

# A Heretic's Guide to Modern Physics

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## A MORE REALISTIC DUALITY?

*Instead of trying to ignore Planck's quantum hypothesis because it conflicts with electromagnetic theory, suppose we were to afford it more than lip-service — what then? New situations would arise that could be tested by experiment.*

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I have suggested that an experiment in the interference of light which was first performed as long ago as 1909 might profitably be repeated with modern photon-counting light detectors. Its purpose would be to explore whether or not a simple alternative concept might be offered in place of the currently-accepted, but philosophically dubious, doctrine of the wave/particle duality of light. The experiment is neither expensive by modern standards nor particularly difficult, but it would require great care; it would require tests to ensure that the apparatus was dealing with single photons rather than with naturally-radiated bunches of photons forming coherent wave-trains. Of the various phenomena in light which could be chosen for test, interference in a space interferometer would seem to afford the greatest facility for detailed analysis and the least scope for dissentient arguments.

It would be very wrong to pre-judge the outcome of this experiment, and we should be careful to avoid doing so. We should also remember that there may be other conceptual alternatives to the duality doctrine to be considered besides this one. This one seems to be the simplest, but that doesn't mean that it is necessarily correct; we may have to try several before Dame Nature smiles on us. For these reasons I have said that I cannot yet offer an alternative doctrine, at any rate with confidence. We really must have recourse to experiment here. Nevertheless it is interesting and quite exciting to speculate as to how the subsequent developments might go if the concept were upheld that light radiation consists of photons travelling at velocity  $c$ , and light "waves" consist of periodic variations of photon density, as Einstein once suggested. Without commitment, we may explore some of the consequences which might follow if that concept were true.

The first point to be cleared up is the business of light travelling happily in a vacuum, where — by the Michelson-Morley experiment — there is no physical ether medium for light waves to undulate

in. Waves of the newly-postulated type, which are *statistical manifestations of varying photon density*, do not require a medium for propagation. Sound waves in air, on the microphysical scale, consist of variations of the density of gas molecules above and below the mean air density, and it is this mean density which establishes the velocity-zero of the "medium" through which, we say, the waves travel. In the case of light there is no mean density; even within a solid crystal such as a diamond the photons are travelling by direct or devious routes through the space (that is, the vacuum) between the adjacent crystal ions. On this concept, then, a wave crest would correspond to a maximum of photon density, while at a wave trough there would be no photons.

The number of photons involved in a light-wave is staggering to comprehend. In a typical medium-wave radio broadcast transmission one half-cycle of radiation — a millionth of a second's worth — will contain about  $10^{25}$  photons. It is not surprising that with such numbers of photons around their average density adds up to a very smooth and precisely-defined wave-shape indeed. That is why the wave theory provides such an accurate description of the behaviour of radio radiation and even of ordinary, visible light. On the other hand, as we move up through the spectrum past the ultra-violet and into the x-ray region, individual photons become heavier and contain more energy, so that in consequence there tend to be fewer of them. In the end there are no longer enough photons present for their average density to establish a reasonably accurate wavelike shape; in such cases x-rays and gamma-rays are found to behave like particles and to show no obvious wave characteristics, and we say that such situations "require quantum treatment". Now we can begin to see why.

This experimental observation is enti-

rely consistent with the photon-waves proposal, but diametrically opposed to the continuity concepts of electromagnetic theory. The proposed mechanism is very different from that of sound waves. At sufficiently high altitudes the effective continuity of air as a wave-propagating medium breaks down and sound is no longer transmitted; individual air molecules are still present and travelling at tremendous speeds, but their motions are random. By contrast, the photons of natural light are generated and travel together thereafter in a systematic way, whose statistical effect is that of a partially-coherent wave system. In this manner the photon-waves concept is able to explain — not just to describe — the wavelike behaviour of light in those low-energy situations where the electromagnetic analogy works to a high degree of approximation, and it is able to explain equally well the particulate behaviour of light in situations where electromagnetic theory fails. There would seem to be a *prima facie* case for taking the concept further, and for performing some of the fundamental experiments that would be required in order to test it in the laboratory.

The celebrated wave-like properties of light which led to the general acceptance of the wave theory in the 19th century are principally those of refraction, diffraction, and interference. According to the photon-waves concept all these phenomena are manifestations of *group behaviour* — that is, of the behaviour of photons in quantities so large that the wave theory is valid as an approximation. Greater detail is not appropriate here, except perhaps to say that it seems a distinction can be made between pure diffraction, due to the deflection of photons in the near vicinity of material objects such as prisms, slits or gratings, and pure interference, due to "exclusion" forces acting between individual photons in space. Practical situations tend to involve combinations in varying amounts of the effects of pure diffraction and pure interference. Because their mechanisms would seem to differ,

the possibility arises that suitable experiments might be able to separate the two effects and thereby quantify both.

