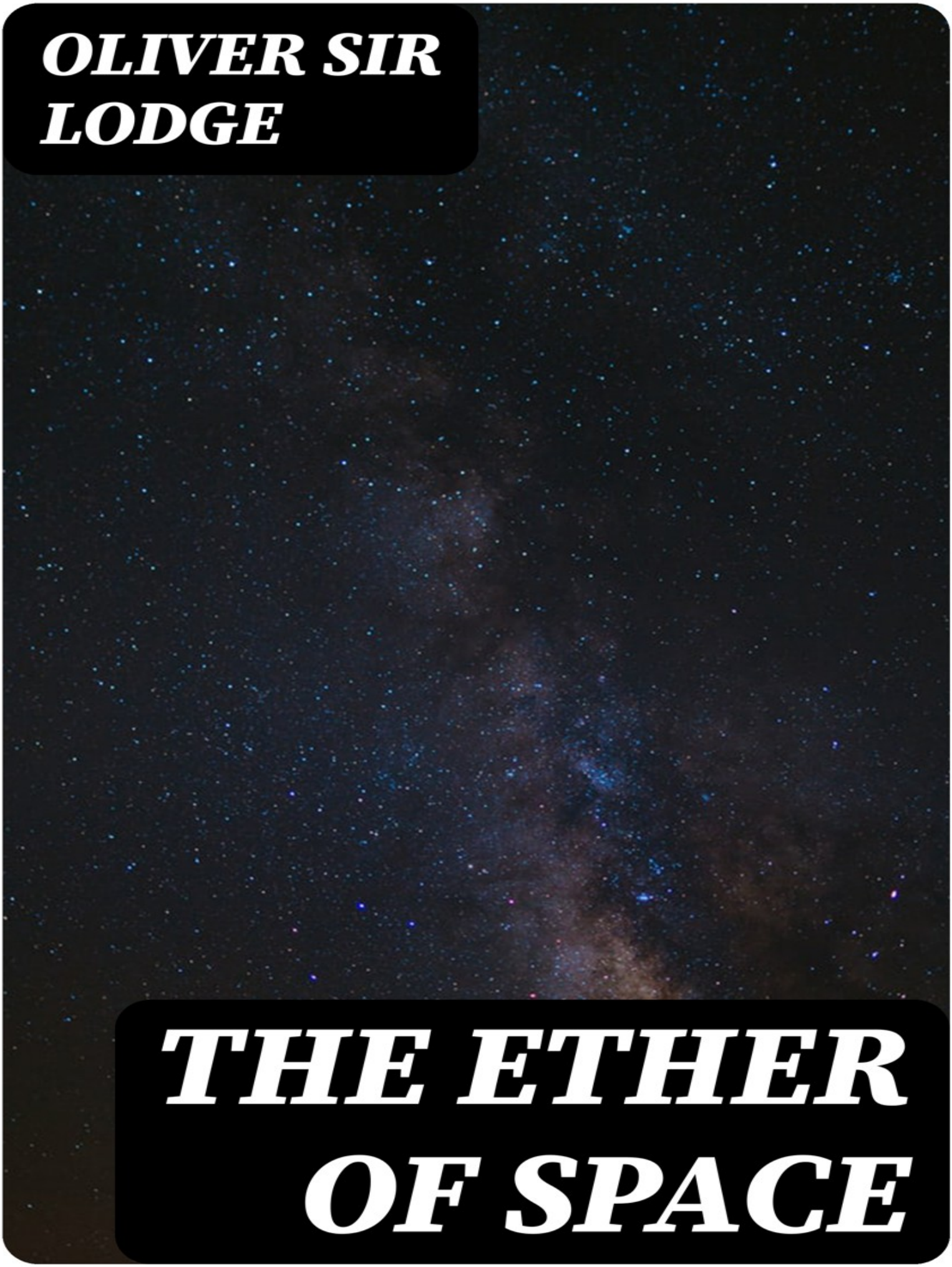
OLIVER SIR LODGE
THE ETHER OF SPACE

Oliver Sir Lodge

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PREFACE

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INVESTIGATION of the nature and properties of the Ether of Space has long been for me the most fascinating branch of Physics, and I welcome the opportunity of attempting to make generally known the conclusions to which I have so far been led on this great and perhaps inexhaustible subject.

