A 1

Dynamical group approach to certain anharmonic oscillator and perturbed Coulomb potentials.
H. DE MEYER, State University of Ghent, Belgium.
On account of the SO(2,1) dynamical group formalism combined with algebraic perturbation theory very high accuracy approximations are obtained for the bound state energies of certain one dimensional Schrödinger problems. A first potential which is considered in more detail is the anharmonic oscillator potential $V(x)=x^2+\lambda x^2/(1+gx^2)$ where λ and g are real parameters. Next, the method is applied to the exponential cosine screened Coulomb potential $V(r)=-\exp(-\lambda r)\cos(\mu r)/r$ with λ and μ positive and real. In the latter case truncation of the series development of the potential in powers of λ can be easily avoided.

A2

Theorem on the Schwinger representations and its Application to the Algebraic Hamiltonian for Diatomic Molecules. Shoon K. KIM, Temple University. A general tranformation theory is developed for the boson creation and annihilation operators under Schwinger representation of a transformation group[1]. Construction of scalar invariants under the orthogonal group is discussed. The theory is then applied to the Schwinger repesentation of the U(4) group to construct the complete algebraic Hamiltonian for a diatomic molecule in the vibron model. The resulting expansion for the rotationally invariant Hamiltonian is equivalent to that derived based on the spherical tensors formalism; the latter is available only up to the two body interactions and hence does not account for vibration-rotation coupling. The present result describes all the interactions completely. Application to H_2 molecules are described. 1. S.K. KIM, I.L. Cooper and R.D. Levine, Chemical Physics, 1, 106 (1986).

A3

Algebraic Foundation for the Triaxial Rotor, J.P. Draayer and Yorck Leschber, Louisiana State University. The SU(3)·SO(3) group structure that is found in shell-model theories of nuclear rotational phenomena is shown to embody in a very natural way an algebraic realization of the rotor. Specifically, there exists a simple analytic mapping between the rotor hamiltonian and a fourth-order SU(3)·SO(3) integrity basis interaction.

$$H_{ROT} = AI_1^2+BI_2^2+CI_3^2 - aL^2+bX_3+cX_4 \doteq H_{SU3}$$

Under the mapping invariants of the collective model are carried over into Casimir invariants of the algebraic theory. And as for the rotor, eigenstates of the integrity basis interaction belong to symmetry classes of the Vierergruppe (D_2). The theory gives physical significance to operators first introduced by Racah in his attempt to provide a canonical resolution of the SU(3)·SO(3) multiplicity problem.

A4

Classification of symmetry preserving cubic interactions in the Interacting Boson Model.
H. DE MEYER, State University of Ghent, Belgium.
For each of the dynamical symmetry limits of the nuclear interacting boson model, i.e. the U(5), O(6) and SU(3) limits, we establish a complete set of O(3) scalars which are of third degree in the symmetry group generators and which are functionally independent in the physical boson state basis. It is furthermore investigated how an arbitrary three-boson interaction decomposes into symmetry conserving cubic terms. In particular, we indicate the symmetry contents of the cubic interactions which induce a stable triaxial shape of the nucleus.

A5

Symmetry conserving higher-order interaction terms in the IBA model : the O(6) limit. G. VANDEN BERGHE, Rijksuniversiteit Gent (Belgium). Explicit matrix elements are found for the generators of the group SO(6) in an arbitrary totally symmetric irreducible representation, using the physical principal SO(3) subgroup in the chain SO(6) ⊃SO(5)⊃SO(3). The internal one missing label problem is solved through the definition of intrinsic states which are associated to the SU(2)×SU(2) subgroup in the chain SO(6)⊃SO(5)⊃SU(2)×SU(2) and out of which is projected a complete set of states in the physical basis by integrations over the physical rotation group manifold. The matrix elements of the SO(6) generators in the SU(2)×SU(2) basis are themselves obtained by the intermediate use of an SU(2)×SU(2)×U(1) basis, the latter group being a subgroup of SO(6) but not of SO(5). It is shown that these obtained reduced matrix elements can be used to calculate closed analytical forms for the eigenvalues of the third-order SO(3) scalar operators which can play a role in the description of the O(6) limit of the IBA model. A comparison with experimental data will be given.

A6

The U(6,1) Model of Pairing and Quadrupole Collectivity. G. ROSENSTEEL, Tulane University. A major objective of the algebraic approach to nuclear structure physics is to achieve a unified theory of the two principal competing aspects of the nuclear mean field: nucleon pairing and quadrupole collectivity. The interacting boson model of Arima and Iachello based upon the compact unitary group U(6) is a model of pairing which has been applied successfully to a wide range of nuclei. However, this tractable model is sustained at the expense of an effective quadrupole transition operator with a substantial effective charge. In order to achieve the requisite experimentally observed quadrupole collectivity, U(6) must be supplemented with noncompact generators associated with the giant quadrupole resonance. The noncompact group U(6,1) is the minimal extension of IBM which meets this physically imposed criterion. The discrete series of U(6,1) and its application to deformed nuclei is reviewed in this talk.

A7

Dynamical Symmetries for Odd-Odd Nuclei. A. B. Balantekin, University of Wisconsin, Madison. Recent work for developing dynamical symmetries and supersymmetries applicable to odd-odd nuclei is reviewed. In particular, several approches are contrasted and their predictions are compared with experimental results.

A8

Isospin and the SO_8 Fermion Model of Collective Motion, J. N. GINOCCHIO, Los Alamos National Laboratory. The SO_8 model of nuclear collective motion[1] has been shown to be in direct correspondence to the Interacting Boson Model of nuclei[2] for nuclei which are not axial rotors. This model has also been incorporated into the Fermion Dynamical Symmetry Model[3] which indicates that the SO_8 model may be applicable to the nuclei (Te, Xe, Ba, Ce, etc.) in which both valence neutrons and protons are filling the 50-82 major shell. Since both neutrons and protons are filling the same major shell, care must be taken to make sure that the shell model states have good isospin, a feature which is generally ignored for collective models of these nuclei. We show that we can introduce isospin simply. The ensuing group structure is shown to be very rich. Both pairing and two types of quadrupole interaction are included, one of which corresponds to the usual SO_6 γ-unstable rotor[1,2,3]. We discuss the types of nuclear spectra and transition rates implied by including the isospin degree of freedom in the SO_8 model.

[1] J. N. Ginocchio, Ann. of Phys. 126, 234 (1980).
[2] A. Arima and F. Iachello, Ann. of Phys. 123, 436 (1979).
[3] C. L. Wu, D. H. Feng, X. G. Chen, J. Q. Chen, M. W. Guidry, Phys. Lett. 168B, 313 (1986).