Such experiments would be quite new. Although we now have photoelectric detectors that can record the arrivals of individual photons, the general acceptance of the duality doctrine has effectively inhibited a systematic re-exploration of this area. Suffice it to say that even if they have been performed, no such experiments have ever been reported in the published literature. Perhaps we should not be too surprised at this. The particular experiments that we have been considering would constitute steps towards determining the size and physical structure, if any, of a photon, and few suggestions would be more likely to excite ridicule in the scientific hierarchy than a proposal to investigate the physical properties of an entity so fundamental as a photon! Such a proposal would cut right across the accepted dogma of modern physics, which holds that because of the "completeness" of the quantum-mechanical theory we already know all that we shall ever be able to know about these fundamental matters . . .

Now: what do we know about photons? By the harsh discipline of experiment — before fundamental experiments became unfashionable — we have been taught that light is radiated in packages or quanta. From the photoelectric experiments in particular we realise that these quanta do not dissipate in flight but remain complete as units, as if they were particles. As particles, we call them photons. From the same experiments we deduce also that photons carry physical energy and physical momentum, the amount of this energy and momentum determining the colour of the photon. To our surprise we conclude (because both photons and "waves" travel at the same velocity and therefore must have constant relative phase) that an individual photon does not possess a frequency or a wave-length — which is *not* what we were taught at school! And we note as a point of great significance that the only means by which we can detect light (in the retina of our eye, on a photographic plate or film, by photocell, or by photosynthesis in plants) is by some variant of the photoelectric effect. *Summa: we deduce* the wavelike properties of light, sometimes; whenever we detect light we seem to be detecting photons.

It is photons, not electromagnetic waves, which eject electrons from light-sensitive materials, and it is worthwhile to ask a few "improper" questions about the photoelectric process. (This, of course, is new and heretical work not approved of by the hierarchy.) If one considers the collision of a single photon with a single, isolated electron and takes the standard, accepted expressions for the energy and momentum of each, and then equates photon energy with electron kinetic energy, photon momentum with electron momentum after collision — that is, if one applies the Conservation Laws to the encounter as if it were an ordinary mechanical collision — then the sum does not work out. A single line of working within the compe-

tence of any sixth-form physics student leads to the result that, whatever the energy of the photon and whatever the mass of the electron (or other particle), the velocity of the electron after the collision must always be twice the speed of light.

Clearly that result is nonsense. We have two choices. On the one hand we can accept the verdict of conventional doctrine, that the question was an "improper" one that should never have been asked — that is, that photons and electrons are mystical, hazy entities, amorphous and structureless, and that one cannot envisage an encounter between them as if it were an ordinary mechanical collision. "Ask a silly question, receive a silly answer" is the kind of supercilious comment that one might expect. On the other hand we can hold fast to the conservation laws — for it is the *conservation laws*, and not mechanics, that conventional doctrine is seeking to by-pass here — and say that the result of our very simple calculation is correct: the situation cannot happen, and we are to interpret the result to mean that *an encounter in which an isolated electron absorbs the entire energy of any photon cannot take place.*

The reason why it can't take place is as simple as the calculation itself: a photon carries far more energy per unit translational momentum than any ordinary "material" particle can contain kinetically. A third object must be present to absorb the excess energy and allow the mechanical energy and momentum equations to balance. What would happen if no material particle besides the electron were present? Energy and momentum must still be conserved in the encounter, and the obvious way for this to happen is for a second photon to be radiated, from the point of impact, to carry away the excess energy.

By now probably someone is screaming that I am giving free rein to fantasy, or at least inventing in a thoroughly unscientific way. How can I dare to treat photons and electrons as if they were ordinary mechanical particles when "everybody knows" that both photons and electrons are *wave systems* that just don't behave like that? I'm sorry to be so tiresome about it, but they really are particles, you know, and according to experiment they do behave like that. I have been describing to you a commonplace phenomenon known as the Compton effect. A. H. Compton applied this same, purely mechanical reasoning to the encounters of gamma-ray photons with electrons in 1923 — after Planck, but before the Copenhagen school got going with their doctrines of matter-waves, statistics, and haziness — and his calculations were confirmed *exactly* by experiment. There is no indication whatever of wavelike properties of either photons or electrons in the Compton effect. Also, the conservation laws are obeyed.

