

TEKST NR 237

1993

**The Wedderburn principal theorem and
Shukla cohomology**

Lars Kadison

TEKSTER fra

IMFUFA **ROSKILDE UNIVERSITETSCENTER**
INSTITUT FOR STUDIET AF MATEMATIK OG FYSIK SAMT DERES
FUNKTIONER I UNDERVISNING, FORSKNING OG ANVENDELSER

Abstract

A finite dimensional algebra A over a perfect field F is a vector space direct sum of its radical ideal J , i.e. its maximal nilpotent ideal, and a subalgebra S : $A = S \oplus J$. For example, $A = \left\{ \begin{pmatrix} \alpha & \beta \\ 0 & \gamma \end{pmatrix} \mid \alpha, \beta, \gamma \in \mathcal{C} \right\}$, $S = \left\{ \begin{pmatrix} \alpha & \beta - \alpha \\ 0 & \beta \end{pmatrix} \mid \alpha, \beta \in \mathcal{C} \right\}$, and $J = \left\{ \begin{pmatrix} 0 & \gamma \\ 0 & 0 \end{pmatrix} \mid \gamma \in \mathcal{C} \right\}$. If S' is another subalgebra of A satisfying $A = S' \oplus J$, then there is a w in J such that $S' = (1 - w)S(1 - w)^{-1}$. The proof of these facts is deep, and was given first by Wedderburn.

In a conceptual breakthrough Hochschild found a cohomological proof of Wedderburn's theorem. His proof makes a reduction to the case where $J^2 = 0$. The quotient map $A \rightarrow A/J$ has a linear right inverse s . The $s(xy) - s(x)s(y)$ defines a J -valued 2-cocycle in a cohomology theory named after Hochschild. Now A/J is a separable F -algebra, so has vanishing positive dimensional cohomology groups; whence there exists a map $g : A/J \rightarrow J$ such that $s(xy) - s(x)s(y) = s(x)g(y) - g(xy) + g(x)s(y)$. Hence $\psi = s + g$ is a homomorphism of algebras that is a right inverse of $A \rightarrow A/J$. Taking S to be the subalgebra $\psi(A/J)$, $A = S \oplus J$ is satisfied.

If A is instead an algebra over a commutative ring that is not a field, a linear right inverse s might not exist: e.g., the natural surjection of \mathcal{Z} -algebras, $\mathcal{Z}_{p^2} \rightarrow \mathcal{Z}_p$ where p is prime. However, the axiom of choice provides a set-theoretic right inverse t for $A \rightarrow A/J$. Forming both $t(xy) - t(x)t(y)$ and $t(x+y) - t(x) - t(y)$, we show that these give a J -valued 2-cocycle in a more refined cohomology theory of algebras discovered by U. Shukla. We carefully present Shukla's not widely known cohomology theory, then obtain a fully generalized cohomological version of Wedderburn's theorem, and discuss its practical uses and limitations.

The Wedderburn principal theorem and Shukla cohomology

Lars Kadison

1 Introduction

A half century or so after their appearance in mathematics, finite dimensional algebras received a big impetus towards their classification at the hands of J. H. M. Wedderburn. His work in the early 1900's is a constant source of powerful generalization - Artin algebras, Jacobson radical, Goldie rings, and Morita's theorems - indeed, also a source of specializations such as quiver algebras and division algebras. His main three theorems are 1) a simple finite-dimensional algebra is a full matrix algebra over a division algebra; 2) a semisimple finite-dimensional algebra is a direct product of simple algebras; and 3) a finite-dimensional algebra over a perfect field is a split extension of a semisimple subalgebra by a nilpotent ideal. The last theorem 3) is especially celebrated as "the principal theorem" in early texts; now at times more routinely referred to as his "factorization theorem." In specific terms, the principal theorem states that a finite-dimensional algebra A over a perfect field has a semisimple subalgebra S and nilpotent ideal J such that $A = S \oplus J$ (a direct sum of vector subspaces). By taking some small matrix examples it is clear that S may not be unique, but any other semisimple subalgebra S' such that $A = S' \oplus J$ is conjugate to S by an element $1 - x$ for some element x in J (a theorem of Malcev).

In 1945 Hochschild introduced in a pair of articles in the *Annals of Mathematics* a cohomology theory of algebras over fields, and gave a conceptually brilliant proof of the principal theorem. The idea is basic to homological algebra: the exact sequence $0 \rightarrow J \rightarrow A \xrightarrow{\sigma} A/J \rightarrow 0$ of natural algebra homomorphisms is split by (a right inverse to σ) an algebra homomorphism. The proof begins by observing that A/J is a separable alge-

bra, then Hochschild introduced the separability element and characterized separable algebras as having vanishing cohomology groups $HH^n(A, M)$ for $n = 1, 2, 3, \dots$ and any A -bimodule M . He then showed that $HH^2(A, M)$ is in one-to-one correspondence with isomorphism classes of exact sequences of algebras $0 \rightarrow M \rightarrow B \rightarrow A \rightarrow 0$ where $M^2 = 0$ (a "square-zero extension of A by M "): the cobounded 2-cocycles corresponding to $B =$ the semi-direct product $A \times M$ with the natural maps and other 2-cocycles giving a nontrivial "twist" to the multiplication of the semi-direct product. If $f(x, y) \in M$ is a 2-cocycle one defines multiplication on $A \times M$ by the well-known formula:

$$(a, m)(a', m') = (aa', am' + ma' + f(a, a'))$$

Conversely, a square-zero extension of A by M with a linear splitting defines a "factor set", i.e., a bilinear M -valued map measuring the failure of ϕ to be multiplicative, and associativity of the multiplication in B implies a cocycle condition on the factor set. For the separable algebra A/J and the special case where $J^2 = 0$ this implies that the factor set is cobounded, since $HH^2(A, J) = 0$, so that a homomorphic splitting exists. The general case is disposed of by an induction argument on the index of nilpotency of J . The theorem Hochschild proved then can be stated easily for algebras over any commutative ring k as the following vast generalization of the principal theorem.

Theorem 1.1 *If a unital k -algebra A contains a nilpotent ideal J such that*

1. A/J is a projective k -module,
2. $HH^2(A/J, M) = 0$ for every A/J -bimodule M ,

then there exists in A a subalgebra S such that $A = S \oplus J$ as k -modules.

This theorem together with its proof is certainly one of the big successes of homological algebra. Algebras enjoying property (ii), vanishing second cohomology groups, are the so-called quasi-free algebras of D. Quillen and J. Cuntz, enjoying a revival because of their role in non-commutative differential geometry. The special case of separable algebras generalizes to separable extensions of algebras by use of the separability element, and together with a condition of splitness possess the desirable features of the basic construction of V. F. R. Jones while combining the disparate examples of finite index

subgroups, coprime degree separable field extensions, matrix extensions, and type II_1 subfactors of finite index.

