

H2 Physics Learning Roadmap

March 16, 2026

Contents

SECTION 0: MATHEMATICAL FOUNDATION	3
Chapter 0: Quantities and Analysis	4
SECTION I: MECHANICS	4
Chapter 1: Kinematics I	5
Chapter 2: Kinematics II	6
Chapter 3: Dynamics I	7
Chapter 4: Dynamics II	8
Chapter 5: Energy	9
Chapter 6: Momentum	10
SECTION II: OSCILLATIONS AND WAVES	10
Chapter 7: Oscillations	11
Chapter 8: Waves I	12
Chapter 9: Waves II	13
SECTION III: Gravity	13
Chapter 10: Gravity	14
SECTION IV: Electricity & Magnetism	14
Chapter 11: Electrostatics	15
Chapter 12: Circuit	16
Chapter 13: Magnetostatics	17
Chapter 14: Electromagnetic Induction	18
Chapter 15: Electrical Appliances	19
SECTION V: THERMAL PHYSICS	19
Chapter 16: Thermal Physics	20
SECTION VI: MODERN PHYSICS	20
Chapter 17: Quantum Physics	21
Chapter 18: Nuclear Physics	22

SECTION 0: MATHEMATICAL FOUNDATION

Chapter 0: Quantities and Analysis

- Units
 - SI units: base units; derived units; unit prefixes
 - Non-SI unit system; e.g.: Gaussian units, natural units
 - Unit and estimation of quantities
 - Units and dimensions
 - * Notation for quantity dimension
 - * Homogeneity of physical equations
 - * Dimensional analysis
- Measurements and Statistics
 - Random and systematic errors of measurements
 - Precision and accuracy of statistics
 - Uncertainty calculations: absolute, fractional, percentage
- Vector Algebra
 - 2D vectors in coordinate systems
 - * Cartesian: x and y coordinates and orthogonal decomposition
 - * Polar: angular and radial coordinates
 - Scalars as 1D vectors
 - Vector arithmetic
 - * Addition, multiplication (scalar, dot, and cross product)
 - * Mention: vector as an $n \times 1$ matrix, and the resulting algebra
 - Unit of vectors and vector products
 - Mention: Complex numbers
 - * How are complex numbers similar to 2D vectors
 - * How they are different
 - Mention: fields
 - * Quantity as a function of spatial, or spatial and time, coordinates
 - * Superposition as vector addition

SECTION I: MECHANICS

Chapter 1: Kinematics I

- Position and its time derivatives
 - Position, displacement, and distance
 - Velocity and speed
 - Acceleration and its magnitude
 - Mention: jerk and higher order derivatives and why they are less often used
- Graphs for 1D motions and analysis
 - Gradients as the rate of change
 - Areas as the accumulation
 - Time dependent graphs: $x-t$, $v-t$, $a-t$
 - * Time derivative advances the curve
 - Briefly mention time independent graphs: $v-x$, $a-v$, $a-x$
 - * What advances the curve here?
- 1D motion with constant \mathbf{a} (forces not mentioned)
 - Equations of uniformly accelerated motion
 - * Derivation based on non-uniform motion
 - * Extra: Energy interpretation of the time independent equation
 - Example: Free fall (with constant gravitational acceleration)

Chapter 2: Kinematics II

- 2D Motion overview
 - Independent analysis along orthogonal directions
 - With an interest over curvature: tangential and centripetal \mathbf{a} by vector decomposition
- 2D motion with constant \mathbf{a} (forces not mentioned)
 - Projectile motion
 - Weight as force in a gravitational field ($W = mg$)
 - Qualitative effects of air resistance, including terminal velocity
- 2D motion with constant centripetal $|\mathbf{a}|$
 - Angular displacement in radians
 - Angular velocity ω
 - Relationship $v = r\omega$
 - Common misconception: \mathbf{a} is not constant for circular motion. $|\mathbf{a}|$ is.
 - Centripetal acceleration ($a = \omega^2 r = v^2/r$)

Chapter 3: Dynamics I

- Mass as inertia (a qualitative mention)
- N1L: $\mathbf{F} = 0 \Rightarrow \mathbf{a} = 0$
- N2L: $\mathbf{F} = m\mathbf{a}$ (actually, $\mathbf{F}(t) = m(t)\mathbf{a}(t)$)
- N3L: $\mathbf{F}_{\text{action}} + \mathbf{F}_{\text{reaction}} = 0$
- Free-body diagrams and vector triangles
- Moment of a force, torque of a couple
- Conditions for equilibrium ($\mathbf{F}_{\text{net}} = 0, \tau_{\text{net}} = 0$) — statics as special case

