IS INDEED INFORMATION PHYSICAL ?

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Dedicated to Marie-Louise Nykamp

Abstract

Information being a relatively new concept in science, the likelihood is pointed out that we do not yet have a good enough grasp of its nature and relevance. This likelihood is further enhanced by the ubiquitous use of information which creates the perception of a manifest, yet in fact, rather superficial familiarity. The paper suggests several aspects which may be essential features of information, or on the contrary, may not be so. In this regard, further studies are obviously needed, studies which may have to avoid with care various temptations to reductionism, like for instance the one claiming that "information is physical".

> "Of all things, good sense is the most fairly distributed : everyone thinks he is so well supplied with it that even those who are the hardest to satisfy in every other repect never desire more of it than they already have."
>
> R Descartes
> Discourse de la Méthode

"... creativity often consists of finding hidden assumptions. And removing those assumptions can open up a new set of possibilities ..."

Henry R Sturman

"History is written with the feet ..."

Chinese Ex-Chairman Mao,
of the Long March fame ...

Science is not done scientifically, since it is mostly done by non-scientists ...

Anonymous

Physics is too important to be left to physicists ...

Anonymous

Is the claim about the validity of the so called "physical intuition" but a present day version of medieval claims about the sacro-sant validity of theological revelations ?

Anonymous

1. Perhaps, a bit of History, for a start ?

History in our times is not exactly the ... flavour of the day ...

A highly influential American, Henry Ford, the founder of the car company named after him, liked to say about a century earlier that, well, history is bunk ...
And he was both reflecting and forming a widespread American attitude to life, according to which all that counts is what counts ... right now ...
In some so called Oriental schools of wisdom, the acme of one's enlightenment is supposed to be reached when one manages to live in the NOW, thus with no concern for past of future, and led only by the realization that the only thing which is real is indeed but the NOW ...
So it comes to pass, at long last, that West meets East in that present day supremacy of the ... right now ...

Well, the history of the slogan "Information is Physical" which seem to haunt wider circles of physicists is quite recent, and eminently Western. It was indeed launched by Rolf William Landauer (1927-1999), [1-3], and after a while it took on a momentum all of its own ...

But why should one be at all concerned about such a slogan ?
Could we not simply let physicists, or for that matter, physics, gobble up yet another newcomer entity to science ?
After all, there was seemingly no objection when ... quanta became, so to say, physical ...
Or when not much earlier ... relativity got appropriated by physics ...
And these two events, and their subsequent trends, were in fact so overwhelming that they ended up even by operating the other way round :

Indeed, nowadays, it is not only that relativity and quanta are physical, but rather that physics, real physics, serious physics, the very foundation of physics, is nothing else but ... relativity and quanta ...

So that, should we really be surprised if one of these days, and not necessarily to the unreserved pleasure of many a physicist, we may end up with ... physics being informational ... ?!?

And then, why not, given such a highly fluid, changing, if not even unstable situation, perhaps it is worthwhile for most of us concerned

- whether we happen to be physicists, or not - to try to see what may really be the relationship between ... information and physics ...

Let us, therefore, see in this regard some relevant record. Recently in [4], a tentative account of various views and definitions of the concept of Information were presented, among others fairly general concerns. One of the comments regarding Information goes as follows :

> Depending on the branch of science where investigation was carried out, Information got a large number of definitions:
>
> > Information is an indication of a content, obtained from external world in the process of adaptation to the world (Wiener)
> >
> > Information is a negation of the entropy (Brillouin)
> >
> > Information is the communication resulting in a decreasing of an uncertainty (Shannon)
> >
> > Information is a transmitting of a diversity (Ashby)
> >
> > Information is an originality, novelty,
> >
> > Information is the measure of a structures complexity (Moll)
> >
> > Information is a probability of a choice (Yaglom)
>
> Each of these definitions reveals one or another aspect of this poly-semantic concept.

Further, a list of what appear to be semantically different and no less than eleven definitions of Information are cited :

> 1. Philosophical encyclopedia : Information (lat. informatio an examination, a notion, a concept):

1.1. a report, a notification about a state of affairs or about something else that is transmitted by a person;
1.2. decreased, removed uncertainty as a result of the communication obtained;
1.3. a notation inherently relating to a control, the signals in the unity of its syntactic, semantic and pragmatic parameters;
1.4. transmission, reflection of the variety of any objects and processes (of alive and non-alive nature).

