

Excursions in Computing Science: Table of Contents

T. H. Merrett*
McGill University, Montreal, Canada

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Week i. Rules and Calculations
Week ii. Powers and Trees
Week iii. Bases and Polynomials
Week iv. Space Math
Week v. Milli-micro-nano-...math Part I
Week v. Milli-micro-nano-...math Part II
Week 1. Polarized Light
Week 2. Operators
Week 3. Speed of Light
Week 4. Two-dimensional Numbers and Turtles
Week 5. Particles with Periods
Week 6. Spin
Week 7a. $E = mc^2$
Week 7b. Quantum Computing (Patrick Hayden)
Week 7c. Coordinates, Angles and Reality
Week 8. Higher Dimensions: 2D Graphics and Internet Search
Book 8c. Symmetry: Simplifying Matrices. Part I Discrete symmetries and molecules.
Book 8c. Symmetry: Simplifying Matrices. Part II Infinite symmetries and crystals.
Book 8c. Symmetry: Simplifying Matrices. Part III Continuous symmetries and the atom.
Book 8c. Symmetry: Simplifying Matrices. Part IV Abstract symmetries and lots of physics.
Book 8d. Rocket Science. Part I Propulsion.
Book 8d. Rocket Science. Part II Orbits.
Book 8d. Rocket Science. Part III The Space Adventure.
Book 8d. Rocket Science. Part IV Spaceship Earth.
Book 8d. Rocket Science. Appendix. Trigonometry and calculus.
Week 9. Many Dimensions: Data Compression and Content
Book 9c. Heat: Histograms and Gases Part I. Histograms, etc.
Book 9c. Heat: Histograms and Gases Part II. Heat.
Book 9c. Heat: Histograms and Gases Part III. Linear Thermodynamics.
Book 9c. Heat: Histograms and Gases Part IV. Melt, Boil, Condense, Freeze
Week 10. The laws of thought
Week 11. Memory, Feedback and Automata
Book 11c. Geometry and Gravity Part I. Fields, Complementary Coordinates, Curved Space
Book 11c. Geometry and Gravity Part II. Gravity
Book 11d. Forces and Invariants Part I. Electrostatics and Electromagnetism
Book 11d. Forces and Invariants Part II. Partial Slope Equations and Quantum Mechanics
Book 11d. Forces and Invariants Part III. Quantum Electromagnetism

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Book 11d. Forces and Invariants Part IV. Quantum Field Theory: Matrix Quantum Mechanics
Book 11d. Forces and Invariants Part V. Functional Integrals
Book 11d. Forces and Invariants Part VI. Quantum Computing
Week 12. Memory and Programming Language: Recursion and Instantiation

Wk Bk	Part	Note	Ex	Page	Topic
i		01		001	Rules and sums.
i		02		003	Some visualizations.
i		03		005	Rules and differences
i		04		005	Rules and programming.
i		05		009	Reasoning with rules.
i		06		010	Square roots and cube roots
i		07		010	Primes.
i		08		012	Multiplication: rectangles.
i		09		012	Division: slopes.
i		10		013	Negative numbers.
i		11		013	Pictures of rules.
i		12		015	Nonlinear plots.
i			01	016	Mathematical truth
i			02	017	Counting in tongues.
i			06	017	Squares.
i			07	017	Cubes.
i			08	017	Simplex numbers.
i			09	018	Hypercube numbers.
i			23	020	Simplexes: higher-dimensional triangles.
i			24	020	Hypercubes: higher-dimensional squares.
i			25	021	Hyperdipyramids: higher-dimensional squares, part 2.
i			40	024	<i>Sieve of Eratosthenes</i>
i			41	025	Rectangular numbers: multiplication
i			44	025	Al jabr
i			44	025	The mystery of cancellation.
i			45	025	Slopes: division
i			45	026	Approximate arithmetic
i			46	027	Brocot fractional approximation
i			47	027	Better than Brocot - continued fractions.
i			48	029	Making fractions clear.
i			49	030	Coprimes and greatest common divisor.
i			50	030	Modular arithmetic and Euclid's algorithm.
i			51	031	Euclid's algorithm.
i			52	032	How many intervals?
i			53	035	Fermat and Euler on modular powers.
i			54	036	Secret codes and encryption.
i			55	038	Cracking RSA.
i			56	039	Fermat's little theorem again.

