

FUNDAMENTAL PHILOSOPHICAL QUESTIONS

PLATO IDEALISM

HUME REALISM

KANT ?

FOCUS ON SPACE

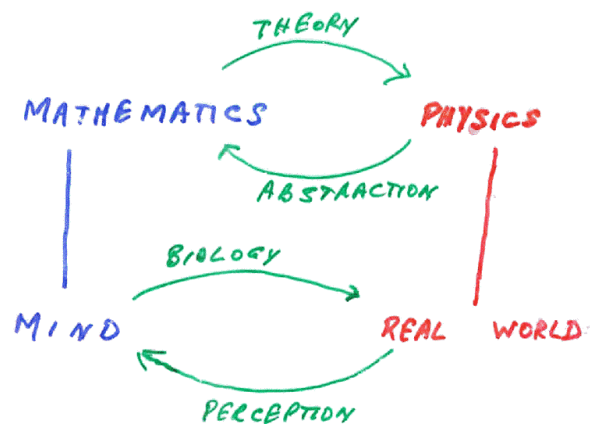
ROLE OF MATHEMATICS

WHAT IS THE NATURE OF

MATHEMATICS [GEOMETRY] ?



Plato



ARE MATHEMATICAL CONCEPTS
AND THEOREMS INVENTED OR
DISCOVERED ?

[NOTE ONLY AN INVENTION CAN BE
PATENTED !]

EXAMPLES NUMBERS

INTEGERS, RATIONALS, IRRATIONALS
TRANSCENDENTAL, IMAGINARY, COMPLEX

[KRONECKER: "GOD MADE THE INTEGERS
ALL ELSE WAS MADE BY MAN"]

COMPLEX NUMBERS SEEM A CONVINCING
EXAMPLE OF INVENTION

BUT ARE FUNDAMENTAL IN THE WORLD
OF QUANTUM PHYSICS

NON-EUCLIDEAN GEOMETRY - EINSTEIN
GENERAL RELATIVITY

ORTHODOX VIEW OF PHYSICISTS :

MATHEMATICS WAS DEVELOPED AS
A LANGUAGE AND TOOL TO DEAL
WITH THE PHYSICAL WORLD

BUT E. WIGNER REFERRED TO :
"THE UNREASONABLE EFFECTIVENESS
OF MATHEMATICS IN PHYSICS"

MANY (MOST?) MATHEMATICIANS STRONG
BELIEVERS IN PLATO'S VIEW OF
MATHEMATICS AS HAVING AN
EXISTENCE "OUT THERE" INDEPENDANT
OF PHYSICAL WORLD.

IN THE WORLD OF
IDEAS

ROGER PENROSE , ALAIN CONNES

MATHEMATICS ORIGINATES FROM
PHYSICAL WORLD BUT IS ORGANIZED
AND DEVELOPED BY HUMAN BRAIN

BIOLOGICAL PERSPECTIVE① EVOLUTIONARY EXPLANATION

MAN EVOLVED BY NATURAL SELECTION
SO HIS MIND IS ADAPTED TO ,
AND REFLECTS , PHYSICAL REALITY
MATHEMATICAL THINKING IS AN
INCIDENTAL CONSEQUENCE OF
EVOLUTION

RULES OF LOGIC DEDUCED FROM
EXPERIENCE OF CAUSE AND EFFECT

BUT [WIGNER]

IN EVOLUTION MAN ONLY HAD TO
DEAL WITH HUMAN SCALE - BUT
MATHEMATICS HAS BEEN ABLE TO
DEAL WITH THE VERY SMALL (NUCLEAR)
AND THE VERY LARGE (COSMOLOGY)
VERY SURPRISING!

② NEURO-PHYSIOLOGY

CURRENT RESEARCH SHEDDING

NEW LIGHT ON HOW BRAIN WORKS
(NATURE OF MIND)

(a) RULES OF LOGIC AND GRAMMAR

(UNDERPINNING MATHEMATICS & LANGUAGE)

APPEAR TO BE "HARD-WIRED" IN
BRAIN

WE WERE BORN WITH THE CAPACITY TO
DO MATHS. AND LEARN LANGUAGE

THIS CAPACITY IS A CONSEQUENCE OF
EVOLUTION

(b) NEW LIGHT ON CONSCIOUSNESS AND

FREE-WILL

EXPERIMENTS RAISE QUESTIONS
ABOUT CONSCIOUS DECISIONS

CONCLUSION

OLD PHILOSOPHICAL QUESTIONS

(INCLUDING NATURE OF MATHEMATICS)

WILL BE TRANSFORMED BY
FUTURE RESEARCH IN NEURO-
PHYSIOLOGY

COMPARE WHAT HAS HAPPENED
TO THE OLD QUESTION

"WHAT IS LIFE?"

