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SOME REMARKS ON AC CONDUCTION IN DISORDERED SOLIDS

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ABSTRACT

A number of remarks are made to both theory and experiment of AC conduction in disordered solids. As regards experiment, it is argued that the observed power-law behavior of the frequency-dependent conductivity, $\sigma(\omega)$, is not fundamental, that the Ngai-relation between DC and AC activation energies follows from independent experimental facts, and that the shape of the modulus peak has no fundamental significance. As regards hopping models for AC conduction, it is shown that three commonly used arguments against the existence of a distribution of activation energies are all wrong, Also, it is shown that $\sigma(\omega) \neq \sigma(0)$ only if there are correlations in the directions of different charge carrier jumps; in particular this result implies $\sigma(\omega) = \sigma(0)$ for all frequencies in the CTRW model. In the final section a number of open problems are listed and suggestions are made for future work.

ABSTRACT

A number of remarks are made to both theory and experiment of AC conduction in disordered solids. As regards experiment, it is argued that the observed power-law behavior of the frequency-dependent conductivity, $\sigma(\omega)$, is not fundamental, that the Ngai-relation between DC and AC activation energies follows from independent experimental facts, and that the shape of the modulus peak has no fundamental significance. As regards hopping models for AC conduction, it is shown that three commonly used arguments against the existence of a distribution of activation energies are all wrong, Also, it is shown that $\sigma(\omega) \neq \sigma(0)$ only if there are correlations in the directions of different charge carrier jumps; in particular this result implies $\sigma(\omega) = \sigma(0)$ for all frequencies in the CTRW model. In the final section a number of open problems are listed and suggestions are made for future work.

1. INTRODUCTION

This paper discusses AC conduction in non-metallic disordered solids. A number of remarks are made, most of which are not new but are still not generally appreciated. The class of disordered solids with interesting AC behavior is very large, including amorphous semiconductors [1,2], ionic conductive glasses [3,4], conducting polymers [5,6], various defective or doped crystals [7-9], and many polycrystals [10,11].

Various representations of AC data are used. One possibility is to use the complex frequency-dependent conductivity, $\sigma(\omega)=\sigma'(\omega)+i\sigma''(\omega)$. A common alternative is the complex electric modulus, $M(\omega)=M'(\omega)+iM''(\omega)$, defined [12] by

$$M(\omega) = i\omega/\sigma(\omega). \tag{1}$$

Data may also be presented in terms of the complex impedance [13,14], or in terms of the complex dielectric constant defined by

$$\varepsilon_o\varepsilon(\omega) = \frac{\sigma(\omega)-\sigma(0)}{i\omega} . \tag{2}$$

Here, ε_o is the vacuum permittivity. The negative imaginary part of $\varepsilon(\omega)$, $\varepsilon''(\omega)$, is referred to as the dielectric loss.

AC conduction in quite different disordered solids shows a number of common features, a surprising fact which is often overlooked. For each of the above listed classes of glassy solids one observes, almost without exception [15-19]: At high frequencies $\sigma'(\omega)$ follows a power-law with an exponent s in the range 0.7-1.0; s goes to one as the temperature goes to zero. At the dielectric loss peak frequency, ω_m , there is a transition to a frequency-independent conductivity below ω_m . The BNN relation [20-22] is satisfied:

$$\sigma(0) = p\ \Delta\varepsilon\ \varepsilon_o\ \omega_m \qquad (3)$$

where $\Delta\varepsilon = \varepsilon(0)-\varepsilon(\infty)$ and p is a numerical constant of order one. Finally, the time-temperature superposition principle is usually obeyed, i. e. , the shape of the $\sigma'(\omega)$-curve is temperature-independent when plotted in a log-log plot.

The outline of the paper is the following. In sec. 2 some points relating to experiment are discussed. Section 3 is devoted to hopping models for AC conduction. Section 4 deals with a number of open problems and gives suggestions for future work. Finally, sec.5 is the conclusion.

2. REMARKS RELATING TO EXPERIMENT

1) The observed power-law frequency-dependence of the conductivity is hardly fundamental.

The large frequency power-law

$$\sigma'(\omega) \propto \omega^s \tag{4}$$

is deduced from $\sigma'(\omega)$ following a straight line in the log-log plot. Since both frequency and conductivity usually vary several decades, it is absolutely reasonable to plot data in a log-log plot. However, log-log plots are dangerous; an old saying [23] warns: "Anything is a straight line in a log-log plot". To illustrate this point, Fig. 1 shows a log-log plot of $\sigma'(\omega)$ where $\sigma(\omega)$ is given by

$$\sigma(\omega) = \sigma(0)\frac{i\omega\tau}{\ln(1+i\omega\tau)} \tag{5}$$

This function gives a good fit to many data [19]. The function follows closely a straight line at high frequencies though there is no power-law hidden in it. Most workers would report an exponent around 0.8 for data following Fig. 1. There is no problem with this as long as one speaks only about **approximate** power-laws. But there is no basis for concluding from experiments that power-laws are **fundamental**, as is often done [24-26].

2) The Ngai-relation follows from the BNN-relation and the time-temperature superposition principle.

The Ngai-relation [27] correlates three quantities, the activation energy of the dielectric loss peak frequency, E_{ω_m}, the AC conductivity activation energy, E_{AC}, and the exponent s of Eq. (4), as follows:

$$E_{AC} = (1-s)E_{\omega_m} \tag{6}$$

Equation (6) is confirmed by experiment [27] (E_{AC} is sometimes derived from NMR experiments which, however, give the same activation energy as that of AC conduction [4,28]). As illustrated in Fig. 1, the loss peak frequency ω_m is the characteristic frequency for the onset of AC conduction. Since the dielectric loss strength $\Delta\varepsilon$ is only weakly temperature-dependent, the essence of the BNN-relation is an approximate proportionality between $\sigma(0)$ and ω_m. Remember that the time-temperature superposition principle is the fact that, at different temperatures, one observes in the log-log plot parallel displacements of the same $\sigma'(\omega)$-curve. Because of the proportionality between $\sigma(0)$ and ω_m, the $\sigma'(\omega)$-curve is displaced in a direction 45° to the x- and y-axis as the temperature changes. Since activation energies are obtained as derivatives of the logarithm, it is now straightforward to show that Eq. (6) is automatically obeyed.

3) The shape of the modulus peak has no fundamental significance.

For all disordered solids the imaginary part of the electric modulus, $M''(\omega)$, has a peak at a frequency of the same order of magnitude as ω_m. The shape of the modulus peak is often attributed to a spectrum of relaxation times [12,29]. This spectrum, however, has no significance reflecting the motion of the charge carriers. This is because there is always, in parallel to the charge transport due to the mobile charge carriers, the current due to the infinitely fast dielectric displacement. The strength of the latter current is given by the infinite frequency dielectric constant, ε_∞. If ε_∞ is changed, the shape of

$M''(\omega)$ is affected [30] even if the mobile charge carriers move about in the solid exactly as before.

4) There are close mechanical analogies to the observed AC behavior.

4a) Many ionic conductive glasses have an internal friction loss peak at the dielectric loss peak frequency [4,31,32]. This mechanical loss must be due to ionic motion. In effect, this means that a mechanical stress induces an ionic current.

4b) The frequency-dependent viscosity, $\eta(\omega)$, of a typical highly viscous liquid, e. g., a polymeric liquid, looks very much like $1/\sigma(\omega)$ for a typical disordered solid. Thus, at low frequencies $|\eta(\omega)|$ is constant whereas at higher frequencies $|\eta(\omega)|$ decreases like an approximate power-law [33]. A possible explanation of this analogy is the following. Suppose a foreign microscopic particle is introduced into a viscous liquid. If the particle is described by hydrodynamics, its frequency-dependent mobility (velocity/force) varies as $1/\eta(\omega)$. Because of the fluctuation-dissipation theorem [34], the analogy between $1/\eta(\omega)$ of a viscous liquid and $\sigma(\omega)$ of a disordered solid implies that (in equilibrium) the particle moves about in the liquid just as a charge carrier moves about in a disordered solid (in zero external field). This has been confirmed by conductivity measurements on ions dissolved in viscous liquids, where the observed conductivity is indeed like that of a disordered solid [35,36].

