2}{rg} = \tan \theta, \quad \frac{v^2}{rg} = \frac{\mu + \tan \theta}{1 - \mu \tan \theta}$

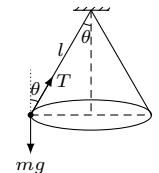
Centripetal force: $F_c = \frac{mv^2}{r}, \quad a_c = \frac{v^2}{r}$

Pseudo force: $\vec{F}_{\text{pseudo}} = -m\vec{a}_0, \quad F_{\text{centrifugal}} = -\frac{mv^2}{r}$

Minimum speed to complete vertical circle:

$$v_{\text{min, bottom}} = \sqrt{5gl}, \quad v_{\text{min, top}} = \sqrt{gl}$$

Conical pendulum: $T = 2\pi \sqrt{\frac{l \cos \theta}{g}}$



1.4: Work, Power and Energy

Work: $W = \vec{F} \cdot \vec{S} = FS \cos \theta, \quad W = \int \vec{F} \cdot d\vec{S}$

Kinetic energy: $K = \frac{1}{2}mv^2 = \frac{p^2}{2m}$

Potential energy: $F = -\partial U / \partial x$ for conservative forces.

$$U_{\text{gravitational}} = mgh, \quad U_{\text{spring}} = \frac{1}{2}kx^2$$

Work done by conservative forces is path independent and depends only on initial and final points: $\oint \vec{F}_{\text{conservative}} \cdot d\vec{r} = 0$.

Work-energy theorem: $W = \Delta K$

Mechanical energy: $E = U + K$. Conserved if forces are conservative in nature.

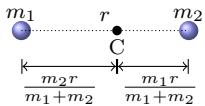
Power $P_{\text{av}} = \frac{\Delta W}{\Delta t}, \quad P_{\text{inst}} = \vec{F} \cdot \vec{v}$

1.5: Centre of Mass and Collision

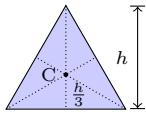
Centre of mass: $x_{\text{cm}} = \frac{\sum x_i m_i}{\sum m_i}$, $x_{\text{cm}} = \frac{\int x dm}{\int dm}$

CM of few useful configurations:

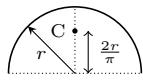
1. m_1, m_2 separated by r :



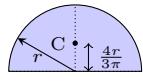
2. Triangle (CM \equiv Centroid) $y_c = \frac{h}{3}$



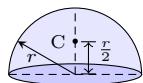
3. Semicircular ring: $y_c = \frac{2r}{\pi}$



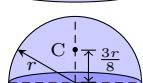
4. Semicircular disc: $y_c = \frac{4r}{3\pi}$



5. Hemispherical shell: $y_c = \frac{r}{2}$



6. Solid Hemisphere: $y_c = \frac{3r}{8}$



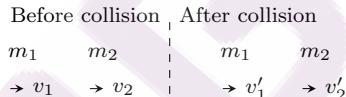
7. Cone: the height of CM from the base is $h/4$ for the solid cone and $h/3$ for the hollow cone.

Motion of the CM: $M = \sum m_i$

$$\vec{v}_{\text{cm}} = \frac{\sum m_i \vec{v}_i}{M}, \quad \vec{p}_{\text{cm}} = M \vec{v}_{\text{cm}}, \quad \vec{a}_{\text{cm}} = \frac{\vec{F}_{\text{ext}}}{M}$$

Impulse: $\vec{J} = \int \vec{F} dt = \Delta \vec{p}$

Collision:



Momentum conservation: $m_1 v_1 + m_2 v_2 = m_1 v'_1 + m_2 v'_2$

Elastic Collision: $\frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2 = \frac{1}{2} m_1 v'_1^2 + \frac{1}{2} m_2 v'_2^2$

Coefficient of restitution:

$$e = \frac{-(v'_1 - v'_2)}{v_1 - v_2} = \begin{cases} 1, & \text{completely elastic} \\ 0, & \text{completely inelastic} \end{cases}$$

If $v_2 = 0$ and $m_1 \ll m_2$ then $v'_1 = -v_1$.

If $v_2 = 0$ and $m_1 \gg m_2$ then $v'_2 = 2v_1$.