In the Hochschild theory it is important that every exact sequence be split over the ground ring k . For example, for p a prime it is easy to compute $HH^2(\mathcal{Z}_p, \mathcal{Z}_p) = 0$ where \mathcal{Z}_p is viewed as a \mathcal{Z} -algebra with its natural bimodule \mathcal{Z}_p . However, the square-zero extensions $0 \rightarrow \mathcal{Z}_p \rightarrow \mathcal{Z}_{p^2} \rightarrow \mathcal{Z}_p \rightarrow 0$ (one for each of $p - 1$ nonisomorphic inclusions followed by the canonical projection) are all nonisomorphic to the semidirect product. To account for this phenomenon one needs a general cohomology theory of algebras that takes the value \mathcal{Z}_p on the algebra-bimodule pair $(\mathcal{Z}_p, \mathcal{Z}_p)$, and reduces to Hochschild's cohomology groups for algebras over fields. Such a cohomology theory was produced by Shukla in his thesis of 1961 [9], after crucial preparatory work by S. Mac Lane[5][6].

In this note I would like to show how to generalize Hochschild's version of the principal theorem using Shukla cohomology. What we prove is Theorem 3.1, which is just the theorem above with Shukla's cohomology group replacing Hochschild's in condition (ii), and condition (i) dropped. This involves showing that two factor sets (one measuring failure of linearity, the other, multiplicativity, of a set-theoretic splitting function) form a Shukla 2-cocycle: a point with technical subtleties that seems not to have been verified in print. Shukla cohomology has led a shadowy existence since its inception, perhaps because of its computational complexity and lack of application. We hope to make some small improvement to this situation by making a new computation of Shukla cohomology in section 2, after giving an updated account of the theory. We then state and prove our main theorem in some detail, also with the aim of making Shukla's theory digestible to interested readers. In section 4 we conclude with a discussion of possible nice formulations of Wedderburn's principal theorem within general ring theory, armed with Shukla cohomology and information gained by A. Cegarra and A. Garzon on the second Shukla group of torsion-free rings. We also point out that the well-known decomposition of divisible groups is an additive analog of the principal theorem, which leads to more success in the classification problem than in the corresponding problem for algebras.

2 Shukla cohomology

We first present Shukla's cohomology groups of an algebra [9] via a standard complex. Given a k -algebra A with unit, one can find a differential graded algebra (V, d) with augmentation $\epsilon : (V, d) \rightarrow A$, (A equipped with zero differential and zero components in nonzero degree) (V, d) , a free resolution of the k -module A ,

$$\cdots \rightarrow V_n \xrightarrow{d_n} V_{n-1} \rightarrow \cdots \rightarrow V_0 \xrightarrow{\epsilon} A \rightarrow 0$$

Thus, V admits a graded product, d satisfies a Leibnitz rule, and ϵ is a homomorphism of k -algebras. First take V_0 to be the free k -module on basis $\{(a) | a \in A, a \neq 0\}$ and define V_n inductively as the free k -module on non-trivial elements of the $\ker(d_{n-1})$ (where $\epsilon = d_0$). Then take $d_n : V_n \rightarrow V_{n-1}$ to be the linear extension of inclusion of basis elements. Similarly we take $\epsilon(\sum_{i=1}^n k_i(a_i)) = \sum_{i=1}^n k_i a_i$ where $k_i \in k, a_i \in A - 0$.

The cubical elements of Mac Lane [6] are embedded in this complex as follows. Denote by (a, b) the basis element of V_1 corresponding to $(a + b) - (a) - (b)$ in $\ker \epsilon$, so that $d_1((a, b)) = (a + b) - (a) - (b)$. The other cubical elements also appear as special basis elements of the V_n 's; e.g., the next level cubical element is the basis element $\begin{pmatrix} a & c \\ b & d \end{pmatrix}$ of V_2 mapping under d_2 to $(a + c, b + d) - (a, b) - (c, d) + (a, c) + (b, d) - (a + b, c + d)$ in $\ker d_1$.

The multiplication in V_0 is given on basis elements by $(a)(b) = (ab)$ and extended linearly. For basis elements $z \in V_n$ and $w \in V_m$ define the multiplication inductively by

$$zw = d_{n+m}^{-1}((d_n(z))w + (-1)^n z d_m(w))$$

where $d_0 = 0$. For example, $(a, b)(c) = (ac, bc)$. Note that V has a homogeneous k -base, i.e. its basis is closed under multiplication (as are the cubical elements). That V is a differential graded algebra augmentation of A and additively a free resolution of the k -module A is now clear.

Definition. V will be referred to as the standard construction over a k -algebra A . Let C_1 be the category of free resolutions of A that possess differential graded algebra structure with homogeneous k -base containing the unity element and with augmentation map to A that is a d.g. algebra epimorphism. V is easily seen to be the unique terminal object in C_1 [9].

Given a k -algebra A with A -bimodule M , the Shukla cohomology groups $HS^n(A, M)$ ($n = 0, 1, 2, \dots$) are defined as the cohomology groups of the chain complex resulting from the application of the functor $\text{Hom}(-, M)$ to the bar resolution of the differential graded algebra V [7] (M is a V -bimodule via the augmentation). Since we will need the nuts and bolts of this definition (at least for 2-cocycles), we present an interpretation of this definition simply as a bicomplex with resulting cohomology groups.

Taking V as before, the graded tensor product $V \otimes_k \cdots \otimes V = V^{\otimes r}$ (r times V) has a natural differential δ_d and grading ($V^{\otimes r}$), as an alternating sum of the differential d applied to each entry at a time, and grade gotten by adding the grades of homogeneous elements in a tensor element. Define cochain groups $C^{p,q} = \text{Hom}_k((V^{\otimes p})_q, M)$ of the bicomplex $C^{**}(V \rightarrow A)$ with vertical differential $\delta_d : C^{p,q} \rightarrow C^{p,q+1}$ and horizontal differential $\delta_b : C^{p,q} \rightarrow C^{p+1,q}$ defined as follows (each u_i a homogeneous element of V of grade $|u_i|$):

$$\delta_d f(u_1, \dots, u_p) = - \sum_{i=1}^p (-1)^{\epsilon_i-1} f(u_1, \dots, du_i, \dots, u_p)$$

$$(f \in C^{p,q}, \epsilon_i = i + |u_1| + \cdots + |u_i|)$$

$$\begin{aligned} \delta_b f(u_1, \dots, u_{p+1}) &= \epsilon(u_1) f(u_2, \dots, u_{p+1}) + \sum_{i=1}^p (-1)^{\epsilon_i} f(u_1, \dots, u_i u_{i+1}, \dots, u_{p+1}) \\ &\quad + (-1)^{q+p+1} f(u_1, \dots, u_p) \epsilon(u_{p+1}) \end{aligned}$$

We take $C^{0,0} = M$ and $\delta_b m(v_0) = \epsilon(v_0)m - m\epsilon(v_0)$. It may be computed that $\delta_b^2 = \delta_d^2 = 0 = \delta_d \delta_b + \delta_b \delta_d$.

Definition. The Shukla cohomology groups of A with values in M are defined to be the cohomology groups of the cochain complex ($C^n = \sum_{p+q=n} \oplus C^{p,q}$, $\delta = \delta_b + \delta_d$), i.e., the total complex of $C^{**}(A)$. We denote these cohomology groups by $HS^n(A, M)$.