B1

Group Theoretical Applications of Generalized Bose Operators: Fractional Boson Squeezed States for SU(2) and SU(1,1), J. KATRIEL, Technion, Haifa, M. RASETTI, Politecnico di Torino, A. I. SOLOMON, The Open University, U.K.. Generalized bose operators are integral powers of boson operators, multiplied by appropriate functions of the number operator so as to satisfy boson commutation relations. The canonical transformations defining the generalized bose operators in terms of the boson operators are shown to form an Abelian group. They are used to introduce generalized k-boson Holstein-Primakoff realizations of SU(2) and SU(1,1) as well as generalized k´-boson position-momentum dynamical variables. The SU(2) and SU(1,1) coherent states constructed in terms of the k-boson realizations are shown to be squeezed with respect to the k´-boson dynamical variables. The results depend only on the fractional boson index $r = k'/k$.

B2

SU(1,1) Coherent States and Squeezed Light Interacting with an Anharmonic Oscillator Christopher C. Gerry St. Bonaventure University. We consider a solvable model of a nonabsorbing nonlinear medium as an anharmonic oscillator interacting with squeezed light described as an SU(1,1) coherent state. We find that the squeezing is eventually revoked and furthermore the greater the initial squeezing, the more rapidly the squeezing is revoked.

B3

Representation of the Generators of Sp(6,R) in a Monomial Basis Associated with a Given Irrep of this Group. M. MOSHINSKY, Instituto de Física, UNAM, México, D.F. The determination of the matrix elements for the generators of a Lie algebra, with respect to the states that are a basis for a given irrep of the corresponding group, is one of the fundamental problems of representation theory. One of the best known examples in this field is the representation in closed form of the generators of the unitary and orthogonal Lie algebras achieved by Gelfand and Zetlin. A similar result was not available for the non-compact real symplectic algebras. In the present paper we show that, for irreps in the positive discrete series, a representation in closed form can be achieved by applying the generators of the symplectic Lie algebras to monomial expressions in the weight raising generators acting on the lowest weight state, where the latter is characterized by the irrep. We shall present the results for the case of sp(6,R) as well their applications to the symplectic model of the nucleus.

B4

SU(n) Representation Theory in Terms of Pseudo-Unitary Groups. C. QUESNE, Université Libre de Bruxelles. The complementarity relation between U(n) and U(p,q) within some positive-discrete series irreps $[\rho]$ of a larger U(pn,qn) group is reviewed. It is used to reformulate in terms of a U(1,1) group the SO(6,2) model of SU(3), proposed by Biedenharn and Flath, and by Bracken and MacGibbon, and to outline the generalization of the latter to a family of n-2 models of SU(n), for $n \geqslant 3$, respectively associated with U(n-2,1), U(n-1,2),..., and U(1,n-2) groups. In addition, the chain $U(p,q) \supset U(p) \times U(q)$ is employed to solve the state labelling problem arising in the reduction of the direct product of p positive-row with q negative-row U(n) irreps. The resulting solution directly reflects the operation of King's branching rule for $U(n) \times U(n) \supset U(n)$, and is also quite useful for practical purposes.

B5

A new perspective on the $U(n)$ Wigner Racah calculus R. LE BLANC, K.T. HECHT *University of Michigan* Recent developments in the theory of group and tensor representations has enabled us to shed a new light on the $U(n)$ Wigner-Racah calculus. Using D.J. Rowe's coherent state theory, it is demonstrated that the construction of and the laddering within bases for the unitary group is extremely simple, thanks to the Gel'fand multiplicity-free decomposition. Using to its full extent the principle of complementarity for boson space representations, the above coherent state theory, and the recent realization that a strict group theoretical meaning can be assigned to the Biedenharn-Louck $U(n)$ tensor operator patterns, we have rederived in a straightforward fashion the values of the elementary Wigner coefficients for the unitary groups. The explicit structure of the elementary Wigner coefficients is given and shown to consist of the product of a $U(n-1)$ Racah coefficient times some dimensional and vector coherent state theory normalization factors. Each sub-component is calculated on its own. It is also shown that our framework allows the computation of *all* $SU(2)$ Wigner coefficients *in a closed form* which explicitly reveals the 72 Regge symmetries (Regge 1958) known to apply to these coefficients.

B6

Symmetries of Some Hypergeometric Series, W. A. BEYER, L. C. BIEDENHARN, J. D. LOUCK, AND P. R. STEIN, Los Alamos National Laboratory. The occurrence of generalized hypergeometric series in Wigner-Clebsch-Gordan and Racah coefficients, as well as in many other physical problems, is well-known. Hence, properties of these series can have significant physical implications. The transformation groups in the parameter space of the ${}_3F_2$ and ${}_4F_3$ series of unit argument are given for both two- and three-term relations. Identities of Thomae and Bailey are key results for extending the group of the parameter space beyond the trivial permutations of numerator and of denominator parameters. The Biedenharn-Elliott identity for Racah coefficients is discussed from the viewpoint of the ${}_4F_3$ terminating Saalschützian series and its symmetries.

On Coherent States for Orthosymplectic Supergroups A. B. Balantekin, University of Wisconsin, Madison, and H. Schmitt, University of Arizona, Tucson. Although the representation theory of supergroups have recently been studied in some detail, little attention has been paid to the coherent states for supergroups. In this contribution, coherent states associated with the superalgebras Osp(1/2) and Osp(2/2) for both compact and non-compact cases are worked out.

B8

On principal subalgebras of Lie superalgebras and unimodality. J. VAN DER JEUGT, State University of Ghent. It is well known that the existence of a principal sl(2) subalgebra for every simple Lie algebra gives rise to the proof of the unimodality of some important partition polynomials, such as the Gaussian polynomials [R. Stanley, in Lecture Notes in Pure and Appl. Math. 57, 1980, 127-136]. The analogue of sl(2) for Lie superalgebras is osp(1,2), a five-dimensional superalgebra. We classify all simple Lie superalgebras which contain a principal five-dimensional osp(1,2) subalgebra. In Kac'notation, this classification consists of the Lie superalgebras A(n+1,n), B(n,n), B(n-1,n), D(n+1,n), D(n,n) and D(2,1;α). Using the existence of such a principal subalgebra, the unimodality of the principally specialized character of a typical finite dimensional highest weight module is derived. This gives rise to some very remarkable unimodal partition polynomials.

B9

Representations of Lie Superalgabra G (3), A. Sciarrino. Dipartimente di Fisica and P. Sorba, LAPP. A method to build up explicitly the content of $SU(2) \times G_2$ irreducible representations for typical and atypical representations of the exceptional Lie superalgabra G(3) is presented. Young supertableaux are introduced to describe representations of G(3).

