

# CHAPTER 2: THE REFORMED CONCEPTS OF SPACE AND TIME

## *Detailed Analysis and Summary*

### SECTION 1: CHAPTER POSITION AND OVERVIEW

#### **Role in the Book's Overall Argument**

Chapter 2 extends the programme of conceptual reform announced in Chapter 1 to the most fundamental framework within which all physical events occur: space and time. Smuts uses Einstein's General Theory of Relativity (1915) as the exemplary case of reformed concepts that accord with "the fluid creative process of nature" rather than the rigid abstractions of nineteenth-century thought.

The chapter serves two essential functions for Smuts's broader argument: (1) it demonstrates that the scientific revolution is not confined to biology but extends to fundamental physics, confirming that the entire Victorian conceptual framework is dissolving; and (2) it establishes that *structure* and *fields* are fundamental features of physical reality itself, not merely useful concepts for understanding life. This grounds Smuts's later holistic principles in the very fabric of the physical universe.

#### **High-Level Summary**

Smuts opens by identifying three revolutionary dates that mark the dissolution of the old fixed concepts: Darwin (1859), Becquerel's discovery of radioactivity (1896), and Einstein's General Relativity (1915). The fixity of species, the fixity of atoms, and the evenness of space and time have all been overturned.

The chapter proceeds to explain Einstein's theory in accessible terms. The core insight is that all motion is relative—there is no absolute rest in the universe. For moving observers, space and time co-vary: space contracts while time expands, in inverse proportion to velocity. This joint variation led Minkowski (1908) to propose that space and time are not independent but form a unified Space-Time continuum.

Einstein extended this to gravitational fields, showing that acceleration and gravitation are equivalent, and that the Space-Time continuum is curved or warped in the neighbourhood of matter. The result is a universe with "definite organised structure"—not the homogeneous empty container that Newton imagined. Gravitation is not a mysterious "attractive force" but simply the curvature of Space-Time that determines the paths events must follow.

The chapter concludes by contrasting Einstein's view with Newton (space and time as real absolutes) and Kant (space and time as subjective mental forms). Einstein's achievement is to show that Space-Time is both subjective and objective, to isolate the observer's contribution from the real structure of the universe, and to reveal that "structure, real differentiated structure, becomes the inmost form not only of matter but also of its real Space-Time field."

#### **Relationship to Other Chapters**

This chapter builds on and extends:

- **Chapter I:** The critique of abstraction and the concept of "fields" introduced there are now shown to have rigorous physical grounding in Relativity theory

This chapter prepares for:

- **Chapter III:** The reformed concept of matter (which will show matter itself as organised structure and energy)
- **Chapter V:** The formal introduction of Holism (which will generalise structure as the fundamental character of all wholes)
- **Chapter VIII:** Further aspects of Evolution (explicitly referenced in this chapter)

## SECTION 2: KEY CONCEPTS

### 2.1 Relativity of Motion

**Definition:** "The germ of the new Relativity mechanics is the almost obvious fact that the motion of a body is never absolute, but is always relative to some other body or point."

**Technical Explanation:** In the actual universe, there is no stationary point of reference. Every observer and every point of reference is itself in motion. "The impression of rest or stationariness to us as observers in the universe is a mere illusion, and the great service of Einstein was to explore this illusion and to show in exact mathematical form to what extent it affects our vision and judgment of movement in the world."

**Significance:** This dissolves the Newtonian fiction of absolute space as a fixed container. Motion can only be measured relative to something else, and that something else is also moving.

### 2.2 Co-variation of Space and Time

**Definition:** To a moving observer, a moving body appears to contract in the direction of motion (space diminishes) while the time it takes to pass a point appears to expand (time increases). "Space contracts and time expands in inverse proportions according to the rate of motion."

**Fitzgerald-Lorentz Formulation:** Smuts summarises their findings: "(A) The train appears a little shorter than it would to a stationary observer. (B) The time taken by the train to pass a point appears a little longer... than it would to a stationary observer."

**Implication:** "To moving observers clocks and standards of measurement in very fast motion are no longer absolute but vary according to the rates of motion." This variation is negligible at ordinary speeds but becomes significant at velocities approaching the speed of light.

### 2.3 Space-Time Continuum

**Definition:** The unified medium in which all events take place, formed by the inseparable conjunction of space and time. Time is treated as a "fourth dimension, not of space, but of the Space-Time continuum in which events really take place."