3. REMARKS RELATING TO HOPPING MODELS

In hopping models DC and AC conduction are both due to hopping charge carriers [37]. The disorder is usually reflected by assuming randomly varying transition rates $\Gamma(s' \rightarrow s)$ between two sites, s' and s. If $P(s,t)$ is the probability for a particle to be at site s at time t, a hopping model is described by the master equation [37,38]

$$\frac{\partial P(s,t)}{\partial t} = - \gamma_s P(s,t) + \sum_{s'} \Gamma(s' \rightarrow s) P(s',t) \qquad (7)$$

where $\gamma_s = \sum_{s'} \Gamma(s \rightarrow s')$. Equation (7) refers to the zero external field situation; more generally Γ depends on the external field. It can be shown that in hopping models $\sigma'(\omega)$ is always an increasing function of ω [39]. No exact analytical methods are available for evaluating $\sigma(\omega)$ in hopping models, but various approximate methods exist [37,40,41].

1) Three common arguments against hopping models are all wrong.

In most hopping models the variation in hopping rates is assumed to derive from a spread in activation free energies, $P(\Delta F)$. The following three arguments have traditionally been put forward against the existence of any $P(\Delta F)$:

1a) **"Any distribution of activation energies implies the DC conductivity is non-Arrhenius."**

This is not necessarily true; in some models $\sigma(0)$ is Arrhenius with an activation energy which is simply the maximum barrier encountered on any "percolation" path between the electrodes. In one dimension exact results are available [42,43]. Here, $p(\Delta F)$=const., or more generally $P(\Delta F) \propto \exp(-\Delta F/\Delta F_o)$, give

an exactly Arrhenius $\sigma(0)$ if a sharp cut-off at a maximum activation energy is assumed. Similar results are obtained from the approximate analytical methods available in three dimensions [37,40,41].

1b) **"The BNN-relation implies that AC conduction is due to processes with activation energy equal to that of $\sigma(0)$."**

The BNN-relation implies that the dielectric loss peak frequency has the same activation energy as $\sigma(0)$. But this does not rule out the possibility that a distribution of activation energies is responsible for the frequency dispersion. Thus, in hopping models ω_m corresponds to the **lowest** effective jump frequency and this quantity is determined by the **maximum** energy barrier, just as $\sigma(0)$ is itself [44].

1c) **"The time-temperature superposition principle contradicts the existence of a distribution of energy barriers."**

It is often claimed that the existence of a distribution of activation energies implies a broadening of the distribution of relaxation times as the temperature is lowered, thereby violating the time-temperature superposition principle. Two points are to be noticed. First, for experimental reasons the time-temperature principle is usually checked only over a relatively narrow range of temperatures and frequencies; here any sufficiently broad distribution of activation energies will obey the time-temperature superposition principle rather accurately. Secondly, for the flat distribution of activation energies, $p(\Delta F) \propto \text{const.}$, the time-temperature superposition principle is obeyed exactly. In this case the distribution of jump frequencies varies as Γ^{-1} at all temperatures. In conclusion, as long as one assumes a

sufficiently broad distribution of activation energies, approaching the flat distribution, there is no contradiction with experiment.

Traditionally, the points 1a), 1b) and 1c) have been thought to imply at most a quite **narrow** $p(\Delta F)$, which obviously cannot account for the observed very **broad** loss peaks. This is why an early model like Stevels' and Taylor's random potential energy model from 1957 [45,46] was never considered a serious candidate for explaining experiments.

2) The conductivity is frequency-dependent only if there are correlations between the directions of charge carrier jumps. Thus, if each jump occurs in a random direction one has $\sigma(\omega)=\sigma(0)$ at all frequencies [38]. To prove this we first recall the fluctuation-dissipation theorem [34] which expresses $\sigma(\omega)$ in terms of the zero-field auto-correlation function of the total current in volume V , $\mathbf{J}(t)$, in the following way

$$\sigma(\omega) = \frac{1}{3k_B TV} \int_0^\infty <\mathbf{J}(0)\cdot\mathbf{J}(t)> e^{-i\omega t} dt \qquad (8)$$

Here k_B is the Boltzmann constant and T is the temperature. In hopping models the jumps are instantaneous and $\mathbf{J}(t)$ is a sum of delta functions. If the i'th jump occurs at time τ_i and displaces a particle by $\Delta\mathbf{r}_i$, one has

$$\mathbf{J}(t) = q \sum_i \Delta\mathbf{r}_i \, \delta(t-\tau_i) \qquad (9)$$

where q is the charge carrier charge. For $<\mathbf{J}(0)\cdot\mathbf{J}(t)>$ to be non-zero at any $t>0$ one must have $<\Delta\mathbf{r}_i\cdot\Delta\mathbf{r}_j> \neq 0$ for at least one pair of $i<j$. But whenever the direction of the latter jump, $\Delta\mathbf{r}_j$, is random, one has $<\Delta\mathbf{r}_i\cdot\Delta\mathbf{r}_j> = 0$. Consequently $<\mathbf{J}(0)\cdot\mathbf{J}(t)> \propto \delta(t)$ and the conductivity is frequency-independent according to Eq. (8). This result has two important consequences:

2a) Any random walk in a spatially homogeneous medium has $\sigma(\omega) = \sigma(0)$.

This is true even for non-markovian random walks. An important example is the continuous time random walk model (CTRW) of Montroll and Weiss [47]. This model is characterized by the so-called waiting-time distribution function, $\psi(t)$, which is the probability for a particle to jump at time t , given the particle last jumped at $t=0$. In 1973 Scher and Lax erroneously calculated $\sigma(\omega)$ in terms of $\psi(t)$ [48]; the error was pointed out by Tunaley who proved by direct calculation that there is no frequency dispersion of the conductivity in the CTRW model [49]. While the CTRW model is itself of no use as a model for AC conduction, the formalism developed by Scher and Lax does give rise to a useful approximation, usually referred to as the CTRW approximation or the Hartree approximation [40].

2b) The existence of a distribution of relaxation times is not enough to ensure frequency-dependence of the conductivity. Consider hopping in a potential where all maxima are equal but the minima vary (Fig. 2). Obviously, in this model there is a distribution of waiting times . But the direction of each charge carrier jump is random so $\sigma(\omega) = \sigma(0)$. This has also been shown by explicit calculation [51,52]. In passing we note that the model of Fig. 2 is a useful model for the transient behavior of photo-excited charge carriers in amorphous semiconductors [53]. Here, a brief laser pulse excites the electrons to random states at $t=0$, and the current in an external field subsequently monitors the thermalisation of the charge carriers. This example shows that, in general, transient currents cannot be calculated from

$\sigma(\omega)$, as has been predicted from the study of specific models [54,55].

4. OPEN PROBLEMS AND SUGGESTIONS FOR FUTURE WORK

1) Are reported data always bulk and not due to contact effects?

Electrode effects may cause serious problems for the interpretation of measurements. One might think it could easily be checked, by simply varying the sample size, whether or not the bulk response is measured. For disordered solids, however, it is often difficult to prepare two samples with identical physical properties, so this method does not always work. The contacts are usually modeled as simple RC-elements, implying the bulk response is measured at sufficiently high frequencies. But it has never been proved that this procedure is correct, and it has even been suggested that contacts and interfaces play a dominant role in the whole range of frequencies measured [56]. While this is probably too drastic a statement, it is a fact that even a quite simple model of the electrode/sample interface predicts a non-trivial frequency-dependence of the measured conductivity varying like $\omega^{1/2}$ [31,57]. In conclusion, it is not obvious that all reported data are bulk, and more work is needed to clarify the role of contacts.

2) Are DC and AC conduction always due to the same mechanism?