We give a simple and important example. A Shukla 2-cocycle is a pair of multilinear M -valued functions $(f, g) \in \text{Hom}_k(V_0 \otimes_k V_0, M) \oplus \text{Hom}_k(V_1, M)$ satisfying the four conditions which we give only on cubical elements for the sake of simplicity:

1. $\delta_b f((c), (d), (e)) = cf((d), (e)) - f((cd), (e)) + f((c), (de))$
 $- f((c), (d))e = 0$

$$2. \delta_d g \left(\begin{pmatrix} c & d \\ e & f \end{pmatrix} \right) = g((c, e)) + g((d, f)) - g((c + d, e + f)) \\ + g((c + e, d + f)) - g((c, d)) - g((e, f)) = 0$$

$$3. \delta_d f((c, d), (e)) + \delta_b g((c, d), (e)) = f((c), (e)) + f((d), (e)) - f((c + d), (e)) + \\ g((ce, de)) - g((c, d))e = 0$$

$$4. \delta_d f((c), (d, e)) + \delta_b g((c), (d, e)) = f((c), (d + e)) - f((c), (d)) - f((c), (e)) + \\ cg((d, e)) - g((cd, ce)) = 0$$

Note the resemblance of the horizontal differential δ_b to the coboundary b of the standard Hochschild cochain complex of A [3]. In fact $\epsilon : V \rightarrow A$ induces a homomorphism of cochain complexes, and corresponding morphism of cohomologies, $\epsilon^* : HH^n(A, M) \rightarrow HS^n(A, M)$. For example, a Hochschild 2-cochain $f(-, -)$ maps to $(f(\epsilon(-), \epsilon(-)), 0)$. ϵ^* is an isomorphism of cohomologies in degree $n = 0$ and $n = 1$, and monomorphism where $n = 2$. This follows from the spectral sequence of a bicomplex filtered by columns: when applied to $C^{*,*}(A)$, it gives $E_2^{n,0} = H_b^n H_d^0(C^{n,0}) = HH^n(A, M)$.

Shukla proves in [9] that there is a certain freedom of choice in choosing V when computing $HS^n(A, M)$ as the cohomology of the bar construction of V . Any object in the category C_1 of free resolutions over A possessing differential graded algebra structure with homogeneous k -base will suffice for V . It is also shown that it suffices to choose only a projective resolution V of A that possesses differential graded algebra structure and a multiplicative right inverse to the augmentation $\epsilon : V \rightarrow A$ and a (set-theoretic) right inverse to each differential $d_n : V_n \rightarrow \ker d_{n-1}$: such resolutions over A form a category C_2 .

For example, if A is projective over k , choose $V = A$, the trivial d.g. algebra with identity map augmentation, and computing $C^{*,*}(V \rightarrow A)$ we get all zeroes except a bottom row, so that $HS^n(A, M) = HH^n(A, M)$ for every $n \geq 0$.

Another example: if A is an algebra over a principal ideal domain (p.i.d.), we use the following simplified resolution V over A . $V_2 = V_3 = \dots = 0$, V_0 and ϵ are as in the standard construction, and $V_1 = \ker \epsilon$, which is automatically free over k . V_0 and V_1 have the same product as before except that $V_1^2 = 0$. Then V is an object in Shukla's category C_2 , and $C^{*,*}(V \rightarrow A)$ is simplified since $C^{p,q} = 0$ if $q > p$.

A simplification in computing Shukla cohomology occurs by using normalized cochains; i.e. a Shukla cochain that vanishes if an argument is a scalar multiple of the unity in V_0 . This is most easily seen by working with chains rather than cochains: a chain complex (D, δ) of Shukla chains with a 1 appearing in some entry is easily shown to be contractible, so that the Shukla chain complex (C, δ) is homology equivalent to the quotient complex $(C/D, \delta)$. (Cf. [7].)

As an application of normalized cochains we compute $HS^n(A, M)$ and $HH^n(A, M)$ where A is an algebra over a p.i.d. k with surjective unit map $u : k \rightarrow A$. Then take for V the resolution $\cdots \rightarrow 0 \rightarrow k \xrightarrow{d} k \xrightarrow{u} A \rightarrow 0$, where $d(n) = nr$ if $\ker(u) = (r)$. The normalized cochain bicomplex is simply $C^{p,q}(V \rightarrow A) = \left\{ \begin{array}{ccc} 0 & p \neq q & \\ M & p = q & \end{array} \right\}$ so that $HS^{2n}(A, M) = M$ and $HS^{2n+1}(A, M) = 0$ for each nonnegative integer n . The spectral sequence relating Hochschild and Shukla cohomologies readily implies that the Hochschild groups are zero except $HH^0(A, M) = M$.

For example, $HS^{2n}(\mathcal{Z}_p, \mathcal{Z}_p) = \mathcal{Z}_p$ for $n \geq 0$. The corresponding Hochschild groups are all zero. It is known that the elements of the group $HS^2(A, M)$ are in 1-1 correspondence with the isomorphism classes of square-zero extensions of A by M , while the Hochschild group $HH^2(A, M)$ corresponds only to those square-zero extensions that are k -split. The argument for this fact is halfway given in [9] by defining a multiplication and addition on $A \times M$ using a Shukla 2-cocycle, and the other half may be read from the proof of theorem 3.1 below; i.e., given a square-zero extension $0 \rightarrow M \rightarrow B \xrightarrow{f} A \rightarrow 0$ a factor set (f, g) (measuring deviation of a set-theoretic right inverse of p from preserving multiplication and addition) is a Shukla 2-cocycle. The full argument is then obtainable by a diligent checking of some details. In the introduction we spotted p nonisomorphic square-zero extensions of $cal\mathcal{Z}_p$ by its module \mathcal{Z}_p : we now see the second Shukla cohomology group as giving the correct "answer."

A further clarification in the relation of Hochschild and Shukla cohomologies was reached by M. Barr in the 1960's [1]. The guiding philosophy then was that adjoint functors give rise to cotriple cohomology theories that include all the classical cohomology theories. Indeed, Shukla cohomology is up to a shift of +1 in dimension the cotriple cohomology of the adjoint functors F and G : F sends the comma category of k -algebras over A to the underlying

sets and their maps in Set , G is the free algebra functor on sets. One must apply the additive functor $Der_k(-, M)$, derivations into an A -module M , to get cohomology with coefficients. Hochschild cohomology occurs the same way except that F and G pass to and from the category of vector spaces over k , F the functor to the underlying vector spaces, G the tensor algebra functor.

3 Main Theorem

Theorem 3.1 *If A is k -algebra with J a nilpotent ideal such that the quotient algebra A/J has vanishing second Shukla cohomology groups, i.e., $HS^2(A/J, M) = 0$ for every A/J -bimodule M , then there exists a subalgebra S in A such that $A = S \oplus J$ as k -modules.*

Proof. First suppose that J is a nontrivial ideal satisfying $J^2 = 0$. Denoting A/J by B ; i , the inclusion of J in A , and $p : A \rightarrow B$ the canonical projection homomorphism, we have the square-zero extension of B by J :

$$0 \rightarrow J \xrightarrow{i} A \xrightarrow{p} B \rightarrow 0$$

By the axiom of choice there exists a set-theoretic right inverse of p , call it $s : B \rightarrow A$ and choose it such that $s(0) = 0$ and $s(1) = 1$. One can make J into a B -bimodule by defining left and right actions simply as $bx = s(b)x$ and $xb = xs(b)$ (suppressing i): as a consequence of $J^2 = 0$, the actions are linear and associative, and indeed independent of choice of right inverse to p .