Wk Bk	Part	Note	Ex	Page	Topic
ii		01		001	Powers.
ii		02		001	Trees
ii		03		003	Inverting trees.
ii		04		004	Properties of powers.
ii		05		005	Interest.
ii		06		006	Binomial coefficients.
ii		07		007	Factorials.
ii		08		008	Really big numbers.
ii		09		014	Really small numbers.
ii			01	017	Perfect numbers
ii			15	019	Golden ratio.
ii			34	023	Monotonic paths.
ii			38	024	(Zeno's dichotomy paradox.)
ii			40	024	Factorial trees.
ii			41	024	Choose trees.
ii			42	025	Ways trees.
ii			47	026	Nine constellations.
ii			60	031	Hypercubes.
iii		01		001	Base 10.
iii		02		003	Base 2.
iii		03		004	Base 3.
iii		04		006	Bases and powers.
iii		05		006	Rationals < 1.
iii		06		007	The Genetic Code.
iii		07		008	Polynomials.
iii		08		009	Multiplying polynomials.
iii		09		010	Polynomial division.
iii		10		012	Bases and polynomials
iii			14	015	Z-order
iii			27	018	Legendre polynomials.
iii			27	018	Hermite polynomials.
iii			29	018	Modular arithmetic.
iv		01		001	Matrix multiplication.
iv		02		002	Vectors.
iv		03		003	Identity matrix.
iv		04		003	Matrix inverse.
iv		05		004	Vectors in space.
iv		06		006	Positions and intervals.
iv		07		006	Transforming space.
iv		08		007	Rotations.
iv		09		008	Shear.
iv		10		009	Diagonalizing matrices.
iv			09	014	Cosine and sine.
iv			10	017	2-dimensional numbers
iv			11	017	Three-dimensional rotations.
iv			16	019	Velocities in timespace.
iv			17	021	Reflections, etc.
iv			21	023	Projection and reflection.
iv			22	024	Diagonalizing matrices.
iv			23	027	Array addressing.
iv			24	028	Simplex arrays.

Wk Bk	Part	Note	Ex	Page	Topic
v	1	01		001	Solving $x^2 - x - 1 = 0$
v	1	02		001	Picture of $x^2 - x - 1 = 0$
v	1	03		002	Cartesian Plane.
v	1	04		004	Symmetry.
v	1	05		004	Functions.
v	1	06		006	Zeros of a function.
v	1	07		006	Symmetry, again.
v	1	08		007	Slopes.
v	1	09		010	Slopes of curves.
v	1	10		012	Centering.
v	1	11		013	Limits.
v	1	12		015	Back to the zeros of $\frac{5}{2}x^2 - \frac{1}{2}x - 2$.
v	1	13		016	Square roots.
v	1	14		018	Self-slope.
v	1	15		020	Infinite series.
v	1	16		021	Programming the infinite series.
v	1	17		023	Slope equations.
v	1	18		024	Ninety-degree rotations.
v	1	19		026	Two-dimensional numbers.
v	1	20		027	Slope of c and s.
v	1	21		028	Connecting with slope equations.
v	1		06	029	Mensuration
v	1		08	030	Inverses.
v	1		09	031	Radians.
v	1		10	031	Rotation generators.
v	1		11	032	3D rotation generators.
v	2	01		001	Cube root of 8.
v	2	02		002	Slope.
v	2	03		002	Approximations.
v	2	04		003	Slope of cubic.
v	2	05		003	The root.
v	2	06		004	Square roots.
v	2	07		004	Antislopes.
v	2	08		005	Areas.
v	2	09		008	Volumes.
v	2	10		009	Antislopes and areas.
v	2	11		010	The Fundamental Theorem of Calculus.
v	2		01	011	Throwing balls: parabola and square roots.
v	2		04	013	Pythagoras.
v	2		11	016	Gini and IGE.
v	2		11	018	Least squares fit.
v	2		11	019	Minimizing.
01		01		001	One polarizing filter
01		02		002	Two polarizing filters
01		03		003	Theory
01		04		004	Cosine
01		05		005	A third polarizing filter
01		06		005	Theory predicts
01		07		007	Theory predicts wrong?
01		08		007	Two polarizing filters again
01		09		008	Testing theory
01		10		008	Theory fixed
01		11		009	Algorithm for scientific theories.