The BNN-relation shows that DC and AC conduction in disordered solids are strongly correlated. The simplest possibility is that DC and AC conduction are both due to the same mechanism, as is the case in hopping models. The existence of a loss peak supports this; loss peaks are hard to explain otherwise. It should be noted that, when there is no dielectric loss peak, a BNN-like

relation may still exist between $\sigma(0)$ and the characteristic frequency ω_m' defined by

$$\sigma'(\omega_m') = 2\sigma(0) \ . \qquad (10)$$

[If a loss peak does exist, ω_m' is close to ω_m .] Suppose $\sigma'(\omega) = \sigma(0)+A\omega$. Then clearly ω_m' is proportional to $\sigma(0)$ although this does not reflect any relation between DC and AC conduction.

3) There are theoretical reasons to expect $\varepsilon''(\omega) \propto \omega^{1/2}$ on the low-frequency side of the dielectric loss peak.

In hopping models one always has $\sigma(\omega) = \sigma(0)+C(i\omega)^{3/2}$ as $\omega \to 0$ [38,58], an example of the celebrated "long time tails". As one of the few general predictions in the field, this should ideally be tested on a number of disordered solids. But unfortunately electrode effects cause very serious problems for measuring accurately the low- frequency side of the loss peak, and the prediction may be close to impossible to verify.

4) Does any solid exist which has $\sigma'(\omega) << \varepsilon_o\omega$?

A puzzling phenomenon is the fact that, apparently, any solid has a conductivity $\sigma'(\omega)$ which is at least of order $\varepsilon_o\omega$ [16]. Thus, at 1 MHz the conductivity is never much less than 10^{-6} $(\Omega\ \mathrm{cm})^{-1}$. This rule seems to apply without exception, even to single crystal insulators. It could be a spurious effect due to contact effects [56], or due to experimental problems in distinguishing properly between $\sigma'(\omega)$ and $\sigma''(\omega)$ [$\sigma''(\omega)$ always has a sizable contribution from the infinite frequency dielectric constant]. If the effect is real an explanation is very much needed. Is it possible that even the most "perfect" single crystal contains enough defects to account for this

observation?

5) What kind of measurements could supplement the measurement of $\sigma(\omega)$?

The AC conductivity is the k=0 component of the more general quantity $\sigma(k,\omega)$ [which, by the fluctuation-dissipation theorem, is related to equilibrium fluctuations of the k'th Fourier component of $\mathbf{J}(\mathbf{r},t)$] . It would be interesting to have measurements of $\sigma(k,\omega)$. For electronic systems it is not obvious how to do this, but for ionic conductors neutron scattering can be applied, at least in principle. Other important measurements to supplement $\sigma(\omega)$ are transient current experiments (only available for electronic conductors) [59], excess current noise measurements [60], or large field experiments [31,61].

6) Is the observed AC behavior due to microscopic or macroscopic inhomogeneities?

The mathematical description of, and predictions for, inhomogeneous conductors are quite similar to that of hopping models [11,14]. Therefore, it is not clear from AC measurements alone whether macroscopic or microscopic inhomogeneities are responsible for the observed frequency dispersion. It is not unlikely that, in some amorphous systems, there are inhomogeneities several hundred Angstroms large. One way to distinguish between macroscopic and microscopic inhomogeneities is to measure the large field response; for macroscopic inhomogeneities one expects nonlinearities to set in at much lower fields than for microscopic inhomogeneities.

7) There are two important open problems relating to hopping

models:

7a) How accurate are the presently available approximate analytical solutions of hopping models?

Perhaps the simplest hopping model is the random free energy barrier model which, when solved in the CTRW approximation, yields Eq. (5) [19]. Numerical solutions of this model should be undertaken to asses the validity of Eq. (5). Preliminary work shows that, in one dimension, Eq. (5) works very well [62]. In general the question 7a) remains unanswered.

7b) What is the cause of the quasi-universality among different models?

As noticed by Summerfield in 1985 [63], different models solved in the extended pair approximation (EPA) yield almost identical predictions for $\sigma(\omega)$ (apart from an overall scaling of σ and ω). This "quasi-universality" applies not only to EPA models, but to most models studied so far. The cause of quasi-universality is not clear. The agreement between different theoretical models is generally much better than the agreement between theory and experiment, where quasi-universality does not really apply. This indicates that the present hopping models are too simple. It seems likely that interactions between the charge carriers have to be taken into account to arrive at a realistic model. (Contrary to what is sometimes claimed, Eq. (7) cannot describe interacting particles [64].)

5. CONCLUSION

There are a number of important unsolved problems in the field of AC conduction. Because of this, measurements of $\sigma(\omega)$ do not yet provide unambiguous insight into the conduction process. More work is needed before this goal is reached, for instance along the lines of sec. 4. In this sense, AC conduction is still a field in its infancy.

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FIGURE CAPTIONS

Fig. 1: Real part of the function $\sigma(\omega)$ given by Eq. (5). Though there is no power-law in this function, it follows closely a power-law at high frequencies. The function gives a good fit to many data [19]; thus one cannot conclude from experiment that a power-law frequency-dependence of the AC conductivity of disordered solids is fundamental. - The vertical line marks the dielectric loss peak frequency which is always found where the conductivity starts increasing.

Fig. 2: Potential energy of a hopping model which, because the direction of each charge carrier jump is random, has no frequency-dependence of the conductivity. This example shows that a distribution of waiting times is not enough to ensure frequency-dependence of the conductivity. Also, since the model has non-trivial transient behaviour [53], the example shows that there is no correlation between AC conduction and transient behaviour.