Elastic collision with $m_1 = m_2$: $v'_1 = v_2$ and $v'_2 = v_1$.

1.6: Rigid Body Dynamics

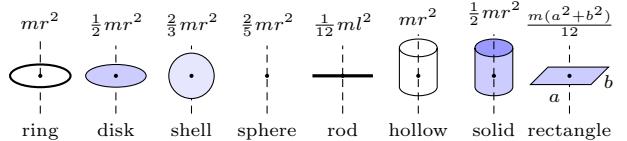
Angular velocity: $\omega_{\text{av}} = \frac{\Delta\theta}{\Delta t}$, $\omega = \frac{d\theta}{dt}$, $\vec{v} = \vec{\omega} \times \vec{r}$

Angular Accel.: $\alpha_{\text{av}} = \frac{\Delta\omega}{\Delta t}$, $\alpha = \frac{d\omega}{dt}$, $\vec{a} = \vec{\alpha} \times \vec{r}$

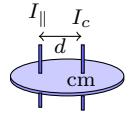
Rotation about an axis with constant α :

$$\omega = \omega_0 + at, \quad \theta = \omega t + \frac{1}{2}\alpha t^2, \quad \omega^2 - \omega_0^2 = 2\alpha\theta$$

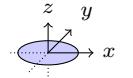
Moment of Inertia: $I = \sum_i m_i r_i^2$, $I = \int r^2 dm$



Theorem of Parallel Axes: $I_{\parallel} = I_{\text{cm}} + md^2$



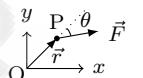
Theorem of Perp. Axes: $I_z = I_x + I_y$



Radius of Gyration: $k = \sqrt{I/m}$

Angular Momentum: $\vec{L} = \vec{r} \times \vec{p}$, $\vec{L} = I\vec{\omega}$

Torque: $\vec{\tau} = \vec{r} \times \vec{F}$, $\vec{\tau} = \frac{d\vec{L}}{dt}$, $\tau = I\alpha$



Conservation of \vec{L} : $\vec{\tau}_{\text{ext}} = 0 \implies \vec{L} = \text{const.}$

Equilibrium condition: $\sum \vec{F} = \vec{0}$, $\sum \vec{\tau} = \vec{0}$

Kinetic Energy: $K_{\text{rot}} = \frac{1}{2} I \omega^2$

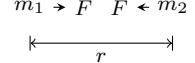
Dynamics:

$$\vec{r}_{\text{cm}} = I_{\text{cm}} \vec{\alpha}, \quad \vec{F}_{\text{ext}} = m \vec{a}_{\text{cm}}, \quad \vec{p}_{\text{cm}} = m \vec{v}_{\text{cm}}$$

$$K = \frac{1}{2} m v_{\text{cm}}^2 + \frac{1}{2} I_{\text{cm}} \omega^2, \quad \vec{L} = I_{\text{cm}} \vec{\omega} + \vec{r}_{\text{cm}} \times m \vec{v}_{\text{cm}}$$

1.7: Gravitation

Gravitational force: $F = G \frac{m_1 m_2}{r^2}$



Potential energy: $U = -\frac{GMm}{r}$

Gravitational acceleration: $g = \frac{GM}{R^2}$

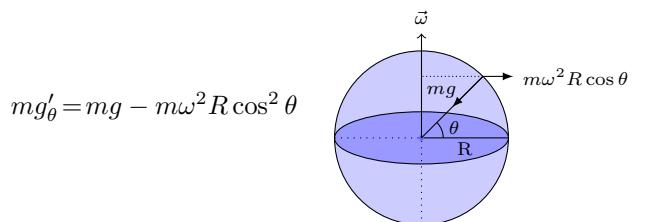
Variation of g with depth: $g_{\text{inside}} \approx g \left(1 - \frac{2h}{R}\right)$

Variation of g with height: $g_{\text{outside}} \approx g \left(1 - \frac{h}{R}\right)$

Effect of non-spherical earth shape on g:

$g_{\text{at pole}} > g_{\text{at equator}}$ ($\because R_e - R_p \approx 21 \text{ km}$)

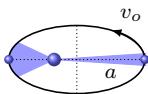
Effect of earth rotation on apparent weight:



Orbital velocity of satellite: $v_o = \sqrt{\frac{GM}{R}}$

Escape velocity: $v_e = \sqrt{\frac{2GM}{R}}$

Kepler's laws:



- First:** Elliptical orbit with sun at one of the focus.
- Second:** Areal velocity is constant. ($\because d\vec{L}/dt = 0$).
- Third:** $T^2 \propto a^3$. In circular orbit $T^2 = \frac{4\pi^2}{GM} a^3$.

