POPULAR LECTURES

AND

ADDRESSES

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IN THREE VOLUMES

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CONSTITUTION OF MATTER

WITH ILLUSTRATIONS

of the force required to move a tuning-fork 400 times a second, and compare that with the force required for a motion of 400 million million times a second. If the mass moved is the same, and the range of motion is the same, then the force would be one million million million million times as great as the force required to move the prongs of the tuning-fork—it is as easy to understand that number as any number like 2, 3, or 4. Consider now what that number means and what we are to infer from it. What force is there in the space between my eye and that light? What forces are there in the space between our eyes and the sun, and our eyes and the remotest visible star? There is matter and there is motion, but what magnitude of force may there be?

I move through this "luminiferous ether" as if it were nothing. But were there vibrations with such frequency in a medium of steel or brass, they would be measured by millions and millions and millions of tons' action on a square inch of matter. There are no such forces in our

air. Comets make a disturbance in the air, and perhaps the luminiferous ether is split up by the motion of a comet through it. So when we explain the nature of electricity, we explain it by a motion of the luminiferous ether. We cannot say that it is electricity. What can this luminiferous ether be? It is something that the planets move through with the greatest ease. It permeates our air; it is nearly in the same condition, so far as our means of judging are concerned, in our air and in the inter-planetary space. The air disturbs it but little; you may reduce air by air-pumps to the hundred thousandth of its density, and you make little effect in the transmission of light through it. The luminiferous ether is an elastic solid, for which the nearest analogy I can give you is this jelly which you see,[1] and the nearest analogy to the waves of light is the motion, which you can imagine, of this elastic jelly, with a ball of wood floating in the middle of it. Look there, when with my hand I vibrate the little red ball

[1] Exhibiting a large bowl of clear jelly with a small red wooden ball embedded in the surface near the centre.

up and down, or when I turn it quickly round the vertical diameter, alternately in opposite directions;—that is the nearest representation I can give you of the vibrations of luminiferous ether.

Another illustration is Scottish shoemakers' wax or Burgundy pitch, but I know Scottish shoemakers' wax better. It is heavier than water, and absolutely answers my purpose. I take a large slab of the wax, place it in a glass jar filled with water, place a number of corks on the lower side and bullets on the upper side. It is brittle like the Trinidad pitch or Burgundy pitch which I have in my hand—you can see how hard it is— but when left to itself it flows like a fluid. The shoemakers' wax breaks with a brittle fracture, but it is viscous and gradually yields.

What we know of the luminiferous ether is that it has the rigidity of a solid and gradually yields. Whether or not it is brittle and cracks we cannot yet tell, but I believe the discoveries in electricity and the motions of comets and the marvellous spurts of light from them, tend to show cracks

in the luminiferous ether—show a correspondence between the electric flash and the aurora borealis and cracks in the luminiferous ether. Do not take this as an assertion, it is hardly more than a vague scientific dream: but you may regard the existence of the luminiferous ether as a reality of science; that is, we have an all-pervading medium, an elastic solid, with a great degree of rigidity—a rigidity so prodigious in proportion to its density that the vibrations of light in it have the frequencies I have mentioned, with the wave-lengths I have mentioned. The fundamental question as to whether or not luminiferous ether has gravity has not been answered. We have no knowledge that the luminiferous ether is attracted by gravity; it is sometimes called imponderable because some people vainly imagine that it has no weight: I call it matter with the same kind of rigidity that this elastic jelly has.

Here are two tourmalines; if you look through them toward the light you see the white light all round, *i.e.* they are transparent. If I turn round one of these tourmalines the light is

The result in a general way is this: The light coming from the blue sky is polarised in a plane through the sun, but the blue light of the sky is complicated by a great number of circumstances and one of them is this, that the air is illuminated not only by the sun but by the earth. If we could get the earth covered by a black cloth then we could study the polarised light of the sky with a simplicity which we cannot do now. There are, in nature, reflections from seas and rocks and hills and waters in an infinitely complicated manner.

Let observers observe the blue sky not only in winter when the earth is covered with snow, but in summer when it is covered with dark green foliage. This will help to unravel the complicated phenomena in question. But the azure blue of the sky is light produced by the reaction on the vibrating ether of little spherules of water, of perhaps a fifty thousandth or a hundred thousandth of a centimetre diameter, or perhaps little motes, or lumps, or crystals of common salt, or particles of dust, or germs of vegetable or animal species wafted about in the air. Now what is the lumini-

ferous ether? It is matter prodigiously less dense than air—millions and millions and millions of times less dense than air. We can form some sort of idea of its limitations. We believe it is a real thing, with great rigidity in comparison with its density: it may be made to vibrate 400 million million times per second; and yet be of such density as not to produce the slightest resistance to any body going through it.

Going back to the illustration of the shoemaker's wax; if a cork will, in the course of a year, push its way up through a plate of that wax when placed under water, and if a lead bullet will penetrate downwards to the bottom, what is the law of the resistance? It clearly depends on time. The cork slowly in the course of a year works its way up through two inches of that substance; give it one or two thousand years to do it and the resistance will be enormously less; thus the motion of a cork or bullet, at the rate of one inch in 2,000 years, may be compared with that of the earth, moving at the rate of six times ninety-three million miles a year, or nineteen miles per second,

through the luminiferous ether ; but when we can have actually before us a thing elastic like jelly and yielding like pitch, surely we have a large and solid ground for our faith in the speculative hypothesis of an elastic luminiferous ether, which constitutes the wave theory of light.

ON THE AGE OF THE SUN'S HEAT.

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THE second great law of Thermodynamics involves a certain principle of *irreversible action in nature*. It is thus shown that, although mechanical energy is *indestructible*, there is a universal tendency to its dissipation, which produces gradual augmentation and diffusion of heat, cessation of motion, and exhaustion of potential energy through the material universe.[1] The result would inevitably be a state of universal rest and death, if the universe were finite and left to obey existing laws. But it is impossible to conceive a limit to the extent of matter in the

[1] See "On a Universal Tendency in Nature to the Dissipation of Mechanical Energy," Proceedings of the Royal Society of Edinburgh, April 19, 1852 ; or the *Philosophical Magazine*, October, 1852 ; also *Mathematical and Physical Papers*, Vol. I. Article LIX.