Primary Mathematics

Beginning Algebra
intermediate algebra
trigonometry courses
course on complex Numbers
overview of primarily mathematics
Chris Pope's lecture notes:1, 2
The complex plane, Cauchy theorems and contour integration.

- [x] ~~Natural numbers: 1, 2, 3, ...~~
- [x] ~~Integers: ..., −3, −2, −1, 0, 1, 2, ...~~
- [x] ~~Rational numbers (fractions): 12, 14, 34, 23791773, ...~~
- [x] ~~Real numbers: Sqrt(2) = 1.4142135... , π = 3.14159265... , e = 2.7182818..., ...~~
- [x] ~~Complex numbers: 2+3i, eia= cos(a) + i sin(a), ... they are very important!~~
- [x] ~~Set theory: open sets, compact spaces.~~
- [ ] Topology.You may be surprised to learn that they do play a role indeed in physics!
- [ ] Algebraic equations. Approximation techniques.
- [ ] Series expansions: the Taylor series.
- [ ] Solving equations with complex numbers.
- [ ] Trigonometry: sin(2x)=2sin x cos x, etc.
- [ ] Infinitesimals. Differentiation. Differentiate basic functions (sin, cos, exp).
- [ ] Integration. Integrate basic functions, when possible.
- [ ] Differential equations. Linear equations.
- [ ] The Fourier transformation. The use of complex numbers. Convergence of series.
- [ ] The complex plane. Cauchy theorems and contour integration (now this is fun).
- [ ] The Gamma function (enjoy studying its properties).
- [ ] Gaussian integrals.
- [ ] Probability theory.
- [ ] Partial differential equations. Dirichlet and Neumann boundary conditions.

Classical Mechanics

An intermediate level course on Analytical Classical Dynamics
A good set of Lecture notes from Harvard
A short course on Classical Mechanics

- [ ] Static mechanics (forces, tension); hydrostatics.
- [ ] Newton’ s Laws
- [ ] The elliptical orbits of planets. The many-body system
- [ ] The action principle. Hamilton’ s equations.
- [ ] The Lagrangean. (Don’ t skip - extremely important!)
- [ ] The harmonic oscillator. The pendulum
- [ ] Poisson’ s brackets
- [ ] Wave equations.
- [ ] Liquids and gases.
- [ ] The Navier-Stokes equations.
- [ ] Viscosity and friction

Optics

A.A. Louro’s lecture Notes on Optics
R. V. Jones lecture notes on Classical and Quantum Optics

- [ ] Fraction and reflection
- [ ] Lenses and mirrors
- [ ] The telescope and the microscope
- [ ] Introduction to wave propagation
- [ ] Doppler effect
- [ ] Huijgens’ principle of wave superposition
- [ ] Wave fronts
- [ ] Caustics

Statistical Mechanics & Thermodynamics

The course “Statistical Mechanics”
Prof. Kelly’s lecture notes on Statistical Physics
Gould/Tobochnik lecture notes
Intermediate level course on Statistical Mechanics

- [ ] The first, second and third laws of thermodynamics
- [ ]

The Boltzmann distribution

- [ ] The Carnot cycle.
- [ ] Entropy.
- [ ] Heat engines
- [ ] Phase transitions.
- [ ] Thermodynamical models
- [ ] The Ising Model (postpone techniques to solve the 2-dimensional Ising Model to later)
- [ ] Planck' s radiation law (as a prelude to Quantum Mechanics)

Electronics

Lessons In Electric Circuits by T. R. Kuphaldt

(Only some very basic things about electronic circuits)

- [ ] Ohm' s law, capacitors, inductors
- [ ] Using complex numbers to calculate their effects
- [ ] Transistors, diodes (how these actually work comes later)

Electromagnetism

Electromagnetism by James Sparks
Notes on Classical Electromagnetism by R. Fritzpatrick
Bo Thide's EM Field theory text(advanced)
Worked out exercises from Jackson's book: Selection 1 / Selection 2

Maxwell' s Theory for electromagnetism:

- [ ] Homogeneous and inhomogeneous
- [ ] Maxwell' s laws in a medium. Boundaries.
- [ ] Solving the equations in:

  Vacumm and homogeneous medium (electromagnetic waves)

  In a box (wave guides)

  At boundaries (fraction and reflection)

- [ ] The vector potential and gauge invariance (extremely important)
- [ ] Emission and absorption on EM waves (antenna)
- [ ]

Light scattering against objects

Computational Physics

Even the pure sang theorist may be interested in some aspects of Computational physics.