C1

Generally Covariant Quantum Field Theory and Scaling Limits. Klaus Fredenhagen and Rudolf Haag, Universitat Hamburg. The formulation of a generally covariant quantum field theory is described. It demands the elimination of global features and a characterization of the theory in terms of the allowed terms of families of states. A simple application is the computation of counting rates of accelerated idealized detectors. As a first orientation we discuss here the consequences of the assumption that the states have a short distance scaling limit. The scaling limit at a point gives a reduction of the theory to tangent space. It contains kinematical information but not the full dynamical laws. The reduced theory will, under rather general conditions, be invariant under translations and under a proper subgroup of the linear transformations in tangent space. One interesting possibility is that it is invariant under SLR(4). Then the macroscopic metric must evolve as a cooperative effect in finite size regions. The other natural possibility is that each family (coherent folium) of states defines a microscopic metric by the scaling limit and the tangent space theory reduces to a theory of free massless fields in a Minkowski space. Irrespective of the assumption of a scaling limit we show that certain states (the fully correlated states defined in section IV) are uniquely determined by their germs so that the thoery can be reconstructed from strictly local information.

C2

On the Covariance Representation of Global Quantum Dynamics and its Symmetries. A. Rieckers, Universitat Göttingen. Certain mechanisms of spontaneous symmetry break down in ground state and equilibrium representations or sufficiently long ranging interactions in non-equilibrium representations lead to a quantum dynamics with time dependent classical (central) observables. In the Heisenberg picture the dynamics and the relevant symmetries act via Jordan-automorphisms in the weak closure of the represented quasi-local field algebra. Traversing different super-selection sectors these transformations in general do not depend continuously on the group parameter and the notion of the infinitesimal generator breaks down. Using the most general form of the Tomita - theory with weights we show that every Jordan-automorphism in an arbitrary (not necessarily σ-finite) W*-algebra has a quasi-covariant implementation by means of a pair of (linear resp. anti-linear) partial isometries (general form of the Wigner theorem). Employing techniques of Borchers we eliminate the continuous part of the transformation group and show the continuity of its representation by the implenting operators. Applications to microscopic models of the Josephson effect are indicated.

C3

Unitary Representations of Photon Polarization Vectors. Y. S. KIM, Univ. of Maryland, D. HAN, STI, MARILYN E. NOZ, New York Univ. Lorentz transformation properties of free photons are studied within the framework of Wigner's little group for massless particles. It is shown that every four-by-four non-unitary matrix applicable to a photon polarization vector can be converted to a rotation matrix through a gauge transformation.

C4

New Geometric Symmetries via Nonlinear Realizations. B.J. DALTON, St. Cloud State University. Limited nonlinear realizations of the Lorentz Group as transformations that mix the local four-velocities with fields, leaving invariant the Minkowski metric form $\dot{x}_\mu \dot{x}_\mu$ have been presented in earlier work.* Here we show that limited extensions of these types of realizations to groups beyond the Lorentz Group, leaving $\dot{x}_\mu \dot{x}_\mu$ invariant, are possible. These realizations affect the $\dot{x}_\mu$ only in the presence of fields. New realizations of SU(2), SU(2)xU(1), SU(2)xSU(2), and the translation group are presented. Limitations, possible extensions and physical implications will be discussed.

*B.J. Dalton, Int. J. Theor. Physics, 23 751 (1984).

C5

Non Linear Representations of the Poincaré Group: G. RIDEAU, Université PARIS VII. We apply to the Poincaré group a general construction proposed elsewhere. Our interest is concentrated on representations with a unitary irreducible linear part and polynomials when restricted to the Lie algebra of the group. From a systematic investigation of the cohomology of extension of irreducible unitary representations by their tensor products, we deduce rather complete results for the group in 2 or 3 space-time dimensions. For 4 space-time dimensions, we have relatively explicit constructions in the interesting particular cases of masslees particles with helicities $\pm 1, \pm 1/2$ and substantial indications inthe general case. Sometimes, we succeed to build linear topological spaces where the formal series is convergent.

C6

Quantized de Sitter Structured Connection and an Example: The Quantum Relativistic Rotator. R. R. ALDINGER, Eastern Illinois University. A quantum geometrical interpretation of the nonlocality of isolated (noninteracting) hadrons is investigated based on Drechsler's soldered de Sitter fiber bundle constructed over Minkowski space. The bundle possesses as its fiber a four-dimensional pseudo-Riemannian space $\mathcal{D}_{3,1}$ of constant negative curvature characterized by a radius of curvature R of the order of one Fermi. The structural (gauge) group of the bundle is a de Sitter SO(4,1) which contains all observable transformations, rotations as well as translations, which are specified by the Lorentz, Γ_μ^{ij}, and the translational, $\mathcal{V}_\mu^k = h_\mu^k + \nabla_\mu x^k$, connection coefficients (gauge potentials). It is shown that after quantization the "inertial" gauge choice, where $(\mathcal{V}_\mu^k, \Gamma_\mu^{ij}) = (h_\mu^k, 0)$, leads to the specific hadron model of the quantum relativistic rotator.

C7

Isogroups of differential ideals of vector-valued differential forms: application to the classical Yang-Mills equations. COSTAS J. PAPACHRISTOU and B. KENT HARRISON, Brigham Young University. An older geometric technique for the study of invariance groups of partial differential equations is generalized and extended to problems involving exterior equations for vector-valued (and, in particular, matrix-valued) differential forms. Symmetry transformations are generated by vector fields defined on jet bundles with "mixed" scalar and vector-valued coordinates. An "internal exterior derivative" is introduced and is used to define the action of the Lie derivative operator on vector-valued one-forms. Due to its very nature, the technique treats geometrical and non-geometrical symmetries in a unified fashion. Application of the above ideas is made to the full and the self-dual Yang-Mills equations. The latter problem demonstrates an interesting connection between symmetry and some integrability characteristics such as "inverse scattering" equations (or linear system) and Bäcklund transformations.

C8

Differential Geometry and Gauge Structure of Maximal-Acceleration Invariant Phase Space. H.E. Brandt, Harry Diamond Labs, Adelphi, MD. —Maximal-acceleration invariant phase space[1-3] is a fiber bundle in which the base manifold is spacetime, and the group manifold is four-velocity space. The differential geometry of the fiber bundle is developed simply in terms of a noncoordinate basis, in which the line element of the bundle manifold is independent of the ordinary spacetime affine connection and splits naturally into the sum of a line element in the base manifold and one in the fiber, without cross terms. The commutation coefficients of the anholonomic basis are calculated, expressions for the connection coefficients and the scalar curvature of the bundle manifold are obtained, and the gauge potential and field tensor are identified. The gauge potential is the inner product of the ordinary spacetime affine connection and the four-velocity.[3] The field tensor can be expressed as an inner product of the spacetime Riemann curvature tensor and the four-velocity, with an added term which is nonvanishing for velocity-dependent metrics and which is simply expressed in terms of the spacetime connection and its gradient with respect to four-velocity. Relationships are discussed between gauge transformations and rotations of the basis vectors of maximal-acceleration invariant phase space.