Thus far the discussion has concentrated on checking the photon-waves concept against various aspects of the experimental evidence, and I assure you that it can be submitted to, and pass, many other such tests that I don't have space to go into here. I would like to go forward now to

report on two new developments that follow from the concept. They suggest alternative interpretations of two details familiar from electromagnetic theory, and represent two differing degrees of conflict with that theory.

The Compton effect as Compton treated it involves the collisions of photons with *free* electrons, but at the temperatures we normally encounter very few electrons are truly free; almost all of them are "bound" in one way or another — usually by electrical forces — to individual atoms or within the general crystalline structure of a conducting or semi-conducting material. When a photon collides with an electron in the presence of a third, massive body (and the minimum such body is a proton, nearly 2000 times heavier than the electron), no secondary photon need be radiated to balance the books. The third body enables the excess energy to be absorbed and the Conservation equations to be satisfied, subject to two very interesting mechanical conditions: one is that almost all the photon's energy must be absorbed by the electron, which takes off at very high speed and leaves the heavy supporting structure almost standing still; the other condition is that the direction of the electron's motion must be *at right-angles* to the incident photon's track to within a few hundredths of an angular degree.

Those results constitute an entirely straightforward, new explanation of the photoelectric effect, calculable to any accuracy one pleases on the purely mechanical basis that both photons and electrons are particles whose interactions obey the conservation laws. It is truly and literally a *quantum-mechanical* calculation. Since no light waves or matter-waves are involved the conventional "quantum mechanics", so called, will have none of it. It does not

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### Summary

Although it would be wrong to pre-judge the outcome of modern low-light-level experiments it is legitimate to speculate on the consequences of a positive result. The wave-like behaviour of "photon-waves" can be accounted for by making a small number of working assumptions which can themselves be tested by experiment (not discussed in detail). Their particle-like behaviour can be explained by purely mechanical arguments — by applying the conservation laws to collisions between photons and electrons treated as particles. The highly successful work of Compton in 1923 can be extended to provide new and simple explanations of the photoelectric effect and of the ionization of the atom (the latter again is not discussed in detail). These arguments raise conflicts with electromagnetic theory, as is to be expected; but the crucial conflict is raised by the statement of the new theory that an isolated electron — a "point charge" — does not radiate energy when accelerated, as electromagnetic theory has always asserted that it must. This particularly important issue could also be put to experimental test.

high priority: the 8275 is programmed to know how many bytes it is expecting from each refill and, if this number is not achieved, the screen goes blank. The 8275 does have five programmable registers, but the waveforms it generates are not as flexible as those produced by a 6845.

Because it is up to the processor to fill the buffers, the processor can decide where to get the bytes from. Normally the software will keep a table of pointers, with the first pointer being the start address of the block of video ram making up the first line on the screen, the second pointer for the second line and so on. Changing the pointers is one easy way of scrolling, and setting all the pointers to be the same would generate a picture with every line on the screen the same.

**Character and screen attributes.** An 'attribute' is an enhancement, such as underline, which can be added to characters or the whole screen. Typical attributes are reverse video (where all that is black becomes white and vice versa), underline, varying intensities or colour, flash and combinations of these. The 8275 can implement most of these attributes automatically by recognizing special codes in the video ram. They are often called field attributes because all the characters following the attribute have that enhancement until a new field attribute is encountered. Suppose part of a text displayed was "A CAT" where cat was to flash, but all succeeding text is normal — the bytes corresponding to this might be:

41H20H	F4H	43H41H54H	FBH
A SPACE	FLASH	C A T	NORMAL
	ATTRIBUTE		ATTRIBUTE

When the c.r.t. controller recognizes an attribute, in this case by bit seven being set, it puts them into separate buffers. The software must ensure that the main buffers

get their full quota or suffer screen blanking.

**Motorola 6845.** Unlike the Thomson chip, this c.r.t. controller can be programmed to run at scan rates other than that of standard television. Like most modern peripheral chips, its programmability is via internal registers, rather than pins on the chip, and is compatible with the 6800 processor bus. The simplest version of the 6845 has nineteen internal registers, mainly write-only, one of which is an address register. To access register five, say, 5 is written onto the address registers. Until that is changed, all further communication is with register five. On power-up, it is up to the user's system to initialize all the registers and, for this reason, programmable c.r.t. controllers can be clumsy to use in a system which does not use a microprocessor. Such a situation would need additional hardware, such as a small prom and counter which, on reset, loads bytes into the controller's registers, and would severely limit flexibility to what is in the initialization prom. The 6845 is extremely versatile — in the horizontal scan, the frequency, sync. width, number of characters and the time from end of sync. to start of video are all programmable. So are the number of rows, vertical sync. rate, time from the end of sync. to video and the number of scan lines per row. Two of the registers define the position of the cursor on the screen, and there is programmable height and flash rate. There is also a light pen input to the chip which, when activated, copies the contents of the memory address lines into two read-only registers.

