The Outline of Wave Mechanics

Physics

A. S. EDDINGTON, in *The Nature of the Physical World* (Macmillan):

Imagine a sub-aether whose surface is covered with ripples. The oscillations of the ripples are a million times faster than those of visible light—too fast to come within the scope of our gross experience. Individual ripples are beyond our ken; what we can appreciate is a combined effect—when by convergence and coalescence the waves conspire to create a disturbed area of extent large compared with individual ripples but small from our own Brobdingnagian point of view. Such a disturbed area is recognized as a material particle; in particular it can be an electron.

The sub-aether is a dispersive medium, that is to say the ripples do not all travel with the same velocity; like water-ripples their speed depends on their wave-length or period. Those of shorter period travel faster. Moreover, the speed may be modified by local conditions. This modification is the counterpart in Schrödinger's theory of a field of force in classifical physics. It will readily be understood that if we are to reduce all phenomena to a propagation of waves, then the influence of a body on phenomena in its neighborhood (commonly described as the field of force caused by its presence) must consist in a modification of the propagation of waves in the region surrounding it.

We have to connect these phenomena in the sub-aether with phenomena in the plane of our gross experience. As already stated, a local stormy region is detected by us as a particle; to this we now add that the frequency (number of oscillations per second) of the waves constituting the disturbance is recognized by us as the energy of the particle. We shall presently try to explain how the period manages to manifest itself to us in this curiously camouflaged way; but however it comes about, the recognition of a frequency in the sub-aether as an energy in gross experience gives at once the constant relation period and energy which we have called the h rule.

Generally the oscillations in the sub-aether are too rapid for us to detect directly; their frequency reaches the plane of ordinary experience by affecting the speed of propagation, because the speed depends (as already stated) on the wave-length or frequency. Calling the frequency v, the equation expressing the law of propagation of the ripples will contain a term in v. There will be another term expressing the modification caused by the "field of force" emanating from the bodies present in the neighbourhood. This can be treated as a kind of spurious v, since it emerges into our gross experience by the same method that v does. If v produces those prenomena which make us recognize it as energy, the spurious v will produce similar phenomena corresponding to a spurious kind of energy. Clearly the latter will be what we call potential energy, since it originates from influences attributable to the presence of surrounding objects.

Assuming that we know both the real v and the spurious or potential v for our ripples, the equation of wave-propagation is settled, and we can proceed to solve any problem concerning wave-propagation. In particular we can solve the problem as to how the stormy areas move about. This gives a remarkable result which provides the first check on our theory. The stormy areas (if small enough) move under precisely the same laws that govern the motions of particles in classical mechanics. *The equations for the motion of a wave-group with given frequency and potential frequency are the same as the classical equations of motion of a particle with the corresponding energy and potential energy.*

It has to be noticed that the velocity of a stormy area or group of waves is not the same as the velocity of an individual wave. This is well known in the study of water-waves as the distinction between group-velocity and wave-velocity. It is the group-velocity that is observed by us as the motion of the material particle.

We should have gained very little if our theory did no more than re-establish the results of classical mechanics on this rather fantastic basis. Its distinctive merits begin to be apparent when we deal with phenomena not covered by classical mechanics. We have considered a stormy area of so small extent that its position is as definite as that of a classical particle, but we may also consider an area of wider extent. No precise delimitation can be drawn between a large area and a small area, so that we shall continue to associate the idea of a particle with it; but whereas a small concentrated storm fixes the position of the particle closely, a more extended storm leaves it very vague. If we try to interpret an extended wave-group in classical language we say that it is a particle which is not at any definite point of space, but is loosely associated with a wide region.

Perhaps you may think that an extended stormy area ought to represent *diffused* matter in contrast to a concentrated particle. That is not Schrödinger's theory. The spreading is not a spreading of density; it is an indeterminacy of position, or a wider distribution of the probability that the particle lies within particular limits of position. Thus if we come across Schrödinger waves uniformly filling a vessel, the interpretation is not that the vessel is filled with matter of uniform density, but that it contains one particle which is equally likely to be anywhere.

