

Joistings 24

Getting into (the Philosophy of) Quantum Mechanics

1. Contexts

I would hope that the parallel with the previous *Joistings 23* would help us along and so I begin by drawing attention to it. So, you might pause, in thinking of either section 2, over the parallel between clasping quantum probabilities and clasping divine Persons. At a later stage we might enlarge on that parallel, drawing on Feynman's view of loving physics.¹ But it is worthwhile to pursue such leisured reflection yourself. Section 1, as before, deals with some contexts.

First, do you have enough physics to get into this topic?² Feynman is amusing about having too much classical physics³ and there is a value in his view which shows up in his approach. Some familiarity with Newtonian and Maxwellian analyses of situation seem necessary for starters, and an entry into the muddles that emerged in the early twentieth century. At least have a simple grip on the history such as George Gamow⁴ offers, and back it up with ventures into text books, not to speak of ventures in laboratories.

¹He regularly remarks about the need for some such an attitude on physics, something that came with his family, "this excitement in the house, this great love of physics": quoted, from an interview of Feynman with Jagdish Mehra, by John Gibbon and Mary Gibbon, *Richard Feynman. A Life in Science*, A Plume Penguin pb, 1999, 9.

²Unless you got a pretty good mathematical education, you wont have enough mathematics. For example, there are rather complex functions and procedures surrounding the study of the spectrum of hydrogen. Worse still, the various peculiar spaces involved right through. And then there is the entire zone of probability theory and functions. Such problems have to be tackled piecemeal.

³He makes the point regularly as he moves through his topic. There are, however, deeper issues involved here regarding complementarity of two approaches. I discussed this in an elementary fashion in *Randomness Statistics and Emergence*, Gill Macmillan and Notre Dame, 1970. But issues that I raise here go beyond that in pointing towards refined complex meanings of the word *aptitude*. See note 32 below and the text around there.

⁴George Gamow, *Thirty Year that Shook Physics*, Doubleday Paperback.

Next there is methodology in Lonergan's sense.⁵ The demands here are massive, way beyond a beginner who is only ten years out to sea on this voyage. What else might I say here? Well, what I do in the second half is presume, not that you are a proficient participant in functional specialization, living in the Standard Model of the end of this 21st century, but that you are going to benefit from the struggle with quantum mechanics to nudge yourself, your self, forward towards the Standard Model, meshed as it is to be in the four meanings of generalized empirical method that were topics in *Joistings 21* and *22*.⁶ A decade of methodological reflection is certainly not enough to put you in what I can call the mature come-about position.⁷

So let me be brief on this matter of methodological maturity. I see very little sign of it in global Lonergan culture after fifty years of the availability of the map named *Insight*. Useful here is to venture into the Cantowers that parallel certain chapters of *Insight*. In particular, of course, there are Cantowers 27-31 which parallel the first five chapters of Feynman's first volume. But there are others worth at least a first read: Cantowers 14-21 parallel the corresponding chapters of *Insight*, ending with that Cantower 21 on contemplation with the obviously paralleling name of *Epilodge*. But here I will restrict myself to two pointings: the identification of energy with what Thomas calls *prime matter*, and what Lonergan calls *the empirical residue* and what I tend to name nudgily *the empirical residence*. The nudge relates to the second pointing: to the

⁵Briefly, the four modes of generalized empirical method: three dealt with in *Joistings 21*; the fourth, functional specialization, named as such at the end of *Joistings 22*.

⁶You shall eventually (February, 2007) have to hand the book, *Lonergan's Standard Model of Effective Global Inquiry*.

⁷The position, of course, is that of *Insight* 388[413]. The come-about text that I refer to continually is on *Insight* 514[537], worth repeating here. "So it comes about that the extroverted subject visualizing extensions and experiencing duration gives place to the subject orientated to the objective of the unrestricted desire to know and affirming beings differentiated by certain conjugate potencies, forms, and acts grounding certain laws and frequencies ". It is a life challenge. Cantower 9, "Position, Poosition, Protopossession", can be a help here.

residence of the forms of physics.⁸ Even without the maturity of the come-about one should struggle to envisage those forms - I am writing now of conjugate forms - as structuring forms - they form the duo-extended actuality that we call *Space-Time*. But I must slide past that huge problem here.