Let $\epsilon : V \rightarrow B$ be the standard construction. Define factor sets $f : V_0 \times V_0 \rightarrow J$ and $g : V_1 \rightarrow J$ by the formulas:

$$f((x), (y)) = s(xy) - s(x)s(y)$$

$$g\left(\sum_{i=1}^n r_i(x_i)\right) = \sum_{i=1}^n r_i s(x_i)$$

where $\sum_{i=1}^n r_i x_i = 0$ ($x, y, x_i \in B$ and $r_i \in k$). Thus, $\sum_{i=1}^n r_i(x_i) \in \ker \epsilon$ whose preimage in the homogeneous k -base under $d_1 : V_1 \rightarrow V_0$ is $(\sum_{i=1}^n r_i(x_i))$. By ordinary linear extension we define morphisms $f \in Hom_k(V_0 \otimes_k V_0, J)$ and $g \in Hom_k(V_1, J)$. Hence, (f, g) is a Shukla 2-cochain.

We next show that (f, g) is a Shukla 2-cocycle. As in section 2 there will be four conditions to check (which in the order below correspond to associativity of multiplication, left, then right distributivity of multiplication with respect to addition, and commutassociativity of addition ¹ of the extension).

$$1. (\delta_b f)((x), (y), (z)) = xf((y), (z)) - f((xy), (z)) + f((x), (yz)) - f((x), (y))z = s(x)[s(yz) - s(y)s(z)] - s(xyz) + s(xy)s(z) + s(xyz) - s(x)s(yz) - [s(xy) - s(x)s(y)]s(z) = 0$$

2. If $x, y_i \in B$ and $\sum_{i=1}^n r_i y_i = 0$ then

$$(\delta_b + \delta_d)(f, g)((x), (\sum r_i(y_i))) = xg((\sum r_i(y_i))) - g((\sum r_i(xy_i))) + \sum r_i f((x), (y_i)) = s(x)(\sum r_i s(y_i)) - \sum r_i s(xy_i) + \sum r_i [s(xy_i) - s(x)s(y_i)] = 0$$

3. Same elements as before:

$$(\delta_b + \delta_d)(f, g)((\sum r_i(y_i)), (x)) = g((\sum r_i(y_i x))) - g((\sum r_i(y_i)))x - \sum r_i f((y_i), (x)) = \sum r_i s(y_i x) - [\sum r_i s(y_i)]s(x) - \sum r_i [s(y_i x) - s(y_i)s(x)] = 0.$$

4. A k -homogeneous base element of V_2 is given by $(\sum_{i=1}^m k_i(n_i))$ where $\sum_{i=1}^m k_i n_i = 0$ in V_0 and $n_i = \sum_{j=1}^{m_i} r_{ij}(x_{ij})$ such that $\sum_j r_{ij} x_{ij} = 0$ in B for every i . Then

$$\begin{aligned} (\delta_d g)((\sum k_i(n_i))) &= -g(\sum k_i(n_i)) = -\sum_{i=1}^m k_i g(n_i) \\ &= -\sum_i k_i g((\sum_j r_{ij}(x_{ij}))) = -\sum_i k_i \sum_j r_{ij} s(x_{ij}) \\ &= -g((\sum_{i,j} k_i r_{ij}(x_{ij}))) = -g(0) = 0, \end{aligned}$$

since the last nontrivial argument is equal to $\sum k_i n_i$.

It follows from linearity that (f, g) is a Shukla 2-cocycle. By hypothesis, $HS^2(B, J) = 0$, so that there exists a normalized Shukla 1-cochain $h \in$

$${}^1(x + y) + (z + w) = (x + z) + (y + w) \text{ for every element } x, y, z, \text{ and } w$$

$Hom_k(V_0, J)$ such that $(f, g) = (\delta_b h, \delta_d h)$. Consider the map $\psi : B \rightarrow A$ defined by

$$\psi(x) = s(x) + h((x))$$

for every $x \in B$. We next show that ψ is an algebra homomorphism and a right inverse of p , finishing the proof when $J^2 = 0$ since we take $S = \psi(B)$. Towards this end note that

1. $p \circ \psi = Id_B$ since $p \circ s = Id_B$ and $p \circ h = 0$;
2. ψ is k -linear: given $\sum_{i=1}^n r_i x_i \in B$, note that

$$\begin{aligned} s(\sum r_i x_i) - \sum r_i s(x_i) &= g((\sum r_i x_i) - \sum r_i(x_i)) \\ &= (\delta_d h)((\sum r_i x_i) - \sum r_i(x_i)) = \sum r_i h((x_i)) - h((\sum r_i x_i)) \end{aligned}$$

Whence $\psi(\sum r_i x_i) = s(\sum r_i x_i) + h(\sum r_i x_i) = \sum r_i s(x_i) + \sum r_i h(x_i) = \sum r_i \psi(x_i)$.

3. ψ is multiplicative: $\psi(x)\psi(y) = [s(x)+h((x))][s(y)+h((y))] = s(x)s(y) + h((x))y + xh((y)) = s(xy) - f((x), (y)) + \delta_b h((x), (y)) + h((xy)) = s(xy) + h((xy)) = \psi(xy)$.

To finish the proof we employ the well-known induction argument of Hochschild on the degree n of nilpotency of the ideal J . First, note that $0 \rightarrow J/J^2 \rightarrow A/J^2 \rightarrow B \rightarrow 0$ splits by our argument for $n = 2$. Then there exists a subalgebra C of A such that $0 \rightarrow J^2 \rightarrow C \rightarrow B \rightarrow 0$ is an exact sequence, which splits as well by the induction hypothesis. Take S to be the image of B in C under the splitting homomorphism. S satisfies $A = S \oplus J$, which completes the proof.

4 Shukla cohomology and ring theory

Before discussing what Shukla cohomology might do for ring theory, we need a discussion of what Wedderburn factorization has done for algebras. Aside from its philosophical import on the algebraic community, the principal theorem of Wedderburn seems to have led directly to a classification of algebras only in the case of algebras over an algebraically closed field with square-zero radical (see [8]). Otherwise one is left with the not small task of describing

the multiplicative bimodule structure of the radical over the semisimple subalgebra.

A purely additive analog of Wedderburn's principal theorem - and one with enormous success for the classification problem within its own category - is the following:

Proposition 4.1 *A divisible abelian group D with torsion subgroup D_t has a torsion-free subgroup E such that $D = E \oplus D_t$.*

Thus the classification of divisible groups is accomplished with the dimension of the rational vector space E and the $Z(p^\infty)$ -group components of D_t . Now any abelian group has a maximal torsion subgroup D_t ; if D is divisible, then D_t is an injective Z -module, so that $\text{Ext}_Z^1(A, D_t) = 0$ for every abelian group A . Whence the proposition above may be stated more generally in the cohomological statement below (by recalling the 1-1 correspondence of Ext^1 groups with extensions of modules [7]).