2. Information means some order, a communication is the creation of the order from a disorder or, at least, growing of the regulation that existed before the communication was obtained.

3. Information is the manifestation of the property of the objects of alive nature to reflect in the form of some mental sensations the movement of the objects in surrounding World.

4. Information is a quality of the objects, phenomena, processes in the objective reality, of man-made controllers, which lies in the capacitance to conceive an internal state as well as the state and the impacts of an environment and to preserve, sometime, the results; to transmit the data about the internal state and cumulative data to another objects, phenomena, processes.

5. Information is a philosophical category that is considered along with such as Space, Time and Matter. In the most common form information can be presented as a notation, i.e. a form of some relations between a source which communicates and a receiver which obtains a notation.

6. Information, as well as Matter, exists and has always

existed information is some integral attribute of Matter and Movement which realizes a certain way of Matter existence and presents some measure of the changes which follow all processes occurring in the World.

7. (Weizscker, 1959, quoted in [6, p. 39]) Now many peoples begin to recognize that it is necessary to consider Information as something third that differs from Matter and Consciousness This is Platos Idea, Aristotelian Form, invested by such a way that the human of the 20-th century assumes to know something new from it.

8. (Wiener, 1948) Information is information, not matter or energy. No materialism which does not admit this can survive nowadays.

9. The phenomenon of information is a multi-stage, irreversible process of coming into being of a structure in some open imbalanced system that begins at a random memorized choice which this system carries out when it transforms from chaos to an order, so the process is completed with a purposeful action according to an algorithm or program that are in accordance with the semantics of the choice, [7].

10. Information is some qualitative and quantitative characteristic of the level of reflection. Generally information is a quasi-force which is directed against disorder and chaos; in this sense it can not be separated from structure and regularity of material systems, [8].

11. If you are interested in the question "what is information?" and find corresponding definition in some book (which is, generally speaking, rather difficult since the authors usually keep from giving such a definition), then in great likelihood other authors will not agree with this definition, [9].

And then, as if to add to it, it is mentioned that [10] presents more than twenty different definitions of information, while to cap it all, a dissertation quoted in [11] lists no less than hundreds of definitions of information ...

In view of such a state of affairs, one may indeed risk to show a lack of awareness of relevant scientific literature when, merely upon a singular argument like that brought up by Landauer, one makes the total and life long commitment to the reductionist slogan "Information is Physical" ...

2. When it is quite silly to say that "A is B" ?

Regardless of the above, however, let us pause for a moment, and have a brief look at what may indeed be the elementary sine-qua-non conditions for a statement "A is B" to have any meaning at all.

Obviously, whenever the statement "A is B" is made, such a statement has no meaning, unless the entity "B" is well defined, and of course, it is defined a priori. Thus, in the case of the above reductionist slogan related to information, what is meant by "physical" must be clearly defined in advance of stating that slogan, in order for that slogan to have any chance at all to avoid being a mere trivial nonsense.

Here however, one faces a manifestly serious problem. Indeed, the term "physical" has even during recent times proved to have a significantly changing and expanding meaning. Just consider how since Newton it got enlarged by incorporating electro-magnetism, relativity, atoms, quanta, particle physics, and so on.

And then, the question arises : is the reductionist slogan "information is physical" a latest re-definition of Physics, one that tries to further expand Physics by incorporating phenomena related to information, or on the contrary, that slogan is a mere claim in which the concepts of "physical" and "information" are only assumed to be defined in some vague and tacitly accepted ways, and Physics merely tries in some rather naive manner to appropriate a fashionable term in order

further to buttress its prestige ?

If that reductionist slogan is a new expansion in the definition of Physics, then everything is all right, provided of course that the concept of "physical" is well defined, and defined so before that slogan is launched upon the innocent and unsuspecting world ...

Otherwise, as seen above, that slogan is quite nonsensical ...

3. An ever more Foundational role of Information in Physics

Regarding the nuanced, varied and deeper role of information, as well as entropy, in Physics, recent literature, such as in [12-33], can be relevant.

In this respect, in view of [34] for instance, it may be noted the need for a considerable care which should be exhibited whenever the concept of information is used in Physics. Indeed, as it turns out, the whole of Quantum Mechanics can be reconstructed from no more than three axioms with clear physical motivation, the first of which is called :

> Information Capacity : All systems with information carrying capacity of one bit are equivalent.