Fig. 1

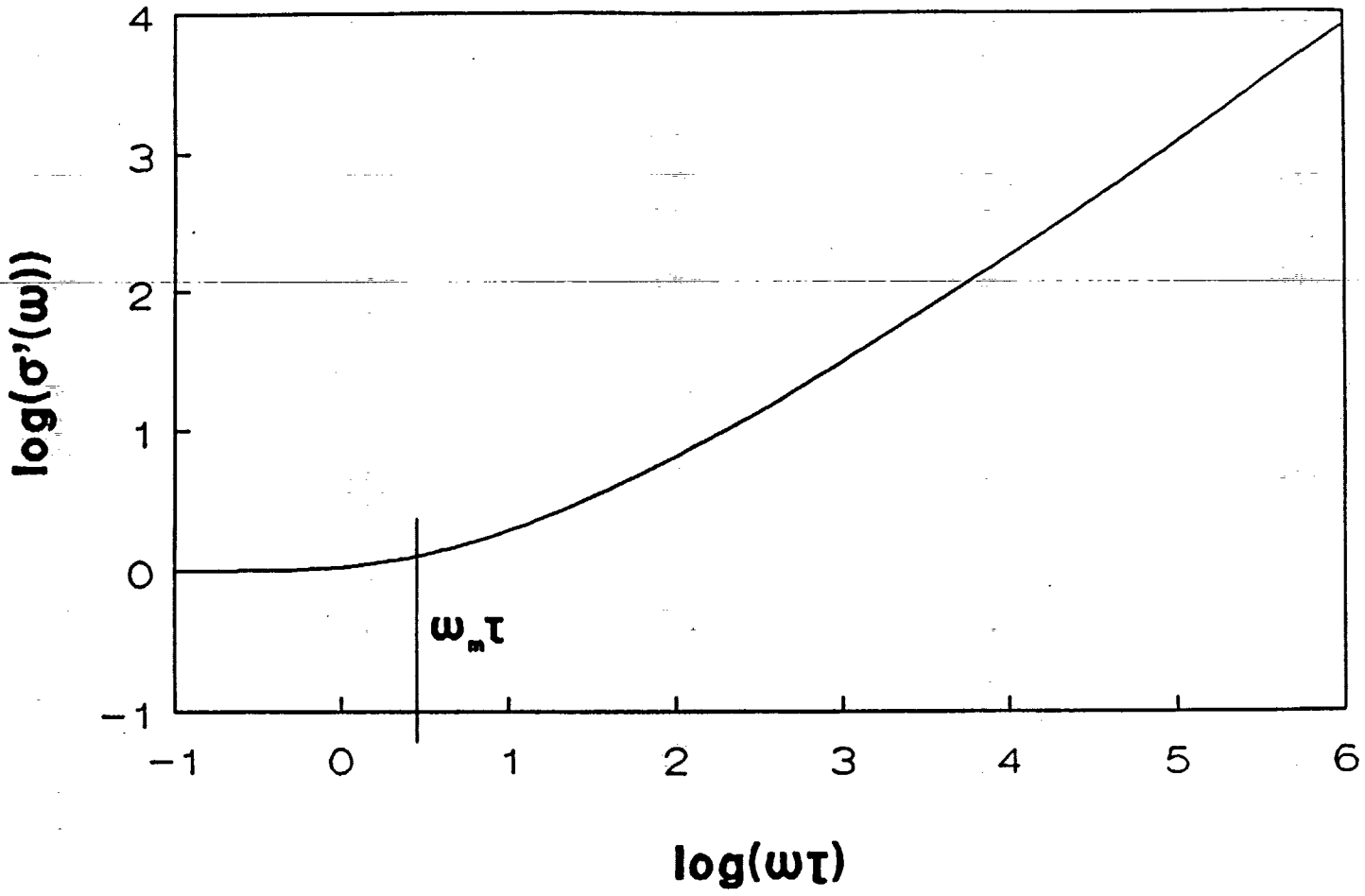
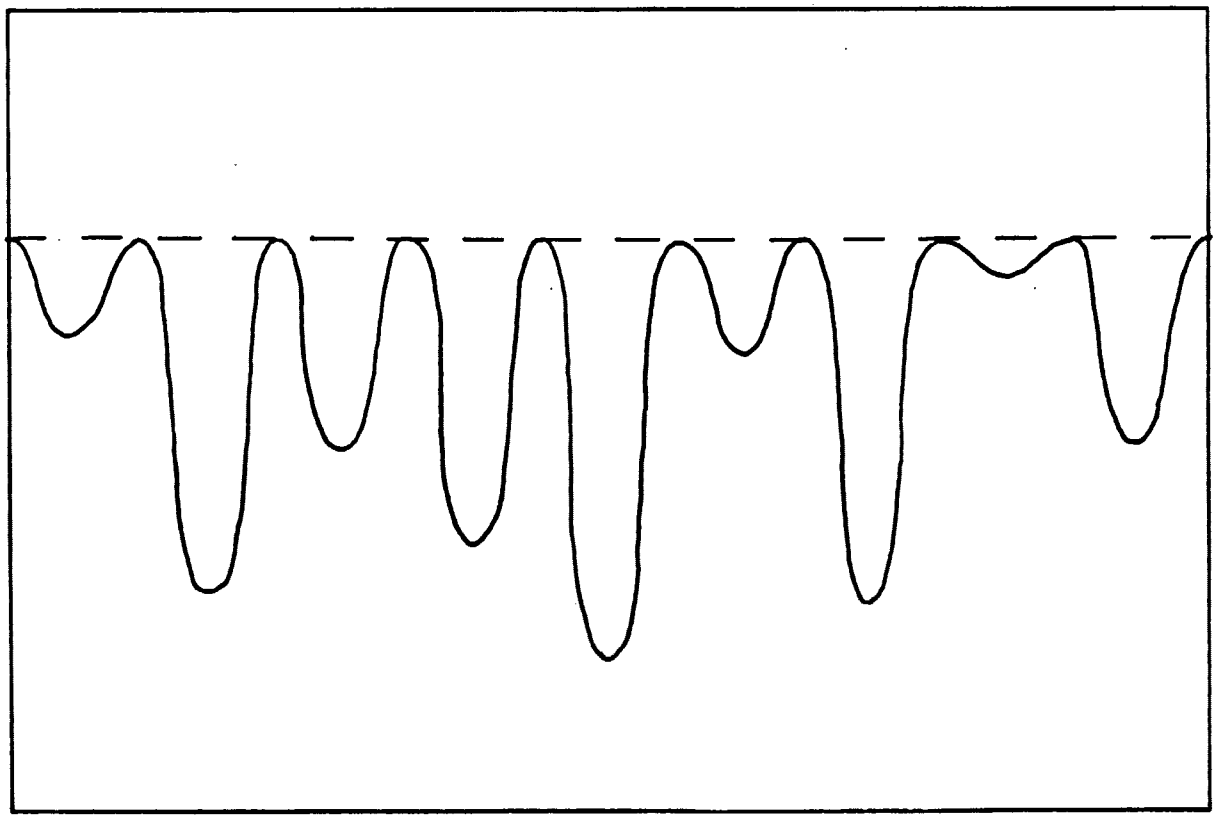


Fig. 2



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5/78 "BIBLIOGRAFISK VEJLEDNING til studiet af DEN MODERNE FYSIKS HISTORIE".
Af: Helge Kragh.
Nr. 5 er p.t. udgået.

6/78 "NOGLE ARTIKLER OG DEBATINDLÆG OM - læreruddannelse og undervisning i fysik, og - de naturvidenskabelige fags situation efter studenteroprøret".
Af: Karin Beyer, Jens Højgaard Jensen og Bent C. Jørgensen.

7/78 "MATEMATIKKENS FORHOLD TIL SAMFUNDSØKONOMIEN".
Af: B.V. Gnedenko.
Nr. 7 er udgået.

8/78 "DYNAMIK OG DIAGRAMMER". Introduktion til energy-bond-graph formalismen.
Af: Peder Voetmann Christiansen.

9/78 "OM PRAKSIS' INDFLYDELSE PÅ MATEMATIKKENS UDVIKLING". - Motiver til Kepler's: "Nova Stereometria Doliorum Vinariom".
Projektrapport af: Lasse Rasmussen.
Vejleder: Anders Madsen.

10/79 "TERMODYNAMIK I GYMNASIET".
Projektrapport af: Jan Christensen og Jeanne Mortensen.
Vejledere: Karin Beyer og Peder Voetmann Christiansen.

11/79 "STATISTISKE MATERIALER".
Af: Jørgen Larsen.

12/79 "LINEÆRE DIFFERENTIALLIGNINGER OG DIFFERENTIALLIGNINGSSYSTEMER".
Af: Mogens Brun Heefelt.
Nr. 12 er udgået.

13/79 "CAVENDISH'S FORSØG I GYMNASIET".
Projektrapport af: Gert Kreinøe.
Vejleder: Albert Chr. Paulsen.

14/79 "BOOKS ABOUT MATHEMATICS: History, Philosophy, Education, Models, System Theory, and Works of".
Af: Else Høyrup.
Nr. 14 er p.t. udgået.

15/79 "STRUKTUREL STABILITET OG KATASTROFER i systemer i og udenfor termodynamisk ligevægt".
Specialeopgave af: Leif S. Striegler.
Vejleder: Peder Voetmann Ckristiansen.

16/79 "STATISTIK I KRÆFTFORSKNINGEN".
Projektrapport af: Michael Olsen og Jørn Jensen.
Vejleder: Jørgen Larsen.

17/79 "AT SPØRGE OG AT SVARE i fysikundervisningen".
Af: Albert Christian Paulsen.

18/79 "MATHEMATICS AND THE REAL WORLD", Proceedings af an International Workshop, Roskilde University Centre, Denmark, 1978.
Preprint.
Af: Bernhelm Booss og Mogens Niss (eds.)

19/79 "GEOMETRI, SKOLE OG VIRKELIGHED".
Projektrapport af: Tom J. Andersen, Tommy R. Andersen og Per H.H. Larsen.
Vejleder: Mogens Niss.

20/79 "STATISTISKE MODELLER TIL BESTEMMELSE AF SIKRE DOSER FOR CARCINOGENE STOFFER".
Projektrapport af: Michael Olsen og Jørn Jensen.
Vejleder: Jørgen Larsen

21/79 "KONTROL I GYMNASIET-FORMÅL OG KONSEKVENSER".
Projektrapport af: Crilles Bacher, Per S.Jensen, Preben Jensen og Torben Nysteen.

22/79 "SEMIOTIK OG SYSTEMEGENSKABER (1)".
1-port lineært response og støj i fysikken.
Af: Peder Voetmann Christiansen.

