Information in Physical Systems
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!. Interpretation of the action in terms of order/disorder

The laws of Physics allow us to get information about a physical system. It is natural to ask then how do these laws limit or generally identify the amount of information so obtained. Most all laws of physics derive from an action principle. We wish here to probe the question of how does the action and then the equations of motion of physics define the extent of information that they lead to. The following is a preliminary attempt at connecting the action to the information we propose is what nature "allows" observers to know.

Information about a system is measured by the amount of uncertainty about that system. The more well determined a system the less information it has available to the observer. The less ordered the more information is available. Entropy of a system measures an equivalent uncertainty, consequently information available to an observer of a system is proportional to its entropy. Both are then proportional to the number of states available to that system.

The Kinetic energy of a physical system measures the un inhibited motion associated with that system. This motion can be in any direction. On its own and with no boundaries this motion increases the physical volume occupied by this system. Such motion would then tend to increase disorder in that system, as it increases the states available for it.
Uninhibited motion may include random elastic collisions that preserve the total kinetic energy. If these random collisions are determined by physical forces (obtained from potentials or otherwise) either new bound states may occur or restrictions on the consequent motions follow that collision that conserve total energy: some kinetic energy may transform into potential energy. That is to Potentials that determine these forces. In all cases physical forces restrict the free arbitrary motion and is responsible for placing the system in states that are fewer than when such forces are not present.
It is then possible to identify a potential energy function, or forces in general, by the reason for decreasing the number of states available for a system and hence "increasing order" in that physical system compared to the arbitrary free motion associated with pure kinetic energy.

When one then considers the action density, as KE -V (that is the difference between kinetic energy and potential energy) one is looking at the competition between the increase (KE) and the decrease (V) of allowable states of a physical system. The integral over the volume of the system (or all of space time available to it) then measures the total result of such a competition. The net result is a measure of the disorder available to the system and hence a measure of its entropy. This then is also a measure of the amount of information one can know about the system. The higher the disorder (number of states) the more information is available.

The global minimum of the integral of the action is then the optimum state of order/disorder in this physical system. This optimum then that determines the optimum amount of information one can get from the system. The maximum information available if for pure kinetic energy and this is reduced by the presence of a potential or generally a set of forces.

If this optimum is a deterministic state, then one gets all the information allowed as there is no indeterminism left. Information one may recall is a measure of the uncertainty left in a system: The measure of its entropy.

Thus, in Classical Mechanics, for example, all coordinates and momenta at future times are known exactly as determined by an initial set of conditions. All are known and there is no more information to be obtained. Full determinism follows.

If the initial set is not known the information still to be drawn would then be a function of such conditions. (Note here that the equations determined by the minimization of the action then do not alone determine whether information is zero or not. The determining factors are the initial conditions).

The equations of motion themselves tell us about the rate of change of kinetic energy (rate on increase of entropy, or rate of increase of available information) in terms of the rate of suppression of such increase as determined by the negative derivative of the potential energy function (rate of decrease of information due to forces).

The equations of motion which lead to Liouville's Theorem indicate that in Classical Mechanics The optimum information is obtained when the volume occupied by the system in generalized coordinates space (position and momentum) remains constant. Thus, Equilibrium between KE and PE is a steady state and no further information other than the definition of the initial state is available.

When the relevant variables describing a physical system carry implicit in-determinism, then although the equations that determine the future values of such variables, although they may be fully deterministic, one cannot determine the future values then with certainty. Hence the uncertainty and the measure of information available is input through such initial states of the relevant variables.

Thus, although one does get from minimizing the action (amount of possible information or disorder) the selection of variables describing the system of interest also selects the state of indeterminism of that system.

For Quantum Mechanics stating that a state function is the correct variable to use , implies that whatever information derivable from any system is given by how much information one puts in such state functions. The equations of Quantum Mechanics, that are deterministic, simply transform one state to another. Indeterminism is then implicit in the use of a state functions.

II. Quantum Mechanical Steady States

In solving for states in a Quantum system the equations minimizing the action (giving optimum information) would lead to states whose final determination depends on some boundary conditions. These states normally are eigen states of energy (Hamiltonian) and consequently only other variables commuting with the Hamiltonian. These common eigenstates define then the optimum of information release (least) by the system. This embodies the exact eigenvalues values for the all observables that commute with the Hamiltonian. Uncertainty remains for all other observables that do not commute with the Hamiltonian. Available information involves all such other observables. The action simply does not allow such information to be completely determined; their eigenstates states cannot arise from such an action at the same time as the value of energy for example.

