The wave function.

Basic Postulates - Pure wave mechanics, no to interpret.
Fundamental quantity the wave function itself.

Interpretation through Correlations - existence of classical objects, etc. The ideal observer.

The measuring process, effect on total wave function.

Interpretation as splitting of observers.

Metatheorem: If this system inconsistent, then so is normal system. Obvious simply through consideration of measurement made on universe by some super observer for his future deterministic history, according to usual interpretation. (Recording device as correlations, macro-tine)

Examples of measurements: (von Neumann, etc.)

Theory of Approximate measurement: (Differential normal theories)

Correlations in non-commuting Variables.

Laxness Theorem

Advantages of viewpoint: gain field ability to use proper statistics later also for all types of measurements, not only probabilities.

Philosophical Considerations
Introduce notion of relative wave function (conditional if... describe situations where it is valid such as correlated systems). Examine when such WFs exist within bigger systems where only mixtures would be expected as result of measurement (i.e. why we can assign WFs after an initial measurement).

Introduce mechanical observer which is to be a servomechanism + memory, i.e. a system which changes its configuration according to its "sensations" so that it will operate in the future differently according to its past sensations. Show that this in all respects resembles human observer.
Consider sequence of approx position measurements and notice correlations between first two and 3rd (prediction by momentum (velocity) estimate).

Parameters T or first, T and T on second (time of making also important)

final to be exact at predetermined time.

Try to optimize prediction (may need to constrain the

be not too near final time.

Try to relate interaction Hamiltonians of measurements to the corresponding system operators.

Through canonical representation

operator corresponds to that which

is canonical with of sector (under H)
Thus when the observer has interacted with another system, there no longer exists any single observer state, the composite system state becomes a superposition of pairs of subsystem states, each pair consisting of a definite observer state and a definite object system state.

One introduces Servais' then deduces subjective phenomena which is quite proper.

It is a fundamental fact that after an observation there is no longer any single observer who has perceived a definite result, but only a superposition of pairs of states, each of which describes a definite observer which has perceived a definite result; the result may differ for the different terms of the superposition.
IV. Measurements and Observation

In accordance with our plan to develop quantum mechanics along the grounds of pure wave mechanics, we must investigate the result of regarding the process of measurement as a natural process, and treating it, in its entirety, wave mechanically.

Measurement regarded only as introduction of correlation between system and observer (apparatus) 

As an example of the complete treatment of a measuring process we cite the example of Von-Neumann.

Correlation introduced

Discussion of relative wave functions, and whole system viewed as a superposition.

Generalization to arbitrary processes.
Introduction of ideal observer

Discrimination, memory, etc.

Sensation of that appearance to the observer.

The role of square amplitudes as measure in space of superpositions (only corrected to application at all levels).

Difficulty of choice of measure no less than that in order class itself, much as finally chosen simply one which has special properties (Smoluchowski's phase space).

Independence of components of superposition.

Existence of many of classical objects (rigid bodies, etc.) as correlations.

Concert of information.

Reversibility and Irreversibility. Speculative.

Relative to observer only.

Actual measurements of various sorts (metastatic modifications).
\[ F(a) = (a^*a)^m \]

\[ F(ab) = (ab(ab)^*)^m \]

In general any function of the amplitude which is multiphysical will satisfy the law.

\[ \Rightarrow \] require also additivity i.e., for \( \frac{ab}{a^*a} \)

To be measured:

- measure of space spanned by \( (a_1 + a_2 + a_3) \)
- \( \sigma_1 \sigma_2 \sigma_3 \)

\[ \sigma_1 \sigma_2 \sigma_3 \]
Although we have given a definition of correlation valid for all probability distributions, we have not yet extended the definition of information past discrete distributions. We cannot, in fact, define an absolute information for arbitrary probability measures over direct products, but can only define information for the probability measure relative to some basic measure which in turn is a product measure of measures on the sets. The probability measure then leads to a probability density relative to the basic measure, and we define the information relative to the basic measure as the expectation of the logarithm of the relative probability density. Thus for joint probability measures over real numbers, the choice of the basic measure as the product Lebesgue measure leads to the definition of the information for a joint probability density \( p(x, y, z) \):

\[
I_{x,y,z} = \int p(x,y,z) \log p(x,y,z) \, dx \, dy \, dz. 
\]

which is the most natural choice, and which we shall henceforth use for continuous distributions.

