5×10^4 l.y. $\times$ 6×10^{12} m $\approx$ 2×10^{17} m

The Backbone of Darkness: An Introduction to the Natural Sciences

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I. The Strategy of ~~the Natural~~ Science

The rules of the game. "Common sense." The resistance to new ideas.
Experiment: The life of Leonardo da Vinci
(with excerpts from his work). Science, human welfare and war.
Physical + social sciences: a comparison.
The power of quantitative ~~information~~ reasoning: The identification of amino acids.
Laws of nature: why should the universe be comprehensible? Post hoc ergo propter hoc! arguments.
Alternative approaches: solipsism (sp?), arguments from design. Huygens' demonstration of marijuana on the planet Jupiter.
Langmuir on pathological science. Platt on alternative models. Scientists as human beings.
Folk science: astrology, ESP, UFO's.
Verifiability and prediction ~~Falsification~~ as a criterion of science.
Biological evolution.
The laws of nature are beautiful: Science as Art ~~Science~~
The laws of nature work: Science as Power

II. The Shape of the Earth: A Case Study

~~What~~ The sky and the Earth: what are they?

Primitive cosmologies.

Views of Pythagoras, Plato, Aristotle, Ptolemy and Aquinas (with sketches of their lives and excerpts from their works).

Scripture: the appeal to authority. Excerpts from A.D. White's "The Warfare of Science with Theology."

Evidence: the constellations at different latitudes

Ships and horizons

Eclipses: the Earth's shadow on the Moon

1519: Magellan

FM and TV transmission

The basis of scientific belief

~~Contemporary~~ Modern flat Earth societies: "That picture was faked."

The Earth from space: A collection of color photographs.

III. Distance

Units of distance: fermis, cm, l.y., Mpc. Powers of ten. Logarithms.

The measurement of distance:

Rulers

Microscopes, telescopes, and spectroscopes

Triangulation on Earth

Triangulation in space

The period-luminosity relation

Cepheid variables and RR Lyrae stars

The brightness of galaxies

The Doppler effect and Hubble's law.

The resolution of telescopes: Is there intelligent life on Earth? Military reconnaissance satellites.

Life as a disequilibrium phenomenon.

A logarithmic scale of distances (stills and/or movie after "The Universe in 40 Jumps.")

IV. Time

Units of time: picoseconds and aeons.

The measurement of time

Mechanical, electrical, + atomic clocks

Radioactive decay and paleontological dating

Ages of the Earth, the Moon, and the meteorites.

Stellar evolution and the ages of stars

Hubble's law and the age of the universe

Ancient history of the Earth (with illustrated Pesek painting?)

A logarithmic scale of distances (stills and/or movie)

Roemer and the velocity of light

V. ~~Matter~~ Matter

The evidence for atoms: Democritus to high-resolution electron microscopy. "Did you ever see one?"

Elementary particles. Waves and the uncertainty principle.

Matter is mostly nothing: electrical forces.

Matter and antimatter.

Cosmic abundances

Molecules: chemical bonds.

Organic chemistry

Life

Minerals

Planets

Stars

Galaxies

The gas laws. The Maxwell-Boltzmann distribution.

Units: cgs and others.

VI. Collision Physics: ~~Case Study of an Powerful~~
A Simple Theory of Great Power

The general theory
Bird-watching on Earth and life-detection on Mars
Molecular collisions
~~The definition of a~~ Planetary exosphere
~~Wh~~ Collisions of asteroids and comets with the Earth.
~~Digression: The work of Immanuel Velikovsky~~
~~Tooth~~ Are the planets remnants of a stellar collision?
Collision models of quasars
Galactic collisions and cosmic radio sources
The growth of interstellar grains
Is there life in interstellar space?

VII. Models of Planetary Motions
(with biographical sketches and excerpts from the works of leading practitioners)

The earliest view
Ptolemy
Copernicus
Galileo
Tycho
Kepler
Conic sections
Kepler's Laws

The nature of the problem: Search for a workable model. Occam's Razor.