The key point is to consider that the search of quantum mechanics is not for the goings-on of certainly entities in, e.g. a Minkowski space-time, but for acts that in their aggregation give structure to what are named *space* and *time*. It is helpful to hold to the notion here that the general Einstein equations, even boosted by Maxwellian anti-symmetries, are pretty much like the old gas laws of the type $PV = C$. And another help I would offer is Feynman's highly successful effort to give a popular glimpse of quantumelectrodynamics.⁹ His weird approach, shadow of the path integral method, nudges us towards a shake-up of the naivete of simple light paths in an obvious world.¹⁰ The topic of **two things in radiant conjugation** is quite another ball park, and at present there is no metaphysical control over the meaning of things and conjugations. In a hundred years or so I expect a luminous shuffle of the classes of the things of physics and their couplings. Perhaps, as a useful distracting pause, you might take time to get an eyeful of a distant rose. You can get that eyeful from another corner of the garden and, indeed, with help, from quite a distance. What do you think of the outreach of the rose, and what do you think of its greeting of the sun's outreach? Your

⁸One gets a start from two nudges of Lonergan. First there is *Insight* 437[462-3]“...mass-velocity will be a conjugate act; the mass, defined by its intelligible relations to other masses, will be a conjugate form; the space-time continuum of the trajectory will be a conjugate potency ...”. Then there is getting past Aristotle,'s view of local motion, perhaps less of a problem for the contemporary student. See the key text of Lonergan in *Phenomenology and Logic*, note 13 of page 13.

⁹Richard P. Feynman, *Q.E.D. The Strange Theory of Light and Matter*, Princeton University Press. 1985.

¹⁰There is the advanced Feynman presentation of this, worth venturing into if you are up to it: R.P.Feynman, *Quantum Mechanics and Path Integrals*, edited by A.R.Hibbs, McGraw Hill, 1965.

philosophic children will think quite differently of it in their shared come-about world.

I would not expect you to add the (third) complex context of the past century's debates about interpretations of quantum mechanics. On that debate Carver Mead is quite blunt,¹¹ but I would not recommend his book for a beginner's effort: it could be picked up after the final chapter of Feynman III, which it praises for its fresh turn.¹² But if you do have the itch to move into that area, or at least to build a little library, the I would list three books. The more recent book, Jeffrey Bub, *Interpreting the Quantum World*, tops my list.¹³ Then there is earlier book, Michael Redhead, *Incompleteness Nonlocality and Realism. A Prolegomenon to the Philosophy of Quantum Mechanics*.¹⁴ My third suggestion is by that controversial Irishman, John Bell: *Speakable and Unspeakable in Quantum Mechanics. Collected Papers in Quantum Mechanics*.¹⁵

And if I were to recommend one introductory reading it would be a short essay in that last book, "Six Possible Worlds of Quantum Mechanics". There Bell lines up, quite nicely, six views of the goings-on of quantum realities.

A fourth preliminary context-identification is symbolized by a phrase from chapter 16 of *Insight*: "an abstract relation field."¹⁶ It nudges towards a more serious grip on chapter 5 of *Insight*, and towards a fuller intussusception of the final pages of that chapter. The issue is getting a grip on the distinction between primary relations and secondary determinations: part of that difficult second context above. Here it is helpful

¹¹He regularly comments on it in his *Collective Electrodynamics. Quantum Foundations of Electromagnetism*, MIT Press, 2000. The Preface (pp. 2-7) and the index under *Bohr* give the flavour of his rejection of Bohr and his "clan", but the technical side needs serious work.

¹²*Op. Cit.*, p. xviii.

¹³Cambridge University Press, 1999 paperback.

¹⁴Clarendon Press, Oxford, 1992 paperback.

¹⁵Cambridge University Press, 1987.

¹⁶*Insight*, 494[517].

to add a somewhat popular identification of the crisis in physics that bubbled up in the beginning of the twentieth century. Think of the push of physics up till then as primarily a hunt for forms, laws. When these laws were applied, one added or sought boundary conditions, initial or final conditions. And continuity ruled the day: secondary determinations could run right along the mathematical continuum. But what if reality, or as Feynman would say, Nature, did not cosy up to this view?¹⁷ Then, even if initial conditions and conditions of discovery could be fluffed into a semblance of continuity, Nature could, would, say **No** to the final conditions of prediction. The classic cases here, of course, are the law of black-body radiation and the law of chemical spectra. Recall our first context above: you cannot afford to slip over these. But we will see in Part 2 how Feynman winds them into his pedagogical effort. How is one to handle, cope with, generate, discrete predictions, discrete secondary determinations? So, you come to Heisenberg's question and attitude, one that dominates Feynman's presentation.