OLIVER LODGE.

UNIVERSITY OF BIRMINGHAM,
March, 1909.

TO THE FOUNDERS OF
UNIVERSITY COLLEGE, LIVERPOOL,
ESPECIALLY TO THOSE BEARING THE NAMES
OF RATHBONE AND OF HOLT
THIS BOOK IS INSCRIBED

INTRODUCTION

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"ETHER or Æther (αιθηρ probably from αιθω I burn,) a material substance of a more subtle kind than visible

bodies, supposed to exist in those parts of space which are apparently empty."

So begins the article "Ether," written for the ninth edition of the *Encyclopædia Britannica*, by James Clerk Maxwell.

The derivation of the word seems to indicate some connexion in men's minds with the idea of Fire: the other three "elements," Earth, Water, Air, representing the solid, liquid, and gaseous conditions of ordinary matter respectively. The name Æther suggests a far more subtle or penetrating and ultra-material kind of substance.

Newton employs the term for the medium which fills space—not only space which appears to be empty, but space also which appears to be full; for the luminiferous ether must undoubtedly penetrate between the atoms—must exist in the pores so to speak—of every transparent substance, else light could not travel through it. The following is an extract from Newton's surmises concerning this medium:—

> "Qu. 18. If in two large tall cylindrical Vessels of Glass inverted, two little Thermometers be suspended so as not to touch the Vessels, and the Air be drawn out of one of these Vessels, and these Vessels thus prepared be carried out of a cold place into a warm one; the Thermometer *in vacuo* will grow warm as much and almost as soon as the Thermometer which is not *in vacuo*. And when the vessels are carried back into the cold place, the Thermometer *in vacuo* will grow cold almost as soon as the other Thermometer. Is not the Heat of the warm Room conveyed through the Vacuum by the Vibrations of a much subtiler Medium than Air,

which after the Air was drawn out remained in the Vacuum? And is not this Medium the same with that Medium by which Light is [transmitted], and by whose Vibrations Light communicates Heat to Bodies?... And do not the Vibrations of this Medium in hot Bodies contribute to the intenseness and duration of their Heat? And do not hot Bodies communicate their Heat to contiguous cold ones by the Vibrations of this Medium propagated from them into the cold ones? And is not this Medium exceedingly more rare and subtile than the Air, and exceedingly more elastic and active? And doth it not readily pervade all bodies? And is it not (by its elastic force) expanded through all the Heavens?"

"Qu. 22. May not Planets and Comets, and all gross Bodies, perform their motions more freely, and with less resistance in this Æthereal Medium than in any Fluid, which fills all Space adequately without leaving any Pores, and by consequence is much denser than Quick-silver and Gold? And may not its resistance be so small, as to be inconsiderable? For instance; if this *Æther* (for so I will call it) should be supposed 700000 times more elastic than our Air, and above 700000 times more rare; its resistance would be above 600000000 times less than that of Water. And so small a resistance would scarce make any sensible alteration in the Motions of the Planets in ten thousand Years."

That the ether, if there be such a thing in space, can pass readily into or through matter is often held proven by tilting a mercury barometer; when the mercury rises to fill the

transparent vacuum. Everything points to its universal permeance, if it exist at all.

But these, after all, are antique thoughts. Electric and Magnetic information has led us beyond them into a region of greater certainty and knowledge; so that now I am able to advocate a view of the Ether which makes it not only uniformly present and all-pervading, but also massive and substantial beyond conception. It is turning out to be by far the most substantial thing—perhaps the only substantial thing—in the material universe. Compared to ether the densest matter, such as lead or gold, is a filmy gossamer structure; like a comet's tail or a milky way, or like a salt in very dilute solution.

To lead up to and justify the idea of the reality and substantiality, and vast though as yet largely unrecognised importance, of the Ether of Space, the following chapters have been written. Some of them represent the expanded notes of lectures which have been given in various places—chiefly the Royal Institution; while the first chapter represents a lecture before the Ashmolean Society of the University of Oxford in June, 1889. One chapter (viz. Chap. II) has already been printed as part of an appendix to the third edition of *Modern Views of Electricity*, as well as in the *Fortnightly* and *North American Reviews*; but no other chapters have yet been published, though parts appear in more elaborate form in Proceedings or Transactions of learned societies.