Proposition 4.2 *An abelian group D is isomorphic to $D_t \times D/D_t$ if*

$$\text{Ext}_Z^1(D/D_t, D_t) = 0$$

As an abelian group any ring R will have a maximal torsion subgroup R_t which is in fact an ideal, and behaves like a radical. R/R_t will of course be a torsion-free ring - not an idle remark since we have the following subtle relation between Shukla cohomology and the Ext groups when $n = 2$:

Proposition 4.3 (Cegarra, Garzon [2]) *Suppose k is an integral domain and A is a unital k -algebra that is torsion-free as a k -module. Then*

$$HS^2(A, M) = \text{Ext}_{A \otimes_k A^{\text{op}}}^2(A, M)$$

for every A -bimodule M .

This theorem requires a subtle proof but should not come as a major surprise to the reader because if we had the stronger condition of projectivity on the k -module A , then for all $n \geq 0$ we have $HS^n(A, M) = HH^n(A, M) = \text{Ext}_{A \otimes_k A^{\text{op}}}^n(A, M)$, the last identity brought out by Cartan and

Eilenberg in their classic. One could now state the main theorem (3.1) for torsion-free rings (\mathcal{Z} -algebras) or torsion-free algebras over an integral domain in the more familiar terms of Ext^2 -groups.

It would indeed be nice to state a theorem as elegant as the principal theorem for a certain class of rings - that they automatically factor as a direct sum of some radical and a semisimple subalgebra. But this class of rings must first be found - without just a rediscovery of finite-dimensional algebras over a perfect field. The next example is a basic obstruction to several attempts at such generality. For example, it is a counterexample to the two conjectures:

1. A torsion-free left (right) artinian ring is always a direct sum of a semisimple subring and its nil radical.
2. Goldie's third theorem (a right noetherian principal left ideal ring R is a direct sum of a semiprime principal left ideal ring and an artinian ring) has cohomological proof along the lines of finding the quotient of R by its prime radical and applying theorem 3.1.

Example. Let $A = Q(t_1, t_2)$ be the field of rational functions in two indeterminates. Consider the A -valued Hochschild 2-cocycle f defined by

$$f(u, v) = \frac{\delta u}{\delta t_1} \frac{\delta v}{\delta t_2}$$

Define multiplication on the Q -vector space $A \oplus A$ by

$$(u, v)(w, z) = (uz + vw + f(v, z), vz)$$

and call the resulting Q -algebra B . Since any 2-coboundary ($bg(a, a') = ag(a') - g(aa') + g(a)a'$) is clearly symmetric over the commutative algebra A , it is clear that f is noncobounded since it is not symmetric in its variables. Hence, B is a torsion-free artinian ring with no direct sum decomposition $B = A \oplus J$ as a consequence of the pairing of the Hochschild cohomology group $HH^2(A, A)$ with square-zero extensions of A by A . Also, B is a principal left ideal ring with prime radical A and quotient ring A of projective $A \otimes A^{\text{op}}$ -dimension 2.

References

- [1] M. Barr, Shukla cohomology and triples, *Journal of Algebra* **5** (1967), 222 - 231. Addendum: **6** (1967) 411 - 412.
- [2] A. M. Cegarra and A. R. Garzon, Vanishing theorems of the Shukla cohomology groups with coefficients in injective modules, *C.R.Acad. Sci. Paris* **296** (1983), 299-302.
- [3] G. Hochschild, On the cohomology groups of an associative algebra, *Annals of Math.* **46** (1945), 58 - 67.
- [4] G. Hochschild, On the cohomology theory for associative algebras, *Annals of Math.* **47** (1946), 568 - 579.
- [5] S. Mac Lane, Homologie des anneaux et des modules, *Colloque de Topologie Algebrique*, (1956), 55-80.
- [6] S. Mac Lane, Extensions and obstructions for rings, *Ill. Journ. of Math.* **2** (1958), 316 - 345.
- [7] S. Mac Lane, *Homology*, Grundlehren, Springer Verlag, Berlin, 1963.
- [8] R. Pierce, *Associative Algebras* (Springer graduate texts 88, Berlin, 1980).
- [9] U. Shukla, Cohomologie des algèbres associatives, *Ann. Sci. de l'École Normale Sup.* **78** (1961), 163 - 209.

Address: Department of Mathematics and Physics, Roskilde University, Post-box 260. 4000 Roskilde, Denmark. e-mail adress: kadison@fatou.ruc.dk.

- 1/78 "TANKER OM EN PRAKSIS" - et matematikprojekt.
Projektrapport af: Anne Jensen, Lena Lindenskov, Marianne Kesselhahn og Nicolai Lomholt.
Vejleder: Anders Madsen
- 2/78 "OPTIMERING" - Menneskets forøgede beherskelsermuligheder af natur og samfund.
Projektrapport af: Tom J. Andersen, Tommy R. Andersen, Gert Kreinø og Peter H. Lassen
Vejleder: Bernhelm Boss.
- 3/78 "OPCAVESAMLING", breddekursus i fysik.
Af: Lasse Rasmussen, Aage Bonde Kræmmer og Jens Højgaard Jensen.
- 4/78 "TRE ESSAYS" - om matematikundervisning, matematiklæreruddannelsen og videnskabsrindalismen.
Af: Mogens Niss
Nr. 4 er p.t. udgået.
- 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 Vinariorum".
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 Kreinø.
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 Christiansen.
- 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 SIKKE DOSEER 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 OF EARLY WAVE MECHANICS - with special emphasis on the role of reality".
Af: Helge Kragh.
-
- 24/80 "MATEMATIKOPFATTELSE hos 2.C'ERE".
a+b 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 OF SCIENCE IN PAUL DIRAC'S PHYSICS".
Af: Helge Kragh.
- 28/80 "DILEMMATISK RELAXATION - et forslag til en ny model bygget på væskernes viscoelastiske egenskaber".
Projektrapport af: Gert Kreinø.
Vejleder: Niels Boye Olsen.
- 29/80 "ODIN - undervisningsmateriale til et kursus i differentiaalligningsmodeller".
Projektrapport af: Tommy R. Andersen, Per H.H. Larsen og Peter H. Lassen.
Vejleder: Mogens Brun Heefelt.
- 30/80 "FUSIONSENERGIEN - - - ATOMSAMFUNDETS ENDESTATION".
Af: Oluf Danielsen.
Nr. 30 er udgået.
- 31/80 "VIDENSKABSTEORETISKE PROBLEMER VED UNDERVISNINGSSYSTEMER BASERET PÅ MØNGDELERE".
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 - GER MOSSBAUEREFPEKIMÅLINGER".
Projektrapport af: Crilles Bacher og Preben Jensen.
Vejledere: Niels Boye Olsen og Peder Voetmann Christiansen.
- 33/80 "KONSTITUERING AF FAG INDEN FOR TEKNISK - NATURVIDENSKABELIGE UDDANNELSER. I-II".
Af: Arne Jakobsen.
- 34/80 "ENVIRONMENTAL IMPACT OF WIND ENERGY UTILIZATION".
ENERGY SERIES NO. 1.
Af: Bent Sørensen
Nr. 34 er udgået.