MECHANISM OF THE
DOUBLE HELIX

DNA

OUR BRAIN INTERPRETS (OR PICTURES) OUTSIDE
WORLD IN ITS OWN TERMS ALREADY AN
ABSTRACTION PROCESS → MATHEMATICS

HISTORY OF PHYSICS

ANCIENT VIEW OF "HEAVENS"

MOTIONS OF PLANETS

PTOLEMY THEORY OF EPICYCLES

[CIRCLES ROLLING ON CIRCLES]

(CIRCLE = PERFECT SHAPE)

PTOLEMY THEORY AGREED VERY WELL

WITH OBSERVATION - LASTED 1000 YEARS

COPERNICUS SUN AT CENTRE

|| SIMPLER MATHEMATICAL THEORY
AIM OF ALL PHYSICS

KEPLER WANTED TO EXPLAIN

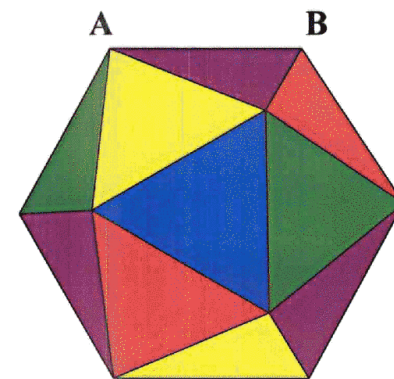
NUMBER OF PLANETS AND

SIZES OF THEIR ORBITS

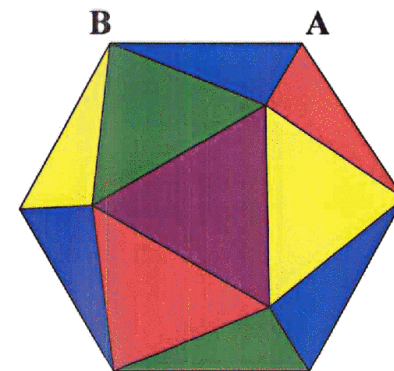
5
PLATONIC
SOLIDS

COMETS ? NEWTON - HALLEY

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Front



Back

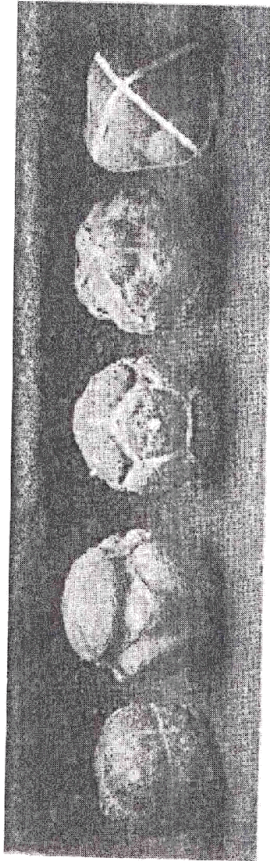
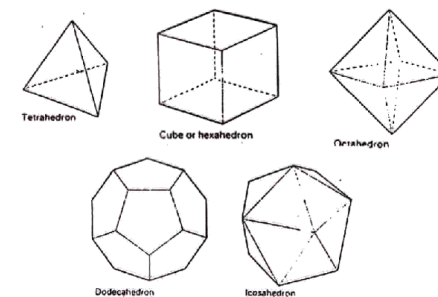


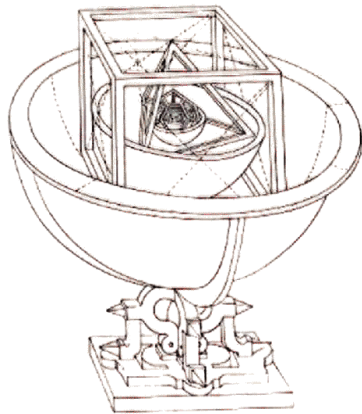
FIGURE 2.1. Stone models of the cube, tetrahedron, dodecahedron, icosahedron and octahedron. They date from about 2000BC and are kept in the Ashmolean Museum in Oxford.

Johannes Kepler 1571 – 1630

Kepler was a mathematician of genius, who had the technical skill to analyse Tycho's magnificent set of data on the planetary orbits. Unlike Tycho, he was a convinced Copernican from the beginning.

In 1597, he published his model for the Solar System, involving the embedding of the 5 regular platonic solids within one another. Remarkably, the model could account for the orbits to within an accuracy of about 5%.