**Origin:** Minkowski's "great idea, first formulated in 1908, that in natural events Space and Time are not independent factors."

**Philosophical Significance:** "The old notion of the separate reality of space and of time involved both the errors of analysis and of abstraction to which attention was drawn in the last chapter, and Minkowski's brilliant idea has simply brought us back to the natural fact as it occurs

in experience, where nothing ever happens in space alone or in time alone, but always in both together."

**Terminological Note:** Smuts explicitly connects this to his Chapter 1 critique: separate Space and separate Time are abstractions that violate concrete experience. The real is the Space-Time event, not spatial bodies abstracted from temporal process.

## 2.4 Euclidean vs. Non-Euclidean Space-Time

**Euclidean Space:** "The same and homogeneous all through and in all directions." This is the space assumed by Newton's mechanics, where movements can be represented by straight-line geometrical figures.

**Non-Euclidean Space-Time:** "Curved and warped" in the neighbourhood of matter. "The space of the disc is not straight-line homogeneous uniform Euclidean space, but curved and non-Euclidean."

**Significance:** In the real universe, which is full of rotating and accelerating masses, the Space-Time continuum is everywhere curved. Events follow these curves rather than abstract straight lines.

## 2.5 Equivalence of Acceleration and Gravitation

**Definition:** "Acceleration and gravitation are really the same phenomena and only different in appearance to observers. Acceleration and gravitation are, in fact, equivalent expressions."

**Einstein's Closed Cage:** Smuts describes Einstein's famous thought experiment: a man in a closed cage accelerating in distant space (with no gravitation) would experience exactly the same effects as if he were in a gravitational field. "Einstein's closed cage may yet become as historic as Newton's falling apple."

**Consequence:** Since rotation is a special case of acceleration, and acceleration is equivalent to gravitation, the curved Space-Time characteristics of rotating bodies apply to all gravitational fields.

## 2.6 Gravitational Field (Reformed Concept)

**Old Conception:** Gravitation as a mysterious "attractive power" of matter—a force acting at a distance.

**Reformed Conception:** "The apparent attraction is simply the curved or bent paths due to the movements in the universe of masses charged with energy." Gravitation "now becomes the curves of the real Space-Time world in the neighbourhood of matter; it marks the inevitable paths which all events must follow in the physical universe."

**Ontological Status:** "So far from being subjective or merely relative to the observer, gravitation becomes the very structure of the real world and connotes the stratification which characterises the vast fields of the Space-Time continuum."

## 2.7 Structure as Fundamental

**Definition:** "According to the new Space-Time concept, structure, definite organised structure, becomes the essential characteristic of the physical universe and its vast fields."

**Contrast with Old View:** "Instead of conceiving the universe as consisting of material bodies floating in a medium of uniform homogeneous space, we now look upon the masses of 'matter'

(themselves due to high-speed energies) as developing huge 'fields,' in which the curves of the lines can be calculated and the course of events happening in them can be predicted."

**Connection to Holism:** This is crucial for Smuts's argument: if structure is fundamental even to physical Space-Time, then the "whole-making" principle he will call Holism operates at the most basic level of reality, not merely in the biological domain.

## 2.8 Events vs. Bodies as Units of Reality

**Definition:** "From this point of view bodies and things as merely spatial are not real but abstractions, while events, which involve both Space and Time, are real and form the units of reality."

**Significance:** This reinforces the processual, dynamic character of reality that Smuts emphasised in Chapter 1. Reality is not static "things" but temporal "events" or "happenings" within the Space-Time continuum.

## Inter-relationships Between Concepts

The concepts form a progressive argument:

1. **Relativity of motion** → there is no absolute frame of reference
2. **Co-variation of space and time** → neither is independent of the other
3. **Space-Time continuum** → they form one unified medium
4. **Equivalence of acceleration and gravitation** → gravitational fields have the same properties as rotating systems
5. **Curved Space-Time** → the universe is not homogeneous but structured
6. **Structure as fundamental** → fields with definite organisation are the basic feature of physical reality

## SECTION 3: DIALECTICAL CONTEXT

### 3.1 Views Being Compared

Smuts explicitly contrasts three conceptions of Space and Time:

**Newton's View:** "For Newton both Space and Time were absolutes; that is to say, were real invariable permanent entities or characters of things and events. They were each homogeneous and continuous and therefore adequately expressible by the geometry of Euclid. There was nothing subjective about them."