A similar, albeit more complicated recent foundation of all of Quantum Mechanics based solely on information can be found in [35], while in [36], Quantum Field Theory is built up upon the concept of information.

Apart, however, from the above arguments, and of a surprisingly more fundamental relevance is the recent major discovery in [37]. According to it, if one is indeed to fall for any kind of reductionist sloganeering, then a far more appropriate one would be the *reverse* one, namely :

> "Physics is but a mere sub-realm of Information"

Indeed, as B. Roy Frieden shows it in convincing and rigorous detail in [37], major theories of Physics, both Classical and Quantum, can

rather directly be obtained from an optimization of suitable applications of the well known statistical concept of Fisher Information.
Not surprisingly, this approach - which renders so much of Physics to a mere discipline in the study of Information - seems to encounter a certain controversy on the part of a number of physicists, albeit one that has so far not been pursued deeply and widely enough by its opponents.

4. Is Physics indeed a mere Sub-Discipline of some other Science ?

Apart from [37], by far the most surprising challenge so far regarding the status of Physics among sciences has been brought about by the so called *Mathematical Universe Hypothesis*, MUH, suggested by Max Tegmark in 2008, [38]. And as it happens, that challenge has been received with some appreciation even on the part of those who may not agree fully with the MUH, [39, 40].

Not to mention that far more daring proposals are being made as well. One of the rather thought provoking ones is due to George Svetlichny, [41], in which nothing short of an identification between one's subjective world, and on the other hand, the curse of the good old Copenhagen Interpretation, namely, the so called collapse of the wave function is argued in some detail.

Now, one may indeed start to wonder : are the days of Physics as an independent and fundamental science numbered ?!?

No wonder that quite a number of physicists, even if perhaps more intuitively than consciously, rally around the slogan "Information is Physical", a slogan which may hopefully prolong for a while longer the present special status of their much beloved discipline ...

5. And now, back to Information, to what may indeed be so Special about Information ...

Back to [4], it is worth mentioning the no less than eight properties which they list as being specific to Information.

Here, we mention other specific properties of Information, [42]. For that purpose, it is convenient first to recall two important features of many of physical concepts, namely :

1. Simultaneous Presence

2. Total Involvement

Indeed, we can note a distinction between, on one hand, concepts such as :

> mass, motion, velocity, acceleration, force, energy, electric charge, magnetism,

and on the other hand :

> information and entropy

And for convenience, let us start with a Classical Non-Relativistic setup. Concepts of the first above kind can not only be measured, and thus be associated with appropriate unique numbers, but their effective physical instances, that is, the given physical entities which instantiate such concepts, can be brought into a variety of physical interactions with other effective physical entities. Indeed, the very measurement itself of a physical entity corresponding to a concept of the first kind is nothing else but the result of a particular case of such a physical interaction.

Now, an essential feature of such physical interactions, a feature without which the very possibility of measurements would cease to exist, is the following. Given a specific physical entity E instantiating one of such concepts of first kind, say, C, like for instance, mass, motion, velocity, acceleration, force, energy, electric charge, or say, magnetism. Then in a large variety of physical interactions with other physical entities, the entity E will in its various such interactions exhibit precisely

the whole, and the very same uniquely determined amount of what is described by the concept C.

For instance, a mass of 1 kg will in a large variety of physical interactions manifest itself with all of its mass of 1 kg, and thus, with nothing less, and with nothing more, than 1 kg. Certainly, in terms of Newton's Law of Universal Attraction, for instance, that mass will attract every other mass, say, m, with the force $f = Gm/r^2$, where G is the gravitational constant and r is the distance between the two masses.

After all, measurement in Classical Physics is essentially based on that feature of physical interactions. And this is precisely why in Classical Physics one does not face a "measurement problem", unlike it happens in Quantum Physics.

Let us call by *Total Involvement* the above phenomenon typical for effective physical entities which instantiate concepts such as for instance mass, motion, velocity, acceleration, force, energy, electric charge, or say, magnetism.

A second phenomenon related to various effective physical entities is the possibility of the *Simultaneous Presence* of several instantiations of physical concepts within the same given effective physical entity.