[1]H.E. Brandt, "Maximal Proper Acceleration Relative to the Vacuum," Lett. Nuovo Cimento 38, 522(1983); 39, 192 (1984).
[2]H.E. Brandt, "The Maximal Acceleration Group," XIIIth International Colloquium on Group Theoretical Methods in Physics, W.W. Zachary, editor, World Scientific, Singapore, 519 (1984).
[3]H.E. Brandt, "Maximal-Acceleration Invariant Phase Space," Proc. of the First International Conference on the Physics of Phase Space, Springer Verlag (1986).

C9

The Spacetime Diffeomorphism Group as a Doubly Semi-Direct Product, PHILIP B. YASSKIN, Texas A&M University. For the purpose of studying the initial value formulation of relativistic field theories the spacetime diffeomorphism group is decomposed so as to isolate the gauge freedom in the initial data from that in the evolution. It is shown that locally the spacetime diffeomorphism group is a doubly semi-direct product of two subgroups: the time-dependent spacial diffeomorphisms and the space-dependent temporal diffeomorphisms. Each of these is then a semi-direct or doubly semi-direct product. The doubly semi-direct product is a generalization of the semi-direct product which uses two actions instead of one.

D1

Symmetry and Subgroups of the Regular Tetrahedron in 4-Dimensions. S. Deonarine, Bronx Community College, New York and J.L. Birman, City College, New York.
The point symmetry operations (384) of the group G_0 of the regular tetrahedron in 4-dimensions are represented in terms of permutations on 8 symbols. All subgroups $G \subset G_0$ are derived using representation theory and presented in the form of a family tree. Applications to phase transitions are described.

Part support by NSF-DMR, BHE-FRAP grants.

D2

Symmetry of Quasiperiodic Lattices in 2-D as Subsymmetries of 4-D Crystallographic Symmetry. J. P. Lu and J. L. Birman, CCNY. An N dimensional quasiperiodic lattice can be regarded as a projection of a slice of crystal lattice in M dimensions(M-D). M is the number of independent lattice vectors needed to index the quasilattice. We show that each R-reducible and Q-irreducible[1] subgroup of an M-D crystal point group gives rise to an aperiodic lattice in lower dimension. If Q-irreducibility is restricted to N-D, one obtains a class of quasilattices in N-D which can be embedded in M-D. Therefore the classification of quasilattices can be obtained. We give examples for M=4, N=2 case. Since 4-D crystal point and space groups have been completely given, we obtain the classification of quasilattices in 2-D which are embedded in 4-D. The 2-D Penrose lattice is a particular example of our discussion.

* This work is supported in part by NSF-DMR-83-03981.

[1] H. Brown et al "Crystallographic group of Four-dimensional Space", John Wiley & Sons, N. Y. 1978

D3

Quasi-lattices associated with the Icosahedral and Dihedral Groups, R W HAASE, TU Wien
P KRAMER, Universität Tübingen

A systematic approach is given for the construction of families of polytopes associated with a given group G and subgroup H. The emphasis is placed on the role of the induced representation theory and projection to E^3. This procedure is applied to both the icosahedral group and the dihedral group D_{10}. They provide various types of quasi-lattices associated with these groups and hence are candidates for modelling the quasicrystal structures for the icosahedral and decagonal phases of aluminium-transition metal alloys.

D4

Tensorial Properties which Distinguish Icosahedral Symmetry from Cubic or SO(3) Symmetry, S.Y. Goshen, Nucl. Res. Center, Negev; J.L. Birman, City College, NY.
The electron-diffraction experiment by Shechtman et al [1] showing a diffraction pattern with icosahedral symmetry was explained by the concept of quasiperiodicity. Crystallographic structures were proposed [2] and Fourier transforms analyzed and compared with experiment.
Here, we discuss macroscopic physical properties which may distinguish between icosahedral (I) symmetry and isotropic or cubic ones. It is shown that the difficulty of finding appropriate tensorial properties arises from the fact that the $\ell=2$ representation of SO(3) does not split under I. Higher rank tensorial properties which may serve for the investigation are enumerated. Detailed calculations for the third order elastic coefficients are presented, including the invariants and the sound velocity under hydrostatic and uniaxial pressure. The dependence on the icosahedral elastic coefficients is discussed.

Part support by NSF-DMR, BHE-FRAP grants.

1. D. Schechtman, et al, PRL 53,195(1985).
2. A. Katz, M. Duneau J.Phys.47,181(1986).

D5

<u>The Unstable Chemical Structure of Quasicrystalline Alloys</u>, C. Radin, <u>University of Texas at Austin</u>. In joint work with Jacek Miekisz we predict, on the basis of calculations with typical toy models, that the chemical structure of quasicrystals is (in contrast to that of ordinary crystals) only neutrally stable with respect to changes in chemical potentials.

D6

<u>Group Theory and Elasticity of Quasicrystals</u>. M. V. JARIĆ, <u>Harvard University</u>. A calculation of elastic constants of quasicrystals leads to an interesting use of invariant theory. We shall first derive some general results for G-invariant sums over G-covariants. Then, we shall give the explicit forms of the relevant basic icosahedral tensors. We shall also rederive already known tensorial form of the generalized elasticity tensor for icosahedral quasicrystals. Finally, we shall discuss some consequences to Landau, group theory approaches to stability of these quasicrystals.

D7

<u>Symmetry and Phase Transitions in Decagonal Quasi-Crystals</u>. D.B. Litvin and J.L. Birman, <u>City College of CUNY</u> and V. Kopsky, <u>Penn State-Berks</u>. The possible non-crystallographic point group of the decagonal quasi-crystal phase of Al-Mn alloys has been shown by Bendersky to be either C_{10h} or D_{10h}. For the physically irreducible representations of these groups, we derive the extended integrity basis, Clebsch-Gordan coefficients, stability spaces, and tensorial covariants. The point groups which can arise in phase transitions are determined along with corresponding tensorial parameters which could drive the transition. It is shown that equilibrium tensorial properties whose components transform as the components of the electrogyration or elasto-optic tensors can distinguish between the C_{10h} and D_{10h} point group symmetry of the decagonal phase.

Supported in part by NSF DMR-8303981 and DMR-8406196.

E1

Implementing an Algebraic, Maximal Entropy Approach to Molecular Collisions, M. BERMAN and R.D. LEVINE, The Hebrew University. Lie Algebraic techniques are useful in deriving and solving equations of motion for mean values of observables in many-body dynamics. This can be done in a self consistent fashion which in a few cases is also exact. By combining such equations with the maximum entropy approach one can solve for the time evolution of initial states and thereby obtain a (self consistent or exact) description of the dynamics. Of particular note is that only relevant aspects of the evolution need be computed which offers considerable saving for mixed (i.e. not fully state selected) initial states. Numerical implementation of such an approach will be discussed.