- 35/80 "HISTORISKE STUDIER I DEN NYERE ATOMFYSIKS UDVIKLING".
Af: Helge Kragh.
- 36/80 "HVAD ER MENINGEN MED MATEMATIKUNDERVISNINGEN?".
Fire artikler.
Af: Mogens Niss.
- 37/80 "RENEWABLE ENERGY AND ENERGY STORAGE".
ENERGY SERIES NO. 2.
Af: Bent Sørensen.
-
- 38/81 "TIL EN HISTORIEFØRTEORI OM NATURERKENDELSE, TEKNOLOGI OG SAMFUND".
Projektrapport af: Erik Gade, Hans Heddal, 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 VEKSTØKONOMIEN".
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.
- 41/81 "PLANNING AND POLICY CONSIDERATIONS RELATED TO THE INTRODUCTION OF RENEWABLE ENERGY SOURCES INTO ENERGY SUPPLY SYSTEMS".
ENERGY SERIES NO. 3.
Af: Bent Sørensen.
- 42/81 "VIDENSKAB TEORI SAMFUND - En introduktion til materialistiske videnskabsopfattelser".
Af: Helge Kragh og Stig Andur Pedersen.
- 43/81 1. "COMPARATIVE RISK ASSESSMENT OF TOTAL ENERGY SYSTEMS".
2. "ADVANTAGES AND DISADVANTAGES OF DECENTRALIZATION".
ENERGY SERIES NO. 4.
Af: Bent Sørensen.
- 44/81 "HISTORISKE UNDERSØGELSER AF DE EKSPERIMENTELLE FORUDSÆTNINGER FOR RUTHERFORDS ATOMMODEL".
Projektrapport af: Niels Thor Nielsen.
Vejleder: Bent C. Jørgensen.
-
- 45/82 Er aldrig udkommet.
- 46/82 "EKSEMPLARISK UNDERVISNING OG FYSISK ERKENDELSE-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 TEKNISKUM".
Projektrapport af: Lis Eilertzen, Jørgen Karrebæk, Troels Lange, Preben Nørregaard, Lissi Pedersen, Laust Rishøj, Lill Røn og Isac Showiki.
Vejleder: Mogens Niss.
- 49/82 "ANALYSE AF MULTISPEKTRELE 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.
- 52/82 "DESUSPENSION OF SPLITTING ELLIPTIC SYMBOLS".
Af: Bernhelm Booss og Krzysztof Wojciechowski.
- 53/82 "THE CONSTITUTION OF SUBJECTS IN ENGINEERING EDUCATION".
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.
-
- 57/83 "ASPECT EKSPERIMENTET"-
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.
Af: Else Høyrup.
- 63/83 "CREATING ENERGY FUTURES: A SHORT GUIDE TO ENERGY PLANNING".
ENERGY SERIES NO. 8.
Af: David Crossley og Bent Sørensen.
- 64/83 "VON MATEMATIK UND KRIEG".
Af: Bernhelm Booss og Jens Høyrup.
- 65/83 "ANVENDT MATEMATIK - TEORI ELLER PRAKSIS".
Projektrapport af: Per Hødegård 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 Fris Dahl.
Vejledere: Jørgen Larsen og Anders Hede Madsen.
- 67/83 "ELEPSOIDE METODEN - EN NY METODE TIL LINEÆR PROGRAMMERING?".
Projektrapport af: Lone Billmann og Lars Boye.
Vejleder: Mogens Brun Heefelt.
- 68/83 "STOKASTISKE MODELLER I POPULATIONSGENETIK" - til kritikken af teoriladede modeller.
Projektrapport af: Lise Odgård Gade, Susanne Hansen, Michael Hviid og Frank Mølgård Olsen.
Vejleder: Jørgen Larsen.

- 69/83 "ELEVFORUDSÆTNINGER I FYSIK"
- en test i l.g med kommentarer.
Af: Albert C. Paulsen.
- 70/83 "INDLÆRINGS - OG FORMIDLINGSPROBLEMER I MATEMATIK PÅ VOKSENUNDERVISNINGSNIVEAU".
Projektrapport af: Hanne Lisbet Andersen, Torben J. Andreasen, Svend Åge Houmann, Helle Glenrup Jensen, Keld Fl. Nielsen, Lene Vagn Rasmussen.
Vejleder: Klaus Grünbaum og Anders Hede Madsen.
- 71/83 "PIGER OG FYSIK"
- et problem og en udfordring for skolen?
Af: Karin Beyer, Sussanne Blegaa, Birthe Olsen, Jette Reich og Mette Vedelsby.
- 72/83 "VERDEN IFVLGE PEIRCE" - to metafysiske essays, om og af C.S Peirce.
Af: Peder Voetmann Christiansen.
- 73/83 "'EN ENERGIANALYSE AF LANDBRUG"
- økologisk contra traditionelt.
ENERGY SERIES NO. 9
Specialeopgave i fysik af: Bent Hove Jensen.
Vejleder: Bent Sørensen.
-
- 74/84 "MINIATURISERING AF MIKROELEKTRONIK" - om videnskabeliggjort teknologi og nytten af at lære fysik.
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.
- 76/84 "KERNEKRAFT I DANMARK?" - Et høringssvar indkaldt af miljøministeriet, med kritik af miljøstyrelsens rapporter af 15. marts 1984.
ENERGY SERIES No. 10
Af: Niels Boye Olsen og Bent Sørensen.
- 77/84 "POLITISKE INDEKS - FUP ELLER FAKTA?"
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 GITTERSTRUKTUR I AMORFT GERMANIUM".
Specialrapport af: Hans Medal, Frank C. Ludvigsen og Finn C. Physant.
Vejleder: Niels Boye Olsen.
- 79/84 "MATEMATIK OG ALMENDANNELSE".
Projektrapport af: Henrik Ooster, Mikael Wennerberg Johansen, Povl Kattler, Birgitte Lydholm og Morten Overgaard Nielsen.
Vejleder: Bernhelm Booss.
- 80/84 "KURSMATERIALE TIL MATEMATIK B".
Af: Mogens Brun Heefelt.
- 81/84 "FREKVENSafhængig LEDNINGSEVNE I AMORFT GERMANIUM".
Specialrapport 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".
Specialrapport af: Per Hedegård Andersen, Carsten Holst-Jensen, Else Marie Pedersen og Erling Møller Pedersen.
Vejleder: Stig Andur Pedersen.
- 86/84 "SECURITY IMPLICATIONS OF ALTERNATIVE DEFENSE OPTIONS FOR WESTERN EUROPE".
PEACE RESEARCH SERIES NO. 2
Af: Bent Sørensen.
- 87/84 "A SIMPLE MODEL OF AC HOPPING CONDUCTIVITY IN DISORDERED SOLIDS".
Af: Jeppe C. Dyre.
- 88/84 "RISE, FALL AND RESURRECTION OF INFINITESIMALS".
Af: Detlef Laugwitz.
- 89/84 "FJERNVARMEOPTIMERING".
Af: Bjarne Lillethorup og Jacob Mørch Pedersen.
- 90/84 "ENERGI I L.G - EN TEORI FOR TILRETTELÆGGELSE".
Af: Albert Chr. Paulsen.
-
- 91/85 "KVANTETEORI FOR GYMNASIET".
1. Lærervejledning
Projektrapport af: Biger Lundgren, Henning Sten Hansen og John Johansson.
Vejleder: Torsten Meyer.
- 92/85 "KVANTETEORI FOR GYMNASIET".
2. Materiale
Projektrapport af: Biger Lundgren, Henning Sten Hansen og John Johansson.
Vejleder: Torsten Meyer.
- 93/85 "THE SEMIOTICS OF QUANTUM - NON - LOCALITY".
Af: Peder Voetmann Christiansen.
- 94/85 "TREENIGHEDEN BOURBAKI - generalen, matematikeren og ånden".
Projektrapport af: Morten Blomhøj, Klavs Frisdahl og Frank M. Olsen.
Vejleder: Mogens Niss.
- 95/85 "AN ALTERNATIVE DEFENSE PLAN FOR WESTERN EUROPE".
PEACE RESEARCH SERIES NO. 3
Af: Bent Sørensen
- 96/85 "ASPEKTER VED KRAFTVARMEFORSYNING".
Af: Bjarne Lillethorup.
Vejleder: Bent Sørensen.
- 97/85 "ON THE PHYSICS OF A.C. HOPPING CONDUCTIVITY".
Af: Jeppe C. Dyre.
- 98/85 "VALGMULIGHEDER I INFORMATIONSDEREN".
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 "TALSISTEMETS 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 KØRS FODEROPFÆLSE OG - OMSPINNING".
Projektrapport af: Lis Eilertzen, Kirsten Habekost, Lill Røn og Susanne Stender.
Vejleder: Klaus Grünbaum.