The fifth context is again a detail of the methodological context, to be mentioned but not developed except as you sweat your way through Feynman's text. It is the context pointed to in the section on "measurement" in chapter five of *Insight*. The issue is handled broadly, but the serious issue of micro-measurement is passed over. Nor could it be handled in that early pedagogy-driven context. It needs the precisions of a mature metaphysics. Still, we may edged towards some of those precisions as we move beyond Feynman's Volume in Joistings 30.

Finally, there is the context of your own efforts, which we may well share in so far as, when reading this or Feynman's third volume, you communicate with me. Your context may well reach towards the full topic of a biography in history and post-history: so, for instance, there would emerge issues of adult and eschatological growth.

¹⁷A key zone here is the zone of the Bell, or the Einstein, paradox. "Nature apparently doesn't see the paradox" (F18, p.9). I comment on this in note 8 of the *Joistings* 25.

But let us, in conclusion, think more pragmatically of your own contexts of teachers and texts. My own education in this area ended in 1956, with a graduate course given, as part of the M.Sc. Program, to Lochlainn O’Raifeartaigh and myself by Dr. Shiela Tinney in University College Dublin on quantum electrodynamics, an in-topic at the time. I had, of course, no idea of what was going on, but we both did brilliantly - myself with the benefit of technical competence - in the final written exam. Now, those I am writing to may have the same challenge of getting through: then I repeat Lonergan’s advice to me when I was having trouble in Oxford; give the guy what he wants. Master the relevant techniques, the selected topics: don’t try to persuade professors on your way through that the focus of quantum mechanics is on discrete secondary determinations or, worse still, try to persuade them to read *Insight*.

But, back to practical matters, you may find that the texts I refer to are already dated, or not the ones you are using. So I would note that since 1956 I have been self-educated: I have not heard a lecture, or even had a conversation, about quantum theory, since 1956. The texts that I refer to, then, are texts that I found by luck, so I recommend them with that qualification. Is Lindsay and Margenau’s *Foundations of Physics* still worth reading? I would say a definite yes. Lonergan fought his way through it alone, with magnificent results.¹⁸ My suggested supplement to it is Ian D. Lawrie, *A Unified Grand Tour of Theoretical Physics*.¹⁹ In quantum mechanics itself I refer here to two texts, one an Introductory text, the other a more comprehensive graduate text. The comprehensive text is J.J.Sakurai, *Modern Quantum Mechanics*.²⁰ That is the main text

¹⁸This is something that requires later research and interpretation. You would find useful here the second section of *Joistings 2*, where I point out the manner in which Maxwell’s work is included in the book *Insight*.

¹⁹Institute of Physics Publishing, Bristol and Philadelphia, 1998 paperback.

²⁰Addison Wesley Longman, 1994, hardback; edited posthumously by San Fu Tuan. This book is more of a graduate text: a fine presentation but not easy for beginners especially those lacking in laboratory physics. I wish to note, gratefully, that this text was given to me by John Mann with whom this Joisting is undertaken. At stages I would hope that, like Alessandra Drage

that I will use for correlation to Feynman's presentation. My elementary text is Walter Greiner, *Quantum Mechanics. An Introduction*.²¹ You may have some such introduction to hand, or wish to acquire one, in which case I would say that the more detail regarding the physics in an introductory text, the better.²²

2. Clasp Quantum Probability

F0. I might well have named this sermon "coming to Grips with the meaning of Probability in Volume 3 of Feynman's Lectures". Such a titling would help towards glimpsing the fuller meaning of the challenge of the sermon in the previous Joistings. For, there is a parallel title-shift possible there: "Coming to Grip's with the meaning of **Decision** in Volume 2 of Aquinas's *Summa*." Further, there is a helpful parallel in the pedagogical development of the topic that is needed in both cases. A ten-minute encouragement to think about menu-reading is very far from the effort needed to grapple with the fifty pages of Aquinas in qq. 6-17 of the piece of the *Summa*; similarly here.²³ But here we have the added difficulty that Feynman, brilliant though he is, is muddled about the meaning of probability in his volume, whereas Thomas is pretty clear-headed about decision-making. So, a re-writing of Aquinas for a range of specialized audiences is a lesser task than the parallel in Feynman's Third Volume.

in the previous Quodlibet series, dialogue would emerge between us here. Another dialogue partner is Professor Terrance Quinn.

²¹Springer-Verlag, 2001, paperback. There are over a dozen of the Greiner texts on various topics. Two others that I would recommend in so far as your interest spreads to a fuller view on particle physics are Walter Greiner and Joachim Reinhardt, *Quantum Electrodynamics* 2003 and Walter Greiner, Stefan Schramm and Eckhart Stein, *Quantum Chromodynamics*, 2002.