Kepler's model
of the Solar
System from his
*Mysterium
Cosmographicum*
- nested
polyhedra

'The Earth's orbit is the measure of all things: circumscribe around it a dodecahedron and the circle containing it will be Mars; circumscribe around Mars a tetrahedron, and the circle containing this will be Jupiter; circumscribe about Jupiter a cube and the circle containing this will be Saturn. Now inscribe within the Earth an icosahedron and the circle contained in it will be Venus; inscribe within Venus an octahedron, and the circle contained in it will be Mercury. You now have the reason for the number of planets.'

Kepler's 'Harmony of the World'

Ioannis Kepleri
**HARMONICES
M V N D I**

LIBRI V. QVORVM

PRIMVS GEOMETRICVS, De Figurarum Regularium, quarum Proportiones Harmonicas constituunt, ortu & demonstrationibus.
 SECUNDVS ARCHITECTONICVS, seu ex GEOMETRIA FIGVRATA, De Figurarum Regularium Congruentia in plano vel folido:
 TERTIUS PROPRIETATVM HARMONICVS, De Proportionum Harmonicarum ortu ex Figuris: deque Natura & Differentiis rerum ad cantum pertinentium, contra Veteres:
 QVARTVS METAPHYSICVS, PSYCHOLOGICVS & ASTROLOGICVS, De Harmoniarum mentali Essentiâ earumque generibus in Mundo; praeterea de Harmonia radiorum, ex corporibus caelestibus in Terram descendentibus, eiusque effectû in Natura seu Anima fabulari & Humana:
 QVINTVS ASTRONOMICVS & METAPHYSICVS, De Harmoniis absolutissimis motuum caelestium, ortuque Eccentricitatum ex proportionibus Harmonicis.
 Appendix habet comparationem huius Operis cum Harmonicis Cl. Ptolemaei libro II. I. cumque Roberti de Fluctibus, dicti Flud. Medici Oxoniensis speculationibus Harmonicis, operi de Macrocosmo & Microcosmo insertis.



Cum S. C. M. Privilegio ad annos XV.

Lincii Austriae,

Sumptibus GODOFREDI TAMPACHII Bibl. Francof.
Excudebat IOANNES PLANCVS.

ANNO M. DC. XIX.

The 'Harmony of the World' as a Grand Unified Theory

NEWTONIAN GRAVITY
(CALCULUS)

17TH
CENTURY

PARADIGM FOR ALL SUBSEQUENT

PHYSICAL THEORY

FIND SIMPLE UNIVERSAL

MATHEMATICAL LAWS

PLANETS
COMETS
TIDES
"APPLES"