- 103/85 "ØDSLE KOLDKRIGERE OG VIDENSKABENS LYSE IDEER".
Projekt rapport af: Niels Ole Dam og Kurt Jensen.
Vejleder: Bent Sørensen.
- 104/85 "ANALOGREGNEMASKINEN OG LORENZLIGNINGER".
Af: Jens Jøger.
- 105/85 "THE FREQUENCY DEPENDENCE OF THE SPECIFIC HEAT OF THE GLASS TRANSITION".
Af: Tage Christensen.

"A SIMPLE MODEL OF 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.
Projekt rapport af: Per Hedeboe Andersen, Lars Boye, Carsten Holst Jensen, Else Marie Pedersen og Erling Møller Pedersen.
Vejleder: Jesper Larsen.
- 108/85 "APPLICATIONS AND MODELLING IN THE MATHEMATICS CURRICULUM" - state and trends -
Af: Mogens Niss.
- 109/85 "COX I STUDIETIDEN" - Cox's regressionsmodel anvendt på studenteroplysninger fra RUC.
Projekt rapport af: Mikael Wennerberg Johansen, Poul Katler og Torben J. Andreasen.
Vejleder: Jørgen Larsen.
- 110/85 "PLANNING FOR SECURITY".
Af: Bent Sørensen
- 111/85 "JORDEN RINDT PÅ FLADE KORT".
Projekt rapport af: Birgit Andresen, Beatriz Quinones og Jimmy Staal.
Vejleder: Mogens Niss.
- 112/85 "VIDENSKABELIGGØRELSE AF DANSK TEKNOLOGISK INNOVATION FREM TIL 1950 - BELYST VED EKSEMPLER".
Projekt rapport af: Erik Odgaard Gade, Hans Hedal, Frank C. Ludvigsen, Annette Post Nielsen og Finn Physant.
Vejleder: Claus Bryld og Bent C. Jørgensen.
- 113/85 "DESUSPENSION OF SPLITTING ELLIPTIC SYMBOLS II".
Af: Bernhelm Booss og Krzysztof Wojciechowski.
- 114/85 "ANVENDELSE AF GRAFISKE METODER TIL ANALYSE AF KONTIGENTABELLER".
Projekt rapport af: Lone Billmann, Ole R. Jensen og Arne-Lise von Moos.
Vejleder: Jørgen Larsen.
- 115/85 "MATEMATIKKENS UDVIKLING OP TIL RENESSANSEN".
Af: Mogens Niss.
- 116/85 "A PHENOMENOLOGICAL MODEL FOR THE MEYER-NELDEL RULE".
Af: Jeppe C. Dyre.
- 117/85 "KRAFT & FJERNVARMOPTIMERING".
Af: Jacob Mørch Pedersen.
Vejleder: Bent Sørensen
- 118/85 "TILFÆLDIGHEDEN OG NØDVENDIGHEDEN IFØLGE PEIRCE OG FYSIKKEN".
Af: Peder Voetmann Christiansen
- 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, IMFUA, RUC.
- 124/86 "OPGAVESAMLING I MATEMATIK".
Samtlige opgaver stillet i tiden 1974-jan. 1986.
- 125/86 "UVBY, B - systemet - en effektiv fotometrisk spektral-klassifikation af B-, A- og F-stjerner".
Projekt rapport af: Birger Lundgren.
- 126/86 "OM UDVIKLINGEN AF DEN SPECIELLE RELATIVITETSTEORI".
Projekt rapport af: Lise Odgaard & Linda Szkotak Jensen.
Vejledere: Karin Beyer & Stig Andur Pedersen.
- 127/86 "GALOIS' BIDRAG TIL UDVIKLINGEN AF DEN ABSTRAKTE ALGEBRA".
Projekt rapport af: Pernille Sand, Heine Larsen & Lars Frandsen.
Vejleder: Mogens Niss.
- 128/86 "SMÅKRYB" - om ikke-standard analyse.
Projekt rapport af: Niels Jørgensen & Mikael Klinton.
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/historie-projekt om naturanskuelsens historiske udvikling og dens samfundsmæssige betingethed.
Projekt rapport af: Jakob Heckscher, Søren Brønd, Andy Wierød.
Vejledere: Jens Høyrup, Jørgen Vogelius, Jens Højgaard Jensen.
- 132/86 "FYSIK OG DANNEELSE"
Projekt rapport 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 Viscor
- 135/87 "INTUITIONISTISK MATEMATIKS METODER OG ERKENDELSESTEORETISKE FORUDSÆTNINGER"
MATEMATIKSPECIALE: 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"
Projekt rapport 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.
- 119/86 "DET ER GANSKE VIST - - EUKLIDS FEMTE POSTULAT KUNNE NOK SKABE RØRE I ANDEDAMMEN".
Af: Iben Maj Christiansen
Vejleder: Mogens Niss.