²²My own handy introduction of this type (of no special significance: accidentally picked up cheap) which I will refer to occasionally is A.S.Davydov, *Quantum Mechanics*, 2nd edition, Pergamon Press, 1976, paperback..

²³An introduction to the problem is given in *Joistings 3*.

By that range of course I mean the cycle of functional specialization with its output of cultural dialogue. But I must add that identifying the Aquinas-work as a lesser task should not be deemed as considering the digestive task as easier. Indeed, I have pointed towards the fact that Aquinas task is internal to the challenge of the Feynman muddle and indeed various other contemporary muddles.²⁴

So, there is the matter of a research and interpretation that would rescue 'The World of Feynman' in a manner analogous to rescuing 'The World of God' in its poor expression of its muddles.²⁵ What is required to rescue 'The World of God' from its poor perspective in a fully-contextualized²⁶ theology of the Trinity; what is required to rescue 'The World of Feynman' is a similar concrete theory of probability. Then one is up to adequate detecting.²⁷ But I would assume that the detecting that I must envisage here is the detecting of the learner, and I would hope that this distinction helps towards grasping the distinction between adequate functional specialization and learning. The functional specialist, at least in a hundred years or so, is comfortable in the Standard Model of Global Inquiry. What I am interested in are those who wish to generate the world, the history, that is thus comfortable.

But what I start out with now are those who are willing to learn quantum mechanics by struggling with Feynman's text. What help can I offer? First, I might offer a goal: the goal of interpreting, in some anticipation of the second functional specialty, Feynman's text's meaning of *probability*. That would point to a later reading of the text, first as researcher, then as interpreter. Later? Certainly I would not advise it as a first

²⁴This is a large issue: a context is given in note 30 of Joistings 25.

²⁵*Joistings* 23 deals with various aspects of this problem; it includes a 'popular' sermon on the Trinity.

²⁶The full contextualization for both Feynman and theology is that pointed to in chapter 6 of *Method in Theology and Botany*. Even as one struggles personally that fuller context should be borne, born, in mind.

²⁷See note 37 below.

reading: we will get to that first reading shortly. But gradually, after the full 21 chapters have been somewhat seriously digested, clasped as a detailed whole,²⁸ a sort of paradigm effort at doing research and interpretation could emerge. I have, of course, done this myself, and it would, I suppose, be quite valuable to make that available. But here I am playing the Trinitarian God strategy of history: or perhaps I am, more modestly, playing the role of John the evangelist.

But no: I am, however elementarily, turning the reader towards the four meanings of generalized empirical method. And within that turning I am pointing to a paradigmatic turning towards thorough research. So, in the next section, I invite an initial cataloguing of the occurrence of the word *probability* (and, for full thoroughness, related words like *chance*, *luck*, *likelihood*, *frequency*, etc) in the text. The cataloguing is controlled all the better in so far as one has clasped the Standard Model. Then lurking in the mind-bent are the expanding set of contexts that would anticipate the interpreter's reach for pure formulations of content and contexts.²⁹

But back to the challenge of a first reading, and what generic help I can give. First, then, I would suggest a serious month-long struggle with the first three chapters of the Volume. That struggle is helped considerably by a beginning presence of the contexts written of in the first part of the essay, but let us leave that aside here: it would not be aside, however, in direct tutoring or teaching, but that throws us forwards to the dynamics of arriving and implementing the eighth specialty. So I putter on here in the generic conventional fashion that later cultures will eliminate.

The three-chapter struggle involves integrative re-readings and I would point to two helps in that integrative push. First, pick up on **F1.3** and in particular on the phrase near the end: "a large amplitude and therefore a large intensity." Appeal to the earlier

²⁸I am thinking here of that pointer Lonergan gives on page 151 of *The Ontological and Psychological Constitution of Christ*, the strategic diagrammatic demands to be met here.