Indeed, a given effective physical entity can at the same time instantiate, for instance, both mass and motion. Clearly, in the case of such simultaneous presence there may, even within a Classical Non-Relativistic setup, be a certain relation between the concepts instantiated, such as for instance between mass, velocity and energy. However, such a relationship is obviously not always compulsory.

Within a Relativistic setup in Classical Physics, both total involvement and simultaneous presence still apply. What may change is the result of measurements which, of course, will depend on the frame of reference of the observers.

Coming back now to the concept of Information, as well as to its various effective physical instantiations, however, the situation changes

significantly.

For instance, the smallest possible amount of information, namely, one single bit, can be registered on a physical entity given by, say, a mass of 1 trillion kg, or on the contrary, it can be conveyed by one single photon. Also, the same bit can be registered on two physical entities which are at rest with respect to one another, or move with considerable velocity.
Similarly, the energy of a physical entity upon which a single bit may be registered can range within very large limits.
And so on.

Consequently, the instantiation of information by an effective physical entity need not necessarily occur with a total involvement of that entity.

In fact, the occurrence of information - unlike with the effective physical entities corresponding to concepts of the above first kind - can have an *optional* aspect.
To put is simply, even if somewhat brutally : when a stone of, say, 1 kg. falls on one's head, one is not free to say : sorry, I do not want it, or I only want 1 gr. of it. On the other hand, when one is faced with an information, one can often have the option to simply disregard it, consider only part of it, or why not, just misinterpret it.

Let us further note in this regard several facts pertinent to the instantiation of information by an effective physical entity.

First, presently it is not known how small it may in the limit be the effective physical entity capable to convey one single bit of information.

Of course, Quantum Physics can suggest some lower limit which is related to the Planck scale. Yet it would be a highly unsafe bet to consider that the present state of Quantum Physics is indeed the ... Final Theory of Physics ...

Second, when an effective physical entity conveying one single bit of information is larger than the mentioned assumed to exist lower limit,

then typically a part of that physical entity is redundant in the process of conveying that bit.

On the other hand, and as noted, a similar redundancy does not usually happen when a mass interacts with another mass, or some other interaction takes place between effective physical entities corresponding to concepts of the above first kind.

Third, given a physical record on an effective physical entity of a certain amount of information, that information can be interpreted in more than one way.

Namely, the very existence of that record as a piece of information depends on an a priori convention about the way it is recorded and about the way it is read.

On the other hand, in the usual case, for instance, of a mass interacting with another mass, there is neither a need, nor a possibility to interpret that mass in any other, but in a unique way, since there is one and only one way which exists as relevant, namely, that mass being a mass. Consequently, there is neither the need, nor the possibility to make any a priori convention about that mass, other than being a mass prior, during, and following that respective interaction process.

Or to put it simply : when, for instance, a human messenger delivers a certain information, the race, sex, age, or for that matter, say, religion of that person is irrelevant, as long as the message itself is conveyed precisely.

On the other hand, when by some accident, that human messenger happens to fall off a cliff, then all of his or her mass, that is, nothing less and nothing more, will be involved in the process.

Fourth, two different amounts of mass cannot be instantiated, thus be simultaneously present as a total involvement, in the same given effective physical entity. And the same goes for the other concepts in the first above category.

On the other hand, a given effective physical entity can simultaneously instantiate more than one information, and obviously can do so without total involvement in at least one of the cases.

Fifth, as seen in [], the information carrying capacity of an effective physical entity is of a fundamental nature, since it can be involved in one of the three physically motivated axioms which reconstruct the whole of Quantum Mechanics.

Therefore, one should not disregard the above issues of total involvement and simultaneous presence when dealing with the information instantiated by effective physical entities.

As for the kind and the amount of entropy in a specific effective physical entity, they clearly depend on an a priori concept of information with which the respective concept of entropy is to be uniquely associated. For instance, if we have a meeting hall capable to seat, say, 100 people, then we can, among other situations, have the following two different entropies : first, we are only interested in how many people are in the hall, or second, we are also interested in the sex of the people in the hall. Needless to say, if we consider the age of the people, or any other possible features, then we are led to corresponding different entropies.

It follows that the above phenomena mentioned related to effective physical instantiations of Information have an inevitable bearing upon the effective physical instantiation of Entropy as well.