23/79 "ON THE HISTORY AF EARLY WAVE MECHANICS - with special emphasis on the role af realitivity".
Af: Helge Kragh.

24/80 a+b "MATEMATIKOPFATTELSER HOS 2.C'ERE".
1. En analyse. 2. Interviewmateriale.
Projektrapport af: Jan Christensen og Knud Lindhardt Rasmussen.
Vejleder: Mogens Niss.

25/80 "EKSAMENSOPGAVER", Dybdemodulet/fysik 1974-79.

26/80 "OM MATEMATISKE MODELLER".
En projektrapport og to artikler.
Af: Jens Højgaard Jensen m.fl.

27/80 "METHODOLOGY AND PHILOSOPHY AF SCIENCE IN PAUL DIRAC's PHYSICS".
Af: Helge Kragh.

28/80 "DIELEKTRISK RELAXATION - et forslag til en ny model bygget på væskernes viscoelastiske egenskaber".
Projektrapport af: Gert Kreinøe.
Vejleder: Niels Boye Olsen.

29/80 "ODIN - undervisningsmateriale til et kursus i differentialligningsmodeller".
Projektrapport af: Tommy R. Andersen, Per H.H. Larsen og Peter H. Lassen.
Vejleder: Mogens Brun Heefelt.

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Af: Oluf Danielsen.
Nr. 30 er udgået.

31/80 "VIDENSKABSTEORETISKE PROBLEMER VED UNDERVISNINGS-SYSTEMER BASERET PÅ MÆNGDELÆRE".
Projektrapport af: Troels Lange og Jørgen Karrebæk.
Vejleder: Stig Andur Pedersen.
Nr. 31 er p.t. udgået.

32/80 "POLYMERE STOFFERS VISCOELASTISKE EGENSKABER - BELYST VED HJÆLP AF MEKANISKE IMPEDANSMÅLINGER MÖSSBAUEREFFEKTMÅLINGER".
Projektrapport af: Crilles Bacher og Preben Jensen.
Vejledere: Niels Boye Olsen og Peder Voetmann Christiansen.

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Af: Arne Jakobsen.

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ENERGY SERIES NO. I.
Af: Bent Sørensen
Nr. 34 er udgået.

35/80 "HISTORISKE STUDIER I DEN NYERE ATOMFYSIKS UDVIKLING".
Af: Helge Kragh.

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Fire artikler.
Af: Mogens Niss.

37/80 "RENEWABLE ENERGY AND ENERGY STORAGE".
ENERGY SERIES NO. 2.
Af: Bent Sørensen.

38/81 "TIL EN HISTORIETEORI OM NATURERKENDELSE, TEKNOLOGI OG SAMFUND".
Projektrapport af: Erik Gade, Hans Hedal, Henrik Lau og Finn Physant.
Vejledere: Stig Andur Pedersen, Helge Kragh og Ib Thiersen.
Nr. 38 er p.t. udgået.

39/81 "TIL KRITIKKEN AF VÆKSTØKONOMIEN".
Af: Jens Højgaard Jensen.

40/81 "TELEKOMMUNIKATION I DANMARK - oplæg til en teknologivurdering".
Projektrapport af: Arne Jørgensen, Bruno Petersen og Jan Vedde.
Vejleder: Per Nørgaard.

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Af: Bent Sørensen.

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Af: Helge Kragh og Stig Andur Pedersen.

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2."ADVANTAGES AND DISADVANTAGES OF DECENTRALIZATION".
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Af: Bent Sørensen.

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Projektrapport af: Niels Thor Nielsen.
Vejleder: Bent C. Jørgensen.

45/82 Er aldrig udkommet.

46/82 "EKSEMPLARISK UNDERVISNING OG FYSISK ERKENDESE-
1+11 ILLUSTRERET VED TO EKSEMPLER".
Projektrapport af: Torben O.Olsen, Lasse Rasmussen og Niels Dreyer Sørensen.
Vejleder: Bent C. Jørgensen.

47/82 "BARSEBÄCK OG DET VÆRST OFFICIELT-TÆNKELIGE UHELD".
ENERGY SERIES NO. 5.
Af: Bent Sørensen.

48/82 "EN UNDERSØGELSE AF MATEMATIKUNDERVISNINGEN PÅ ADGANGSKURSUS TIL KØBENHAVNS TEKNIKUM".
Projektrapport af: Lis Eilertzen, Jørgen Karrebæk, Troels Lange, Preben Nørregaard, Lissi Pedesen, Laust Rishøj, Lill Røn og Isac Showiki.
Vejleder: Mogens Niss.

49/82 "ANALYSE AF MULTISPEKTRALE SATELLITBILLEDER".
Projektrapport af: Preben Nørregaard.
Vejledere: Jørgen Larsen og Rasmus Ole Rasmussen.

50/82 "HERSLEV - MULIGHEDER FOR VEDVARENDE ENERGI I EN LANDSBY".
ENERGY SERIES NO. 6.
Rapport af: Bent Christensen, Bent Hove Jensen, Dennis B. Møller, Bjarne Laursen, Bjarne Lillethorup og Jacob Mørch Pedersen.
Vejleder: Bent Sørensen.

51/82 "HVAD KAN DER GØRES FOR AT AFHJÆLPE PIGERS BLOKERING OVERFOR MATEMATIK ?"
Projektrapport af: Lis Eilertzen, Lissi Pedersen, Lill Røn og Susanne Stender.

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Af: Bernhelm Booss og Krzysztof Wojciechowski.

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Af: Arne Jacobsen og Stig Andur Pedersen.

54/82 "FUTURES RESEARCH" - A Philosophical Analysis of Its Subject-Matter and Methods.
Af: Stig Andur Pedersen og Johannes Witt-Hansen.

55/82 "MATEMATISKE MODELLER" - Litteratur på Roskilde Universitetsbibliotek.
En biografi.
Af: Else Høyrup.

Vedr. tekst nr. 55/82 se også tekst nr. 62/83.

56/82 "EN - TO - MANGE" -
En undersøgelse af matematisk økologi.
Projektrapport af: Troels Lange.
Vejleder: Anders Madsen.

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Skjulte variable i kvantemekanikken?
Projektrapport af: Tom Juul Andersen.
Vejleder: Peder Voetmann Christiansen.
Nr. 57 er udgået.

58/83 "MATEMATISKE VANDRINGER" - Modelbetragtninger over spredning af dyr mellem småbiotoper i agerlandet.
Projektrapport af: Per Hammershøj Jensen og Lene Vagn Rasmussen.
Vejleder: Jørgen Larsen.

59/83 "THE METHODOLOGY OF ENERGY PLANNING".
ENERGY SERIES NO. 7.
Af: Bent Sørensen.

60/83 "MATEMATISK MODEKSPERTISE"- et eksempel.
Projektrapport af: Erik O. Gade, Jørgen Karrebæk og Preben Nørregaard.
Vejleder: Anders Madsen.

61/83 "FYSIKS IDEOLOGISKE FUNKTION, SOM ET EKSEMPEL PÅ EN NATURVIDENSKAB - HISTORISK SET".
Projektrapport af: Annette Post Nielsen.
Vejledere: Jens Høyrup, Jens Højgaard Jensen og Jørgen Vogelius.

62/83 "MATEMATISKE MODELLER" - Litteratur på Roskilde Universitetsbibliotek.
En biografi 2. rev. udgave.
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Af: David Crossley og Bent Sørensen.

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Af: Bernhelm Booss og Jens Høyrup.

65/83 "ANVENDT MATEMATIK - TEORI ELLER PRAKSIS".
Projektrapport af: Per Hedegård Andersen, Kirsten Habekost, Carsten Holst-Jensen, Annelise von Moos, Else Marie Pedersen og Erling Møller Pedersen.
Vejledere: Bernhelm Booss og Klaus Grünbaum.