E2

SCALING LAW OF A SPACE CHARGE FLOW, CHAU-CHIN WEI, Tsing Hua University, Hsinchu, Taiwan, REN-JYE YEH, Memorex Corporation, Santa Clara, Calif. 95052, CHIA-YU WANG, Chung Shan Institute of Science and Technology, Lungtang, Taiwan. A space charge flow governed by the following equations is discussed. The Lorentz equation of motion,

$$d\vec{v}/dt = -\eta(\vec{E} + \vec{v} \times \vec{B}) \qquad (1)$$

the divergence relations,

$$\vec{v}\cdot\vec{\nabla}n + \vec{v}\cdot\vec{\nabla}n = 0 \qquad (2)$$

$$\vec{\nabla}\cdot\vec{E} = \rho/\varepsilon_0 \qquad (3)$$

$$\vec{\nabla}\cdot\vec{B} = 0 \qquad (4)$$

the curl equation where the beam contribution is neglected

$$\vec{\nabla} \times \vec{B} = 0 \qquad (5)$$

where

$$\rho(\vec{x}) = q\int_{\vec{V}} n(\vec{x}, \vec{v})\,d^3v \qquad (6).$$

The notations are: the particle velocity $\vec{v}$, $\eta = -q/m$, the electric field $\vec{E}$, the magnetic field $\vec{B}$, and the distribution function $n(\vec{x}, \vec{v})$, dielectric constant ε_0, particle charge q, mass m. We obtain the Lie operators which leave the equations invariant and from the scaling operator(s) among them we reduce the scaling law(s). The result(s) is compared with the computer simulation.

E3

LIE OPERATORS OF NONLINEAR SCHROEDINGER EQUATION, CHAU-CHIN WEI, Tsing Hua University, Taiwan, REN-JYE YEH, Memorex Corporation, Santa Clara, Calif. 95052, CHIA-YU WANG, Chung Shan Institute of Science and Technology, Lungtang, Taiwan. We consider the following generalized nonlinear Schroedinger equation

$$i\,u_t + \beta u_{xx} + i\delta' u^* u u_x + \delta u^* u u = 0$$

where β, δ', δ are real constants, * stands for the complex conjugate and the lower suffix represents partial differentiation. We obtain the Lie operators from the prolongation structure and τ function approach developed by Sato et al. The differences are compared and the consequences are discussed.

E4

SYMPLECTIC DECOMPOSITION OF REACTION CHANNELS. P. KRAMER and Z. PAPADOPOLOS, Institut für Theoretische Physik der Universität Tübingen, F.R.G. In a nuclear reaction the channels described in terms of fragments and their relative motion can be labeled by U(3) representations. The U(3) principle[1)] for the systems $^{16}O+^{12+b}X$, $0 \leq b \leq 4$ imposes selection rules and causes the occurence of certain types of molecular resonances. We extend this analysis to the symplectic group $Sp(6,\mathbb{R})$. The branching of symplectic compound states into reaction channels has been considered in [2,3,4,5)]. We study the symplectic decomposition of U(3) reaction channels and show that the corresponding reactions are governed by the stronger symplectic selection rules[6)].

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E5

Group Deformations and the Algebraic Approach to Scattering. A. FRANK. Universidad Nacional Autónoma de México. The algebraic approach to scattering represents a novel application of group theoretical techniques to the description of unbound systems. It is shown that a general mathematical framework, that of group contractions and expansions, permits a systematic analysis of possible dynamical symmetries in scattering systems. The group deformations describe the distortion of physical states when evolving from one kind of symmetry to another. The basic step for the evaluation of S-matrices in these processes is the expansion of the generators of a given group in terms of those of its contracted partner. Some examples are discussed, together with an assessment of possible future applications.

E6

GROUP CONTRACTION AND THE ALGEBRAIC APPROACH TO SCATTERING. E. CELEGHINI*, F. IACHELLO°, M. TARLINI*, G. VITIELLO°°, *Università di Firenze, °Yale University, °°Università di Salerno. The relation is studied between the role played by group contraction in the algebraic treatment of scattering and the phenomenon of dynamical rearrangement of symmetry in spontaneously broken symmetry theories, which also is controlled by group contraction.

E7

CONSTRAINED HAMILTONIANS, BRS AND HOMOLOGICAL ALGEBRA

Jim Stasheff - UNC

Several problems in theoretical physics (both gauge theory and gravity) have lead to the introduction of terms of higher order into the classical Lie representation theory of particle physics. With the increased use of cohomological techniques, these terms of higher order can now be identified with similar terms which occur in the homotopy theory of loop spaces on the one hand and in algebraic deformation theory on the other.

The comparison is most straight-forward in the constrained Hamiltonian formalism of symplectic manifolds and Poisson algebra. This leads to the mathematical construct: twisted differential graded comodules over the Grassmann coalgebra on a Lie algebra. In the finite dimensional case, the Grassmann algebra suffices and the construct involves both the Koszul resolution for a regular ring and the Weil-Cartan model for principal bundles.

E8

PROPERTIES OF THE STRONG FACTOR IN DYNAMICALLY GENERATED S-MATRICES R. D. Amado and D. A. Sparrow University of Penn. and Temple University. Alhassid, Iachello and Wu (ALH 86) have identified the conditions that dynamic symmetries impose on the scattering matrix, S, and have constructed these matrices for a number of groups. The group SO(2,3), describes scattering from a modified Coulomb interaction. The S-matrix elements may be written as ratios of Gamma functions of L, f and w, where $f=Z_1Z_2e^2/hv$, and w is an arbitrary function of the momentum and angular momentum, and pure Coulomb scattering is obtained for the case w=0.

We have re-written the S-matrix as a product $S(L,k) = S_{coul} * S_{strong}$ and investigated the analytic properties of S_{strong}. We show how to write S_{strong} in infinite product form to display the poles and their residues. Since the product form for the S-matrix is equivalent to a sum for the phase shifts, replacing this sum by an integral leads to a simple analytic approximation for the phase shift in terms of logarithms of L, f, and w. For peripheral scattering the phase shift may be approximately represented as

$$\delta = -(w\, f)/(2\, L\, (L+1)).$$

This implies a particular relationship, at least in the periphery, between w and the r-dependence of an effective potential. These and other general features of this dynamical approach to scattering will be presented.

(ALH 86) Y. Alhassid, F. Iachello, and J. Wu, Phys Rev. Lett. 56, 271 (1986)

E9

Unified Model of Superconductivity and Density Waves with SO4xSO4 Dynamical Symmetry†: J.L. Birman, CCNY and A.I. Solomon, Open Univ. The general mean-field Hamiltonian unifying singlet and triplet superconductivity with spin and charge density waves has dynamical symmetry su(8).[1] Here, we analyse the structure of various mean-field submodels in terms of chains of subalgebras, with special emphasis on one physical model with SO4xSO4 symmetry permitting coexistence. For this model calculations were carried out for the coherent eigenstates and for the expectation values of all 12 operators in the Dynamical Algebra in the ground state. Nonzero expectation values are "order parameters" in the Landau sense. We find possible coexistence of various combinations of singlet-triplet superconductivity, charge and spin density waves. We prove spontaneous generation of homogeneous triplet superconductivity (TS) from an initial Hamiltonian where TS is absent.