1.8: Simple Harmonic Motion

Hooke's law: $F = -kx$ (for small elongation x .)

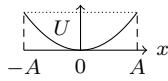
Acceleration: $a = \frac{d^2x}{dt^2} = -\frac{k}{m}x = -\omega^2 x$

Time period: $T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}}$

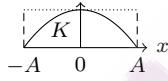
Displacement: $x = A \sin(\omega t + \phi)$

Velocity: $v = A\omega \cos(\omega t + \phi) = \pm\omega\sqrt{A^2 - x^2}$

Potential energy: $U = \frac{1}{2}kx^2$



Kinetic energy $K = \frac{1}{2}mv^2$



Total energy: $E = U + K = \frac{1}{2}m\omega^2 A^2$

Simple pendulum: $T = 2\pi\sqrt{\frac{l}{g}}$



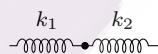
Physical Pendulum: $T = 2\pi\sqrt{\frac{I}{mgI}}$



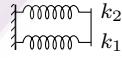
Torsional Pendulum $T = 2\pi\sqrt{\frac{I}{k}}$



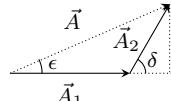
Springs in series: $\frac{1}{k_{eq}} = \frac{1}{k_1} + \frac{1}{k_2}$



Springs in parallel: $k_{eq} = k_1 + k_2$



Superposition of two SHM's:



$$x_1 = A_1 \sin \omega t, \quad x_2 = A_2 \sin(\omega t + \delta)$$

$$x = x_1 + x_2 = A \sin(\omega t + \epsilon)$$

$$A = \sqrt{A_1^2 + A_2^2 + 2A_1 A_2 \cos \delta}$$

$$\tan \epsilon = \frac{A_2 \sin \delta}{A_1 + A_2 \cos \delta}$$

1.9: Properties of Matter

Modulus of rigidity: $Y = \frac{F/A}{\Delta l/l}$, $B = -V \frac{\Delta P}{\Delta V}$, $\eta = \frac{F}{A\theta}$

Compressibility: $K = \frac{1}{B} = -\frac{1}{V} \frac{dV}{dP}$

Poisson's ratio: $\sigma = \frac{\text{lateral strain}}{\text{longitudinal strain}} = \frac{\Delta D/D}{\Delta l/l}$

Elastic energy: $U = \frac{1}{2} \text{stress} \times \text{strain} \times \text{volume}$

Surface tension: $S = F/l$

Surface energy: $U = SA$

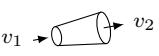
Excess pressure in bubble:

$$\Delta p_{\text{air}} = 2S/R, \quad \Delta p_{\text{soap}} = 4S/R$$

Capillary rise: $h = \frac{2S \cos \theta}{\rho g}$

Hydrostatic pressure: $p = \rho gh$

Buoyant force: $F_B = \rho Vg$ = Weight of displaced liquid

Equation of continuity: $A_1 v_1 = A_2 v_2$ 

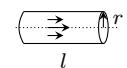
Bernoulli's equation: $p + \frac{1}{2}\rho v^2 + \rho gh = \text{constant}$

Torricelli's theorem: $v_{\text{efflux}} = \sqrt{2gh}$

Viscous force: $F = -\eta A \frac{dv}{dx}$

Stoke's law: $F = 6\pi\eta rv$



Poiseuilli's equation: $\frac{\text{Volume flow}}{\text{time}} = \frac{\pi pr^4}{8\eta l}$ 

Terminal velocity: $v_t = \frac{2r^2(\rho - \sigma)g}{9\eta}$

Waves

2.1: Waves Motion

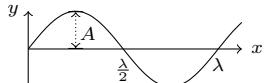
General equation of wave: $\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2} \frac{\partial^2 y}{\partial t^2}$.