**Kant's View:** "Space and Time are nothing but the necessary forms of man's sensuous perception; they do not exist in external reality, but are imposed by the mind on all objects of sense." Kant accepted the homogeneous Euclidean character Newton ascribed to space and time but denied they were features of external reality—they were purely mental contributions.

**Einstein's View:** "Space and Time in the theory of Relativity as conjoint co-ordinate forms belong both to the mind and to things; and the whole effort of Einstein was to separate the subjective appearance from the objective reality." Einstein shows that the observer's motion introduces measurable distortions, but that behind these distortions lies the real structure of Space-Time.

### 3.2 Thinkers Engaged

**Positively:**

- **Einstein:** The hero of the chapter; his General Theory of Relativity (1915) provides the model of reformed concepts
- **Minkowski:** His 1908 formulation of the Space-Time continuum is called a "brilliant idea" that "brought us back to the natural fact"
- **Fitzgerald and Lorentz:** Their mathematical formulations of space-time contraction prepared the way for Einstein
- **Michelson and Morley:** Their "most accurate experiments" confirmed the constancy of light's velocity
- **Darwin:** Identified as one of three revolutionary figures (alongside Becquerel and Einstein)
- **Copernicus:** Used as benchmark—Einstein's view will become as evident "as the heliocentric conception of Copernicus has become"

**Critically Assessed:**

- **Newton:** Respected as founder of classical mechanics, but his concepts of absolute space and time are superseded
- **Kant:** His subjectivist solution is rejected; space and time are not purely mental forms
- **Leibniz:** Mentioned as holding Space and Time to be "the pre-established permanent universal order of co-existence and succession among things"—this too is a "metaphysical abstraction"

### **3.3 The Problem the Chapter Addresses**

The problem is how to understand the framework within which all physical events occur. The old Newtonian conception of absolute, homogeneous, Euclidean space and time provided a fixed stage on which events happened. But this conception is shown to be both scientifically inadequate (failing to account for relativistic phenomena) and philosophically misleading (treating abstractions as concrete realities).

Smuts frames the deeper problem as: "Our problem is to break away from the hard and narrow conceptions of the Victorian age, to see Nature once more in her fluid and creative plasticity, and to formulate our conceptions afresh from this deeper point of view." Einstein's theory provides the model of such reformed conceptions in the physical domain.

## SECTION 4: MAIN ARGUMENTS

### ARGUMENT 1: The Dissolution of Fixed Concepts

#### Premises:

1. Darwin (1859) dissolved the fixity of organic species
2. Becquerel (1896) dissolved the fixity of inorganic elements (radioactivity shows atoms can transmute)
3. Einstein (1915) dissolved the evenness of space and time

**Reasoning:** "The fixity of organic species is gone; the fixity of inorganic elements is gone; the evenness of space and time is gone. The position is once more becoming fluid, the old rigid order is visibly dissolving."

**Conclusion:** "The task awaits the future out of this fluid situation and these instabilities once more to build a stable world of ideas, which will be in closer harmony with the reality around us and within us."

### ARGUMENT 2: The Co-variation Argument

#### Premises:

1. To a moving observer, the space occupied by a moving body contracts
2. Simultaneously, the time taken by that body expands
3. These variations are joint and inseparable, occurring in inverse proportion

**Reasoning:** "This joint and inseparable variation of Space and Time was not only most important in itself, but led directly to the revolutionary conception that neither of them existed independently."

**Conclusion:** "In fact separately Space and Time must be mere abstractions, as in all actual movements they are always found in inseparable conjoint action."

### ARGUMENT 3: The Space-Time Unity Argument

#### Premises:

1. Nothing ever happens in space alone or in time alone, but always in both together
2. Objects are not observed by themselves but always as elements in the stream of perceived events
3. Succession (time) requires enduringness (space) to form a series; co-existence (space) requires succession (time) to be extended

**Reasoning:** "The very ideas of Space and Time interpenetrate each other and are dependent on each other. Succession or the time-series, and co-existence or the space-series, are necessary to each other and would not be even intelligible apart from each other."

**Conclusion:** "Minkowski's brilliant idea has simply brought us back to the natural fact as it occurs in experience." The Space-Time continuum is the real; separate space and separate time are abstractions.