**Scrolling.** The 6845 has twelve video-ram address lines and so can access 4K of memory, enough for two large pages of text. Bearing this in mind, scrolling can be implemented in two ways. Firstly the user's processor, on detecting that the screen is full, can copy each byte on the

screen into a new video ram position — equivalent to the text scrolling up one line. This, however, places a heavy burden on the processor and should really be avoided.

The second technique is to tell the c.r.t. controller to start taking bytes from a different block of video ram rather than the block right at the beginning. Imagine that blocks of 80 characters were positioned in video ram, with the first byte of each row having the addresses 000H, 050H, 0A0H, etc. Before a scroll occurred, the c.r.t. controller would start taking bytes from address 000H at the top of each page. After one scroll that first address would become 050H, and so on. The 6845 can handle this, having two registers defining the address of the first byte. This considerably reduces processor overheads: to implement a scroll, four bytes (two address, two data) are issued to the c.r.t. controller. The video ram is considered as a sphere with the screen being a window on the surface of the sphere, movable in the north/south direction. Occasionally the microprocessor will have to clear areas of video ram, when a new clean line is needed for a scroll. The 6845 cannot be used when each line on the screen can be a number of contiguous bytes in the video ram. To cope with this, a different type of c.r.t. controller is needed, such as the Intel 8275.

Several manufacturers make the 6845 and updated versions which offer more facilities, and recently the price has dropped below £15 for one. It should be remembered that it is not easy to use the 6845 without a processor controlling it, and calculating the bytes with which it is to be loaded is not straight-forward. However, I consider the 6845 the most programmable and useful of all the c.r.t. controllers I have considered.

Although there are now a handful of c.r.t. controllers on the market, for a one-off design of a fixed format screen, discrete logic is still cheaper. WWW

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require the obscurely transverse waves of "electric force" of electromagnetic theory to account for the observed behaviour of a radio dipole or television H-aerial, but it explains the transverse induced current — that is, the transverse motion of photoelectrons — in a simple and natural way. The reception of radio energy, like the detection of all light, is seen to depend on the mechanical photoelectric mechanism; in accord with experiment there is no indication anywhere that light in transit *in vacuo* is influenced by electric or magnetic fields or that photons are electromagnetic. Finally, when the mechanism is applied to the Rutherford/Bohr/Sommerfeld model of the hydrogen atom it provides, for the first time, a mechanically-plausible description of what happens when an atom absorbs or radiates a light quantum.

As early products of the proposed photon-waves concept these examples may be thought to represent substantial successes. But one can't make scientific omelettes without breaking scientific eggs and we are now going to shatter an egg that has been

around for a very long time. That same logic of particle mechanics and observance of the conservation laws which once explained the Compton effect, and which has now described the photoelectric mechanism of the detection of light and radio energy, leads equally surely to the inverse statement: *a photon cannot be radiated by an isolated electron*, but only by a "Planckian oscillator". This is likely to lead to a first-rate argument, because according to the electromagnetic theory an isolated "point charge" (ie, an electron) must radiate electromagnetic energy when it is accelerated, while according to the tale I have been telling you it does not and cannot.

This very long-standing prediction of the electromagnetic theory has never been tested in the laboratory, although the means for testing it have been available for half a century. The radiation due to electrons being accelerated in an ordinary electron gun (as in a television picture tube) should be detectable with a sensitive radio receiver — in fact it might be expected to interfere with radio reception —

but no such interference has ever been reported. (To forestall a probable objection, let me say that neither the so-called synchrotron radiation nor man-made x-radiation seems to be due to the acceleration of *isolated* electrons.)

An experiment on these lines could be performed quite easily, and it might be thought very important. It would provide an opportunity to test the mechanical quantum concept against electromagnetic theory on an issue unclouded by the mystical arguments of wave/particle duality. If it should turn out that an electron circulating mechanically around an atomic nucleus has no tendency to lose energy and "run down" — as *electromagnetic theory* has predicted that it must run down — then one of the founding premises of modern *quantum theory* would turn out to have been a false lead.

It is time we took a look at quantization, which by itself is easy to understand, and at some of the very odd ideas that grew out of it when Alice re-visited Wonderland, during the years 1925 to 1930. WWW