† This work supported in part by NATO grant 86/233, PSC-BHE-CUNY grant 6-65280 and NSF-DMR-83-03981.

[1] A.I. Solomon and J.L. Birman. This Colloquium; and to be published.

E10

Dynamical SU (8) - A Laboratory for Phase Coexistence. Allan I. Solomon, Open University and Joseph L. Birman City College. We consider a model hamiltonian for the coexisting many-electron phenomena of superconductivity charge density waves and ferro-and anti-ferromagnetism. The spectrum-generating-algebra (SGA) for such a model is su (8). We identify all 63 generators of this Lie algebra in physically meaningful bases for which the Cartan elements correspond to symmetries conserved at high temperature, and broken at zero temperature. The remaining 56 generators are shown to correspond to the order parameters of the various phases present in the model. A chain of subalgebras is exhibited, and the associated phenomena identified.

E11

The Algebraic Method for Relativistic Systems - Spectrum and Radiative Transitions. A. BOHM, M. LOEWE, P. MAGNOLLAY: University of Texas, Austin. The purpose of the algebraic method in relativistic physics is to develop a quantum mechanics of relativistic extended objects. The physical basis has been taken from molecular and nuclear physics, where low energy spectra and transitions are described by collective models of rotators and oscillators. The mathematical tools are spectrum generating groups and subgroups. We use $SU(2,2) \supset SO(3,2)$ as a relativistic spectrum generating group (and $SU(2,2/1) \supset Osp(1,4)$ as a spectrum supersymmetry) to describe hadron resonances as vibrational and rotational excitations. The mass spectrum is obtained from a postulated relativistic Hamiltonian using constrained Hamiltonian mechanics. Radiative decay amplitudes are calculated using an interaction Hamiltonian which is obtained by coupling the center of mass and the intrinsic momentum minimally to the electromagnetic field. The preliminary results show encouraging agreement with the experimental γN decay couplings.

E12

Stereographic Projection in Hyperbolic Space and the Kepler Problem, R.K. Perline, Drexel University. The existence of "hidden symmetries" for the Kepler problem (K.P.) can be explained by showing the equivalence of K.P. to geodesic flow on the sphere (for negative energy surfaces) and the hyperboloid (for positive energy surfaces). The equivalence of the two problems is demonstrated by the use of a canonical transformation based on classical stereographic projection (Fock, Moser). We describe a new geometric construction, analogous to that of stereographic projection, based on the geometry of hyperbolic space, which gives an alternative proof of the equivalence and suggests generalizations to other geometries.

F1

SU(2) X SU(2) X U(1) Charge Symmetric, Color-Electroweak Model, R. Morris, F. Reifler, RCA. We address an asymmetry in all currently used Dirac equations. We study the physical consequences of symmetrizing the usual Dirac equation using a 4 dimensional irreducible representation of the gauge group SU(2) X SU(2) X U(1) to represent all first generation colored quarks and leptons. We show that the symmetric Dirac equation is derived from a renormalizable SU(2) X SU(2) X U(1) gauge invariant Lagrangian. We also show that like momentum and spin, the charges a fermion carries are simply parameters which label the solutions of the symmetric Dirac equation. By including in the Lagrangian interactions with Higgs and gauge bosons, we show that the fermions are energetically forced into particular charged states. Since the charges like momentum and spin, label the solutions of the symmetric Dirac equation, a single 4 dimensional irreducible representation of SU(2) X SU(2) X U(1) suffices for all fermions.

F2

Interacting Parastring Theories*. FREYDOON MANSOURI, University of Cincinnati. Interacting parastrings[1] provide us with the possibility of constructing string theories directly in four (as well as a number of other) space-time dimensions. These theories are consistent with Lorentz invariance and Lovelace analiticity. We report here recent progress in these theories. It includes: (1) a reformulation[1] in terms of a new ansatz which affords considerable computational simplification; (2) computation of loop corrections and the demonstration of consistency with Lorentz invariance and Lovelace analiticity. (3) Construction of actions in light-cone guage. For supersymmetric actions we show that the corresponding actions are supersymmetric. (4) The study of the spectrum, in particular the massless sector. (5) Modular invariance of the closed string sector.

*Supported, in part by DOE under the contract DOE-AS-2-76ER02978.

1.F. Ardalan and F. Mansouri, Phys. Rev. Lett., 56, 2456, 1986, and University of Cincinnati preprint UCTP-101/86.

F3

Ω_{BRST} Cohomology - a Mechanism for Getting Rid of Negative Norm States, with an Application to the Bosonic String. M. SPIEGELGLAS *Institute for Advanced Study, Princeton.* We study the action of Ω, a BRST operator on a negative norm space. We describe the mechanism, which gives our Hilbert Space a subspace ($Ker\Omega$) which is free of "ghosts", negative norm states. The mechanism gives a further reduction to a Physical subspace free of 0 norm states(the cohomology of Ω). The *completeness* of Ω, which implies this mechanism, is formulated below, in a couple of equivalent ways. No-"ghost" theorems may be proven by checking this *completeness* condition. We check it for the Bosonic String by calculating the Ω cohomology, the "Lie Group Cohomology" of the Virasoro Algebra. Thus we give a simple new proof of the No-"ghost" theorem for the Bosonic String. For Ω (which obeys $\Omega^2 = 0$ and $\Omega^\dagger = \Omega$), the *completeness* condition is that all the 0 norm states in $Ker\Omega$, actually belong to $Im\Omega$. This condition also allows us to choose a Physical space free of 0 norm states, namely the 0 ghost number cohomology class of Ω. The "split a pair mechanism", responsible for the "ghosts" disappearance, is explained. We give an index theorem formulation of the *completeness* condition: the dimension of the cohomology saturates its lower bound given by the index of C (a Euclidean complex conjugation, which includes a ghost number charge conjugation). This general setting is casted for the Bosonic String case, giving a general heuristic argument for the completeness of Ω. We then specialize to String in flat target space time and explicitly calculate the "Virasoro Algebra Cohomology" induced by Ω and the index of C. We find them both to be equal to the number of Physical light cone states, for any given L_0 level. Thus, we prove the No-"ghost" theorem, checking that the Bosonic String has enough gauge symmetries ($Im\Omega$ is large enough), to give a "ghosts" free Physical space.