### ARGUMENT 4: The Equivalence Argument

#### Premises:

1. A body under constant acceleration behaves identically to a body in a gravitational field (Einstein's closed cage)
2. The distinctive feature of gravitation—that all objects fall at the same rate regardless of size or material—is replicated in acceleration
3. Rotation is a special case of acceleration

**Reasoning:** "What is really due to acceleration appears to be a case purely and simply of gravitation. Thus we see acceleration and gravitation are really the same phenomena and only different in appearance to observers."

**Conclusion:** "Acceleration and gravitation are, in fact, equivalent expressions." The non-Euclidean characteristics of rotating systems (curved Space-Time) apply equally to gravitational fields.

## **ARGUMENT 5: The Structural Universe Argument**

### **Premises:**

1. The Space-Time continuum is curved in the neighbourhood of matter (gravitational fields)
2. Events follow the curves of Space-Time ("the pathways of the physical universe which all physical events must follow")
3. The universe is full of matter, therefore full of gravitational fields
4. Homogeneous Euclidean Space-Time would only exist beyond all real fields—"simply a limiting conception of thought"

**Reasoning:** "The result is that the entire universe acquires a definite structural character, and is not a diffuse homogeneity as was formerly supposed."

**Conclusion:** "According to the new Space-Time concept, structure, definite organised structure, becomes the essential characteristic of the physical universe and its vast fields, and this structural character accounts for many hitherto inexplicable phenomena."

## **ARGUMENT 6: The Synthesis of Newton and Kant**

### **Premises:**

- Newton held space and time to be real but objective only
- Kant held space and time to be real forms but subjective only
- Both were partly right, but one-sided

**Reasoning:** Einstein's analysis shows that moving observers introduce real distortions (the subjective element), but that behind these distortions lies the real structure of Space-Time (the objective element). "That Space and Time were not, on the one hand, merely subjective conditions of experience as Kant held, nor, on the other, merely objectively given elements for experience as Newton held, but that they were both subjective and objective contributions to experience."

**Conclusion:** Einstein's achievement is "an achievement of the most outstanding importance not only for science but also for philosophy"—the proper sorting out and rigorous determination of both the subjective and objective elements.

## **SECTION 5: EVIDENCE AND EXAMPLES**

### **Empirical Evidence Cited**

- **Michelson-Morley experiments:** "The most accurate experiments" confirming that "the velocity of light is always the same, whatever the velocity of its source, and however great may be the difference in velocities of the moving observers"
- **Astronomical confirmations:** "The deposition of the old Space and Time and their replacement by Space-Time have been tested in the most searching way both in the immense world of astronomy and the most minute world of the atom, and in both cases the new concepts have been found to work satisfactorily"
- **Light bending in gravitational fields:** "A ray of light passing through the field will similarly follow the nearest curve instead of a straight line... These deductions from theory have been experimentally verified in most important particulars"

## Thought Experiments and Illustrations

- **Moving train and motor-car:** Smuts's accessible illustration of the Fitzgerald-Lorentz contraction—a train observed by someone in a parallel moving vehicle
- **Einstein's closed cage:** A man in a cage accelerating in distant space experiences exactly what he would experience in a gravitational field—demonstrating their equivalence
- **Rotating disc:** An observer on a rotating disc finds that clocks run at different rates depending on distance from the centre, and measuring rods vary in length—demonstrating non-Euclidean Space-Time
- **Cosmic motion chains:** A point on Earth rotates around Earth's centre; Earth rotates around the Sun; the Sun moves relative to a star in Hercules; that star moves relative to the Milky Way—demonstrating the impossibility of finding absolute rest

## Scientific Sources

- **Einstein's Special Theory of Relativity (1905):** Explaining uniform motion and the constancy of light's velocity
- **Einstein's General Theory of Relativity (1915):** Extending to accelerated motion and gravitation
- **Minkowski's Space-Time formulation (1908):** Introducing time as the fourth dimension of the continuum
- **Fitzgerald-Lorentz transformations:** The mathematical formulation of space-time variation for moving observers

## SECTION 6: KEY QUOTATIONS

### On the Revolutionary Character of the Change

*"The fixity of organic species is gone; the fixity of inorganic elements is gone; the evenness of space and time is gone. The position is once more becoming fluid, the old rigid order is visibly dissolving, the fixed landmarks and beacon-points by which former generations steered their course in science are becoming submerged."*