Wk Bk	Part	Note	Ex	Page	Topic
01			01	010	Quantitative thinking is important.
01			03	010	Measuring angles.
01			06	011	(Trig. and triangles)
01			07	011	Eugene's Clock
01			08	012	Celtic knots and other fun with cos and sin.
01			14	016	Useful cos and sin.
01			15	017	Trigonometry can help us locate the stars.
01			16	021	Hyperspheres.
01			19	022	Can quantum physics be made more complete?
01			20	024	Quantum key distribution.
02		01		001	Operators - polarizing light
02		02		002	Light beam as vector
02		03		002	Horizontal component
02		04		002	Component at angle
02		05		003	Vector multiplication
02		06		005	Polarizing filter as projection operator
02		07		005	Three projections
02		08		006	c^2 , s^2 , cs
02		09		007	two rotations, Pythagoras
02		10		008	product of functions, sum of arguments
02			02	009	values for cos, sin
02			16	011	linear operator
02			17	012	ruler and compass
03		01		001	time and distance
03		02		001	speed
03		03		001	timespace, Galileo, Stan and Trav
03		04		003	maximum speed
03		05		004	modifying Galileo, eigenvalues
03		06		005	matrix from fixed directions, eigenvalues
03		07		005	unit determinant
03		08		006	Digression on determinants.
03		09		007	Lorentz transformation
03		10		009	Using the Lorentz transformation.
03		11		010	Physical principles behind special relativity.
03			18	012	time dilation
03			19	013	Lorentz ($c \neq 1$).
03			20	013	The weird fizzle matrices.
04		01		001	Matrices as numbers?
04		02		001	One-dimensional numbers and 90-degree rotation
04		03		001	90-degree rotation as $\sqrt{-1}$
04		04		002	$\cos + \sqrt{-1}\sin$ as rotation
04		05		002	$x + \sqrt{-1}y$ as vector
04		06		002	$\sqrt{-1}$ as "imagine that!", 2-dimensional numbers
04		07		003	formal properties of numbers
04		08		003	Adding 2-numbers
04		09		003	Multiplying 2-numbers
04		10		004	Turtle graphics. Total Turtle Turning

Wk Bk	Part	Note	Ex	Page	Topic
04			01	006	De Moivre
04			03	007	Logo programming language
04			04	007	Army ant Eciton burchellie bivouacs
04			05	007	Treasure Island
04			06	008	Interpreting numbers
04			07	008	Moving parabolas and their shadows
04			09	010	Roots of unity.
04			10	010	Conjugates.
04			11	010	shear and 2-numbers
04			12	010	eigenvalues of rotation
04			13	011	anticommuting matrices
04			14	011	Fourier transform inverse
04			15	011	field axioms
04			16	011	ruler and compass cannot trisect angles
04			18	011	Field trip modulo arithmetic, solving by radicals
04			21	014	ring axioms
04			22	014	“Symmetric polynomials”.
05		01		001	Amplitudes as 2-numbers
05		02		001	Photons
05		03		002	Feynman’s rules
05		04		002	Probabilities for Young’s double slit
05		05		003	Wavelength
05		06		004	Trigonometry for double slit
05		07		005	Light travels in straight lines
05		08		007	Two ways to collide alpha-particles
05		09		008	Two ways to collide electrons - new Feynman rule - bosons, fermions
06		01		001	States.
06		01		001	Two polarization states of light
06		02		001	Two polarization states of electrons
06		03		002	Euler angles, transformation matrix
06		04		003	Half angles
06		05		003	Pauli matrices
06		06		003	Special Euler angles
06		07		004	Transforming amplitudes
06		08		004	Two q-bits
06		09		004	Symmetric and antisymmetric states
06		10		005	Spin-1 and polarized light
06		11		005	Circular to linear polarization
06		12		006	Linear polarization rotates in two dimensions
06		13		006	Lightspeed eliminates a third dimension
06		14		007	Fermions and Bosons.
06			11	008	Spin 3/2.
06			12	010	Spin 2.
06			15	010	The periodic table