As a brief conclusion, we can note that, when speaking about Information and Entropy, we cannot automatically assume :

> the total involvement of the effective physical entity which may instantiate them,
>
> the existence in that instantiation of one and only one kind of Information or Entropy,

a presence of a unique amount of Information or Entropy,

the inevitability of having to receive and accept the whole of the Information or Entropy

the inevitability of a correct reception and acceptance of the Information or Entropy

6. Information : a New kind of Physical Interaction

In view of the above, we can note a new kind of physical interaction brought about by Information.

The effective physical entities E which correspond to physical concepts C of the above first kind, are involved in *usual* interactions upon entities S, namely

(UI) $\quad E \longrightarrow S$

which, among others, manifest simultaneous presence and total involvement.

The way effective physical instantiations of Information occur and may affect certain entities S, namely

(NI) $\quad I \stackrel{option}{\longrightarrow} S$

includes the cases not present either in Classical or Quantum Physics, when the entity S has the following *four combinations of options* :

- to receive the information in I in its fullness, or only partly
- to receive the information in I and accept it as it is, or to misinterpret it to some extent

7. Elements of Subjectivity ?

In view of the above effects of the options related to information processing, one may ask whether the corresponding new ways information may interact with suitable entities S can be seen as also opening ways to what may be considered as a possible *subjective* type behaviour ?

8. A tentative Mathematical Model of Information

The above may deserve an attempt to a kind of mathematical modelling of Information. This can tentatively be done along the following lines.

Step 1.

Claude Shannon, in the 1940s, defined a *measure* for quantities of information, and based on it, established several basic properties of channels that transmit information.
His studies, however, did not consider the *nature* or *structure* of the possible relationships between information and its physical support. In this regard, as noted above, concepts such as *total involvement* and *simultaneous presence* can be useful, as well as the *optional* nature in which information may act on various entities.

Here the focus will be on modelling the possible nature or structure of the more usual relationships between information and its physical support. And in doing so, it will emerge that, unlike earlier well entrenched basic physical concepts, such as for instance, mass, motion, velocity, acceleration, force, energy, electric charge, magnetism, spin, etc., which are indeed assumed to be inseparable from corresponding physical supports, in the case of information there can often be a far more loose connection or relationship between information and the supporting physical structures. And the freedom in this regard of which information may benefit when it comes to its involvement with physical structures may possibly go so far that the lack of a usual physical support need not necessarily disable the presence of information.

Such a state of affairs, however, need not seem so strange. Indeed,

thoughts and ideas, for instance, may as well be seen as having a being all of their own in the sense of being not necessarily conditioned by the presence of some customarily known physical support. And such a view need not necessarily be based on the adoption of any Cartesian type duality with its division between "res extensa" and "res cogitans".
Indeed, as mentioned in [48], for instance, there are everyday and rather typical phenomena related to thinking and ideas in which the presence of a supporting usual kind of physical structure does not seem to be so obvious. As an immediate example, let us recall that in Einsteinian Mechanics a basic assumption is that there cannot be any propagation of physical action faster than light. Yet just like in the case we happen to think in terms of Newtonian Mechanics, our thinking in terms of Einsteinian Mechanics can again instantly and simultaneously be about phenomena no matter how far apart from one another in space and/or time. Consequently, the question arises :

- Given the mentioned relativistic limitation, how and where does such a thinking happen ?

And certainly, information can be seen in a somewhat similar way with entities like thoughts and ideas, rather than with mass, motion, velocity, acceleration, force, energy, electric charge, magnetism, or say, spin, etc.

In this regard, it is important to note that *intent* at its production, as well as *interpretation* at its reception, may play crucial roles in information. And such an intent or interpretation need clearly not necessarily be there when mass, motion, velocity, acceleration, force, energy, electric charge, magnetism, spin, etc., are manifested.
Indeed, here, namely with the possible presence of intent and interpretation in the case of information, we may see an important *similarity* between information and entropy, as mentioned in the sequel, see also [42,47].

Let us further note that the presence of *time* seems to be a sine-qua-non for the presence of information. Thus a model for information should include the presence of time.
Here, in order not to preclude generality, we shall take for time any

linearly ordered set $(T, \leq)$, being thus able to model discrete, as well as continuous time.