If one insists on such non-eigenstates states as initial states their time development can be obtained by the action of the Hamiltonian leading to a spectrum of such states. One is forced into an increase of available information. No information change is incurred if one time develops solutions of the equations of motion. Increase of available information (increase of entropy) occurs for all observables that do not commute with the Hamiltonian.

The conclusion in this case is that nature seems to favor commuting sets of observables with the Hamiltonian (KE + V)!

Not all observables can commute with Hamiltonian as then the Hamiltonian would be trivially the identity.

III. States or solution that do not minimize information?

All observables not commuting with the Hamiltonian seem not to minimize information available to observables. They can take a number of values. Nature does not restrict them to their eigenvalues! As they do not optimize information available about them unless they commute with a specific Hamiltonian and then only within that system. One can conclude that all information is known only about the set of observables whose operators commute with that of the Hamiltonian. None is known about those that do not have this property. Quantum systems are “allowed” to give only partial information by nature.

Further then, starting with an arbitrary state, its quantum time evolution can be determined, and the result will optimize release of information according to the criteria above: observables commuting with the Hamiltonian only are fully known; Information about all others is not known. In this latter case the likelihood of measuring a value can though be computed. Information comes with an inherent statistical probability distribution.

IV. Bell’s Theorem. This theorem proves that once operators are associated with observables, information cannot be attributed to the existence of underlying “hidden variables”. Thus,

Operators and their algebra are essential to the determination of available information in a quantum system.
(This theorem shows that any hidden variable approach in computing spin expectations will lead to classical statistical values that are LARGER than what one gets when non-commuting operators of the spin operators are used for the same expectation. Question: Can one show from information theory alone that operators always give a lower value than a pure classical statistical expectations?)

V. Planck's Constant:

Space-time has many operations whose generators are noncommutative. Rotations, and several other space time transformations (Lorentz etc..) are such transformations. The fundamental Poincare transformations are the basis of defining single particle states and carry their own non-commutative algebra. Since observations we make within this space-time rely on observables that are space -time dependent, it would be natural that some such physical observables be dependent on such generators. Planck's constant simply relates such physical observables to geometrical transformations by setting the scale of the physical system. It cannot be zero for dimensional reasons. It can however take any value.

Since all of Physics that depends on noncommutativity depends on the existence of h, Planck's constant the question is why is h not equal to zero? We can understand this from the relationship between space time and physical observables.

If it is close to zero then quantum states may not be recognizable as separate. Atomic or nuclear energy levels may be very close in separation. When Planck's constant is very large or infinite atomic and nuclear states cannot be recognized as belonging to the same system. For example, atomic and molecular states would be continuous in the former and be very close to be indivisible. They would appear to have single ground states and nonother in the latter. Other states are far separated in energy. Chemistry would not exist and neither would we. Human consciousness would not exist. One hence might argue of an anthropic principle that the value of the Planck constant is chosen such that other creatures exist and we humans are around to recognize its presence and its essential usefulness for nature.

The limit of h=0, has to be outside Quantum Mechanics. It does not change the nature of the geometrical transformations and does not allow Physical observables to be expressed in terms of such non-commuting objects. One may not assume then that this limit is that of classical Mechanics.

In classical mechanical treatments, some physical observables may still be represented by the regular variables used there of position and momenta coordinates only. Orbital angular momenta for example but not intrinsic spin. One concludes then that classical mechanics can only be an incomplete description of nature. It is a relevant theory for only such situations when in the limit h=0 no non-commuting observables are involved. Thus, Classical Mechanics describes a subset of natures' observables but it is NOT necessarily the limit of Quantum Mechanics when h=0.

Physical principles that are derived from Classical Mechanics need then not apply to Quantum systems although some of those derived from the latter may not be observable in the former. Some quantum states do not reduce to corresponding classical ones.
A case in point is the EPR so called paradox. If classical mechanics teaches us that within it light does not travel faster than a fixed speed, and hence so would information exchanged, one may Quantum Mechanically question this edict?

When quantum phenomena describe a situation, the same edict may be questioned also.

VI. Black Holes

An observer traveling towards a black hole, would take according to classical general relativity, an infinite amount of time, as seen by observers on earth, to get to the black hole horizon. Therefor according to such observers such traveler will never get there! This is however NOT a coordinate dependent result and is eliminated by a different choice: Kruskal Coordinates. These coordinates eliminate the artificial singularity at the horizon and time as measured by earth observers must use this different time coordinate to properly describe the motion of a traveler to a black hope horizon and beyond.
One then must assume that earth observer and traveler clocks should follow the new forward variable coordinate from zero time onwards!

Classical analysis tells us that no information can come from inside the black hole as light does not escape from it. Do quantum phenomena respect this result for information as well? EPR suggests otherwise.