Wk Bk	Part	Note	Ex	Page	Topic
07a		01		001	Overview.
07a		02		001	Phase of particle $e^{-i\omega t}$
07a		03		002	Phase is independent of observer
07a		04		002	Energy, momentum and frequency, wavenumber - Planck's constant
07a		05		003	Anti-Pythagoras
07a		06		003	Interval is invariant
07a		07		004	Dimensional analysis and pre-timespace limits.
07a		08		004	The pre-timespace limit for freqnum.
07a		09		005	Gives the transformation of energentum, $E^2 - c^2 p^2 = m^2 c^4$
07a		10		005	Energentum is conserved.
07a		11		006	Inelastic collisions
07a		12		006	Centre-of-mass reference frame
07a		13		007	Fusion
07a		14		007	Fission
07a		15		008	Elastic collision
07a		16		009	Equations of relativistic quantum mechanics
07a			01	010	Waves
07a			02	010	Visualizing waves
07a			11	012	Spin statistics, etc.
07a			16	013	Energy bands in crystals
07b		01		001	Strong Church-Turing thesis
07b		02		001	Switch-light question needs 1 function call
07b		03		001	Logic circuits and gates, not, Hadamard
07b		04		003	Classical circuit for switch-light
07b		05		003	Quantum circuit for switch-light
07b		06		004	State space and entanglement
07b		07		005	Developments after Deutsch's seminal 1985 paper
07b		08		005	Physical construction of quantum computers
07c		01		001	Vectors are real.
07c		02		002	Some pairs are not vectors
07c		03		003	Height, width as eigenvalues not coordinates
07c		04		004	Is twirl a tensor?
07c		05		005	Twirl and area are "pseudovectors" or "axial vectors"
07c		06		006	Vectors and Areas and .. All Together
07c		07		007	Rotation
07c		08		008	Reflection
07c		09		009	3D rotations
07c		10		010	Intervals plus locations.
07c		11		010	Interval algebra in 3D.
07c		13		013	Appendix; Summary of vector and matrix operations
07c			01	014	Dot product.
07c			16	015	Tetrahedron.
07c			20	017	Five Platonic solids
07c			24	017	Euler's formula, edges, faces, vertices
07c			26	018	Relational composition
07c			30	019	Direction cosines.
07c			31	020	Gibbs cross product
07c			32	020	Nonorthogonal axes and tensor notation.
07c			33	024	Tensor Calculator I. Matrix representation.
07c			34	026	Tensor Calculator I. Relational representation.
07c			37	031	Factoring sums and differences of squares by Clifford algebra.
07c			38	031	Matrix representations of Clifford "numbers".
07c			39	033	Matrix Mechanics.
07c			40	038	Spin and Clifford Algebra.
07c			41	045	Creation and Annihilation.

Wk Bk	Part	Note	Ex	Page	Topic
08		01		001	Importance of a web page - cycles
08		02		002	Importance of a web page - no cycles
08		03		003	Add equal columns of small numbers as source vector
08		04		004	Linear equations - Elementary row operations
08		02		005	Gauss elimination
08		06		006	3D for 2D graphics - tetrahedron to triangle to collinear
08		07		007	Sketchpad example 1 (linear constraint)
08		08		008	Sketchpad example 2 (nonlinear constraint)
08		09		010	Iterate!
08		10		011	Underdetermined equations - Sketchpad example 3 (point collinear with li
08		11		012	Minimize subject to constraint
08		12		013	Overdetermined equations
08		13		014	Overdetermined equations
08			10	017	Factor analysis/Principal components analysis in the measurement of personal
08			14	021	Null spaces and stoichiometry.
08			15	024	Quadratic forms and stability.
08			16	025	Binomial coefficients
08			28	027	Slopes of cos and sin.
08			38	032	Surveying
08c	1	01		001	Triangle symmetry
08c	1	02		002	Generating reflections
08c	1	03		002	Permutation notation
08c	1	04		003	Group properties
08c	1	05		003	Reflecting rotations, rotating reflections
08c	1	06		004	Invariant sets
08c	1	07		005	Invariant (normal) subgroups
08c	1	08		005	Matrix invariant sets share eigenvalues, determinant, trace
08c	1	09		006	Other representations - trivial, direct, permutation
08c	1	10		007	Using traces to block-diagonalize a whole matrix representation
08c	1	11		008	Regular representation
08c	1	12		010	Molecules 1D
08c	1	13		012	Triangle molecule
08c	1	14		017	Greenhouse gases CO₂
08c	1	15		018	Greenhouse gases H₂O
08c	1	16		019	Tetrahedron.
08c	1	17		024	Hexa/Octahedra.
08c	1	18		025	Dodeca/Icosahedra.
08c	1		06	028	Car wheels
08c	1		37	031	Spring constants.
08c	1		53	034	Symmetric field trip - Galois and the quintic
08c	2	19		002	Infinite groups
08c	2	20		003	1D crystals, gratings, CDs
08c	2	21		006	2D crystals
08c	2	22		011	2D waves
08c	2	22		012	Periodic boundary conditions
08c	2	23		015	Brillouin zone.
08c	2	24		016	Non-translational crystal symmetries.
08c	2	25		016	Wallpaper groups.
08c	2		03	022	poetic symmetry
08c	2		04	023	CDs and DVDs
08c	2		13	023	Dot product.
08c	2		23	026	Wallpaper groups.
08c	2		38	028	Periodic interactions, vernier, moiré