²⁹This is a very remote project. See below, note 37 and the follow up of note 30 in *Joistings 25*.

comment on that same page: “You can imagine a gadget which measures the height of the wave motion, but whose scale is calibrated to the *square* of the actual height, so that the reading is in proportion to the intensity of the wave.” You are here in a skirmish of the long war of human minding to gain control of imagination.³⁰ But think positively of this skirmish or battle that is at the heart of quantum mechanics. I did not say, *imagine positively*, even if positive imaging is possible, actual, necessary, as Gilbert Durand tells us. I wish you to push towards **thinking** of amplitude, large or small, but helpfully renamed *aptitude*. You can help yourself forward here by catching on to the difficulty of thinking of a die or dice, six-sided in its aptitude to fall - normally - in one of six ways, yet not having the six sides. Imagine - counter-imagine - it as spherical, yet apt to fall in six precise ways, on six points of the sphere. We are, then, talking about six unimaginable aptitudes. Are they hidden aptitudes? Well, yes: hidden from imagination, yet somehow belonging to the sphere, the actual form of the sphere.³¹ Indeed, we may push our thinking to consider that the six points are not symmetrical, like the normal dice, in their aptitudes. In the present context, our unimaginable measuring gadget squares the unimaginable aptitude to give the usual frequency probability. And we might muse over the possibility that our “six-point” sphere has different values for the six aptitudes, perhaps somehow related to angles in a Euclidean geometry.³²

³⁰This is an element in the come-about mentioned in note 7 above.

³¹A point worth working on here, since it is completely general, is the distinction between the geometric form and the physical - or physico-chemical - form of any reality or real situation. Think of the distinction between Kepler’s geometric laws (with their inclusion of secondary determinations) and Newton’s laws.

³²You may think here of the functions involved in the quantum mechanic of Hydrogen. Simpler instances are given throughout Feynman’s volume. But the business of **aptitudes** raises much trickier questions that you will find hinted at by Lonergan in section 5 of chapter 3 of *Understanding and Being*. So, carry that context into the reflection of the next *Joistings*. The problem of convergence that Lonergan (and Lindsay and Margenau) raised is one I tackled in chapter 8 of *Randomness, Statistics and Emergence*. But the other problem is the one that lurks

The mention of a sphere, thought of spontaneously as a thing, moreover as a thing-body in Euclidean geometry, that geometry thought of, muddledly, spontaneously as a geometric body-spread, brings up the topic of things mentioned around note¹⁰ above. I would be quite surprised if this comes to be sorted out communally in the next fifty years. You can only do your best here and now to battle against the invitation, popular and professional, to entertain a view of space-time as a wriggly mesh of infinitesimal spheres and lines - so-thin strings. It would have been a topic tackled in the Cantowers dealing with Quantumchromodynamics³³: do what you can with it, even move to turn those missing Cantowers into books, into a culture. But follow up in reading Feynman the nudge to focus on centres of affirmation when you are “thinking of things” and the nudge to think of “dispersed structurings of space-time conjugation” when you are thinking of properties.

F1 - F3

What more might I say that would be helpful in venturing into these three first chapters of **Feynman**?³⁴ There are, of course, the unhelpful things that might be said, things left unsaid at the end of the previous section about “thinking of properties”, about the Standard Model context to be eventually not just normative but normal. So, the community of advanced physics, in a later age, become positional readers of both

here: “is the calculus of probability as it presently exists, in the situation in which Euclidean geometry was before the series of geometries was developed?”(Ibid., 1993, 74). The context then is the one I point to when I mention Eddington’s suggestion (see the quotation at note 40 below). There is the complex issue of controlling the meaning of the divergence of conditions in relation to the concrete reality of geodesics etc etc.

³³Cantowers 60, 61, and 62, were to focus on the zone: “Quantumchromodynamics in the Field Context”; “QC: Quarks and Quirks”; “QC Bags: No Strings Attached”.

³⁴It would seem better to associate the final section of **F3**, on identical particles, with the study of **F4** and its discussion in the next Joistings. Yet it is included here by Feynman because of its relation to the problem of states **distinguishable in principle**.

texts and data. That is not the case now with you: both the text and the imagined quantum goings-on are comfortably out there. What can I say? Work on it!

But the difficulty is a Feynman difficulty also, so a first general comment on these three chapters is that eventually they need massive re-writing. I cannot delay on that topic now, but a good exercise is to delay over the first paragraph of the first chapter or the first sentence of the third chapter.³⁵ You will find it quite a tough, indeed pretty impossible - task to re-express either in an adequate way. The first paragraph has standard muddles that you can stab at sorting out, but the first sentence is a massive challenge of later interpretation with its reach for pure formulation of content and context. "When Schrödinger first discovered the correct laws of quantum mechanics he wrote an equation which described the amplitude to find a particle in various places". What precisely did Schrödinger discover, do we re-discover? At the end of the struggle with Feynman's text - and he is very good at giving leads - that question must come up at various levels of reading and re-reading.