We can also note that, as mentioned, information, in order to function as such, it assumes a *production* process, followed by a *reception* one. Thus the whole process can be seen as having *three* successive stages

(8.1) $\quad A \longrightarrow B \longrightarrow C$

where A is the stage of production, C is the stage of reception, and in between, stage B represents the specific information involved in the process. For further clarification, we note that B is not seen as any sort of "channel'" supposed to convey information from A to C, but instead, it is itself the information *intended* when its production in stage A is made. Consequently, if one wants to talk about any channel at all related to (8.1), then it is rather the two arrows "$\longrightarrow$" in (8.1) which may represent it.

Here, it is important to note that one may as well have an *incomplete* process, namely

(8.2) $\quad A \longrightarrow B \longrightarrow$

in which stage C, that is, of reception, is missing. Indeed, such a situation need not always render the remaining incomplete process meaningless, since as long as (8.2) keeps existing, it is always an open possibility that some C may join in, and thus complete the process to its form in (8.1).

On the contrary, the incomplete process

(8.3) $\quad \longrightarrow B \longrightarrow C$

appears to be of no interest, if not even, as having no sense, since the information represented by stage B is of course supposed to be produced somewhere, thus the stage A of production of information cannot be absent.

Clearly, (8.1), (8.2) can be seen both in a static, and alternatively, dynamic setup.

A first remark about (8.1), and implicitly (8.2), is that stages A and C assume a certain physical existence, the first producing information, and doing so with a possible *intent*, as well as a possible *encoding* type interpretation, while the second receiving it based upon a certain possible *decoding* type interpretation.

On the other hand, and as a second remark about (8.1), (8.2), stage B, which represents information as such, need *not* actually be of any physical nature, since it can consist alone of the event of there being a certain intended information which has been produced by stage A.

The third remark on (8.1), (8.2) is about the fact that, *unlike* in stage A, where the presence of intent or of encoding type interpretation is optional, stage C is meaningless without assuming that it involves a decoding type interpretation.

Step 2.

In view of the above, the scheme (8.1) obtains the following more structured form

$$(8.4) \qquad A = (P_A, P, Intent, E) \longrightarrow B \longrightarrow C = (P_C, R, D)$$

where

P_A is the physical system which is involved in the production, presentation or support of the information

P is the information produced as a physical entity

$Intent$ is a parameter with values 0 and 1, according to the absence or presence of intent in the production of information

(8.5)

E is a possible encoding type interpretation

P_C is the physical system which is involved in the reception of the information

R is the information received as a physical entity

D is a necessary decoding type interpretation of the information received

Clearly, the processes (8.4), (8.5) can have their respective incomplete versions corresponding to (8.2).
Furthermore, stages R and D in (8.5) may exercise any of the options mentioned at the end of section 6.

Step 3.

Let us now look more carefully to the structure in (8.4), (8.5).

A first fact to note is that P_A and P_C in such a situations may usually be subjected both to the phenomenon of *total involvement* and *simultaneous presence*, [42,47]. Let us, therefore, recall briefly these two phenomena. For that, it is useful to separate in two classes various *concepts* in physics, namely

Class I : mass, motion, velocity, acceleration, force, energy, electric charge, magnetism, spin, etc.

(8.6)

Class II : information, entropy, etc.

As mentioned, an important property of effective physical entities which embody manifestations of concepts of Class I is that, when they are in physical interactions with similar entities, they participate in one and only one way, namely, with their *total involvement*.

On the other hand, and as also mentioned, the same clearly need not happen with effective physical entities which embody manifestations of concepts of Class II.

Thus such physical systems need *not* be totally involved when they are parts of processes in (8.4), (8.5). And in case of a lack of total involvement, such physical systems exhibit a respective *redundancy*.

Furthermore, the possibility of a lack of total involvement of physical systems P_A and P_C may allow the *simultaneous* presence of the production or reception of *different* pieces of information.

Such a fact is contrary to what happens to effective physical entities which embody manifestations of concepts of Class I. Indeed, in such cases two different amounts of any concept of Class I *cannot* - due to total involvement - simultaneously be embodied by the very same effective physical entity, as long as such a concept is considered in a given fixed frame of reference.

On the other hand, an effective physical entity may simultaneously embody different concepts of both Classes I and II.

Consequently, in processes (8.4), (8.5), we *cannot* always assume

- the total involvement of the physical systems P_A or P_C,
- the existence of a unique piece of information produced and received.

9. Examples

Let us illustrate the above with a simple, yet relevant example.