Wk Bk	Part	Note	Ex	Page	Topic
08c	3	26		002	Continuous groups.
08c	3	27		004	Spherical symmetry.
08c	3	28		006	Commutator algebra.
08c	3	29		007	Representations of the spherical group.
08c	3	30		013	Spherical harmonics, slope rules
08c	3	31		020	Atomic physics.
08c	3		06	027	Angular momentum
08c	3		09	027	Kepler II.
08c	3		12	028	Half-Pauli matrices
08c	3		16	028	Commutator algebra, Lie groups
08c	3		22	029	Slope rules, product rule, chain rule
08c	3		35	030	Bohr atom.
08c	3		36	031	Kepler III
08c	3		37	032	Conic sections.
08c	3		38	034	Kepler I.
08c	4	32		002	SU(2) formal and informal.
08c	4	33		006	SU(3).
08c	4	34		013	Isospin and quarks
08c	4	35		016	Symmetry and Conservation; Complementary Quantities
08c	4	36		017	Symmetry and Conservation; Energy
08c	4	37		020	Principle of Stationary Action.
08c	4	38		028	Symmetry and Conservation; Noether's Theorem
08c	4	39		030	The Hamiltonian and Schrödinger's Equation
08c	4		19	037	Billiards.
08c	4		20	040	Molecules
08c	4		21	042	Forces and deformations.
08c	4		22	047	Spring oscillators.
08c	4		25	049	Potential energy
08c	4		37	050	Legendre transformation.
08c	4		41	052	Dirac equation
08d	1	01		001	The rocket equation.
08d	1	02		004	Specific impulse.
08d	1	03		004	Fuels.
08d	1	04		010	Multistage rockets.
08d	1	05		010	Thrust.
08d	1	06		011	Photon sails.
08d	1	07		014	Solar wind.
08d	2	08		001	Ideology.
08d	2	09		003	Circles and ellipses.
08d	2	10		005	Pythagoras.
08d	2	11		006	Circular orbits.
08d	2	12		008	Finding and using GM_{Earth}.
08d	2	13		009	Weighing Earth and Sun.
08d	2	14		010	The Solar planets.
08d	2	15		011	Transfer orbits.
08d	2	16		012	Velocities in elliptical orbits.
08d	2	17		014	Momentum and kinetic energy.
08d	2	18		016	Potential energy.
08d	2	19		017	Delta-V for orbit changes.
08d	2	20		018	Surface to LEO.
08d	2	21		019	Travelling the solar system.
08d	2	22		025	Launch windows.
08d	2	23		027	Conic sections.
08d	2	24		031	Gravity assist.
08d	2	25		032	Resonances.
08d	2	26		037	Tides.
08d	2	27		042	The Lagrange points.

Wk Bk	Part	Note	Ex	Page	Topic
08d	3	28		002	Economics.
08d	3	29		006	Microgravity.
08d	3	30		007	Radiation.
08d	3	31		012	Space debris.
08d	3	32		016	Space elevator.
08d	3	33		020	Ecology.
08d	3	34		022	Population.
08d	3	35		023	Genetics.
08d	3	36		025	History.
08d	3	37		026	Self-reproducing probes.
08d	3	38		030	“Where Are They?”
08d	4	39		002	Speeds.
08d	4	40		005	Extinctions.
08d	4	41		006	Herd science.
08d	4	42		007	Climate.
08d	A	43		002	Trigonometry.
08d	A	44		005	Integral calculus.
08d	A	45		010	Differential calculus.
09		01		001	2D numbers give 5D vector space
09		02		002	Fourier transform, FT
09		03		004	Approximating function using important frequencies only
09		04		005	Joint Photographic Experts Group, JPEG
09		05		007	The fast Fourier transform, FFT
09		06		009	Divide and Conquer
09		07		010	The Uncertainty Principle
09		08		012	Compression and Content
09			14	014	FFT again.
09			17	015	Modified inverse FT.
09			18	017	FT with vector k, ℓ.
09			19	019	Continuous FT.
09			20	020	Artefacts of sampling.
09			23	022	Two-dimensional discrete Fourier transform
09			24	022	Digital signal processor, DSP filters.
09			25	033	Tachyons faster than light