VIII. An Introduction to Dynamics

The pre-Socratic paradox: constancy and change.
Common sense physics: Aristotle and Lucretius
Galileo: the influence of experiment.
Instantaneous quantities: Achilles and the tortoise
Calculus as an invention to cope with
the paradox of motion
The most elementary principles of
differential and integral calculus
Newton's laws of motion: a redefinition
of common sense
~~Falling bodies~~
Motion with constant acceleration
Falling bodies
Aircraft bombing runs
Naval gunnery
Digression: The social uses of science

IX. The Conservation of Energy

Conservation laws and the search for simplicity in nature
The definition of work and energy.
Equations of motion and energy conservation.
The transformation of energy.
Entropy and Lord Snow.
Entropy and biology.
Springs.
Pendulums. The measurement of gravity. Excerpts from "The Devil That Failed"

X. Rotating Coordinate Systems

Coordinate transformations: cartesian and polar coordinates. Sketch of the life of Descartes.
Pseudoforces
Centrifugal and centripetal force
Coriolis forces
Meteorology on rapidly and slowly rotating planets.

XI. The Conservation of Angular Momentum

Central forces and a new conservation law.
Ice skaters and piano stools
The distribution of angular momentum
— the solar system: a problem.
Solution I: planets are common throughout the galaxy
Solution II: Solar wind braking
The ecliptic plane.
Digression: The Age of Aquarius in the time of James Monroe.
The evolution of galaxies, with a portfolio of photographs
Pulsars and their origins

Connection with Kepler's second law.

XII. Gravitation and the Inverse Square Law

Early gravitational theories and analogies with light propagation.

The derivation from Kepler's laws.

"We recognize the lion by his paw print": the life of Newton

Gravitational force from a homogeneous sphere

Tests of the inverse square law: the motion of the Moon and of the Galilean satellites of Jupiter

Excerpts from Newton's work "If I have accomplished anything, it is by peering over the heads of dwarfs."

A Newtonian test of astrology.

Why is the inverse square law valid? The issue of meaningless questions.

"Space war," a computer game (with many illustration and/or a movie)

next p.

The meaning of action at a distance.

XIII. Applications of Kepler's Laws

The motion of the planets and satellites

Weighing the solar system

The motion and nature of comets (with a short picture collection). Early comet beliefs

Double and multiple star systems.

Planets of other stars: Barnard's star and van de Kamp's planets

Clusters of galaxies: orbits and stabilities

The Bohr atom: paradigm of a successful physical theory

Non-analogy of atomic and planetary systems. Excerpts from "He Who Shrunk"

Insert from previous p

XIV. Geophysics and Hydrostatic Equilibrium

Pressures in the ocean: scuba diving and deep-sea life

~~Thermometers~~ Barometers

Isostatic compensation

Continents and ocean basins

Continental drift

Sea-floor spreading

Plate tectonics

Project Mohole: Science, money, + politics

Differentiation and the early history of the Earth and the Moon

Lunar and Martian mascons

How deep can you dig a hole?

Heights of mountains on the Earth and elsewhere

Pressures at the centers of planets ~~and stars~~

Diamonds in meteorites: Urey's hypothesis of primary and secondary objects

How large can a potato-shaped moon be? Phobos and the asteroids

The structure of planetary atmospheres

Scale heights

Diffusive equilibrium

The exosphere mean free path

XV. Orbits

The energy equation for the inverse square

Graphical representation

Escape and circular velocities

Composition and evolution of planetary atmospheres: the theory of gravitational escape

Digression: Atmospheric pollution, ice ages, and greenhouse effects. The Venus runaway greenhouse.

Gravitational potential energy

The early evolution of stars

The melting of planets

Can interstellar organic molecules contribute to the origin of life?

Numerical calculation of inverse square orbits

Build your own universe: Graphical and numerical approaches to alternative force laws (with many illustrations and/or a movie)

XVI Spaceflight

Space vehicle mechanics. The rocket equation.
Earth satellites.
Trips to the Moon. Apollo and Lunakhod.
Hohmann interplanetary trajectories. ΔV.
The Mariner Mars 1971 mission
Swingby modes, and the Grand Tour.
Missions to near ~~interplanetary~~ interstellar space: The search for the heliopause
The ~~value of sp~~ human values of space exploration

XVIII. Craters

Volcanic vs. Impact craters on Earth (with illustration)

Energy vs. gravity scaling

Experimental Cratering from chemical and nuclear explosions (with stills and/or movies)

Counting craters and crater quality: the personal variable in science

Computer crater counting: man vs. machine

Crater frequency-diameter curves

Saturation cratering

Effects of erosion

Deducing the population of impacting objects

Lunar craters and the evolution of maria and highlands (with extensive Ranger, Lunar Orbiter and Apollo still and/or movie photography)

Martian craters and the evolution of the surface: ~~of Mars~~ Were there early oceans on Mars? ~~The~~ (with extensive Mariner 6+7 and Mariner 71 photography)

Radar maps of Venus: Long circular basins?