F4

Representation Theory of BRS Algebras. M.K. Patra, K.C. Pati and K.C. Tripathy, University of Delhi. The generation of BRS symmetries for the Lagrangian containing gauge fixing and Faddeev-Popov ghosts have been reviewed. The explicit construction of modules (irreducible and indecomposable) for these algebras are presented. The structure of BRS transformation groups and the correspoinding Campbell-Hausdorff formulas are also discussed. The construction of modules yields in a natural fashion the metric property of basis states. We also present the cohomology (algebraic cohomology) property of BRS algebras and demonstrate that the second cohomology of such algebras are trivial. Such an investigation yields the renormalisation features of a gauge theory possesing BRS symmetries.

F5

Noether Theorems in Superspace Field Theories. U. BRUZZO, University of Genoa, Italy. Recently we have developed a variational calculus on supermanifolds which allows a coherent mathematical treatment of the so-called superspace field theories. The variational principle yields extremality conditions that can be expressed as differential equations on the supermanifold which generalize the Euler-Lagrange equations. Most supergravity models fit into this scheme.

This framework allows very naturally the study of the invariance of the supermanifold Lagrangian under the actions of an internal gauge supergroup or of the group of superdiffeomorphisms of the supermanifold, which is the case for supergravity theories. By a suitable generalization of Noether theorem one can deduce strong conservation laws which are expressed by differential identities on the supermanifold.

F6

N=2 Superconformal Quantum Harmonic Oscillator, D.DEHIN, University of Liege (in collaboration with J.BECKERS & V. HUSSIN). The largest invariance superalgebra of the supersymmetric harmonic oscillator is determined as $[Osp(2/2) \oplus so(n)] \,\square\, sh(n)$ where sh(n) is called the Heisenberg superalgebra, n being the space dimension. It then appears as the largest spectrum generating superalgebra. We effectively give its representation within an energy basis. We consider the one- and three-dimensional cases, the last one being compared with other recent contributions and different ways of supersymmetrization.

F7

Effective Quark-Diquark Supersymmetry and Splitting of Regge Trajectories. SULTAN CATTO (*) and SERDAR KUYUCAK (**), City University of New York. The parallelism of baryonic and mesonic Regge trajectories provides a realisation of supersymmetry in Nature. This hadronic supersymmetry was derived[1] from QCD, the gauge field theory of strong interactions in the elongated bag or lattice gauge theory approximations. The supersymmetry group that leaves a semi-relativistic Hamiltonian invariant was shown to be U(6/21). We show that the fundamental representation of $U(6/21)\times SU(3)^c$-triplet and the adjoint representation of $U(6/21)\times SU(3)^c$-singlet fits in the adjoint representation of U(6/22). Various aspects and implications of this approximate effective supersymmetry and its breaking are discussed. In particular the level splittings of the Regge trajectories and deviations from their linear limit for smaller values of the orbital angular momentum are calculated and are shown to be in good agreement with recent experiments. Also the masses and static properties of hadrons are studied in a relativistic model with QCD potential with a hope of eventually establishing a unified description of all hadrons based on the relativistic equation. Some preliminary results on the relativistic formulation is included.

(1) S. Catto and F. Gürsey, Nuovo Cimento, 86, 201(1985).
(*) Research supported by the PSC-CUNY Research Award.
(**) Permanent adress: Physics Department, Melbourne University

F8

The Chiral Transformation and Invariant Interactions of Superfields, S.K. Choi, D.Son and C. Jue, Kyungpook National Univ., Taegu, Korea The representations of superfields are discussed so as to construct invariant Lagrangians for the chiral transformation of the majorana parameter θ on the superspace.

F9

Superinvariant Chiral and Vector Fields, L. Vinet Université de Montréal. This work is concerned with the characterization of field supermultiplets on 4-dimensional Minkowski space that are stable under the action of subgroups of the superconformal group SU(2, 2/1). We determine the most general scalar and vector superfields whose Lie derivative with respect to a fermionic tangent vector vanishes. Invariance under subgroups of SU(2, 2/1) with more than one odd generator is also discussed.

F10

Bag Formation in a Chiral Model. P. JAIN, Syracuse University. The low energy properties of the nucleon can be qualitatively explained either by considering it as a soliton (Skyrmion) in a theory of mesons or by considering it as a composite state of three quarks trapped in a bag (bubble) in the QCD vacuum. One would like to inquire as to the analog of the vacuum bubble in the chiral model of mesons. Here we discuss a simple extension of the Skyrme model in which a vacuum bubble may be automatically generated for the nucleon. Our toy model is constructed with an additional gluonic "background" field in such a way that the trace anomaly of QCD is satisfied. Although the model is certainly a rough approximation to the "true" low energy effective Lagrangian it does have the nice feature of giving a similar fit to the nucleon parameters as the original Skyrme model, using however the experimental value of the pion decay constant.

F11

Exactly Solvable Supersymmetric Schrodinger Equations, F. COOPER, J. N. GINOCCHIO, AND A. KHARE, Los Alamos National Laboratory. It is shown that the most general one-dimensional Schrodinger equations which can be solved by hypergeometric functions[1,2] or confluent hypergeometric functions are supersymmetric. That is, the potential can be written in the form $U_-=W^2 - W'$. Furthermore it is shown that the corresponding supersymmetric potential $U_+=W^2 + W'$ is shape invariant[3] only for special cases, contrary to speculation.[3]

1. G. A. Natanzon, Vestnik Leningrad Univ. 10, 22 (1971); Teoret. i Mat. Fiz. 38, 146 (1979). (English trans.)
2. J. N. Ginocchio, Ann. of Phys. 152, 203 (1984).
3. L. E. Gendenshtein, JETP Lett. 38, 25 (1983).

F12

Quantized fields in complex superspace, G. Kaiser, Harvard University.

G1

Symmetry in Lie Optics. Kurt Bernardo Wolf, Instituto de Investigaciones en Matemáticas Aplicadas y en Sistemas/Cuernavaca, Universidad Nacional Autónoma de México. An optical system produces a nonlinear canonical transformation of optical phase space. Free propagation in a homogeneous medium has Euclidean symmetry and dynamical algebras under the Poisson-Lie Bracket. Refracting interfaces between homogeneous media exhibit invariants; in particular, a spherical surface possesses an so(3) symmetry algebra that allows the recursive computation of its aberration coefficients to arbitrarily high order. The question of the wavization of a geometrical optical system is addressed.