Notation: Amplitude A , Frequency ν , Wavelength λ , Period T , Angular Frequency ω , Wave Number k ,

$$T = \frac{1}{\nu} = \frac{2\pi}{\omega}, \quad v = \nu\lambda, \quad k = \frac{2\pi}{\lambda}$$

Progressive wave travelling with speed v :

$$y = f(t - x/v), \rightsquigarrow +x; \quad y = f(t + x/v), \rightsquigarrow -x$$



Progressive sine wave:

$$y = A \sin(kx - \omega t) = A \sin(2\pi(x/\lambda - t/T))$$

2.2: Waves on a String

Speed of waves on a string with mass per unit length μ and tension T : $v = \sqrt{T/\mu}$

Transmitted power: $P_{av} = 2\pi^2 \mu v A^2 \nu^2$

Interference:

$$y_1 = A_1 \sin(kx - \omega t), \quad y_2 = A_2 \sin(kx - \omega t + \delta)$$

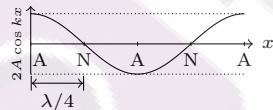
$$y = y_1 + y_2 = A \sin(kx - \omega t + \epsilon)$$

$$A = \sqrt{A_1^2 + A_2^2 + 2A_1 A_2 \cos \delta}$$

$$\tan \epsilon = \frac{A_2 \sin \delta}{A_1 + A_2 \cos \delta}$$

$$\delta = \begin{cases} 2n\pi, & \text{constructive;} \\ (2n+1)\pi, & \text{destructive.} \end{cases}$$

Standing Waves:

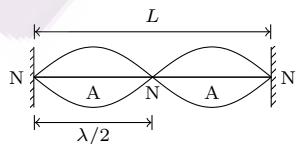


$$y_1 = A_1 \sin(kx - \omega t), \quad y_2 = A_2 \sin(kx + \omega t)$$

$$y = y_1 + y_2 = (2A \cos kx) \sin \omega t$$

$$x = \begin{cases} (n + \frac{1}{2}) \frac{\lambda}{2}, & \text{nodes; } n = 0, 1, 2, \dots \\ n \frac{\lambda}{2}, & \text{antinodes. } n = 0, 1, 2, \dots \end{cases}$$

String fixed at both ends:



1. Boundary conditions: $y = 0$ at $x = 0$ and at $x = L$

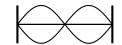
2. Allowed Freq.: $L = n \frac{\lambda}{2}$, $\nu = \frac{n}{2L} \sqrt{\frac{T}{\mu}}$, $n = 1, 2, 3, \dots$

3. Fundamental/1st harmonics: $\nu_0 = \frac{1}{2L} \sqrt{\frac{T}{\mu}}$ |

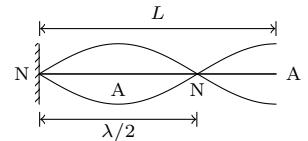
4. 1st overtone/2nd harmonics: $\nu_1 = \frac{2}{2L} \sqrt{\frac{T}{\mu}}$ |

5. 2nd overtone/3rd harmonics: $\nu_2 = \frac{3}{2L} \sqrt{\frac{T}{\mu}}$ |

6. All harmonics are present.



String fixed at one end:



1. Boundary conditions: $y = 0$ at $x = 0$

2. Allowed Freq.: $L = (2n+1) \frac{\lambda}{4}$, $\nu = \frac{2n+1}{4L} \sqrt{\frac{T}{\mu}}$, $n = 0, 1, 2, \dots$

3. Fundamental/1st harmonics: $\nu_0 = \frac{1}{4L} \sqrt{\frac{T}{\mu}}$ |

4. 1st overtone/3rd harmonics: $\nu_1 = \frac{3}{4L} \sqrt{\frac{T}{\mu}}$ |

5. 2nd overtone/5th harmonics: $\nu_2 = \frac{5}{4L} \sqrt{\frac{T}{\mu}}$ |

6. Only odd harmonics are present.



Sonometer: $\nu \propto \frac{1}{L}$, $\nu \propto \sqrt{T}$, $\nu \propto \frac{1}{\sqrt{\mu}}$. $\nu = \frac{n}{2L} \sqrt{\frac{T}{\mu}}$

