

The man behind an identity in quantum electrodynamics

by F. J. Duarte

Introduction

The 6th of May, 2010, marks the 10th anniversary of the passing of John Clive Ward a quiet genius of physics whose ideas and contributions helped shape the post-war quantum era. Since John was an Australian citizen it is only appropriate to remember him in the pages of this journal. First, as a manner of introduction, I will outline John's most salient contributions. Then, I will attempt a description of the physicist, teacher, and friend that I was privileged to know.

Physics

In an approximated chronological order the contributions of John Ward began with a paper published (with Maurice L. H. Pryce) in *Nature* as part of his doctoral research at Oxford (Pryce and Ward, 1947). This was a solution to a problem, that according to John was posed by Dirac, and that J. A. Wheeler had tried to solve (Ward, 2004). The suggestion to tackle this problem was made by Pryce (a former student of R. H. Fowler and John's supervisor). This had to do with the decay of γ particles and the emission of two correlated photons in opposite directions. John correctly predicted the angular distribution of the photon polarization and that these quantum results were incompatible with classical descriptions. Soon thereafter John's prediction was confirmed by experiment (Wu and Shaknov, 1950). These were the first publications that made explicit the incompatibility of quantum mechanics with local theories (Dalitz and Duarte, 2000). Nevertheless, these early entanglement papers remain largely unrecognized.

Next, following a conjecture of Dyson (1949) in his second paper, on the equivalence of the quantum electrodynamics theories of Feynman, Schwinger, and Tomonaga, John introduced his celebrated *Ward Identity* in a very succinct paper (Ward, 1950). This paper was followed by a set of identities a year later (Ward, 1951). Today Ward's contribution is also known in a modified context as the *Ward-Takahashi Identity*.

Then came the collaboration with Salam on the development of the *Standard Model* (Salam and Ward, 1961, 1964a, 1964b). The conversations of John on this topic were sporadic and when they did occur he expressed uneasiness about Salam's propensity to publish prematurely. This is explained at length in his memoirs (Ward, 2004) and became a topic of interest in the recent book *Cosmic Anger* (Fraser, 2008). More about this later.

In addition to these Herculean contributions John collaborated with well-known mathematicians and

theoreticians thus producing a series of brilliant papers on: the Ising Model (Kac and Ward, 1952), quantum solid-state physics (Ward and Wilks, 1952), quantum statistics (Montroll and Ward, 1958), and Fermion theory (Luttinger and Ward, 1960). His last paper was on the Dirac equation and higher symmetries (Ward, 1978).

In a piece written in an Oxford publication it was once stated that Ward "has contributed deeply to an astonishingly broad range of theoretical physics: statistical mechanics, plasma physics, quantum electrodynamics, and particle physics"

and the writer continues "*he has drawn attention to basic truths, and has laid down basic principles, which physicists have followed in subsequent decades, often without knowing it, and generally without quoting him.*" (Dunhill, 1995).

A further appreciation of John's contributions came from Andrei Sakharov who classified him as one of the "*titans*" of quantum electrodynamics alongside Dyson, Feynman, Schwinger, and Tomonaga (Sakharov, 1990). More recently, we have also learned that John Ward was among the early pioneers in the application of *Feynman diagrams* (Kaiser, 2005). I should emphasize that for as long as I knew John he never mentioned this.

In December 1988, in Lake Tahoe, I was introduced to Julian Schwinger. As soon as he knew that I came from Macquarie he asked "Do you know John Ward? Is he difficult to get along with?" Throughout the 1990s I had a

number of conversations, and corresponded, with Willis E. Lamb on quantum measurements. In several occasions our conversations would end on the topic of John Ward as Lamb, who knew him from the 1950s, had great admiration for John's physics.

Days at Macquarie

The first time I heard the name John Ward was in the first semester of third year physics. Some of my fellow physics students using a somewhat mysterious tone used to mention a brilliant physicist due to lecture us. It was 1976 and



we were taking quantum mechanics with Guy Fletcher, a Cambridge physicist. Fletcher was an excellent teacher and wrote neatly on the board. For the second part of the course came John Ward. By contrast, he spoke softly and mumbled a lot. He kept on looking at the board, wrote in a peculiar cryptic style, and kept on shaking coins in his pocket while sometimes talking so softly that it was impossible to make sense of what he was saying. That was my first impression of the brilliant theoretician. Not a good one indeed, especially since I was interested in getting a good grade in the course.