Wk Bk	Part	Note	Ex	Page	Topic
09c	1	01		001	Histograms.
09c	1	02		002	Histogram arithmetic.
09c	1	03		005	Distributions and densities.
09c	1	04		007	Aggregates; the moments of distributions.
09c	1	05		011	Quantum distributions: the density matrix.
09c	1	06		014	The normal distribution.
09c	1	07		021	Expectation, surprise and ignorance.
09c	1	08		024	Does ignorance ever decrease?
09c	1	09		028	Inside knowledge; the clients of Joe and Sue revisited.
09c	1	10		031	Correlation and co-ignorance.
09c	1	11		034	Conditional distributions and ignorance.
09c	1		07	042	Program to add histograms
09c	1		13	043	Mean, median, mode.
09c	1		14	044	Geometric and harmonic means.
09c	1		22	045	Notation, integrals and antislopes
09c	1		24	046	Legendre and Hermite polynomials.
09c	1		34	051	Increasing ignorance.
09c	1		38	053	Newton's method 1.
09c	1		39	055	Newton's method 2.
09c	1		40	057	Continuous distributions.
09c	1		41	058	More on continuous distributions.
09c	1		42	059	Ignorance and continuous distributions.
09c	1		43	061	Continuous distributions by antislope: average distance.
09c	1		44	064	Hyperspheres.
09c	1		46	068	Geometrical interpretations of constant sums.
09c	1		47	069	Simplex coordinates.
09c	1		48	069	When is a distribution the product of its marginals?
09c	1		49	070	Mutual information from Chesapeake clams.
09c	1		51	072	Ascendency.
09c	1		52	074	A playpenful of baby ecologies.
09c	1		53	077	Maximizing ascendency.
09c	1		59	078	Black boxes.
09c	1		61	080	Thongs.
09c	1		62	081	Order of a symbol system.
09c	1		63	082	Marilyn vos Savant on the Monty Hall problem.
09c	1		64	083	Decision trees.
09c	2	12		001	A gas simulation 1; the collisions
09c	2	13		011	A gas simulation 2; statistics.
09c	2	14		016	The Boltzmann and Maxwell distributions.
09c	2	15		021	Fluctuations, variations and samples.
09c	2	16		026	Entropy.
09c	2	17		029	Temperature.
09c	2	18		035	Pressure.
09c	2	19		039	State function for monatomic gases.
09c	2	20		044	Thermostatic equations of state.
09c	2	21		048	More on multivariate slopes.
09c	2	22		052	Work and heat.
09c	2	22		057	Carnot's reversible heat engine, second law of thermodynamics
09c	2	22		061	Emergence.

Wk Bk	Part	Note	Ex	Page	Topic
09c	2		10	064	First simulation.
09c	2		11	064	Doves and hawks. (A kinetic theory of conflict, 1.)
09c	2		12	066	Dominance. (A kinetic theory of conflict, 2.)
09c	2		13	069	Hierarchies.
09c	2		14	071	Cycles.
09c	2		19	074	Maxwell distribution.
09c	2		29	075	Sackur-Tetrode equation.
09c	2		32	076	Local inverses of functions.
09c	2		33	077	Complementary variables.
09c	2		45	078	Causality.
09c	2		46	079	Emergence
09c	3	23		002	Correlation.
09c	3	24		012	Collision theory.
09c	3	25		016	Mobility, diffusivity and Brownian motion.
09c	3	26		019	Three potentials and dissipation.
09c	3	27		022	Active transport and biochemistry.
09c	3	28		024	Combined transport. Onsager relations.
09c	3		05	027	Least squares filter.
09c	3		19	029	Kirchhoff circuits.
09c	3		20	030	Resistors in series and parallel.
09c	3		21	031	Kirchhoff lattices; relations and operators.
09c	3		24	037	Viscosity and heat conduction.
09c	3		25	041	“Ohm’s law” for viscosity.
09c	3		26	041	Elasticity and viscosity: stress, strain and flow tensors. Poisson’s ratio
09c	3		26	044	Hookean solid.
09c	3		26	046	Newtonian liquid.
09c	3		26	047	Principal axes.
09c	3		27	048	Lattice statics and dynamics.
09c	3		30	056	Chemical kinetics and differential equations.
09c	3		30	062	Coupled linear first-order differential equations.
09c	3		31	075	Chemistry in the language of physics.
09c	4	29		002	Phase transitions.
09c	4	30		003	Phase transitions in random graphs.
09c	4	31		009	Point-to-point resistance in a network.
09c	4	32		012	Van der Waals.
09c	4	33		016	Sublimation.
09c	4	34		018	Ferromagnets.
09c	4	35		020	Particle individuality and Bose-Einstein condensation.
09c	4		06	027	Percolation.
09c	4		07	027	Point of inflection.
09c	4		21	029	Infinities.
09c	4		22	029	Gibbs’ paradox.
09c	4		23	030	Ovations.
09c	4		24	033	social phase transitions
09c	4		25	033	Power laws.
09c	4		26	033	Self-Organized Criticality.
09c	4		27	035	Ising model.
10		01		001	Axioms of an algebra
10		02		002	Boolean algebra of two elements
10		03		003	Implication operator
10		04		004	Sixteen binary operators
10		05		005	Switching circuits; halfadder, fulladder
10		06		007	Reversibility controlled-not, controlled-exchange
10		07		010	Operators as matrices
10		09		011	Appendix Binary Arithmetic