- 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 ICMA 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 Višňor
- 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 Višňor
- 150/87 "Structure and the Existence of the first sharp diffraction peak in amorphous germanium prepared in UHV and measured in-situ"
by: Petr Višňor
- 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 "HALVLEDETEKNOLOGIENS 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 Oisen, 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 Teknikfolgenabschätzung"
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 Sandsynlighedsregningen"
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 1986
- 171/88 "The Dirac Equation with Light-Cone Data"
af: Johnny Tom Ottesen
- 172/88 "FYSIK OG VIRKELIGHED"
Kvantemekanikkens grundlagsproblemer i gymnasiet.
Fysikprojekt af:
Erik Lund og Kurt Jensen
Vejledere: Albert Chr. Paulsen og Peder Voetmann Christiansen
-
- 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-STATIONARY SOLUTION TO THE OPERATOR RICCATI EQUATION"
af: Michael Pedersen
- 176/89 "A MAXIMUM 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 "BIOSYNTESSEN 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 "ELEVHEFTE: 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 "MATHEMATICAL 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 varmfylde af en underafkølet væske ved glasovergangen"
af: Tage Emil Christensen
-
- 185/90 "EN NÆSTEN 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 Andreassen
- 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 Višćor, Ole Bakander
- 202/90 "TEGN OG KVANTER"
Foredrag og artikler, 1971-90.
af: Peder Voetmann Christiansen
- 203/90 "OPGAVESAMLING I MATEMATIK" 1974-1990
afleser tekst 170/88
-
- 204/91 "ERKENDELSE OG KVANTEMEKANIK"
et Breddemodul Fysik Projekt
af: Thomas Jessen
Vejleder: Petr Višćor
- 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 Višćor
- 207/91 "SOME REMARKS ON AC CONDUCTION IN DISORDERED SOLIDS"
by: Jeppe C. Dyre
- 208/91 "LANGEVIN MODELS FOR SHEAR STRESS FLUCTUATIONS IN FLOWS OF VISCO-ELASTIC LIQUIDS"
by: Jeppe C. Dyre
- 209/91 "LORENZ GUIDE" Kompendium til den danske fysiker Ludvig Lorenz, 1829-91.
af: Helge Kragh
- 210/91 "Global Dimension, Tower of Algebras, and Jones Index of Split Separable Subalgebras with Unitality Condition."
by: Lars Kadison
- 211/91 "I SAMTIDENS TVERESTE"
- historien bag teorien for de komplekse tal.
af: Lise Arleth, Charlotte Gjerrild, Jane Hansen, Linda Kyndlev, Anne Charlotte Nilsson, Karina Tullinius.
Vejledere: Jesper Larsen og Bernik Egees-Baurle
- 212/91 "Cyclic Homology of Triangular Matrix Algebras"
by: Lars Kadison
- 213/91 "Disease-induced natural selection in a diploid host"
by: Viggo Andreassen and Freddy B. Christiansen

- 214|91 "Hæløj i æteren" - om elektromagnetisme. Oplæg til undervisningsmateriale i gymnasiet.
Af: Nils Kruse, Peter Gastrup, Kristian Hoppe, Jeppe Guldager
Vejledere: Petr Viscor, Hans Hedal
- 215|91 "Physics and Technology of Metal-Insulator-Metal thin film structures used as planar electron emitters
by: A.Delong, M.Drsticka, K.Hladil, V.Kolarik, F.Olsen, P.Pavelka and Petr Viscor.
- 216|91 "Kvantemekanik på PC'eren"
af: Thomas Jessen
-
- 217/92 "Two papers on APPLICATIONS AND MODELLING IN THE MATHEMATICS CURRICULUM"
by: Mogens Niss
- 218/92 "A Three-Square Theorem"
by: Lars Kadison
- 219/92 "RUPNOK - stationær strømning i elastiske rør"
af: Anja Boisen, Karen Birkelund, Mette Olufsen
Vejleder: Jesper Larsen
- 220/92 "Automatisk diagnosticering i digitale kredsløb"
af: Bjørn Christensen, Ole Møller Nielsen
Vejleder: Stig Andur Pedersen
- 221/92 "A BUNDLE VALUED RADON TRANSFORM, WITH APPLICATIONS TO INVARIANT WAVE EQUATIONS"
by: Thomas P. Branson, Gestur Olafsson and Henrik Schlichtkrull
- 222/92 On the Representations of some Infinite Dimensional Groups and Algebras Related to Quantum Physics
by: Johnny T. Ottesen
- 223/92 THE FUNCTIONAL DETERMINANT
by: Thomas P. Branson
- 224/92 UNIVERSAL AC CONDUCTIVITY OF NON-METALLIC SOLIDS AT LOW TEMPERATURES
by: Jeppe C. Dyre
- 225/92 "HATMODELLEN" Impedansspektroskopi i ultrarent en-krystallinsk silicium
af: Anja Boisen, Anders Gorm Larsen, Jesper Varmer, Johannes K. Nielsen, Kit R. Hansen, Peter Bøggild og Thomas Hougaard
Vejleder: Petr Viscor
- 226/92 "METHODS AND MODELS FOR ESTIMATING THE GLOBAL CIRCULATION OF SELECTED EMISSIONS FROM ENERGY CONVERSION"
by: Bent Sørensen
- 227/92 "Computersimulering og fysik"
af: Per M.Hansen, Steffen Holm, Peter Maibom, Mads K. Dall Petersen, Pernille Postgaard, Thomas B.Schrøder, Ivar P. Zeck
Vejleder: Peder Voetmann Christiansen
- 228/92 "Teknologi og historie"
Fire artikler af:
Mogens Niss, Jens Høyrup, Ib Thiersen, Hans Hedal
- 229/92 "Masser af information uden betydning"
En diskussion af informationsteorien i Tor Nørretranders' "Mærk Verden" og en skitse til et alternativ baseret på andenordens kybernetik og semiotik.
af: Søren Brier
- 230/92 "Vinklens tredeling - et klassisk problem"
et matematisk projekt af
Karen Birkelund, Bjørn Christensen
Vejleder: Johnny Ottesen
- 231A/92 "Elektrondiffusion i silicium - en matematisk model"
af: Jesper Voetmann, Karen Birkelund, Mette Olufsen, Ole Møller Nielsen
Vejledere: Johnny Ottesen, H.B.Hansen
- 231B/92 "Elektrondiffusion i silicium - en matematisk model" Kildetekster
af: Jesper Voetmann, Karen Birkelund, Mette Olufsen, Ole Møller Nielsen
Vejledere: Johnny Ottesen, H.B.Hansen
- 232/92 "Undersøgelse om den simultane opdagelse af energiens bevarelse og isærdeles om de af Mayer, Colding, Joule og Helmholtz udførte arbejder"
af: L.Arleth, G.I.Dybkjær, M.T.Østergård
Vejleder: Dorthe Posselt
- 233/92 "The effect of age-dependent host mortality on the dynamics of an endemic disease and Instability in an SIR-model with age-dependent susceptibility
by: Viggo Andreasen
- 234/92 "THE FUNCTIONAL DETERMINANT OF A FOUR-DIMENSIONAL BOUNDARY VALUE PROBLEM"
by: Thomas P. Branson and Peter B. Gilkey
- 235/92 OVERFLADESTRUKTUR OG POREUDVIKLING AF KOKS - Modul 3 fysik projekt -
af: Thomas Jessen
-