66/83 "MATEMATISKE MODELLER FOR PERIODISK SELEKTION I ESCHERICHIA COLI".
Projektrapport af: Hanne Lisbet Andersen, Ole Richard Jensen og Klavs Frisdahl.
Vejledere: Jørgen Larsen og Anders Hede Madsen.

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Projektrapport af: Lone Biilmann og Lars Boye.
Vejleder: Mogens Brun Heefelt.

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Projektrapport af: Lise Odgård Gade, Susanne Hansen, Michael Hviid og Frank Mølgård Olsen.
Vejleder: Jørgen Larsen.

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- en test i 1.g med kommentarer.
Af: Albert C. Paulsen.

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Projektrapport af: Hanne Lisbet Andersen, Torben J. Andreasen, Svend Åge Houmann, Helle Glerup Jensen, Keld Fl. Nielsen, Lene Vagn Rasmussen.
Vejleder: Klaus Grünbaum og Anders Hede Madsen.

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Af: Karin Beyer, Sussanne Blegaa, Birthe Olsen, Jette Reich og Mette Vedelsby.

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Af: Peder Voetmann Christiansen.

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- økologisk contra traditionelt.
ENERGY SERIES NO. 9
Specialeopgave i fysik af: Bent Hove Jensen.
Vejleder: Bent Sørensen.

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Projektrapport af: Bodil Harder og Linda Szkotak Jensen.
Vejledere: Jens Højgaard Jensen og Bent C. Jørgensen.

75/84 "MATEMATIKUNDERVISNINGEN I FREMTIDENS GYMNASIUM"
- Case: Lineær programmering.
Projektrapport af: Morten Blomhøj, Klavs Frisdahl og Frank Mølgaard Olsen.
Vejledere: Mogens Brun Heefelt og Jens Bjørneboe.

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Af: Niels Boye Olsen og Bent Sørensen.

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Opinionsundersøgelser belyst ved statistiske modeller.
Projektrapport af: Svend Åge Houmann, Keld Nielsen og Susanne Stender.
Vejledere: Jørgen Larsen og Jens Bjørneboe.

78/84 "JÆVNSTRØMSLEDNINGSEVNE OG GITTERSTRUKTUT I AMORFT GERMANIUM".
Specialrapport af: Hans Hedal, Frank C. Ludvigsen og Finn C. Physant.
Vejleder: Niels Boye Olsen.

79/84 "MATEMATIK OG ALMENDANNELSE".
Projektrapport af: Henrik Coster, Mikael Wennerberg Johansen, Povl Kattler, Birgitte Lydholm og Morten Overgaard Nielsen.
Vejleder: Bernhelm Booss.

80/84 "KURSUSMATERIALE TIL MATEMATIK B".
Af: Mogens Brun Heefelt.

81/84 "FREKVENSAFHÆNGIG LEDNINGSEVNE I AMORFT GERMANIUM".
Specialerapport af: Jørgen Wind Petersen og Jan Christensen.
Vejleder: Niels Boye Olsen.

82/84 "MATEMATIK - OG FYSIKUNDERVISNINGEN I DET AUTOMATISEREDE SAMFUND".
Rapport fra et seminar afholdt i Hvidovre 25-27 april 1983.
Red.: Jens Højgaard Jensen, Bent C. Jørgensen og Mogens Niss.

83/84 "ON THE QUANTIFICATION OF SECURITY":
PEACE RESEARCH SERIES NO. 1
Af: Bent Sørensen
nr. 83 er p.t. udgået

84/84 "NOGLE ARTIKLER OM MATEMATIK, FYSIK OG ALMENDANNELSE".
Af: Jens Højgaard Jensen, Mogens Niss m. fl.

85/84 "CENTRIFUGALREGULATORER OG MATEMATIK".
Specialerapport af: Per Hedegård Andersen, Carsten Holst-Jensen, Else Marie Pedersen og Erling Møller Pedersen.
Vejleder: Stig Andur Pedersen.

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Af: Albert Chr. Paulsen.

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Projektrapport af: Biger Lundgren, Henning Sten Hansen og John Johansson.
Vejleder: Torsten Meyer.

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Projektrapport af: Morten Blomhøj, Klavs Frisdahl og Frank M. Olsen.
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Af: Bjarne Lilletorup.
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Af: Jeppe C. Dyre.

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Af: Bent Sørensen.

99/85 "Der er langt fra Q til R".
Projektrapport af: Niels Jørgensen og Mikael Klintorp.
Vejleder: Stig Andur Pedersen.

100/85 "TALSYSTEMETS OPBYGNING".
Af: Mogens Niss.

101/85 "EXTENDED MOMENTUM THEORY FOR WINDMILLS IN PERTURBATIVE FORM".
Af: Ganesh Sengupta.

102/85 OPSTILLING OG ANALYSE AF MATEMATISKE MODELLER, BELYST VED MODELLER OVER KØERS FODEROPTAGELSE OG - OMSÆTNING".
Projektrapport af: Lis Eilertzen, Kirsten Habekost, Lill Røn og Susanne Stender.
Vejleder: Klaus Grünbaum.

103/85 "ØDSLE KOLDKRIGERE OG VIDENSKABENS LYSE IDEER".
Projektrapport af: Niels Ole Dam og Kurt Jensen.
Vejleder: Bent Sørensen.

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Af: Jens Jæger.

105/85 "THE FREQUENCY DEPENDENCE OF THE SPECIFIC HEAT AF THE GLASS TRANSITION".
Af: Tage Christensen.

"A SIMPLE MODEL AF AC HOPPING CONDUCTIVITY".
Af: Jeppe C. Dyre.
Contributions to the Third International Conference on the Structure of Non - Crystalline Materials held in Grenoble July 1985.

106/85 "QUANTUM THEORY OF EXTENDED PARTICLES".
Af: Bent Sørensen.

107/85 "EN MYG GØR INGEN EPIDEMI",
- flodblindhed som eksempel på matematisk modellering af et epidemiologisk problem.
Projektrapport af: Per Hedegård Andersen, Lars Boye, CarstenHolst Jensen, Else Marie Pedersen og Erling Møller Pedersen.
Vejleder: Jesper Larsen.

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Af: Mogens Niss.

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Projektrapport af: Mikael Wennerberg Johansen, Poul Katler og Torben J. Andreasen.
Vejleder: Jørgen Larsen.

110/85 "PLANNING FOR SECURITY".
Af: Bent Sørensen

111/85 JORDEN RUNDT PÅ FLADE KORT".
Projektrapport af: Birgit Andresen, Beatriz Quinones og Jimmy Staal.
Vejleder: Mogens Niss.

112/85 "VIDENSKABELIGGØRELSE AF DANSK TEKNOLOGISK INNOVATION FREM TIL 1950 - BELYST VED EKSEMPLER".
Projektrapport af: Erik Odgaard Gade, Hans Hedal, Frank C. Ludvigsen, Annette Post Nielsen og Finn Physant.
Vejleder: Claus Bryld og Bent C. Jørgensen.

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Projektrapport af: Lone Biilmann, Ole R. Jensen og Anne-Lise von Moos.
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Af: Mogens Niss.

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Af: Jeppe C. Dyre.

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Af: Jacob Mørch Pedersen.
Vejleder: Bent Sørensen

118/85 "TILFÆLDIGHEDEN OG NØDVENDIGHEDEN IFØLGE PEIRCE OG FYSIKKEN".
Af: Peder Voetmann Christiansen

119/86 "DET ER GANSKE VIST - - EUKLIDS FEMTE POSTULAT KUNNE NOK SKABE RØRE I ANDEDAMMEN".
Af: Iben Maj Christiansen
Vejleder: Mogens Niss.

120/86 "ET ANTAL STATISTISKE STANDARDMODELLER".
Af: Jørgen Larsen

121/86 "SIMULATION I KONTINUERT TID".
Af: Peder Voetmann Christiansen.

122/86 "ON THE MECHANISM OF GLASS IONIC CONDUCTIVITY".
Af: Jeppe C. Dyre.

123/86 "GYMNASIEFYSIKKEN OG DEN STORE VERDEN".
Fysiklærerforeningen, IMFUFA, RUC.