### On Space and Time as Abstractions

*"In fact separately Space and Time must be mere abstractions, as in all actual movements they are always found in inseparable conjoint action."*

### On Minkowski's Achievement

*"Minkowski's brilliant idea has simply brought us back to the natural fact as it occurs in experience, where nothing ever happens in space alone or in time alone, but always in both together, and where objects are not observed by themselves, but always as elements or items in the stream of perceived events."*

### **On Gravitation Reformed**

*"Gravitation, as we have seen, now becomes the curves of the real Space-Time world in the neighbourhood of matter; it marks the inevitable paths which all events must follow in the physical universe. So far from being subjective or merely relative to the observer, gravitation becomes the very structure of the real world."*

### **On Structure as Fundamental**

*"According to the new Space-Time concept, structure, definite organised structure, becomes the essential characteristic of the physical universe and its vast fields, and this structural character accounts for many hitherto inexplicable phenomena."*

### **On the Field Concept**

*"The concept of the 'field' becomes all-important in science and in thought. The 'field' of matter is simply the curved structure of the real Space-Time, which extends far beyond sensible matter itself."*

### **On the Outcome of Einstein's Analysis**

*"The Space-Time continuum, instead of being a vague, homogeneous, formless, metaphysical concept, becomes a part of physical reality, becomes the 'field' of the material world, with a definite structure of its own. Structure, real differentiated structure, becomes the inmost form not only of matter but also of its real Space-Time field."*

## **SECTION 7: ADVANCEMENT OF TIER 1 CONCEPTS**

### **Holism**

Not yet named, but the conceptual foundation is substantially advanced:

- The Space-Time continuum is a unity, not an aggregate of separate space and separate time
- Structure (organised wholeness) is shown to be fundamental to physical reality
- The errors of analysis and abstraction identified in Chapter 1 are shown to have infected even our basic concepts of space and time

### **The Whole**

Significantly developed through the concept of the Space-Time continuum:

- Space-Time is a whole that cannot be divided into independent parts (space and time separately)
- Events (wholes involving space and time together) are the real units, not bodies (abstractions)
- The universe as a whole has definite structure, not mere aggregation of parts in empty space

### **Fields**

**Major development in this chapter.** The field concept introduced in Chapter 1 is now given rigorous physical grounding:

- "The concept of the 'field' becomes all-important in science and in thought"
- "The 'field' of matter is simply the curved structure of the real Space-Time, which extends far beyond sensible matter itself"
- Fields are not empty regions but have real structure that determines the paths events must follow
- The gravitational field is the paradigm case: it extends far beyond the material body and shapes all events within it

## **Creative Evolution / Synthesis**

Indirectly supported through:

- The dissolution of fixed categories (species, atoms, space-time) makes room for genuine novelty
- Events rather than static bodies as the units of reality emphasises process and becoming
- The chapter explicitly states this is part of the same revolution as Darwin's Evolution

## **Mind**

Not directly advanced, but the epistemological discussion of Newton vs. Kant vs. Einstein is relevant:

- The observer's contribution is real but can be isolated and distinguished from objective reality
- This suggests that mind and world are not utterly separate (contra Kant) but interpenetrate
- Space and Time "are given elements just as colour, weight and the rest"—treated as part of physical experience, not purely mental forms

## **SECTION 8: CONTEMPORARY RELEVANCE MARKERS**

This chapter's arguments connect to several developments in contemporary science and philosophy:

- **Spacetime physics:** Smuts's presentation of Relativity remains accurate in its essentials. The Space-Time continuum is now the standard framework for all of modern physics.
- **Field theories in physics:** The emphasis on fields as fundamental has been vindicated by the development of quantum field theory, where fields (not particles) are the basic entities.
- **Quantum gravity research:** Contemporary attempts to unify general relativity with quantum mechanics (loop quantum gravity, string theory) continue to treat spacetime structure as a fundamental problem.
- **Process philosophy:** The emphasis on events rather than static bodies as the units of reality aligns with Whitehead's process philosophy, which developed contemporaneously.
- **Structural realism:** The claim that "structure, real differentiated structure, becomes the inmost form" of reality anticipates contemporary structural realism in philosophy of science.
- **Relational approaches:** The emphasis on relations (the relative character of motion, the co-variation of space and time) over intrinsic properties anticipates relational approaches in physics and metaphysics.

— *End of Chapter 2 Analysis* —