Haziness and its applications

How belief in the wave theory of matter and the indeterminacy of Nature – coupled with a third (gross) philosophical error, the wilful confusion of measurement with fact – so undermined the discipline of experimental and logical thought that the chaos in modern physics became complete.

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It is often said that the indeterminacy of a physical measurement arises as a natural consequence of the postulated wave-like properties of matter itself and that it affords proof of those properties, but that is not so. Heisenberg himself was ambivalent about it: his preferred *derivation* of the Indeterminacy Principle was on wave-theory lines that took an electron to be a "wave packet" of de Broglie-type matter waves, whereas his arguments in *demonstration* took a light quantum to be a wave system but envisaged an electron to be a particle. In fact it is not necessary even for the light to consist of waves, because the Compton effect (which provided the basis of Heisenberg's own illustrations of the Principle) does not require waves for its physical explanation, as already discussed. The indeterminacy does not follow from any postulated wave-like properties of matter or light, but simply from the essential granularity or "quantization" (type one) of microphysical Nature – that is, from the fact that one's most fundamental measuring instruments, electrons and photons, behave like discrete, indivisible, self-consistent *particles*, of small but finite mass.

The wave theory actually entered the philosophical lists by means of a characteristically specious argument in the following manner. If, despite all the contrary evidence, an electron were to consist of a wave packet of matter waves, then the shape of that wave packet might perhaps be arbitrary. (After all, nobody has ever *seen* an electron). Axiomatically a wave packet is distributed in space, so that one cannot really define its position – that is, where its exact centre is – especially if it is a long wave-packet. On the other hand if it is a short one its position will be better defined, but in the nature of things it can then contain only very few waves. This means that its wavelength must be ill-defined, and according to the duality doctrine an electron's apparent wavelength as a wave system is to be associated inversely with its mechanical momentum as a particle. (The premise I refer to here is $p=h/\lambda$). So this concept seemed to fit Heisenberg's indeterminacy formula like a glove: if an electron were a wave packet, then its position and momentum would be mutually indeterminate for natural reasons. The indeterminacy would lie not with our measurements but within the structure of the electron itself. In that case, note well, our human failure to make precise predictions of its behaviour would arise simply because the electron's behaviour was itself imprecise or "indeterminate".

The attractiveness of this idea lies in the way in which it places the reason for our difficulties so firmly elsewhere; if Nature herself is indeterminate, how shall the physicists be blamed? It would provide a balm for nettled professional pride and a sop to human vanity if it were true, but of course it isn't. We cannot allow that an electron must become long and thin or short and fat according to the way in which *we* may choose to perform an experiment; that proposal conflicts with the general and consistent experimental evidence that electrons are indistinguishable. Nor do electrons dissipate like wave packets, any more than photons do. And between ourselves we have already rejected the doctrine of the indeterminacy of Nature on the logical ground of the unlimited precision of retrospective measurement. Appealing though it may have seemed to some people, that scheme just isn't on.

Nevertheless the concept of an electron as a wave packet persists. It leads directly to the established "doctrine of haziness" – the erroneous doctrine that fundamental physical particles are essentially and necessarily structureless, amorphous, and of indeterminate size and shape. The philosophical error which allowed that doctrine to flourish was the blandly false identification of the true, physical extent of the structure of a particle with the vague, probabilistic boundaries of *our knowledge* of its position. The error was made possible by the continued association of the statistics of position measurement with the mythical probability waves of the wave theory of matter – the mistake that has already been exposed in the "Reduction of the wave packet".

How can I be so sure that the identification was wrong? I offer two proofs, both independent of wave theory. One is that the form of a particle is a physical matter while our knowledge of its location is a metaphysical matter, and as before we may not identify chalk with cheese. The other is that *the imprecision of a measurement* (Δx) is not to be identified with *imprecision in the quantity measured* (δx) – more especially when, as in this case, the measuring instrument is granular or "quantized" and in that sense imperfect. It is like claiming that a precision-ground ball bearing is non-spherical and faulty because one can't measure its diameter very accurately with a domestic rule!