2.3: Sound Waves

Displacement wave: $s = s_0 \sin \omega(t - x/v)$

Pressure wave: $p = p_0 \cos \omega(t - x/v)$, $p_0 = (B\omega/v)s_0$

Speed of sound waves:

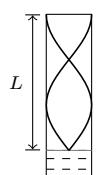
$$v_{\text{liquid}} = \sqrt{\frac{B}{\rho}}, \quad v_{\text{solid}} = \sqrt{\frac{Y}{\rho}}, \quad v_{\text{gas}} = \sqrt{\frac{\gamma P}{\rho}}$$

$$\text{Intensity: } I = \frac{2\pi^2 B}{v} s_0^2 v^2 = \frac{p_0^2 v}{2B} = \frac{p_0^2}{2\rho v}$$

Standing longitudinal waves:

$$p_1 = p_0 \sin \omega(t - x/v), \quad p_2 = p_0 \sin \omega(t + x/v)$$

$$p = p_1 + p_2 = 2p_0 \cos kx \sin \omega t$$



Closed organ pipe:

1. Boundary condition: $y = 0$ at $x = 0$

2. Allowed freq.: $L = (2n+1) \frac{\lambda}{4}$, $\nu = (2n+1) \frac{v}{4L}$, $n = 0, 1, 2, \dots$

3. Fundamental/1st harmonics: $\nu_0 = \frac{v}{4L}$ |

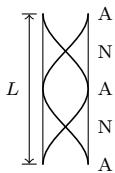
4. 1st overtone/3rd harmonics: $\nu_1 = 3\nu_0 = \frac{3v}{4L}$ |

5. 2nd overtone/5th harmonics: $\nu_2 = 5\nu_0 = \frac{5v}{4L}$



6. Only odd harmonics are present.

Open organ pipe:



1. Boundary condition: $y = 0$ at $x = 0$

Allowed freq.: $L = n\frac{\lambda}{2}$, $\nu = n\frac{v}{4L}$, $n = 1, 2, \dots$

2. Fundamental/1st harmonics: $\nu_0 = \frac{v}{2L}$



3. 1st overtone/2nd harmonics: $\nu_1 = 2\nu_0 = \frac{2v}{2L}$

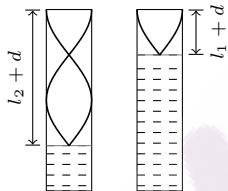


4. 2nd overtone/3rd harmonics: $\nu_2 = 3\nu_0 = \frac{3v}{2L}$



5. All harmonics are present.

Resonance column:



$$l_1 + d = \frac{\lambda}{2}, \quad l_2 + d = \frac{3\lambda}{4}, \quad v = 2(l_2 - l_1)\nu$$

Beats: two waves of almost equal frequencies $\omega_1 \approx \omega_2$

$$p_1 = p_0 \sin \omega_1(t - x/v), \quad p_2 = p_0 \sin \omega_2(t - x/v)$$

$$p = p_1 + p_2 = 2p_0 \cos \Delta\omega(t - x/v) \sin \omega(t - x/v)$$

$$\omega = (\omega_1 + \omega_2)/2, \quad \Delta\omega = \omega_1 - \omega_2 \quad (\text{beats freq.})$$

Doppler Effect:

$$\nu = \frac{v + u_o}{v - u_s} \nu_0$$

where, v is the speed of sound in the medium, u_0 is the speed of the observer w.r.t. the medium, considered positive when it moves towards the source and negative when it moves away from the source, and u_s is the speed of the source w.r.t. the medium, considered positive when it moves towards the observer and negative when it moves away from the observer.

Heat and Thermodynamics

4.1: Heat and Temperature

Temp. scales: $F = 32 + \frac{9}{5}C$, $K = C + 273.16$

Ideal gas equation: $pV = nRT$, n : number of moles

van der Waals equation: $(p + \frac{a}{V^2})(V - b) = nRT$

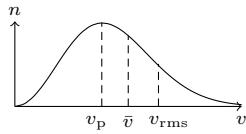
Thermal expansion: $L = L_0(1 + \alpha\Delta T)$,
 $A = A_0(1 + \beta\Delta T)$, $V = V_0(1 + \gamma\Delta T)$, $\gamma = 2\beta = 3\alpha$