124/86 "OPGAVESAMLING I MATEMATIK".
Samtlige opgaver stillet i tiden 1974-jan. 1986.

125/86 "UVBY,β - systemet - en effektiv fotometrisk spektralklassifikation af B-,A- og F-stjerner".
Projektrapport af: Birger Lundgren.

126/86 "OM UDVIKLINGEN AF DEN SPECIELLE RELATIVITETSTEORI".
Projektrapport af: Lise Odgaard & Linda Szkotak Jensen
Vejledere: Karin Beyer & Stig Andur Pedersen.

127/86 "GALOIS' BIDRAG TIL UDVIKLINGEN AF DEN ABSTRAKTE ALGEBRA".
Projektrapport af: Pernille Sand, Heine Larsen & Lars Frandsen.
Vejleder: Mogens Niss.

128/86 "SMÅKRYB" - om ikke-standard analyse.
Projektrapport af: Niels Jørgensen & Mikael Klintorp.
Vejleder: Jeppe Dyre.

129/86 "PHYSICS IN SOCIETY"
Lecture Notes 1983 (1986)
Af: Bent Sørensen

130/86 "Studies in Wind Power"
Af: Bent Sørensen

131/86 "FYSIK OG SAMFUND" - Et integreret fysik/historieprojekt om naturanskuelsens historiske udvikling og dens samfundsmæssige betingethed.
Projektrapport af: Jakob Heckscher, Søren Brønd, Andy Wierød.
Vejledere: Jens Høyrup, Jørgen Vogelius, Jens Højgaard Jensen.

132/86 "FYSIK OG DANNELSE"
Projektrapport af: Søren Brønd, Andy Wierød.
Vejledere: Karin Beyer, Jørgen Vogelius.

133/86 "CHERNOBYL ACCIDENT: ASSESSING THE DATA.
ENERGY SERIES NO. 15.
AF: Bent Sørensen.

134/87 "THE D.C. AND THE A.C. ELECTRICAL TRANSPORT IN AsSeTe SYSTEM"
Authors: M.B.El-Den, N.B.Olsen, Ib Høst Pedersen, Petr Viščor

135/87 "INTUITIONISTISK MATEMATIKS METODER OG ERKENDELSESTEORETISKE FORUDSÆTNINGER"
MASTEMATIKSPECIALE: Claus Larsen
Vejledere: Anton Jensen og Stig Andur Pedersen

136/87 "Mystisk og naturlig filosofi: En skitse af kristendommens første og andet møde med græsk filosofi"
Projektrapport af Frank Colding Ludvigsen
Vejledere: Historie: Ib Thiersen
Fysik: Jens Højgaard Jensen

137/87 "HOPMODELLER FOR ELEKTRISK LEDNING I UORDNEDE FASTE STOFFER" - Resume af licentiatafhandling
Af: Jeppe Dyre
Vejledere: Niels Boye Olsen og Peder Voetmann Christiansen.

138/87 "JOSEPHSON EFFECT AND CIRCLE MAP."

Paper presented at The International Workshop on Teaching Nonlinear Phenomena at Universities and Schools, "Chaos in Education". Balaton, Hungary, 26 April-2 May 1987.

By: Peder Voetmann Christiansen

139/87 "Machbarkeit nichtbeherrschbarer Technik durch Fortschritte in der Erkennbarkeit der Natur"

Af: Bernhelm Booss-Bavnbek
Martin Bohle-Carbonell

140/87 "ON THE TOPOLOGY OF SPACES OF HOLOMORPHIC MAPS"

By: Jens Gravesen

141/87 "RADIOMETERS UDVIKLING AF BLODGASAPPARATUR - ET TEKNOLOGIHISTORISK PROJEKT"

Projektrapport af Finn C. Physant

Vejleder: Ib Thiersen

142/87 "The Calderón Projektor for Operators With Splitting Elliptic Symbols"

by: Bernhelm Booss-Bavnbek og
Krzysztof P. Wojciechowski

143/87 "Kursusmateriale til Matematik på NAT-BAS"

af: Mogens Brun Heefelt

144/87 "Context and Non-Locality - A Peircean Approach

Paper presented at the Symposium on the Foundations of Modern Physics The Copenhagen Interpretation 60 Years after the Como Lecture. Joensuu, Finland, 6 - 8 august 1987.

By: Peder Voetmann Christiansen

145/87 "AIMS AND SCOPE OF APPLICATIONS AND MODELLING IN MATHEMATICS CURRICULA"

Manuscript of a plenary lecture delivered at ICMTA 3, Kassel, FRG 8.-11.9.1987

By: Mogens Niss

146/87 "BESTEMMELSE AF BULKRESISTIVITETEN I SILICIUM"

- en ny frekvensbaseret målemetode.

Fysikspeciale af Jan Vedde

Vejledere: Niels Boye Olsen & Petr Viščor

147/87 "Rapport om BIS på NAT-BAS"

redigeret af: Mogens Brun Heefelt

148/87 "Naturvidenskabsundervisning med Samfundsperspektiv"

af: Peter Colding-Jørgensen DLH
Albert Chr. Paulsen

149/87 "In-Situ Measurements of the density of amorphous germanium prepared in ultra high vacuum"

by: Petr Viščor

150/87 "Structure and the Existence of the first sharp diffraction peak in amorphous germanium prepared in UHV and measured in-situ"

by: Petr Viščor

151/87 "DYNAMISK PROGRAMMERING"

Matematikprojekt af:
Birgit Andresen, Keld Nielsen og Jimmy Staal

Vejleder: Mogens Niss

152/87 "PSEUDO-DIFFERENTIAL PROJECTIONS AND THE TOPOLOGY OF CERTAIN SPACES OF ELLIPTIC BOUNDARY VALUE PROBLEMS"

by: Bernhelm Booss-Bavnbek
Krzysztof P. Wojciechowski

153/88 "HALVLEDERTEKNOLOGIENS UDVIKLING MELLEM MILITÆRE OG CIVILE KRÆFTER"

Et eksempel på humanistisk teknologihistorie
Historiespeciale

Af: Hans Hedal

Vejleder: Ib Thiersen

154/88 "MASTER EQUATION APPROACH TO VISCOUS LIQUIDS AND THE GLASS TRANSITION"

By: Jeppe Dyre

155/88 "A NOTE ON THE ACTION OF THE POISSON SOLUTION OPERATOR TO THE DIRICHLET PROBLEM FOR A FORMALLY SELFADJOINT DIFFERENTIAL OPERATOR"

by: Michael Pedersen

156/88 "THE RANDOM FREE ENERGY BARRIER MODEL FOR AC CONDUCTION IN DISORDERED SOLIDS"

by: Jeppe C. Dyre

157/88 " STABILIZATION OF PARTIAL DIFFERENTIAL EQUATIONS BY FINITE DIMENSIONAL BOUNDARY FEEDBACK CONTROL: A pseudo-differential approach."

by: Michael Pedersen

158/88 "UNIFIED FORMALISM FOR EXCESS CURRENT NOISE IN RANDOM WALK MODELS"

by: Jeppe Dyre

159/88 "STUDIES IN SOLAR ENERGY"

by: Bent Sørensen

160/88 "LOOP GROUPS AND INSTANTONS IN DIMENSION TWO"

by: Jens Gravesen

161/88 "PSEUDO-DIFFERENTIAL PERTURBATIONS AND STABILIZATION OF DISTRIBUTED PARAMETER SYSTEMS:

Dirichlet feedback control problems"

by: Michael Pedersen

162/88 "PIGER & FYSIK - OG MEGET MERE"

AF: Karin Beyer, Sussanne Blegaa, Birthe Olsen,
Jette Reich , Mette Vedelsby

163/88 "EN MATEMATISK MODEL TIL BESTEMMELSE AF PERMEABILITETEN FOR BLOD-NETHINDE-BARRIEREN"

Af: Finn Langberg, Michael Jarden, Lars Frellesen

Vejleder: Jesper Larsen

164/88 "Vurdering af matematisk teknologi
Technology Assessment
Technikfolgenabschätzung"

Af: Bernhelm Booss-Bavnbek, Glen Pate med
Martin Bohle-Carbonell og Jens Højgaard Jensen

165/88 "COMPLEX STRUCTURES IN THE NASH-MOSER CATEGORY"

by: Jens Gravesen

166/88 "Grundbegreber i Sandsynligheds-regningen"

Af: Jørgen Larsen

167a/88 "BASISSTATISTIK 1. Diskrete modeller"

Af: Jørgen Larsen

167b/88 "BASISSTATISTIK 2. Kontinuerte modeller"

Af: Jørgen Larsen

168/88 "OVERFLADEN AF PLANETEN MARS"
Laboratorie-simulering og MARS-analoger undersøgt ved Mössbauerspektroskopi.