Mathematica for Students of Science by James Kelly
Angus MacKinnon, Computational Physics
Prof. Mathews' projects on Numerical Analysis

Quantum Mechanics (Non-relativistic)

Introduction to QM and special relativity: Michael Fowler
Niels Walet lecture course on QM (Manchester)
Lecture Notes on QM from MIT: Undergraduate / Graduate
James Branson, Quantum Physics (UCSD)

MIT：Quantum Theory I

MIT：Quantum Theory2

MIT：Quamtum Physics1

MIT:Quamtum Physics2

MIT:Quamtum Physics2

UCSD：Quantum Physics

- [ ] Bohr' s atom
- [ ] DeBroglie' s relations (Energy-frequency, momentum-wave number)
- [ ] Schrödinger' s equation (with electric potential and magnetic field)
- [ ] Ehrenfest' s theorem
- [ ] A particle in a box
- [ ] The hydrogen atom, solved systematically. The Zeeman effect. Stark effect
- [ ] The quantum harmonic oscillator
- [ ] Operators: energy, momentum, angular momentum,
- [ ] Creation and annihilation operators
- [ ]

Their commutation rules

- [ ] Introduction to quantum mechanical scattering.
- [ ] The S-matrix.
- [ ] Radio-active decay

Atoms & Molecules

Notes on General Quantum Chemistry from Georgiatech
Lecture notes on Physical Chemistry by Darin J. Ulness

- [ ] Chemical binding
- [ ] Orbitals
- [ ] Atomic and molecular spectra
- [ ] Emission and absorption of light
- [ ] Quantum selection rules
- [ ] Magnetic moments

Solid State Physics

An introduction to Solid State Physics by Yuri M. Galperin
A course in Solid State Physics by Mark Jarrell
Solid State Physics: notes by Chetan Nayak (UCLA)

- [ ] Crystal groups
- [ ] Bragg reflection
- [ ] Dielectric and diamagnetic constants
- [ ] Bloch spectra
- [ ] Fermi level
- [ ] Conductors, semiconductors and insulators
- [ ] Specific heat
- [ ] Electrons and holes
- [ ] The transistor
- [ ] Supraconductivity
- [ ] Hall effect

Nuclear Physics

Five lectures on Nuclear Theory by D. B. Kaplan

Five lectures on Nuclear Theory by D. B. Kaplan
A primer in nuclear theory by J. Dobaczewski

- [ ] Isotopes
- [ ] Radio-activity
- [ ] Fission and fusion
- [ ] Droplet model
- [ ] Nuclear quantum numbers
- [ ] Magic nuclei
- [ ] Isospin
- [ ] Yukawa theory

Plasma Physics

Introduction to plasma physics by R. Fritzpatrick

- [ ] Magneto-hydrodynamics
- [ ] Alfvén waves

Advanced Mathematics

See John Heinbockel, Virginia.
See Chr. Pope: Methods2.
Mathematics textbooks list. (Link not working; working on finding an alternative)
G.'t Hooft: Lie groups in Physics, (now also in English) + exercises.
For Lie Groups, see also the last section of Chr. Pope's lectures (under "General Relativity").
The special functions and polynomials(PDF) (just understand the principles).

- [ ] Group theory, and the linear representations of groups
- [ ] Lie group theory
- [ ] Vectors and tensors
- [ ] More techniques to solve (partial) differential and integral equations
- [ ] Extremum principle and approximation techniques based on that
- [ ] Difference equations
- [ ] Generating functions
- [ ] Hilbert space
- [ ]

Introduction to the functional integral

Special Relativity

Peter Dunsby's lecture course on tensors and special relativity
Prof. Firk's book on Special Relativity

- [ ] The Lorentz transformation
- [ ] Lorentz contraction, time dilatation
- [ ] E = mc2
- [ ] 4-vectors and 4-tensors
- [ ] Transformation rules for the Maxwell field
- [ ] Relativistic Doppler effect