This arbitrariness of the basic chosen for relative information manifests itself even for discrete distributions, where we could have equally well defined the information for the distribution \( q_{ij \cdots k} \) to the

\[
I_{x,y,z} = \sum_{i,j \cdots k} q_{ij \cdots k} \log \frac{q_{ij \cdots k}}{p_{ij \cdots k}} \cdot \ln \frac{p_{ij \cdots k}}{q_{ij \cdots k}} = \exp \left[ \sum_{i,j \cdots k} \frac{p_{ij \cdots k}}{q_{ij \cdots k}} \right]. 
\]
and thus take as the information for the partition $P$, relative to the information measure:

$$I^{P}_{x_1 \ldots z} = \sum_{i,j \ldots k} M_p(x, y, \ldots, z) \cdot \ln \frac{M_r(x, y, \ldots, z)}{u_x(x) \cdot u_y(y) \cdots u_z(z)}$$

and similarly for the marginals:

$$I^P_x = \exp \left[ \ln \frac{M_p(x)}{u(x)} \right]$$

we get a relation analogous to Theorem 2.
Theorem 4: \( I_{x \rightarrow y}^{p'} \geq I_{x \rightarrow y}^{p} \) for \( p' \leq p \)

that is, the information relative to the information measure never increases upon refinement. Again, we have monotone functions on the directed set for which the limit is always well defined (e.g., the partitions). Now, for functions \( f, g \) on a directed set, the existence of \( \lim f \) and \( \lim g \) is a sufficient condition for the existence of \( \lim (f + g) \) which is then equal to \( \lim f + \lim g \).

Therefore, we have the theorem: Using the fact (3.7) that (3.9) holds for any basis.

Theorem 5

\[
\{x \rightarrow y^p\} = \lim \{x \rightarrow y^p\} = \lim \left[ I_{x \rightarrow y}^{p} - I_{x}^{p} - \ldots - I_{y}^{p} \right]
\]

\[
= I_{x \rightarrow y} - I_{x} - \ldots - I_{y}
\]

where the information is taken relative to any information measure for which the above expression is not indeterminate.
Theorem 3 is very useful for the computation of correlations, since it allows any choice of information measure for which the expression is not indeterminate. I.e., given an arbitrary probability distribution, we need only choose some measure so that the integrals for the information are finite. Actually, all that is required is that \( I_x \) \( \ldots \) \( I_y \) not be positively infinite, since in all other cases \( I_{x\ldots y} \) is determinate, because \( I_{x\ldots y} \)

\[ I_{x\ldots y} \] is sufficient to choose the individual measures \( I_x \) \( \ldots \) \( I_y \), so that the marginal distributions \( P_x(a) \) \( \ldots \) \( P_y(t) \) have not positively infinite information, in order to ensure that the correlation is given by (3.7).

This result is useful for quantum mechanics, where occasionally variables have both continuous and discrete spectra. By choosing the basic measure as Lebesgue measure on the continuous range and uniform discrete measure on the discrete spectrum, we can define information in a manner which will always yield the correct correlation by (3.7). Thus if for operator \( A \) and wave function \( \psi \), the square amplitudes over the eigenvalues are \( P(a) \) for the continuous spectrum and \( \tilde{P}(\xi) \) over the discrete spectrum, the information is:

\[ I_A = \int P(a) \ln P(a) \, da + \sum \tilde{P}(\xi) \ln \tilde{P}(\xi) \]
It is also interesting, as a side issue, to give an example of the usefulness of the more general definition of relative information. Suppose we have a stochastic process with a finite number of states \( s_i \).

Suppose that the process takes place at discrete times, and that the transition probability for going to the state \( i \) to \( j \) is \( T_{ij} \). The probabilities \( T_{ij} \) then form what is a stochastic matrix, i.e. the elements are between 0 and 1, and \( \sum_j T_{ij} = 1 \). If at any time the system has probability distribution \( p_i \) over the states, then at the next interval of time its distribution will be \( p'_i = \sum_j p_i T_{ij} \). In the special case where the matrix is doubly stochastic, which means that both \( \sum_j T_{ij} = 1 \) and \( \sum_i T_{ij} = 1 \), and which amounts to a principle of detailed balance being holding, it is known that the entropy, defined as \(-\sum_i p_i \ln p_i\), is a monotonically increasing function of time. This entropy, however, is simply the negative of the information relative to the uniform distribution measure.

One can extend this result to the general case of arbitrary stochastic matrices, if one defines the entropy to be the negative of the information relative to the stationary distribution measure.

\[ H = -\sum_i p_i \ln \frac{p_i}{\pi^*_i} \]

This value is a monotone increasing function of the time. Note that the stationary distribution \( \pi^* \) of a doubly stochastic matrix is the uniform distribution, which explains the theorem for the special case of doubly stochastic matrices.
We shall find another use for the relative definition of large for discrete distributions in connection with degenerate operators in quantum mechanics in the next section.
This description gets away from the pointwise definition and avoids the mathematical complexity inherent in considering probability measure over point fields. It does, however, require that in some sense the fields be almost continuous. Otherwise, the envisaged limit process would break down.

Quantum description: To each

Partition of space-time into regions there

corresponds a function \( Y(\mathcal{R}_1, \ldots, \mathcal{R}_j, \ldots) \)

Furthermore, these field operators which when acting \( Y \) give the joint distribution of the average field value in \( \mathcal{R}_i \) in the usual manner.