CLERK MAXWELL

19TH
CENTURY

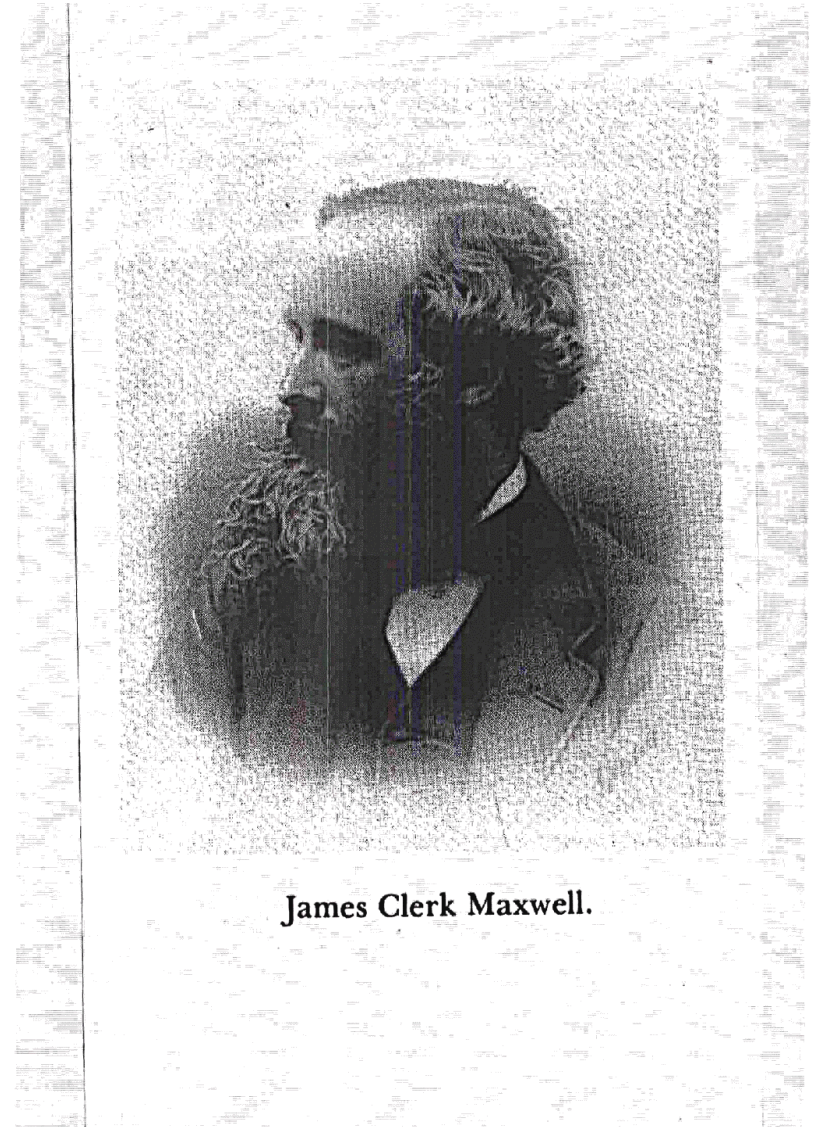
EQUATIONS FOR

ELECTRO-MAGNETISM

"SIMPLE"

[FEYNMAN]

POWER
LIGHT
RADIO
COMPUTER



James Clerk Maxwell.

EARLY 20TH CENTURY

EINSTEIN

SPECIAL RELATIVITY SPACE + TIME
 3 + 1
 " "
 4

* GENERAL RELATIVITY

GRAVITATION = CURVATURE OF SPACE-TIME

BASIC GEOMETRIC IDEA
 FORMULATED IN "SIMPLE"
 MATHEMATICAL EQUATIONS
 MODIFICATION OF NEWTONIAN GRAVITY
 INFLUENCED BY MAXWELL
 AND VELOCITY OF LIGHT

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QUANTUM MECHANICS [1920'S]

TOTALLY NEW VIEW-POINT

USES COMPLEX NUMBERS

UNCERTAINTY PRINCIPLE

EXPERIMENTS

⇒ SPECTACULAR SUCCESS

BASIS OF ATOMIC PHYSICS

⇒ COMPUTER + ... + ...

MATHEMATICALLY MORE SOPHISTICATED

THAN NEWTON, MAXWELL, EINSTEIN

GREAT PHILOSOPHICAL DEBATE

EINSTEIN / BOHR

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EINSTEIN (a) DID NOT BELIEVE IN QM
AS FINAL THEORY
(b) TRIED TO FIND UNIFIED FIELD
THEORY (TO INCLUDE GR + EM)

ORTHODOX VIEW : EINSTEIN WAS WRONG
ON BOTH COUNTS

MID 20TH CENTURY [EXPERIMENTAL DATA]

NUCLEAR FORCES STUDIED
GEOMETRICALLY INTERPRETED
AND COMBINED WITH MAXWELL
WOULD HAVE PLEASED EINSTEIN
BUT QM STILL USED AND GR NOT
INCLUDED


LAST QUARTER OF 20TH CENTURY

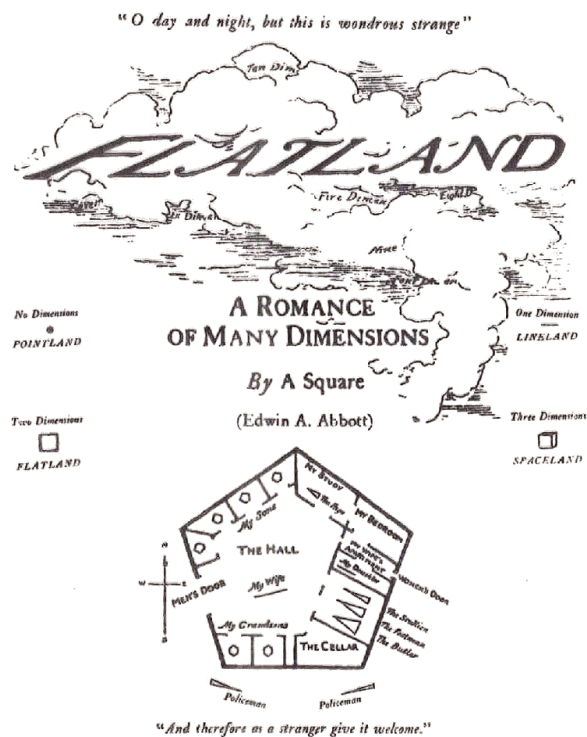
RISE OF STRING THEORY AIMING
TO COMBINE ALL FORCES (GR, EM, NUCLEAR)