Advanced Quantum Mechanics

Prof. Stringari's course on Ultracold Fluids.
Introduction to the Quantum Hall effect by A.H. MacDonald
Introduction to Coherent States and Quantum Information Theory by K. Fujii
Tutorial on Quantum information by Peter Zoller
Intoduction to Quantum Computation by A. Chatterjee
Advanced QM by Freeman J. Dyson
K. Schulten's notes on advanced QM
James Branson, Advanced Quantum Theory

- [ ] Hilbert space
- [ ] Atomic transitions
- [ ] Emission and absorption of light
- [ ] Stimulated emission
- [ ] Density matrix
- [ ] Interpretation of QM
- [ ] The Bell inequalities
- [ ] Towards relativistic QM: The Dirac equation, finestructure
- [ ] Electrons and positrons
- [ ]

BCS theory for supraconductivity

- [ ] Quantum Hall effect
- [ ] Advanced scattering theory
- [ ] Dispersion relations
- [ ] Perturbation expansion
- [ ] WKB approximation, Extremum principle
- [ ] Bose-Einstein condensation
- [ ] Superliquid helium

Phenomenology

Lecture notes on phenomenology by R. Casalbuoni.
Paolo Franzini's notes on elementary particles.

Subatomic particles (mesons, baryons, photons, leptons, quarks) and cosmic rays; property of materials and chemistry; nuclear isotopes; phase transitions; astrophysics (planetary system, stars, galaxies, red shifts, supernovae); cosmology (cosmological models, inflationary universe theories, microwave background radiation); detection techniques.

General Relativity

Introduction + exercises by G. 't Hooft
Sean M. Carrol's lecture notes on GR
Chr. Pope, Geometry and Group Theory, PDF

- [ ] The metric tensor
- [ ] Space-time curvature
- [ ] Einstein' s gravity equation
- [ ] The Schwarzschild black hole
- [ ] Reissner-Nordström black hole
- [ ] Periastron shift
- [ ] Gravitational lensing
- [ ] Cosmological models
- [ ] Gravitational radiation

Cosmology

Cosmology and Astrophysics are relatively young branches of science where a lot is happening. It is recommended to take notice of these important subjects, and devote time on them according to your taste. Indeed you must know that there is feedback from cosmology, astrophysics and astroparticle physics in solving various physics questions. But I can go on this way: what about the physics of other special branches of science: biophysics, geophysics, the physics of music, ... I encourage you to search for other such subjects of interest on the web.

Astro-Physics & Astronomy

Cosmology and Astrophysics are relatively young branches of science where a lot is happening. It is recommended to take notice of these important subjects, and devote time on them according to your taste. Indeed you must know that there is feedback from cosmology, astrophysics and astroparticle physics in solving various physics questions. But I can go on this way: what about the physics of other special branches of science: biophysics, geophysics, the physics of music, ... I encourage you to search for other such subjects of interest on the web.

Quantum Field Theory

Pierre van Baal's notes on QFT.
The Conceptual Basis of Quantum Field Theory by G. 't Hooft
A chapter in Handbook of the Philosophy of Science.
Magnetic monopoles and instantons.

- [ ] Classical fields: Scalar, Dirac-spinor, Yang-Mills vector fields.
- [ ] Interactions, perturbation expansion. Spontaneous symmetry breaking, Goldstone mode, Higgs mechanism.
- [ ] Particles and fields: Fock space. Antiparticles. Feynman rules. The Gell-Mann-Lévy sigma model for pions and nuclei. Loop diagrams. Unitarity, Causality and dispersion relations. Renormalization (Pauli-Villars; dimensional ren.) Quantum gauge theory: Gauge fixing, Faddeev-Popov

determinant, Slavnov identities, BRST symmetry. The renormalization group. Asymptotic freedom.

- [ ] Solitons, Skyrmions. Magnetic monopoles and instantons. Permanent quark confinement mechanism. The 1/N expansion. Operator product expansion. Bethe-Salpeter equation. Construction of the Standard Model. P and CP violation. The CPT theorem. Spin and statistics connection. Supersymmetry.

Supersymmetry & Supergravity

Astro Particle Physics

Super String Theory

Introduction + exercises
E. Kiritsis' Introduction to Superstring Theory
A more general site for superstrings