The first great success of this theory was in representing the emission of light from a hydrogen atom—a problem far outside the scope of classical theory. The hydrogen atom consists of a proton and electron which must be translated into their counterparts in the sub-aether. We are not interested in what the proton is doing, so we do not trouble about its representation by waves; what we want from it is its field of force, that is to say, the spurious v which it provides in the equation of wave-propagation for the electron. The waves traveling in accordance with this equation constitute Schrödinger's equivalent for the electron; and any solution of the equation will correspond to some possible state of the hydrogen atom. Now it turns out that (paying attention to the obvious physical limitation that the waves must not anywhere be of infinite amplitude) solutions of this wave-equation only exist for waves with particular frequencies. Thus in a hydrogen atom the sub-aethereal waves are limited to a particular discrete series of freqquencies. Remembering that a frequency in the sub-aether means an energy in gross experience, the atom will accordingly have a discrete series of possible energies. It is found that this series of energies is precisely the same as that assigned by Bohr from his rules of quantisation. It is a considerable advance to have determined these energies by a wave-theory instead of by an inexplicable mathematical rule. Further, when applied to more complex atoms Schrödinger's theory succeeds on those (*Turn to page* 166)

Wave Mechanics—*Cont'd*

points where the Bohr model breaks down; it always gives the right number of energies or "orbits" to provide one orbit jump for each observed spectral line.

It is, however, an advantage not to pass from wave-frequency to classical energy at this stage, but to follow the course of events in the sub-aether a little farther. It would be difficult to think of the electron as having two energies (i. e. being in two Bohr orbits) simultaneously; but there is nothing to prevent waves of two different frequencies being simultaneously present in the sub-aether. Thus the wave-theory allows us easily to picture a condition which the classical theory could only describe in paradoxical terms. Suppose that two sets of waves are present. If the difference of frequency is not very great the two systems of waves will produce "beats". If two broadcasting stations are transmitting on wave-lengths near together we hear a musical note or shriek resulting from the beats of the two carrier waves; the individual oscillations are too rapid to affect the ear, but they combine to give beats which are slow enough to affect the ear. In the same way the individual wave-systems in the sub-aether are composed of oscillations too rapid to affect our gross senses; but their beats are sometimes slow enough to come within the octave covered by the eye. These beats are the source of the light coming from the hydrogen atom, and mathematical calculation shows that their frequencies are precisely those of the observed light from hydrogen. Heterodyning of the radio carrier waves produces sound; hetrodyning of the sub-aether waves produces light. Not only does this theory give the periods of the different lines in the spectra, but it also predicts their intensities—a problem which the older quantum theory had no means of tackling. It should, however, be understood that the beats are not themselves to be identified with light-waves; they are in the sub-aether, whereas light-waves are in the aether. They provide the oscillating source which in some way not yet traced sends out light-waves of its own period.

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There are nine states which have less than half a million people apiece.

The Cuban humming bird, weighing less than a gram, holds the record for the world's smallest bird.

Deadly Gas—*Cont'd*

and explosions, the gaseous products of combustion of powder and dynamite and other explosives, blast-furnace stack gas, coke-oven gas, coal gas, producer gas, gas ranges and room heaters burning natural and manufactured gas, automobile exhaust gas, smoke from burning buildings, and railroad locomotive stack gas.

Automobile exhaust gas can be dangerous outside of garages, although it is always lack of oxygen that is the real cause of death, so that small closed spaces are danger spots in which to run motors. However, two truck drivers recently met death from exposure to carbon monoxide poisoning out on the road. They had stopped their truck but left the engine running, presumably to warm the driver's cab, which they had closed tight. They were found unconscious. The fact that the police did not at once recognize them as victims of carbon monoxide poisoning signed their death warrants. For they were locked up in jail where the scanty supply of oxygen in the air finished the job begun by the deadly gas from their truck's exhaust. Restorative measures taken some time later failed to revive them.

Allowing motors to idle while in traffic is one way to increase the amount of carbon monoxide in the air. This is particularly true because while waiting for the traffic control to change drivers often use the accelerator several times to keep their engines from stalling. This practice yields relatively high amounts of carbon monoxide and smoke, the Bureau of Mines found.

To avoid death from this poison gas, a plentiful supply of oxygen or of fresh air must be maintained at all times. In addition, correct adjustment of automobile carbureters, and careful attention to tubes and connections on domestic stoves, etc., should be made.

Fresh air, or oxygen from an oxygen tank, and absolute rest are the essentials of treatment for carbon monoxide poisoning. Both these measures should be prolonged for several hours, because it takes a long time to drive all the carbon monoxide out of the blood.

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There is no plant life in the sea below the point where sunlight can penetrate.

The longest jumping that a flea can do is about 13 inches horizontally and about six inches vertically.