Collisions with the Earth: The Tunguska and Icarus episodes

Digression: The work of Immanuel Velikovsky

XIX Mechanics and Nuclear Physics: Life

Pressures at the centers of stars

Temperatures at the centers of stars

Nuclear reactions

Why does the Sun shine? ~~Inadequacy of~~

A chemical model

~~analog models~~

Accretion models

The age problem: Kelvin vs. Darwin

Stellar systematics: the Hertzsprung-Russell diagram

The ages of stars and the lifetimes of galaxies

G-star chauvinism: what stellar types are likely to have inhabited planets?

Are OH emission regions the work of extraterrestrial intelligence?

The origin of the chemical elements:

Primeval fireball and stellar interiors

Stellar evolution and supernovae

Main-sequence solar evolution: a paradox for the evolution of life, and its solution

Life as a consequence of stellar nucleosynthesis

The fate of the Earth

XX Mechanics and Nuclear Physics: Death

Practical application of science: the Prometheus legend

The physics of nuclear weapons: fission and fusion

~~Demonstration~~ Calculation of the weights of nuclear weapons from first principles

Delivery systems: missiles and suitcases

The effects of nuclear weapons: blast, firestorm, radiation; long-term medical and genetic consequences (with many illustrations and/or movies)

A short history of nuclear weapons development

Strategy: the balance of terror

ICBM, ABM, MIRV, + FOB: escalation, countermeasures, and penetration aids

Consequences of a "limited" nuclear exchange

The problem of nuclear war: accidental and otherwise; the n-nation problem.

The ~~$~~ dollar and human cost of strategic nuclear weapons

The physics of strategic missile systems.

XXI. Relativity

A re-examination of rulers and clocks:
common sense again

The Lorentz transformation

Equations of motion — special relativity

$E = mc^2$ and all that: popular attitudes to science

Einstein: a short biographical sketch

Relativistic interstellar spaceflight: can we circumnavigate the universe in a human lifetime?

Excerpts from Poul Anderson's "Tau Zero."

Ether and the Michelson-Morley experiment

General relativity

XXII. Cosmology

Why is the sky dark at night?

Quantitative Newtonian cosmological models with cosmological constant

Comparison with observation: big bang, steady state, and oscillating universes

The microwave background radiation: fires of creation?

The missing mass: is the universe open or closed?

Black holes in space: the Schwarzschild singularity

Quasar absorption lines and Lemaître universes

~~Cosmologies for other force laws~~

Build your own universe: cosmologies for other force laws

Causality in a collapsing universe: will effects precede causes?

Cosmology: an interface between science and religion

(full Britt. article!)

XXIII. Life ~~([illegible])~~

Definitions of life
- Physiological
- Metabolic
- Biochemical
- Genetic
- Thermodynamic

Life on Earth
- Mechanism and vitalism
- Nucleic acids
- Commonalities among organisms on Earth
- Metabolism
- Eucaryotes and procaryotes
- Metazoa, embryology and sex
- The varieties of organism and environments
- Behavior and sensory capabilities

Charles Darwin and the Voyage of the "Beagle": A biographical sketch with excerpts from his work.

~~The origin of life~~
- ~~Hypothesis of origin~~
- ~~The primitive atmosphere~~

XXIV. Exobiology

The origin of life

Hypotheses of origin

The primitive atmosphere

Production of simple organic molecules

Production of polymers

The origin of the genetic code

The earliest living systems

The antiquity of life

Extraterrestrial life

The chemistry of extraterrestrial life

Is there life beyond the Earth?

An exobiological survey of the solar system

Intelligent life beyond the solar system