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John was a tall fellow and kept himself in fairly good shape. At the time he was about 52. He wore thick glasses and sometimes stylish clothing. He also taught us solid state physics. As I became more used to his mannerisms the lectures became clearer and sometimes extremely lucid. This is all I can say about third year physics with John Ward. As I went into my physics honours year, in 1977, John and I began to interact in the physics tea room due to the issue of the *science reform movement* which was created to reform the degree structure of the university via the introduction of a B.Sc (that would be added to the universal Oxbridge style BA). Then, something extraordinary happened. John Ward as a full physics professor had a luxuriously large office. His secretary had an adjoined office. It turns out that for some reason John did not get along with her and decided to move out to a small bare office where he took a few books with him. Remarkably enough he suggested that I and a fellow post graduate student, Milan Brandt, move into his spacious office. So we did. By now the campaign for the B.Sc. had intensified. Parenthetically: when the science students revolted, with widespread support from the science faculty, and the physics faculty in particular, John assumed a valiant posture openly granting interviews to the press in support of the science cause.

Otherwise, John Ward, the man, was distant and profoundly immersed in his physics. During this time he even managed to publish a paper (Ward, 1978). I say “managed to publish” because with John, publication was only considered once a truly new piece of physics was produced. Besides, he was highly critical of himself which explains the relatively small number of publications that he authored and co-authored: about twenty in total. In addition he was a master of succinctness. His doctoral thesis was only 47 pages long (Ward, 1949). His paper on the incompatibility of quantum mechanics and local theories was less than 2/3 pages long (Pryce and Ward, 1947). The paper that eventually gave rise to the famed *Ward identities* was less than a ½ page long (Ward, 1950).

During our conversations in his bare office, at Macquarie, John often went back to his days at Aldersmaston where he participated in Britain’s H-bomb effort.

Once, going through *The Feynman Lectures on Physics* (Feynman *et al.*, 1965) we came across the quantum representation of the polarization of the photon which was directly related to his 1947 paper and his doctoral thesis (Pryce and Ward, 1947; Ward, 1949). There, in a very tentative and shy manner, he conveyed to us that he was the first to construct those equations. But he did not actually say it in an explicit open manner it had to be almost deduced.

Perhaps because of his involvement in the British hydrogen bomb project, or perhaps due to a previous project with the Australian Atomic Energy Commission (Pryor, 1997), he was keenly interested in the performance of narrow-linewidth tunable lasers which was partly the topic of my doctoral research. One of the main applications for these lasers (Duarte and Piper, 1984) is atomic vapor laser isotope separation. Following afternoon tea, at the 8th floor of the Mathematics and Physics building, we would come down to the second floor and carry on the conversations in his small bare office. Topics would range from physics to the raging science battles. By this time he would mostly wear a light brown leather jacket and he would seat on a semi reclining oak chair that made an annoying noise every time he moved. He never bothered to have it fixed.

John’s attitude towards the faculty was rather admirable. I never heard him say anything pejorative towards any member of the faculty. In fact, he hardly ever said anything about them. He thought highly of teaching and respected those engaged in that activity. In terms of interactions he seemed most at ease with people like Dick Makinson, Ron Aitchinson, Fredy Chong, Elmer Laisk, and later Jim Piper. One exception was the disagreement with Peter Mason the other physics chair at Macquarie. Peter, who was a generalist with interests in biophysics, decided not to support the science reform movement. On that issue John was highly critical of Peter’s position but, very wisely, did not make that criticism public.

In general, John was very supportive, and regarded highly, the electronic engineering faculty. He had great admiration for anything practical. Let us remember that prior to being a physicist he was an engineer (Ward, 2004). This admiration also applied to experimental physics. His attitude towards mathematics was different. He expected us physicists to do well in mathematics and I clearly remember him saying “almost all mathematics is trivial.” Whether he meant that as a joke, or not, he never elaborated further. However, John perfectly understood the enormous importance of a good mathematical education and he encouraged us to take courses in applied mathematics. Being in a unique *School of Mathematics and Physics* a friendly rivalry existed between us and the mathematicians thus we never questioned John’s comment. In addition to Professor Chong the school had several well-known mathematicians including A. G. R. McIntosh, R. H. Street, and of course J. E. Moyal. A perspective on mathematics at Macquarie, during this time, is given by Ann Moyal (2006).