Chapter 4: Dynamics II

- Types of forces: gravitational, electric, magnetic, normal, friction, viscous, buoyant
- Centre of gravity
- Buoyancy
- Friction ($f_k = -\mu_k F_N \hat{v}$, $f_{s,\max} = -\mu_s F_N \hat{v}$)
- Drag (general model: polynomial with coefficients. more usually: linear / quadratic)
- Hooke's law ($\mathbf{F} = -k\Delta x$)
- Projectile and circular motion revisited
- Basic constrained motion — kinematic relationships; inclined planes, pulleys, connected bodies

Chapter 5: Energy

- Energy stores and transfers, conservation of energy
- Work done by a force ($dW = \mathbf{F} \cdot d\mathbf{l} = |\mathbf{F}| |d\mathbf{l}| \cos \theta$)
- Kinetic energy — derivation from work, $E_k = \frac{1}{2}m|\mathbf{v}|^2$
- Gravitational potential energy near Earth ($\Delta E_p = mg\Delta h$)
- Elastic potential energy — area under force-extension graph
- Power ($P = E/t$, $P = Fv$)
- Energy transmission in constrained systems
- Efficiency

Chapter 6: Momentum

- Momentum — $\mathbf{p} = m\mathbf{v}$
- Impulse — $\mathbf{J} = \Delta\mathbf{p}$, area under force–time graph
- Conservation of momentum (Linear and Angular)
- Elastic and inelastic collisions in one dimension
 - Relative speed of approach = relative speed of separation (perfectly elastic)
 - Perfectly inelastic
 - Kinetic energy changes in collisions
- Extra: non-heads-on collisions

SECTION II: OSCILLATIONS AND WAVES

Chapter 7: Oscillations

- Free oscillations, experimental investigation
- Amplitude, period, frequency, angular frequency, phase, phase difference
- Defining equation of SHM ($a = -\omega^2 x$)
- General solution: ...
- Particular solutions: $x = x_0 \sin \omega t$, $v = v_0 \cos \omega t$, $v = \pm \omega \sqrt{x_0^2 - x^2}$
- Graphical relationships ($x-t$, $v-t$, $a-t$, $v-x$, $a-v$, $a-x$)
- Energy interchange in SHM
- Damped oscillations (light, critical, heavy), critical damping applications
- Forced oscillations and resonance — amplitude response, sharpness, practical examples

Chapter 8: Waves I

- General wave equation
- Sinusoidal 1D wave as a function of x and t
- Displacement, amplitude, period, frequency, wavelength, speed ($v = f\lambda$)
- Graphical representation — transverse and longitudinal
- Energy transfer by waves, intensity ($I \propto \text{amplitude}^2$)
- Inverse square law for point sources
- Polarisation (transverse waves), Malus' law ($I = I_0 \cos^2 \theta$)

Chapter 9: Waves II

- Principle of superposition in 1D
- Standing waves for a general wave — formation, nodes, antinodes (pressure vs displacement for sound)
- Examples: microwaves, strings, air columns, wavelength determination
- Qualitative understanding: Huygens' Principle
- Diffraction, interference, coherence, phase and path difference
- Two-source interference — conditions, double-slit ($a\lambda/D = \lambda$)
- Diffraction grating ($a \sin \theta = n\lambda$), wavelength determination
- Single-slit diffraction — first minima ($b \sin \theta = \lambda$)
- Rayleigh criterion for resolution ($\theta \approx \lambda/b$)

SECTION III: Gravity

Chapter 10: Gravity

- Concept of field: quantity as a function of coordinates
- Newton's law of gravitation ($F = Gm_1m_2/r^2$) [change it to vector form]
- Gravitational field strength — definition ($g = F/m$) and point mass formula ($g = GM/r^2$)
- Field lines — uniform and radial
- Gravitational potential ($\phi = -GM/r$) and potential energy ($U = -GMm/r$)
- Field strength as negative potential gradient
- Escape velocity — energy considerations
- Circular orbits — equating gravitational force to centripetal force
- Geostationary satellites — characteristics and applications

SECTION IV: Electricity & Magnetism

Chapter 11: Electrostatics

- Electric field strength — definition ($E = F/Q$) [Change everything to vector form]
- Coulomb's law ($F = (1/4\pi\epsilon_0)(Q_1Q_2/r^2)$)
- Field strength for point charge ($E = (1/4\pi\epsilon_0)(Q/r^2)$)
- Field lines and equipotentials
- Electric potential ($V = (1/4\pi\epsilon_0)(Q/r)$) and potential energy ($U = (1/4\pi\epsilon_0)(Q_1Q_2/r)$)
- Field strength as negative potential gradient
- Uniform fields between parallel plates ($E = V/d$), force on charge, motion of charged particles
- Capacitance ($C = Q/V$)
- Energy stored in a capacitor — $U = \frac{1}{2}QV = \frac{1}{2}Q^2/C = \frac{1}{2}CV^2$, area under V - Q graph
- Capacitors in series and parallel