Wk Bk	Part	Note	Ex	Page	Topic
10			11	013	More than one kind of infinity
10			12	015	Continued fractions
10			26	017	Analogic reasoning
10			34	019	Sets and probability
10			36	036	Birthday paradox
10			37	020	Genetic overlap
10			52	021	Matrix logic.
10			53	024	xor and and .
10			54	026	C^kN circuits.
10			55	026	Basic matrices for logic.
10			60	028	Euclid's Elements.
11		01		001	Memory flipflop, feedback automata
11		02		005	Control thermostat
11		03		006	Electric blanket control
11		04		008	Biology the lac operon of E.coli, gene expression, attractors
11		05		009	Language parsing by finite automaton
11		06		011	evaluation by actions
11		07		013	nested parentheses and pushdown automaton
11		08		014	evaluation by reverse Polish; shunting
11		09		016	automata hierarchy
11			22	018	attractors
11			26	019	attractors
11			29	019	tipping point
11			30	019	gene expression, microarrays
11			35	021	rich and poor
11			37	022	Traffic memory.
11			40	023	concrete poetry
11			48	025	Turing machine
11c	1	01		001	Fields and slopes.
11c	1	02		002	"Reality" and coordinates.
11c	1	03		005	Index notation and tensors.
11c	1	04		008	Protors.
11c	1	05		011	The protor calculator 1.
11c	1	06		013	Divergence and Curl.
11c	1	07		018	Classical gravity.
11c	1	08		023	Gypsum coordinates.
11c	1	09		029	The metric.
11c	1	10		031	Fields in gypsum.
11c	1	11		035	Polar coordinates.
11c	1	12		037	The affine connection.
11c	1	13		041	Parallel transport and geodesics.
11c	1	14		043	Absolute slopes.
11c	1	15		046	Gradient, divergence and curl with absolute slope.
11c	1	16		049	Spherical polar coordinates.
11c	1	17		053	Curvature.
11c	1	18		061	Negative curvature.
11c	1	19		065	The Ricci tensor.
11c	1	20		067	More protor calculator.

Wk Bk	Part	Note	Ex	Page	Topic
11c	1		01	075	Slopes commute?
11c	1		13	077	Newton's constant.
11c	1		14	077	Gauss' law for volume and surface integrals
11c	1		15	077	Message through the Earth.
11c	1		16	079	Falling traffic lights
11c	1		23	081	Levi-Civita symbol, alternating tensors.
11c	1		24	083	Physical tensors.
11c	1		25	084	Orthonormal polars.
11c	1		36	087	Hotplate geometry.
11c	1		37	090	Absolute slope and curvature.
11c	1		38	090	Bianchi identities.
11c	1		39	091	Divergence-free curvature.
11c	1		40	092	Number of components of the curvature tensor.
11c	1		41	092	Angular excess at fixed latitude.
11c	1		42	096	Local flatness.
11c	1		43	099	The boundary of boundary is zero.
11c	1		46	100	Curvature of lines.
11c	1		49	104	What functions for ch, sh?
11c	1		51	106	Hyperboloid.
11c	1		52	107	Paraboloid.
11c	2	22		002	Curved timespace.
11c	2	23		005	Gravitational redshift.
11c	2	24		009	Spherically symmetric gravity.
11c	2	25		011	Schwarzschild orbits and black holes.
11c	2	26		016	Rotationally symmetric gravity.
11c	2	27		019	Kerr orbits and black holes.
11c	2	28		026	Tides.
11c	2	29		028	Light orbits.
11c	2	30		030	The source of gravity.
11c	2	31		033	Cosmology.
11c	2	32		037	Negative pressure and dark energy.
11c	2	33		039	Gravitational irreversibility.
11c	2	34		043	Alternatives to geometry.
11c	2		02	048	Schwarzschild metric.
11c	2		09	049	The ergosphere.
11c	2		24	052	Newtonian limit.
11c	2		25	052	Inflation.
11c	2		28	053	Negative energy; warp drives.
11c	2		29	056	Negative mass.
11c	2		30	056	Blandford-Znajek mechanism.
11c	2		32	056	Gravitational waves.
11d	1	01		001	Central Forces.
11d	1	02		004	Gravity vs. Electricity.
11d	1	03		004	Energy and momentum scales.
11d	1	04		008	Divergence, gradient and $\vec{\text{div}} \vec{\text{grad}}$.
11d	1	05		009	Electrodynamics departs from gravitation.
11d	1	06		013	Invariants, cross-products and convention.
11d	1	07		019	Electromagnetic waves.
11d	1		04	022	Gauss' law for fields from charge.
11d	1		09	022	Visualizing magnetic fields.