It is difficult to describe John’s sense of humor. He did tell a few engineering jokes but what I remember most is his ability to laugh at unusual situations. For instance, he laughed

particularly hard every time we outwitted our political opponents. One hot summer morning, at the tea room, we were informed that a package had arrived. The postgraduate, for whose experiment the package came in, said: "Have to walk a whole bloody mile." To which I pointed out: "It is only 1.61 kilometers." Immediately, John began to laugh while repeating "only 1.61 kilometers."

Around campus, and in physics circles, he was known as eccentric and peripatetic. His incomplete hair cuts, apparently done by himself, did nothing to dispel this image. It was also peculiar, that in modern times, he still took a boat to America. He lived in Pymble, not far from Macquarie, where he had a large house surrounded by tall old trees. The house was nearly empty, almost completely devoid of furniture. At the center of his spacious living room, with ample windows in the perimeter... a grand piano.

As the number of post graduate students grew John decided to teach a course at the honours level called Topics in Physics. Topics included general relativity, quantum mechanics, and physics relevant to our experimental work. He would lecture in one class and set up an assignment problem for the next one. At the problem session he would call on one of the students to offer a solution. In one of those sessions I was asked to discuss my solution to a problem related to the diffusion of an electron in a plasma within cylindrical coordinates. I proceeded using a Fourier approach. As I went along I noticed John, on my peripheral vision, getting increasingly restless. Unperturbed I continued until I wrote down the final answer. It had taken me about 20 minutes and a lot of equations. John said nothing and proceeded to clean the board. Half board later, in about five minutes, he arrived at the same solution. The master of succinctness had made his point.

John openly discouraged his physics students from pursuing a theoretical career. The uncertainty of his younger years probably had a lot to do with this attitude (Ward, 2004). As such, he never took a Ph.D. student despite open efforts by some mathematicians. More explicitly, John was highly critical of some "Ph.D. factories" in theoretical physics. On various occasions he used the word "rackets" to refer to some of those establishments.

When it came to politics John had no definite ideology. He was a truly independent thinker. He cherished individual freedoms and was critical, and suspicious, of big government. He detested corruption and waste of taxpayer's money. In this regard, he thought that the education of the young, via subjects that required critical thinking, was important. There was also a humanitarian side to his ethos. It was John who made it possible for Dick Makinson to come to Macquarie as an Associate Professor knowing full well that Dick had gotten himself in trouble for his left wing tendencies. Also, for a long time John supported financially the widow of one of his former friends. I learned this by looking at his papers, after his death, since he never mentioned it.

Greg Sheridan wrote in *The Bulletin*: "One of Ward's few close friends at Macquarie is a young Chilean postgraduate student, Frank Duarte... The two make an odd couple

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– the restrained, rather distant Englishman and the intense, earnest South American" (Sheridan, 1980). This was a fair observation since we came from very distinct backgrounds. In my opinion the factors that cemented our friendship were physics and an elusive sense of righteousness. Then, there were the peripherals. John praised my political maneuvering and willingness to speak to crowds. Also he repeatedly mentioned my ability to be seen in the company of attractive young ladies. One day that he brought this up I replied: "But John, you are *the professor*, why don't you get a beautiful young secretary?... I've seen many in administration." He replied, while laughing in a shy manner: "That's why! *those bastards* get the first pick."

In 1981 I accepted a postdoc in laser spectroscopy, with Brian Orr, at New South Wales. At this time I also began to correspond with some US researchers interested in experiments to test Bell's inequalities. When I discussed this with John he advised me to work on very sensitive interferometers instead. He was neither bothered by issues of interpretation nor did he have doubts on the correctness of quantum mechanics. Later when I had to describe a newly invented *N*-slit laser interferometer I did it using Dirac's notation to the dismay of some of my colleagues. The description is valid for either single-photon illumination or illumination using an ensemble of indistinguishable photons as in the case of narrow-linewidth lasers (Duarte, 1993). John was pleased. His thoughts on quantum mechanics are beautifully expressed in his memoirs (Ward, 2004).

The Year 1979

1979 turned out to be a year of contrasts. First, following two years of an intense political and academic campaign, the Academic Senate of Macquarie University finally approved the introduction of a B.Sc degree. As science rebels we were victorious in a confrontation important to us and described as a "nasty, bitter, bureaucratic struggle" (Sheridan, 1980).

Secondly, that year a Nobel Prize was given for the Standard Model of particle physics... and John was left out. He was annoyed. In his memoirs he refers to a premature disclosure by Salam as a factor in this episode.