Thermal stress of a material: $\frac{F}{A} = Y \frac{\Delta l}{l}$

4.2: Kinetic Theory of Gases

General: $M = mN_A$, $k = R/N_A$

Maxwell distribution of speed:



RMS speed: $v_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{M}}$

Average speed: $\bar{v} = \sqrt{\frac{8kT}{\pi m}} = \sqrt{\frac{8RT}{\pi M}}$

Most probable speed: $v_p = \sqrt{\frac{2kT}{m}}$

Pressure: $p = \frac{1}{3}\rho v_{rms}^2$

Equipartition of energy: $K = \frac{1}{2}kT$ for each degree of freedom. Thus, $K = \frac{f}{2}kT$ for molecule having f degrees of freedoms.

Internal energy of n moles of an ideal gas is $U = \frac{f}{2}nRT$.

4.3: Specific Heat

Specific heat: $s = \frac{Q}{m\Delta T}$

Latent heat: $L = Q/m$

Specific heat at constant volume: $C_v = \left. \frac{\Delta Q}{n\Delta T} \right|_V$

Specific heat at constant pressure: $C_p = \left. \frac{\Delta Q}{n\Delta T} \right|_p$

Relation between C_p and C_v : $C_p - C_v = R$

Ratio of specific heats: $\gamma = C_p/C_v$

Relation between U and C_v : $\Delta U = nC_v\Delta T$

Specific heat of gas mixture:

$$C_v = \frac{n_1 C_{v1} + n_2 C_{v2}}{n_1 + n_2}, \quad \gamma = \frac{n_1 C_{p1} + n_2 C_{p2}}{n_1 C_{v1} + n_2 C_{v2}}$$

Molar internal energy of an ideal gas: $U = \frac{f}{2}RT$,
 $f = 3$ for monatomic and $f = 5$ for diatomic gas.

4.4: Thermodynamic Processes

First law of thermodynamics: $\Delta Q = \Delta U + \Delta W$

Work done by the gas:

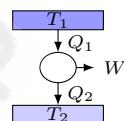
$$\Delta W = p\Delta V, \quad W = \int_{V_1}^{V_2} p dV$$

$$W_{\text{isothermal}} = nRT \ln \left(\frac{V_2}{V_1} \right)$$

$$W_{\text{isobaric}} = p(V_2 - V_1)$$

$$W_{\text{adiabatic}} = \frac{p_1 V_1 - p_2 V_2}{\gamma - 1}$$

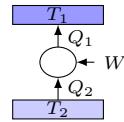
$$W_{\text{isochoric}} = 0$$



Efficiency of the heat engine:

$$\eta = \frac{\text{work done by the engine}}{\text{heat supplied to it}} = \frac{Q_1 - Q_2}{Q_1}$$

$$\eta_{\text{carnot}} = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$$



Coeff. of performance of refrigerator:

$$\text{COP} = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2}$$

Entropy: $\Delta S = \frac{\Delta Q}{T}$, $S_f - S_i = \int_i^f \frac{\Delta Q}{T}$

Const. T : $\Delta S = \frac{Q}{T}$, Varying T : $\Delta S = ms \ln \frac{T_f}{T_i}$

Adiabatic process: $\Delta Q = 0$, $pV^\gamma = \text{constant}$

4.5: Heat Transfer

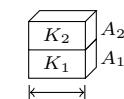
Conduction: $\frac{\Delta Q}{\Delta t} = -KA \frac{\Delta T}{x}$

Thermal resistance: $R = \frac{x}{KA}$

$$R_{\text{series}} = R_1 + R_2 = \frac{1}{A} \left(\frac{x_1}{K_1} + \frac{x_2}{K_2} \right)$$

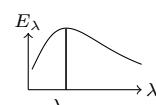


$$\frac{1}{R_{\text{parallel}}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{x} (K_1 A_1 + K_2 A_2)$$



Kirchhoff's Law: $\frac{\text{emissive power}}{\text{absorptive power}} = \frac{E_{\text{body}}}{a_{\text{body}}} = E_{\text{blackbody}}$

Wien's displacement law: $\lambda_m T = b$



Stefan-Boltzmann law: $\frac{\Delta Q}{\Delta t} = \sigma e A T^4$

Newton's law of cooling: $\frac{dT}{dt} = -bA(T - T_0)$