Chapter 12: Circuit

- Electric current ($I = Q/t$), drift velocity ($I = nAvq$)
- Potential difference ($V = W/Q$)
- Electrical power ($P = VI = I^2R = V^2/R$)
- Distinguishing e.m.f. and p.d.
- Resistance ($R = V/I$), resistivity ($R = \rho l/A$)
- I–V characteristics — ohmic resistor, diode, filament lamp, NTC thermistor
- Temperature dependence of resistivity — metals (drift velocity), semiconductors (number density)
- Internal resistance — effect on terminal p.d. and output power
- Resistors in series and parallel
- Potential divider circuits — including thermistors and LDRs
- Charging and discharging a capacitor — $Q = Q_0[1 - e^{-t/\tau}]$, $Q = Q_0e^{-t/\tau}$, time constant $\tau = RC$

Chapter 13: Magnetostatics

- Magnetic field from currents and permanent magnets
- Field lines — long straight wire, flat circular coil, long solenoid
- Biot-Savart Law
- Magnetic flux density formulas: $B = \mu_0 I / (2\pi d)$, $B = \mu_0 NI / (2r)$, $B = \mu_0 nI$
- Force on current-carrying conductor ($F = BIl \sin \theta$), Fleming's left-hand rule
- Definition of magnetic flux density ($B = F/Il$ for \perp)
- Force between two current-carrying conductors
- Force on moving charge ($F = BQv \sin \theta$)
- Deflection of charged particles in electric and magnetic fields
- Velocity selection — crossed fields

Chapter 14: Electromagnetic Induction

- Magnetic flux ($\Phi = BA$), flux linkage ($N\Phi$)
- Experimental evidence — changing flux induces e.m.f.
- Faraday's law and Lenz's law — direction opposes change
- Simple applications
- Alternating current — period, frequency, peak value, r.m.s.
- Sinusoidal AC: $x = x_0 \sin \omega t$, $I_{\text{rms}} = I_0/\sqrt{2}$, $V_{\text{rms}} = V_0/\sqrt{2}$
- Mean power in resistive load — half peak power for sine wave

Chapter 15: Electrical Appliances

- Half-wave rectification using a single diode
- Ideal transformer — $N_s/N_p = V_s/V_p = I_p/I_s$, principle of operation

SECTION V: THERMAL PHYSICS

Chapter 16: Thermal Physics

- Thermodynamic temperature scale, absolute zero, conversion °C to K
- Ideal gas equation: $pV = NkT$
- Avogadro constant, molar gas constant, Boltzmann constant
- Kinetic theory assumptions
- Derivation of $pV = \frac{1}{3}Nm\langle c^2 \rangle$
- Mean translational KE = $\frac{3}{2}kT$
- Internal energy — sum of microscopic KE and PE, determined by macroscopic state
- Temperature — proportional to mean KE
- Thermal contact, thermal equilibrium, Zeroth law
- Work done by a gas ($W = p\Delta V$ at constant pressure)
- First law of thermodynamics ($\Delta U = Q + W$)
- Specific heat capacity and specific latent heat

SECTION VI: MODERN PHYSICS

Chapter 17: Quantum Physics

- Photoelectric effect — threshold frequency, evidence for particle nature
- Photon energy ($E = hf$) and momentum ($p = h/\lambda$)
- Electron diffraction — evidence for wave nature
- de Broglie wavelength ($\lambda = h/p$)
- Uncertainty principle
- Discrete electronic energy levels in atoms (e.g. hydrogen)
- Emission and absorption line spectra
- Photon transitions between energy levels

Chapter 18: Nuclear Physics

- Rutherford α -scattering — existence and small size of nucleus
- Nucleon number (A), proton number (Z), isotopes, notation A_ZX
- Spontaneous and random nature of decay, fluctuations in count rate
- Background radiation — origin and significance
- α , β , γ radiations — nature and properties
- Activity ($A = \lambda N$), decay constant
- Exponential decay: $x = x_0 e^{-\lambda t}$ (activity, undecayed nuclei, count rate)
- Half-life: $t_{1/2} = \ln 2 / \lambda$
- Applications and hazards of radioactivity (based on half-life, penetration, ionising ability)
- Nuclear equations and conservation laws (nucleon number, charge, mass-energy)
- Prediction of (anti)neutrino in β decay (conservation of momentum and energy)
- Mass defect, binding energy, $E = mc^2$
- Binding energy per nucleon vs nucleon number — graph and relevance to fusion and fission