Wk Bk	Part	Note	Ex	Page	Topic
11d	2	08		001	Partial Slope Equations; Laplace's Equation.
11d	2	09		007	The Wave Equation.
11d	2	10		010	The Schrödinger Equation I; Physics.
11d	2	11		013	The Schrödinger Equation II; Animating in 1D.
11d	2	12		019	The Schrödinger Equation III; Animating in 2D.
11d	2		04	024	Stability of numerical solutions of the wave equation.
11d	2		05	025	The Hamiltonian.
11d	2		07	026	Dispersion relations.
11d	3	13		001	The electromagnetic Schrödinger equation.
11d	3	14		003	Simulating a charged wavepacket moving near a current.
11d	3	15		006	Links with geometry.
11d	3	16		008	Local action versus action-at-a-distance.
11d	3	17		009	Other symmetries, other forces.
11d	3		01	012	Aharonov-Bohm effect.
11d	3		03	013	Maxwell's tensor and equations.
11d	3		04	013	Gauge theory.
11d	3		06	014	Abelian and non-Abelian symmetries.
11d	3		07	016	Goldstone and Higgs mechanisms.
11d	3		08	020	Quarks and vacuum.
11d	4	18		001	Introduction to Quantum Fields.
11d	4	19		008	Small matrices.
11d	4	20		011	Tensor products.
11d	4	21		014	Spin.
11d	4	22		018	Vectors and spinors.
11d	4	23		021	Multiple and independent systems.
11d	4	24		024	A simple field.
11d	4	25		028	The Yukawa potential.
11d	4	26		031	Perturbation approximations.
11d	4	27		033	Fermions.
11d	4	28		035	Slopes and antislopes of 2D numbers, etc.
11d	4	29		042	Charge conservation and antimatter.
11d	4	30		045	Relativistic quantum field theory redux, so far.
11d	4		02	046	Heisenberg uncertainty.
11d	4		03	046	More uncertainty.
11d	4		06	048	Sphere of reflections.
11d	4		07	049	Density matrices and inverse tensor product.
11d	4		08	049	Certainty and entanglement.
11d	4		09	050	Can quantum physics be made more complete? (Part II).
11d	4		26	054	Tensor product transposes.
11d	4		31	054	Hermitian transposes of reflections, etc.
11d	4		33	055	Slopes of Clifford functions.
11d	5	31		002	Fermions.
11d	5	32		005	Functionals.
11d	5	33		008	Gaussian integrals.
11d	5	34		013	Diagrams and QED.
11d	5	35		016	Chirality and electroweak.
11d	5	36		023	Green's functions.
11d	5	37		030	Propagators.
11d	5		03	034	Programming path integrals.
11d	5		06	035	Matrix Gaussians.
11d	5		09	036	Even moments.
11d	5		14	037	Current from faze invariance.
11d	5		22	038	Huygens 3D.
11d	5		25	038	Feynman's program Hamiltonian.

Wk Bk	Part	Note	Ex	Page	Topic
11d	6	38		003	Quantum Computing.
11d	6	38		004	Quantum Computing Binary gates.
11d	6	38		008	Quantum Computing Measurement.
11d	6	38		012	Quantum Computing Ternary gates.
11d	6	39		012	Binary Fourier transform.
11d	6	40		013	Quantum Fourier transform.
11d	6	41		015	Finding periods.
11d	6	42		017	Quantum key distribution.
11d	6	43		018	No cloning.
11d	6	44		019	Database search.
11d	6	45		024	Detecting and correcting errors.
11d	6	46		028	Nonlocality; Einstein-Podolsky-Rosen.
11d	6	47		029	Building a quantum computer.
11d	6		07	033	Implement swap gate.
11d	6		10	034	Representing functions.
12		01		001	Recursion. Define “ancestor” in terms of “parent”.
12		02		001	Precedence without parentheses
12		03		002	Fractals
12		04		003	Mathematical induction.
12		05		004	Recursion. Programming languages.
12		06		004	L-systems
12		07		006	Instantiation.
12		08		007	Copying state.
12			07	009	Peano curve
12			13	010	Euler’s formula, edges, faces, vertices
12			14	010	<i>Hexagonal numbers</i>
12			18	012	Calculus.
12			19	017	Continuity.
12			20	019	Series. Binomial coefficients.
12			28	021	Fractional dimension