That last misidentification (of measurement with fact, $\Delta x=\delta x$) is such an obvious error that it should not be accepted from a sixth-form student; yet here we have found apparently-responsible physicists and teachers of physics not only perpetrating it, but *perpetuating* it for fifty years! From their contemporary writings there are grounds for suspecting that it, and the corresponding misidentifications in the case of momentum (Δp), energy (ΔE), and time (Δt), may have been made wilfully by the Copenhagen School in the 1930s, rather than through ignorance of the philosophical issues involved. This is not to impute to those concerned any motives other than the highest: they were genuinely seekers after fundamental truth. But it does seem that they may have been carried away by the sheer excitement of the new ideas that were developing in natural philosophy, and entranced by the mysticism into which these ideas were so inexorably leading them. They *wanted* the world of electrons and photons to be mystical and mysterious. Their picture of that world could be summed up fairly accurately as follows:

– Everything in microphysics is indeterminate (or hazy).

– Everything in microphysics is "quantized" (or precise).

Unless care is taken over the definition of terms these two statements are mutually contradictory. (An example of their conflict was developed in the, *WW* June 1982 article, page 81). I have argued that the first is untrue and I could argue similarly about the second, but instead I will tell a fairy story and leave the judgement to you.

Once upon a time a young man was measuring the speeds at which beta particle (fast-moving electrons) were being ejected from radioactive atomic nuclei. He found that their energies varied smoothly over at least a ten-to-one range, which surprised him because he had expected to find instead a series of sharp energy values like a line spectrum in light. On the other hand, gamma rays (photons) that left the nuclei at approximately the same time did show a line spectrum, which was interpreted as evidence that the internal structure of the nucleus is "quantized" (type two) into definite energy levels – like a Rutherford/Bohr planetary atom, only more so.

I think everybody would agree that atomic nuclei are quantized (type one), in that every nucleus is constructed out of a definite number of discrete particles, protons and neutrons, that can be recognised in the free state by their consistent properties and behaviour. But according to the new ideas the *mechanics* of everything small is also quantized (type two), and because the atomic nucleus is very much smaller than the complete atom, *a fortiori* should the mechanical energy and momentum within the nucleus be quantized. Yet the beta radiation, which is associated with the radioactive decay of one neutron into a proton inside the nucleus, apparently is not quantized. It was an article of the new faith that it should be quantized . . . "Therefore", said the quantum theorists, "the conservation of energy must have failed (Niels Bohr); or, alternatively, the experimental evidence of the beta decay must be wrong".

Wolfgang Pauli saved the day, by postulating the existence of a completely unexpected *neutrino* or "small neutral particle" which had about the same mass as an electron but no electric charge. Such a particle, he suggested, would not show up in any ordinary particle counter or photograph. So: if one neutrino were to be emitted along with every radioactive beta electron, nobody would ever be able to detect the fact; but the invisible neutrino would carry away energy too, so that it and the beta electron, between them, could possess the quantized line spectrum of energy that the theory demanded although the visible beta electron did not. (The failure to quantize the sharing of this energy between the neutrino and the beta electron in fixed proportions was not explained).

Now if you feel this to be a somewhat implausible, *ad hoc* suggestion, designed to make the experimental facts agree with the theory and not far removed from a confidence trick, be sure I share your suspicions. The question before us is: Do we believe in neutrinos? We would not be alone if we didn't. Neutrinos are essential to the modern quantum theory, however, and their existence is assumed as a matter of course when describing nuclear reactions, yet not even their owners seem to be very sure about them. When first invented by Pauli they had about the same mass as an electron (so as to share the missing energy equitably, on average); then suddenly it was proved that they could have no rest mass, but must be like some kind of non-radiant, indetectable photon. However, to make up for that they must be spinning – "but not *mechanically*, of course, since there is no structure there to spin". More recently it has been declared that they probably do have rest mass but very, very little (actual amount unspecified), and that there must be at least four different kinds of them. It does not add up to a very convincing story.

From the theorists' viewpoint the delightful thing about neutrinos is that they are virtually indetectable. Being so light, and electrically neutral, it is said that most of them fly right through the planet Earth, touching neither nucleus nor electron and leaving no trace of their passage. (There is another logical inconsistency here too, but we needn't labour every one!). Very occasionally a particle counter registers inside a 12ft-thick steel box near the target area of the big CERN accelerator at Geneva, and this effect, like some others, is attributed to a neutrino collision because "it couldn't be anything else". Then one day the astrophysicists discovered that, according to current theory, the Sun should be pouring out neutrinos at a calculable, fabulous rate; and accordingly an enormous neutrino detector was built in the United States especially to look for them, deep below ground in a diamond mine where unidentified particles would be unlikely to be mistaken for neutrinos and confuse the results.