The problem of the constitution of the Ether, and of the way in which portions of it are modified to form the atoms or other constituent units of ordinary matter, has not yet been

solved. Much work has been done in this direction by various mathematicians, but much more remains to be done. And until it is done, some scepticism is reasonable—perhaps laudable. Meanwhile there are few physicists who will dissent from Clerk Maxwell's penultimate sentence in the article "Ether" of which the beginning has already been quoted:—

> "Whatever difficulties we may have in forming a consistent idea of the constitution of the æther, there can be no doubt that the interplanetary and interstellar spaces are not empty, but are occupied by a material substance or body, which is certainly the largest, and probably the most uniform body of which we have any knowledge."

THE ETHER OF SPACE

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CHAPTER I

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THE LUMINIFEROUS ETHER AND THE MODERN THEORY OF LIGHT

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THE oldest and best known function for an ether is the conveyance of light, and hence the name "luminiferous" was applied to it; though at the present day many more functions are known, and more will almost certainly be discovered.

To begin with it is best to learn what we can, concerning the properties of the Interstellar Ether, from the phenomena of Light.

For now wellnigh a century we have had a wave theory of light; and a wave theory of light is quite certainly true. It is directly demonstrable that light consists of waves of some kind or other, and that these waves travel at a certain well-known velocity,—achieving a distance equal to seven times the circumference of the earth every second; from New York to London and back in the thirtieth part of a second; and taking only eight minutes on the journey from the sun to the earth. This propagation in time of an undulatory disturbance necessarily involves a medium. If waves setting out from the sun exist in space eight minutes before striking our eyes, there must necessarily be in space some medium in which they exist and which conveys them. Waves we cannot have, unless they be waves in something.

No ordinary matter is competent to transmit waves at anything like the speed of light: the rate at which *matter* conveys waves is the velocity of sound,—a speed comparable to one-millionth of the speed of light. Hence the luminiferous medium must be a special kind of substance; and it is called the ether. The *luminiferous* ether it used to be called, because the conveyance of light was all it was then known to be capable of; but now that it is known to do a variety of other things also, the qualifying adjective may be dropped. But, inasmuch as the term 'ether' is also applied to a familiar organic compound, we may distinguish the ultra-material luminiferous medium by calling it the Ether of Space.

Wave-motion in ether, light certainly is; but what does one mean by the term wave? The popular notion is, I suppose, of something heaving up and down, or perhaps of something breaking on a shore. But if you ask a mathematician what he means by a wave, he will probably reply that the most general wave is such a function of x and y and t as to satisfy the differential equation

$$d^2y / dt^2 = (v^2)\, d^2y / dx^2;$$

while the simplest wave is

$$y = a \sin (x - vt).$$

And he might possibly refuse to give any other answer.

And in refusing to give any other answer than this, or its equivalent in ordinary words, he is entirely justified; that *is* what is meant by the term wave, and nothing less general would be all-inclusive.

Translated into ordinary English the phrase signifies, with accuracy and comprehensive completeness, the full details

of "a disturbance periodic both in space and time." Anything thus doubly periodic is a wave; and all waves—whether in air as sound waves, or in ether as light waves, or on the surface of water as ocean waves—can be comprehended in the definition.

What properties are essential to a medium capable of transmitting wave-motion? Roughly we may say two: *elasticity* and *inertia*. Elasticity in some form, or some equivalent of it,—in order to be able to store up energy and effect recoil; inertia,—in order to enable the disturbed substance to overshoot the mark and oscillate beyond its place of equilibrium to and fro. Any medium possessing these two properties can transmit waves, and unless a medium possesses these properties in some form or other, or some equivalent for them, it may be said with moderate security to be incompetent to transmit waves. But if we make this latter statement one must be prepared to extend to the terms elasticity and inertia their very largest and broadest signification, so as to include any possible kind of restoring force, and any possible kind of persistence of motion, respectively.