While preparing the article for *Physics Today* (Dalitz and Duarte, 2000) I was enlightened by some long conversations with Dick Dalitz, a particle physicist, who himself was a giant of Australian physics known for the *Dalitz Plot* and the *Dalitz pair*. Dick was a life long friend of John via an interaction that apparently began when Dick independently derived John's results on the quantum polarization of the photon back in 1948 (Ward, 2004). Dick, who was intimately aware of John's abilities and theoretical know-how, told me that he spent a lot of time studying the Salam-Ward papers and his conclusion was: "John's contribution to the Standard Model was a lot more than popularly accepted." Also, P. W. Anderson conveyed to me, that among his peers, there were those that thought that John should have been included. An additional, and interesting, perspective (related to Salam) is

provided in the book *Cosmic Anger* (Fraser, 2008). Years later, in 1999, this issue surfaced again. By then, it was apparent that John had moved beyond this omission.

Final Conversations

When I came to the US we maintained sporadic contact via mail. Once he moved to Vancouver, to be relatively close to his sister Mary, he called me and thus began a series of phone conversations that revolved around current issues of physics, and my experiences in industrial America, with him occasionally warning me about “imbeciles.”

John loved Mexican food and when in Canada he would visit down south to sample authentic cuisine. He also liked good seafood and several times brought up his wish of sampling Chilean lobsters. Thus, we arranged for a rendezvous. On December 29, 1999, at 11 am my brother Henry and I met John at the Sheraton, in Santiago. He had flown from Punta Arenas (Southern Chile). Almost 17 years had passed but he was the same John. We sat down over a bottle of wine and lunch as he commented that with our shorts and hats we looked Australian more than anything else.

He needed a new pair of glasses and that afternoon we took him to an optics shop, in downtown Santiago. It was a hot afternoon so afterwards we sat at a cheap bar to drink beer prior to visiting an internet café to check on some physics sites. It was then that we noticed that all was not well with John. He became very tired and began to sweat profusely. We took a taxi back to his hotel. We agreed to have dinner next time at our house located at the foot of the Andes Mountains in the East part of Santiago. We picked him up from his hotel in my 1971 Bronco. Like a young man he could not hide his joy while riding propelled by a roaring V8 engine. After introducing him to my parents we sat on a table under a traditional grape vine canopy. Soon John and Henry were engaged in a detailed discussion on international finances and Australian tax law which demonstrated yet another facet of John's complexity. During dinner we mainly discussed geopolitics. After tea he asked me for photographs of my children (he knew two of them as toddlers, Rosa and Frank) and, in a moment of reflection, expressed regret at not having a family of his own. John had been briefly married whilst in the US but never remarried.

We met again for most of the day the 1st of January, 2000 at the Sheraton where we had lunch. By now, John regarded our reform of Macquarie as one of the most important accomplishments of his life. His eyes sparkled as he reminisced on the subtleties of the campaign. I would also add that the creation of a fine physics program at Macquarie, based on *The Feynman Lectures on Physics*, was a great contribution to the university and to the lives of many students who were fortunate enough to experience it. In retrospect it is clear that the significance of John's physics, or his vision, were neither understood nor appreciated by the Macquarie establishment.

Back in Western New York, one early afternoon by mid April, 2000, I was doing some experiments when John called from Vancouver. He thanked me for his updated internet page and laughed when I told him of a small insert in *The Australian*

Physicist, celebrating the 50th anniversary of the *Ward Identity*. At the end of this conversation he told me that he was not well. He called once again to let me know that he was going to a hospital. He had a respiratory disease. His sister Mary said that John's mind was clear until the end and requested that his memoirs be passed on to me for publication.

During our conversations in his bare office, at Macquarie, John often went back to his days at Aldersmaston where he participated in Britain's H-bomb effort. The theme came up again during our meeting in Santiago. Months after his death, while looking at his papers, I found correspondence between him and historian Lorna Arnold. Albeit Arnold pays due respect to John's absolute brilliance, as a physicist, she concludes that John's design was an “advanced concept... However, it was not developed” (Arnold, 2001). Unaware of Arnold's project Dick Dalitz and I spent considerable effort on this subject while we were preparing the article for *Physics Today*. We wrote and discarded many drafts of the article and at one stage Dick said: “We cannot leave it for the historians.” The paragraph in our article includes the sentence “Ward had independently conceived a two-stage device” (Dalitz and Duarte, 2000).

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