Fysikspeciale af:

Birger Lundgren

Vejleder: Jens Martin Knudsen
Fys.Lab./HCØ

169/88 "CHARLES S. PEIRCE: MURSTEN OG MØRTEL TIL EN METAFYSIK."

Fem artikler fra tidsskriftet "The Monist" 1891-93.

Introduktion og oversættelse:

Peder Voetmann Christiansen

170/88 "OPGAVESAMLING I MATEMATIK"

Samtlige opgaver stillet i tiden 1974 - juni 1988

171/88 "The Dirac Equation with Light-Cone Data"

af: Johnny Tom Ottesen

172/88 "FYSIK OG VIRKELIGHED"

Kvantemekanikkens grundlagsproblem i gymnasiet.

Fysikprojekt af:

Erik Lund og Kurt Jensen

Vejledere: Albert Chr. Paulsen og Peder Voetmann Christiansen

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173/89 "NUMERISKE ALGORITMER"

af: Mogens Brun Heefelt

174/89 " GRAFISK FREMSTILLING AF FRAKTALER OG KAOS"

af: Peder Voetmann Christiansen

175/89 " AN ELEMENTARY ANALYSIS OF THE TIME DEPENDENT SPECTRUM OF THE NON-STATONARY SOLUTION TO THE OPERATOR RICCATI EQUATION

af: Michael Pedersen

176/89 " A MAXIUM ENTROPY ANSATZ FOR NONLINEAR RESPONSE THEORY"

af : Jeppe Dyre

177/89 "HVAD SKAL ADAM STÅ MODEL TIL"

af: Morten Andersen, Ulla Engström, Thomas Gravesen, Nanna Lund, Pia Madsen, Dina Rawat, Peter Torstensen

Vejleder: Mogens Brun Heefelt

178/89 "BIOSYNTESEN AF PENICILLIN - en matematisk model"

af: Ulla Eghave Rasmussen, Hans Oxvang Mortensen, Michael Jarden

vejleder i matematik: Jesper Larsen
biologi: Erling Lauridsen

179a/89 "LÆRERVEJLEDNING M.M. til et eksperimentelt forløb om kaos"

af: Andy Wierød, Søren Brønd og Jimmy Staal

Vejledere: Peder Voetmann Christiansen
Karin Beyer

179b/89 "ELEVHÆFTE: Noter til et eksperimentelt kursus om kaos"

af: Andy Wierød, Søren Brønd og Jimmy Staal

Vejledere: Peder Voetmann Christiansen
Karin Beyer

180/89 "KAOS I FYSISKE SYSTEMER eksemplificeret ved torsions- og dobbeltpendul".

af: Andy Wierød, Søren Brønd og Jimmy Staal
Vejleder: Peder Voetmann Christiansen

181/89 "A ZERO-PARAMETER CONSTITUTIVE RELATION FOR PURE SHEAR VISCOELASTICITY"

by: Jeppe Dyre

183/89 "MATEMATICAL PROBLEM SOLVING, MODELLING. APPLICATIONS AND LINKS TO OTHER SUBJECTS - State. trends and issues in mathematics instruction

by: WERNER BLUM, Kassel (FRG) og
MOGENS NISS, Roskilde (Denmark)

184/89 "En metode til bestemmelse af den frekvensafhængige varmefylde af en underafkølet væske ved glasovergangen"

af: Tage Emil Christensen

185/90 "EN NESTEN PERIODISK HISTORIE"

Et matematisk projekt

af: Steen Grode og Thomas Jessen

Vejleder: Jacob Jacobsen

186/90 "RITUAL OG RATIONALITET i videnskabers udvikling"

redigeret af Arne Jakobsen og Stig Andur Pedersen

187/90 "RSA - et kryptografisk system"

af: Annemette Sofie Olufsen, Lars Frellesen og Ole Møller Nielsen

Vejledere: Michael Pedersen og Finn Munk

188/90 "FERMICONDENSATION - AN ALMOST IDEAL GLASS TRANSITION"

by: Jeppe Dyre

189/90 "DATAMATER I MATEMATIKUNDERVISNINGEN PÅ GYMNASIET OG HØJERE LÆREANSTALTER

af: Finn Langberg

190/90 "FIVE REQUIREMENTS FOR AN APPROXIMATE NONLINEAR RESPONSE THEORY"

by: Jeppe Dyre

191/90 "MOORE COHOMOLOGY, PRINCIPAL BUNDLES AND ACTIONS OF GROUPS ON C*-ALGEBRAS"

by: Iain Raeburn and Dana P. Williams

192/90 "Age-dependent host mortality in the dynamics of endemic infectious diseases and SIR-models of the epidemiology and natural selection of co-circulating influenza virus with partial cross-immunity"

by: Viggo Andreasen

193/90 "Causal and Diagnostic Reasoning"

by: Stig Andur Pedersen

194a/90 "DETERMINISTISK KAOS"
Projektrapport af : Frank Olsen

194b/90 "DETERMINISTISK KAOS"
Kørselsrapport

Projektrapport af: Frank Olsen

195/90 "STADIER PÅ PARADIGMETS VEJ"
Et projekt om den videnskabelige udvikling der førte til dannelse af kvantemekanikken.

Projektrapport for 1. modul på fysikuddannelsen, skrevet af:

Anja Boisen, Thomas Hougård, Anders Gorm Larsen, Nicolai Ryge.

Vejleder: Peder Voetmann Christiansen

196/90 "ER KAOS NØDVENDIGT?"

- en projektrapport om kaos' paradigmatiske status i fysikken.

af: Johannes K. Nielsen, Jimmy Staal og Peter Bøggild

Vejleder: Peder Voetmann Christiansen

197/90 "Kontrafaktiske konditionaler i HOL

af: Jesper Voetmann, Hans Oxvang Mortensen og Aleksander Høst-Madsen

Vejleder: Stig Andur Pedersen

198/90 "Metal-Isolator-Metal systemer"

Speciale

af: Frank Olsen

199/90 "SPREDT FÆGTNING" Artikelsamling

af: Jens Højgaard Jensen

200/90 "LINEÆR ALGEBRA OG ANALYSE"

Noter til den naturvidenskabelige basisuddannelse.

af: Mogens Niss

201/90 "Undersøgelse af atomare korrelationer i amorfe stoffer ved røntgendiffraktion"

af: Karen Birkelund og Klaus Dahl Jensen

Vejledere: Petr Viščor, Ole Bakander

202/90 "TEGN OG KVANTER"
Foredrag og artikler, 1971-90.

af: Peder Voetmann Christiansen

203/90 "OPGAVESAMLING I MATEMATIK" 1974-1990

afløser tekst 170/88

204/91 "ERKENDELSE OG KVANTEMEKANIK"

et Breddemodul Fysik Projekt

af: Thomas Jessen

Vejleder: Petr Viščor

205/91 "PEIRCE'S LOGIC OF VAGUENESS"

by: Claudine Engel-Tiercelin
Department of Philosophy
Université de Paris-1
(Panthéon-Sorbonne)

206a+b/91 "GERMANIUMBEAMANALYSE SAMT A - GE TYNDFILMS ELEKTRISKE EGENSKABER"

Eksperimentelt Fysikspeciale

af: Jeanne Linda Mortensen

og Annette Post Nielsen

Vejleder: Petr Viščor