That experiment was reported in 1976. It detected fewer than one-tenth of the neutrinos of solar origin that it was expected to detect, and maybe none; there is no assurance that the very few nuclear reactions that it did detect were actually due to neutrinos. The astrophysicists have been sent away to do all their sums again. But why should the poor *astro*-physicists take the blame for this negative result? What if Pauli's adventurous speculation should have been wrong, and his postulated neutrino never existed after all? To the theorists such a thought really is unthinkable: for if, after weighing the evidence, we were to determine that on balance of probabilities we did not believe in neutrinos, then we would be suggesting that the atomic nucleus might not be "quantized" (into discrete energy levels, type two). And that thought in its turn would strike at the roots of every modern theory about the physics of elementary particles.

Now I said at the beginning that little was to be gained by attacking established theories and thereby triggering all their devotees into uncompromising battle in their defence. That line is, in modern parlance, "counter-productive". It is much better to examine miracles – physical phenomena that we do not in truth understand, although our various theories may be willing to offer glib but scarcely plausible "explanations" of them at the drop of a hat. Surveying modern physics, it is in the territory of the elementary particles that miracles are thickest on the ground. Vast sums of money and immense efforts of mind have been spent on particle physics over the past fifty years. Each new atom smasher, when eventually it is made to run, generates a host of new problems *but solves no old ones*. There has been no credible outcome from all this outlay. Instead, we find all manner of hypothetical entities cluttering the contemporary letterpress – "as charmed quarks, evincing isospin", for example – concepts which are supported by no physical evidence, untested and *in principle* untestable experimentally. (Pau-

Indeterminacy and elementary particles

The influence of the wave theory was paramount in the arguments which led to the denial of causality. The most obvious example of this – also historically the first – was the doctrine that an electron, as an elementary physical particle, was amorphous and structureless because it was "really" a wave-packet of de Broglie waves. The logical error at the centre of this is identifiable as such without difficulty. Thereafter the technique of bending experimental results to fit in with pre-conceived theoretical notions became established, with the general acceptance of the *ad hoc* postulate of the neutrino. The wilful misinterpretation of the meaning of the Indeterminacy Principle then heralded a final rejection of physical discipline, leading to the invention of "virtual processes" which violate the conservation laws whenever convenient, as exemplified by the "prediction" of the meson. Having got away to such an inauspicious start the study of elementary particles had little chance of recovery; the rather obvious failure of theoretical physics in this area, due to its domination by "quantum" metaphysics and mysticism, is scarcely surprising.

li's neutrino gave only a first glimpse into this modern fantasy world.) Particle physics today is in an almost impenetrable mess, infinitely more confused and less coherent now than it was when Chadwick discovered the neutron in 1932. I wonder why?

It seems to me possible that the lamentable state of this area of physics may reflect, and indeed be the consequence of, its domination by the metaphysical ideas of the "quantum theory" of the Copenhagen School. A quotation from a popular modern textbook (no names, no pack-drill!) may provide a convenient example for analysis:-

"*Because of* the Heisenberg uncertainty principle in quantum mechanics, a particle cannot have a definite position in space-time and a definite energy and momentum. The more localised the particle is in space-time, the larger the uncertainty in its energy and momentum. So that, *virtual processes which do not conserve energy and momentum can occur* over very small intervals in space and time *by virtue of the Heisenberg uncertainty principle,* provided they are followed by processes which ensure conservation of energy and momentum for the whole process." (My italics)

There, good friends, you have it all. The student is being told, *ex cathedra,* that it is legitimate for him to postulate any "virtual process" in his theories (by which is invariably meant a process that violates the conservation laws) *provided he is not found out*! Perhaps, philosophically, we have asked for this: we live in an indisciplined, lawless age, where logical consistency and honesty are no longer demanded. The fundamental error in the passage quoted, which is no misprint but a faithful transcription of currently-established doctrine, lies in the statement that a particle "cannot have" a definite position in space-time and a definite energy and momentum; here is the false doctrine of the Indeterminacy of Nature, rather than the legitimate indeterminacy of *measurement.*

That the misinterpretation was deliberate is well evidenced. In 1935, by an *exact* application of the "virtual process" argument quoted above, Hideki Yukawa "predicted" the likely existence of a mesotron or *meson* (medium-sized particle) – a manifestation of nuclear binding energy which might appear externally in the guise of a discrete particle when an atomic nucleus was disrupted. The meson was duly discovered experimentally and its track photographed two years later, an obvious and brilliant success for the doctrine of haziness. Unfortunately some 35 different kinds of meson are now known (by count dated 1973), and the mechanism of the conservation-dodging "virtual process" as it was argued by Yukawa can reasonably account for only one of them.