? → "THEORY OF EVERYTHING"

STRING THEORY

20TH/21ST
CENTURIES

- 1) REQUIRES MORE DIMENSIONS
10/11 - NOT JUST 4 = 3+1
SPACE/TIME
- 2) BASIC OBJECTS NOT "POINT PARTICLES"
AS IN PAST (ATOMS : ELECTRONS, PROTONS, ...)
BUT STRINGS 
- 3) VERY SOPHISTICATED GEOMETRY USED
INVOLVING VAST AMOUNT OF THEORY, OLD
AND NEW (INCLUDING PLATONIC SOLIDS)
- 4) NO UNIQUE MODEL (PICTURE)
SEVERAL EQUIVALENT ONES
[WHAT HAS HAPPENED TO OUR
"REAL WORLD" ?]
- 5) QM STILL BASIC FRAMEWORK



BASIL BLACKWELL · OXFORD
Price Seven Shillings and Sixpence net

STRING THEORY \Rightarrow NEW MATHEMATICAL RESULTS

- ① ALGEBRAIC GEOMETRY 19TH CENTURY PROBLEM
HOW MANY ALGEBRAIC CURVES ARE THERE WHICH SATISFY CERTAIN CONDITIONS?
- ② TOPOLOGY OF KNOTS
CONSTRUCT NEW INVARIANTS OF KNOTS
 \Rightarrow SOLUTION OF 100 YEAR OLD PROBLEMS
- ③ GEOMETRY OF 4-DIMENSIONAL SPACE
DISCOVERY OF NEW AND UNEXPECTED RESULTS
[VERY DEEP - UNIQUE TO 4 DIMENSIONS]
- ④ ALGEBRA
MANY NEW RESULTS AND IDEAS IN VARIOUS BRANCHES OF ALGEBRA

REMARKABLE IMPACT ON PURE
MATHEMATICS. MANY NEW CONCEPTS AND
RESULTS

VERY MYSTERIOUS!

IF ORTHODOX VIEW CORRECT + FINAL
THEORY EMERGES SOON FROM STRINGS
WE WILL DISCOVER UNIVERSE BUILT ON
FANTASTICALLY INTRICATE MATHEMATICS

? ALTERNATIVE - NEW PARADIGM NEEDED
PERHAPS THE COMPLICATED MATHS. IS
JUST "IN THE EYE OF THE BEHOLDER"
PERHAPS PHYSICAL WORLD IS BUILT ON
A SIMPLER GEOMETRIC PICTURE, BUT
BASIC LAWS TOO COMPLICATED FOR DIRECT
ANALYSIS → STRING THEORY IS OUR WAY
OF APPROXIMATING ?

ATTITUDE OF PHYSICISTS

- (a) DISMISS STRING THEORY ... AS
FANCY MATHEMATICS UNRELATED TO
REAL WORLD
- (b) MATHEMATICAL APPLICATIONS GIVES
CONFIDENCE IN PHYSICAL INSIGHT +
INDICATE THEORY IS ON RIGHT TRACK
[ALTERNATIVE TO EXPERIMENTAL EVIDENCE]
- (c) KEEP PUSHING THEORY FORWARD, WITH
NEW RESULTS + IDEAS EMERGING AS
GUIDE TO FIND FINAL UNIFIED THEORY

SPECULATION

WHAT IS REAL MEANING OF ALL
THIS [QFT, STRING THEORY + MATH. APPLICATIONS]
BOTH FOR GEOMETRY + FOR PHYSICS ??

WHAT WILL THE FUTURE PHYSICAL
THEORY LOOK LIKE ?

AIM IS TO UNIFY

- ① QUANTUM MECHANICS VERY SMALL
- ② GENERAL RELATIVITY VERY LARGE

SUPERSTRING IS A PERTURBATIVE APPROACH

WHAT IS REAL THEORY ? M-THEORY ?

IS THE UNIVERSE REALLY BUILT USING ALL
THIS SOPHISTICATED MACHINERY ?

OR IS THIS MATHEMATICS IMPOSED BY US ?

PERHAPS THE REAL PHYSICS IS "SIMPLER"

OCCAM'S RAZOR

DO WE NEED TO MODIFY QUANTUM THEORY ?

DO WE AWAIT A NEW EINSTEIN ??

21ST CENTURY

HIDING IN THE
MIRROR

LAWRENCE M. KRAUSS

VIKING 2005

PENGUIN