We consider $A = (P_A, P, Intent, E)$ in (8.4) constituted as follows :

1. P_A is a finite tape τ together with a device, or in general, process δ which successively can record on the tape the sign "0" or "1", until a number $\nu \geq 1$ of such signs are recorded

2. P is the resulting physically existing record on the tape

3. $Intent$ and E are for the moment undetermined.

Regarding $C = (P_C, R, D)$ in (8.4), we assume that :

4. P_C contains the same tape τ, together with a device, or in general, process η which can read the signs "0" or "1" on the tape

5. R is the same with P

6. D is undetermined for the time being.

It follows that for B in (8.4) to have meaning it is necessary for E and D to be specified.

Further, it is obvious that a same given P is compatible with a considerable variety of P_A, $Intent$ and E. Similarly, a given specific R is compatible with a considerable variety of P_C and D.

In particular, P_A can be far from a situation of *total involvement* in (8.4), in order to be able to produce, present or support P. In the same way, P_C need not at all exhibit a *total involvement* in (8.4), in order to be able to receive the information R.

As for B itself, it is to a considerable extent independent of P_A, P, P_C and R.

These features of (8.4) in the above example are, of course, essentially different from the physical phenomena and processes in which effective physical entities that embody manifestations of concepts of Class I are alone involved.

So much, therefore, for ... "information being physical" ...

As for the presence of *time* in the above example of (8.4) one can consider it as happening in one single instant, or alternatively, in a suitable finite number of successive instances.

As a second example, let us consider a vessel which contains a certain amount of water, say $N \geq 1$ molecules. In this case we can take $A = (P_A, P, Intent, E)$ in (8.4) constituted as follows :

7. $P_A = P$ is given by the N molecules of water

8. $Intent = 0$

9. E is the identical encoding, that is, no encoding is involved.
As for $C = (P_C, R, D)$ in (8.4), we can assume that :

10. $P_C = R = P_A = P$

11. $D = E$.

In this case, state of the matter in the vessel has *maximum* entropy when that matter is considered as a collection of *molecules*, and the corresponding information involved can easily be computed.

However, as a third example, one can consider the matter in the vessel in an alternative way, namely, as a collection of *atoms*. In this case, instead of 7. above, we shall have

7*. $P_A = P$ is given by the $3N$ atoms of Hydrogen and Oxygen, respectively

with the corresponding modification in 10. above.

And now obviously, the state of the matter in the vessel does *no* longer have maximum entropy, while again, the corresponding information involved can easily be computed.

We can note that the "physics" of the situation in the last two examples above is the same, namely, N molecules of water. What is different is the manner in which P is encoded by E and R is decoded by D.

Thus again, so much for ... "information being physical" ...

Two further related examples can be considered. Namely, one can assume E so that the vessel is seen as containing atoms, while D sees the vessel as containing molecules. Alternatively, one can have the opposite situation, when E sees molecules, while R sees atoms.

In the last four examples we do happen to have the it total involvement of the respective P_A and P_C. Therefore, in this regard, there is no place left for *redundancy*. On the other hand, the same four examples illustrate the possibility of *simultaneous presence* of different kind of information.

10. A Remark

The phenomenon of *total involvement*, or for that matter, lack of it, and the phenomenon of *simultaneous presence* closely related to information, not to mention the options available when receiving information, as they were mentioned above, can lead to a rather *loose* relationship between information and it physical support.

In this regard, it may be instructive to recall Bekenstein's argument in the estimation of the entropy of a black hole, [49], an argument which is basic for the so called "black hole war", [49]. Namely, one is assumed to throw a vessel full of a given amount of matter constituted, say, of the molecules of a specific chemical compound, and do so beyond the horizon of a black hole, following which one assumes that the whole amount of entropy in that amount of matter will simply disappear completely from the universe observable outside of that horizon.
What one can further assume here, based on a widespread enough

agreement in General Relativity, is that the respective amount of matter will indeed disappear from the observable universe.

From here, however, to jump to the conclusion that the same complete disappearance will happen with the entropy of that amount of matter means to disregard the fact that, as seen in the last four examples above, we cannot automatically assume a unique meaning for the entropy of the amount of matter under consideration. Furthermore, we cannot either assume the total involvement of that amount of matter in all forms of entropy which it may support, [42].

Obviously, the same goes for the conclusion that the information corresponding to that entropy will also disappear completely.

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