The unexplained plurality of mesons represents only the tip of the iceberg. The total of recorded elementary particles exceeds 85 (1973 figure)*. I consider myself to be just as radical a thinker as the next man, not at all old-fashioned, and I am quite willing to believe that the 60 or more of the particles currently listed which have immeasurably short life-times – in the trade they are sometimes called "resonances" rather than particles, with good reason – are simply the undifferentiated, non-specific explosion debris of subnuclear disintegrations: isolated, fast-flying packages of energy which are of the wrong mass to form themselves into mechanically stable or partially-stable structures (≡ "particles"), and which are *actually* dissipating, spreading out into space and effectively vanishing before our very eyes. (This would correspond to a loss of detectable energy from the local system, although the conservation law would not be violated in the universe as a whole). I would not expect such ephemeral, neutrino-like things to be "quantized".

What of the remaining elementary particles, of at least 25 known species, whose lifetimes range from the 10^{-10} seconds or so of the principal baryons to the all-time stability of the proton and the electron? (Why are they stable? Why are all the others unstable?). The established dogma of today's "quantum theory" holds that it is improper to ask (or answer) questions about their structures, which can never be observed; but what about their masses, which are very accurately measurable? How, and why, are the masses – or internal energies – of these elementary particles, building-blocks of the physical world, related to each other? Current microphysical theory offers no answers to such fundamental questions, and has made only one memorable prediction (the "omega minus" particle, forecast by extrapolation). It invented a series of qualities for elementary particles which, it held, "must be" quantized plus/minus like spin and therefore "must be" conserved. One of these qualities it called parity. It did not even blush when the first honest experiments showed that parity was *not* conserved. Instead it went on to devise – via relativity theory, if you please! – yet another indetectable particle, a tachyon which *always* travels faster than light . . .

In view of the immense efforts that have been expended in its area, current microphysical theory would seem to have been something of a failure. "Microphysical entities are hazy", we are told by eminent men, "and one should not ask old-fashioned questions about them". Surely such haziness is more likely to lie in human minds than in fundamental physics?

* Over 200 now, ten years later. Is this progress?

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continued from page 59

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a while. At a tape speed of 19.05cm/s the roller will make 5.619 revolutions per second. The timing disc, which is mounted below the roller, has 16 slots (Fig. 2) and therefore produces an output frequency of 5.619×16=89.912Hz. This is counted down to 0.999Hz, which is near enough to 1Hz. The transducer was mounted in place of the tape tension arm.

The tape motion sensor is located underneath the right-hand reel motor (Fig.3). Its timing disc and timing components (Fig. 4) are designed to output a pulse train when the machine is in the play mode and to supply a logic 'high' to the control circuits in the fast wind and rewind modes. It is important that the disc is made as accurately as possible and that the components are chosen appropriately: otherwise the circuit may not detect the exact moment when the tape stops moving, especially if the direction of tape travel is changed directly from one way to the other.

Interfacing the tape recorder function switches to the control logic is done by using the quad line receiver SN75189, which is useful for this purpose because its imputs can withstand up to ± 30V. Equivalent devices are DS1489 (National Semiconductor) and MC1489 (Motorola).

The counter-display section is conventional, except that it is capable of counting both up and down and that the minutes progress to 99 instead of 59. In the present design it was considered undesirable that the minutes counter should go below zero if a rewind beyond the initial starting point took place. Therefore the dotted circuitry was added to ensure that the minutes counter stops at zero when rewinding. In the prototype, this feature was made optional by inserting a dil switch pack. Reset is derived either from a manual switch or from an optional clear leader detector. The variable resistor is adjusted for a 50% duty-cycle at pin 7 of the LM311 during rewind.

The clock requires a stable power supply of 5V at 1A. Proper bypassing of the logic, especially the counters, will be necessary. WW