But what is the aim, and the achievement, of a first reading? It is to tune into the attitude of concrete analysis and to get a preliminary grip on the summary of rules on **F1-10** and on the *first, second and third general principles* of **F3-2** and **F3-3**. To do this you have to trust Feynman and ignore comparison with other approaches. His eccentricity will emerge further in the next two chapters, **F4** and **F5**, but the power of his eccentric approach will really not appear until you have completed the volume and begun the serious work of digesting and integrating the perspective, which will include the comparative work substantially delayed till then.

A preliminary grip: the pedagogy leaves subtle obscurities with which you have to be content. For example, there is the problem of processes "distinguishable in principle" that comes up in these first chapters e.g. on **F3-7**. Later you will discover that Feynman "has in mind" such tricky disputes as those associated with Einstein and

³⁵The second paragraph of the second chapter manages to mesh the two messes.

Bell.³⁶ Again, there is the question of the meaning of the uncertainty principle, a question raised e.g on pages F1-11 and on page F2-3. The foundational issue here is best left for the full integrative reflection.

Above, around note 29, I suggested that you might muse over the meaning of *probability* at some stage and it can certainly be attempted in the context of these three chapters. Associated with this effort are my suggestion in the same place regarding twisting round the meaning of *amplitude*, even trying out a meaning of a replacement, *aptitude*. This throws you into the mess of the Copenhagen interpretation, too big a distraction at this stage, but worth getting the flavour of. Depending on time and energy, you might gather the texts that make mention of *probability* (or some equivalent) in these three chapters and reach for an interpretation of Feynman's meaning. You have a little sampling of two specialties here, if you want to be thorough. Research seems only a matter of picking out the word *probability* in the text, until you face the issue of equivalence. Equivalence pushes you back to your presuppositions, a topic dealt with elsewhere: the main point to hold on to is that research involves an up-to-date viewpoint. So: venture on this task and see if you get e.g. many more than 31 occurrences of *probability* in **F1**. But you may not wish a large distracting task at this stage. Then focus on a page, and venture into interpretation³⁷ in an effort to detect the range of meanings, e.g. of the 6 occurrences of the word *probability* on page **F2-1** or the 6 occurrences on **F3-2**. I won't enlarge on that here, but I simply halt with a leading question. There is an *a priori* probability associated with dice; there are *a posteriori* probabilities associated with population heights: are there ways of generating a heuristics of aggregated concrete systems that would get at a common root of both?

³⁶See note 8 of *Joistings* 25.

³⁷You are placing yourself in the context of *Method in Theology*, chapter 7, and in the more complex context of *Insight* chapter 17. But note the context of chapter 5 of *Insight*, where a very fundamental problem of interpretation is raised, and should be included in a later index to the book: *Insight*, 162-3[186-8].

There are other leading questions here, that eventually must be handled before the century brings forth an expression of the problems and their solution that is luminous in the grasp of and use of metaphysical equivalence.³⁸ But perhaps one such question is worth noting, even if it cannot be followed up immediately. It is the question of the metaphysical equivalent of the word *energy* as well as phrases surrounding that word. Obviously the question throws you into Lonergan's suggestions in *Insight*, and my reflections on them in Cantower 30. But it also throws you, less directly, into questions raised above, about the intelligibility of Space and Time, the nature of the physical continuum, the limitations of frames of reference and the genesis of complex frames by the empirical demands of physics research.³⁹

At any rate, in the context of some sense of those questions it would be a nice nudge towards the future to do with the word *energy* what I suggested for the word *probability*. What you are reaching for here, I suggest, is some sense of the meaning of energy that jives with what Lonergan suggests.

If you want to spice up you brooding further I would suggest the addition of two contexts. There is a context from **F7-1**, which is given by the square-bracketed near the end that adds in the problem of entropy. Then there is the push beyond this that is given by an early suggestion of Arthur Eddington: "since the logarithm of a probability is necessarily negative, we may identify action provisionally with minus the logarithm of the statistical probability of the state of the world that exists. This suggestion is particularly attractive because the Principle of Least Action now becomes the Principle of Greatest Probability."⁴⁰ Now there's a spicy challenge!

³⁸This is a massive challenge to which these two rambling essays point. Read Lonergan's rules, in *Insight* chapter 17, for tackling the problem and then try it out, sentence by sentence, on Feynman's text.

³⁹This throws us into the complex context described briefly in note 30 of *Joistings* 25.

⁴⁰A.Eddington, *Space, Time and Gravitation*, Harper and Row pb, 1958, 178.