These matters may be illustrated in many ways, but perhaps a simple loaded lath, or spring, in a vice will serve well enough. Pull it to one side, and its elasticity tends to make it recoil; let it go, and its inertia causes it to overshoot its normal position. That is what inertia is,—power of overshooting a mark, or, more accurately, power of moving for a time even against driving force,—power to rush uphill. Both causes together make it swing to and fro till its energy is exhausted. This is a disturbance simply periodic in time. A

regular series of such springs, set at equal intervals and started vibrating at regular intervals of time one after the other, would be periodic in space too; and so they would, in disconnected fashion, typify a wave. A series of pendulums will do just as well, and if set swinging in orderly fashion will furnish at once an example and an appearance of wave motion, which the most casual observer must recognise as such. The row of springs obviously possesses elasticity and inertia; and any wave-transmitting medium must similarly possess some form of elasticity and some form of inertia.

But now proceed to ask what is this Ether which in the case of light is thus vibrating? What corresponds to the elastic displacement and recoil of the spring or pendulum? What corresponds to the inertia whereby it overshoots its mark? Do we know these properties in the ether in any other way?

The answer, given first by Clerk Maxwell, and now reiterated and insisted on by experiments performed in every important laboratory in the world, is:—

The elastic displacement corresponds to electrostatic charge,—roughly speaking, to electricity.

The inertia corresponds to magnetism.

This is the basis of the modern electromagnetic theory of light.

Let me attempt to illustrate the meaning of this statement, by reviewing some fundamental electrical facts in the light of these analogies:—

The old and familiar operation of charging a Leyden jar—the storing up of energy in a strained dielectric—any

electrostatic charging whatever is quite analogous to the drawing aside of our flexible spring. It is making use of the elasticity of the ether to produce a tendency to recoil. Letting go the spring is analogous to permitting a discharge of the jar—permitting the strained dielectric to recover itself—the electrostatic disturbance to subside.

In nearly all the experiments of electrostatics etherial elasticity is manifest.

Next consider inertia. How would one illustrate the fact that water, for instance, possesses inertia—the power of persisting in motion against obstacles—the power of possessing kinetic energy? The most direct way would be, to take a stream of water and try suddenly to stop it. Open a water tap freely and then suddenly shut it. The impetus or momentum of the stopped water makes itself manifest by a violent shock to the pipe, with which everybody must be familiar. This momentum of water is utilised by engineers in the "water-ram."

A precisely analogous experiment in Electricity is what Faraday called "the extra current." Send a current through a coil of wire round a piece of iron, or take any other arrangement for developing powerful magnetism, and then suddenly stop the current by breaking the circuit. A violent flash occurs, if the stoppage is sudden enough, a flash which means the bursting of the insulating air partition by the accumulated electromagnetic momentum. The scientific name for this electrical inertia is "self-induction."

Briefly we may say that nearly all electromagnetic experiments illustrate the fact of etherial inertia.

Now return to consider what happens when a charged conductor (say a Leyden jar) is discharged. The recoil of the strained dielectric causes a current, the inertia of this current causes it to overshoot the mark, and for an instant the charge of the jar is reversed; the current now flows backwards and charges the jar up as at first; back again flows the current; and so on, charging and reversing the charge, with rapid oscillations, until the energy is all dissipated into heat. The operation is precisely analogous to the release of a strained spring, or to the plucking of a stretched string.

But the discharging body, thus thrown into strong electrical vibration, is imbedded in the all-pervading ether; and we have just seen that the ether possesses the two properties requisite for the generation and transmission of waves, viz.: elasticity, and inertia or density; hence just as a tuning fork vibrating in air excites aërial waves, or sound, so a discharging Leyden jar in ether excites etherial waves, or light.

Etherial waves can therefore be actually produced by direct electrical means. I discharge here a jar, and the room is for an instant filled with light. With light, I say, though you can see nothing. You can see and hear the spark indeed—but that is a mere secondary disturbance we can for the present ignore—I do not mean any secondary disturbance. I mean the true etherial waves emitted by the electric oscillation going on in the neighbourhood of the recoiling dielectric. You pull aside the prong of a tuning fork and let it go: vibration follows and sound is produced. You charge a