G2

Symmetries of Linear Newtonian Systems. A. González López, Princeton University. We analyze in this paper the structure of the Lie algebra of *global* symmetry vectors of a general linear system of n second-order ODE's. First, we prove rigorously that for $n = 1$ the symmetry algebra of such LNS is isomorphic to $sl(3, \mathbf{R})$. Secondly, for $n > 1$ we disprove a long-standing conjecture, by constructing a simple example of a LNS whose symmetry algebra is *not* isomorphic to $sl(n+2, \mathbf{R})$. Next we find a simple necessary and sufficient condition on the coefficients of a LNS in order that its symmetry algebra be isomorphic to $sl(n+2, \mathbf{R})$. As a by-product of our analysis, we obtain an explicit characterization of all the LNS's which can be locally reduced to the canonical form $\ddot{\vec{x}} = \vec{0}$ by a change of coordinates $(t, \vec{x})$. Finally, we study the structure of the variational symmetry vectors of those LNS whose symmetry algebra is isomorphic to $sl(n+2, \mathbf{R})$. We find that the Lie subalgebra of variational symmetries is *not* semisimple, but instead it is isomorphic to a *fixed* Lie algebra, whose Levi-Mal'cev decomposition is the semidirect sum of an abelian $2n$-dimensional ideal with the semisimple subalgebra $sl(2, \mathbf{R}) \oplus so(n, \mathbf{R})$. Throughout the paper, special attention is paid to the study of global issues.

G3

Nonlinear Differential Equations with Superposition Law for the osp(1,2) Superalgebra. L. GAGNON, P. WINTERNITZ, Montreal University, V. HUSSIN, J. BECKERS, University of Liège. It is shown how the theory of nonlinear ordinary differential equations with superposition formulas can be generalized to the case of "super equations" involving anticommuting Grassmann variables. Equations based on the osp(1,2) superalgebra are analysed in detail and a "super-superposition" formula is obtained.

G4

Hall Magnetohydrodynamics: Conservation Laws and Lyapunov Stability, D. D. Holm, Los Alamos National Laboratory. The conservation laws, Hamiltonian structure, equilibrium state relations, and Lyapunov stability conditions are presented for ideal Hall magnetohydrodynamics (HMHD) in three dimensions. Establishing Lyapunov stability conditions for these equilibria demonstrates well-posedness of the linearized initial-value problem for ideal HMHDV (in the sense of continuous dependence on initial conditions), contrary to recent claims in the literature. The Hamiltonian structure for HMHD is of Lie-Poisson type, associated naturally to the dual of the infinite-dimensional Lie algebra of vector fields acting among themselves by commutation and on differential forms by Lie derivative.

G5

Clebsh Potentials, Lin Constraints and Gauged Lie-Poisson Structures. L.A. IBORT & H. CENDRA, Dpt. of Mathematics, Univ. of California, Berkeley.
We extend to systems defined on nontrivial principal fiber bundles previous results describing variational principles for Lin constraints and Clebsh potentials for systems defined on semidirect products. The relation with variational principles in the reduced phase space with its gauged Lie-Poisson structure are also analyzed. Some applications to free-boundary problems are considered.

G6

Nonholonomical Systems with Symmetry, JAIR KOILLER, UFRJ, Brazil. Let $G \to V \xrightarrow{p} W$ a principal G bundle, $\dim G = r$, $\dim V = n$, and D a connection with 1-form $w: TV \to g$. A metric T in V and a potential function $U: V \to R$ are said to be G-equivariant if the shifts $g: V \to V$ are isometries for T and U projects over a function on W.

The distribution $\ker w = D$ on TV can be interpreted as "nonholonomical constraints" linear in the velocities. One may want to study the classical system with Lagrangian $L=T-V$ and constraints as above.

It is clear that there is a projected vectorfield in TW. Problem: Find out the equations for the reduced system. Is there an Hamiltonian structure for them? Notice that the total energy $H=T+V$ is (trivially) conserved. We observe that in the case of abelian G these systems are precisely those studied by Chaplygin in the turn of the century.

A related problem for which we have a complete solution is the equations for geodesics of left invariant metrics on Lie groups with left invariant constraints. A simple example which illustrates the idea is the classical motion of the "sleigh".

G7

Symmetry Reduction for the Kadomtsev-Petviashili Equation and its Bäcklund Transformation,
D. David, CRM, Université de Montréal. The infinite dimensional symmetry group of the potential Kadomtsev-Petviashili (PKP) equation is found and applied to its Bäcklund transformation (BT). The method of symmetry reduction is then applied to the PKP equation, and simultaneously to its BT. This yields new solutions to the KP equation. These results were obtained in collaboration with D. Levi and P. Winternitz

G8

Construction of solutions of the multi-component K-P hierarchy, G. F. Helminck, Technische Hogeschool, Twente.

G9

Little Groups for Reducible Representations of Space Groups. Dorian M. Hatch and Harold T. Stokes Brigham Young University. An irreducible representation Γ_i of a given space group (G_0) can be used to select subgroups of G_0. Subgroups are determined by looking for little groups (isotropy groups) of vectors $\vec{\eta}$ in the carrier space of the irrep. In some cases a little group G may leave all the vectors of a subspace invariant and thus be associated with the entire subspace. Sets of invariant spaces are collected by little group conjugacy to form the strata of the little group (and its conjugacy class). The listing of the little groups and their conjugacy class is of interest because they correspond physically to possible lower symmetry phases and domains of G_0 when non-reconstructive transitions driven by Γ_i take place. In this manner we have recently obtained the little groups associated with reducible (coupled) representations. All coupled representations arising from $\vec{k}$ points of symmetry for all 230 space groups have been analysed. An example will be given.

G10

The Exact Solutions of Multidimensional Classical ϕ^6 Field Equations, A.M. GRUNDLAND, Memorial University of Newfoundland. The method of symmetry reduction elaborated for a relativistically invariant scalar equation will be applied to the nonlinear classical ϕ^6-field equation $\nabla^2 u = A_2 u + A_4 u^3 + A_6 u^5$ (where ∇^2 denotes the Laplace-Beltrami operator in (3+1) dimensional Minkowski or Euclidean space E). The symmetry group G of this equation is investigated in detail. A set of the symmetry variables ξ (which are invariants of the assumed subgroups G_i of G having generic orbits of codimension 1 in E) enables us to reduce, after some transformations, the basic P.D.E. to the second order O.D.E.s. The Painlevé property is investigated for these O.D.E.s and the following types of exact solutions (mostly the new ones) are obtained: constant solutions, algebraic solutions (with one and two simple poles), kinks, solitary waves (bumps) and doubly periodic solutions (in the terms of Jacobi elliptic functions).

H1

Title to be announced, H. Doebner, Technische Universitat, Clausthal-Zellerfeld.

H2

Unitary Representations of Diffeomorphism Groups and Unusual Particle Statistics. G. A. Goldin, Rutgers Univ. Unitary irreducible representations of Diff(M) and related groups and algebras have entered physics through quantum field theory, gravity, hydrodynamics, and string models. In field theory inequivalent UIR's of Diff(M) describe distinct physical systems, including particles obeying Bose, Fermi, or "para" statistics for $M = \mathbf{R}^3$, and θ-statistics for $M = \mathbf{R}^2$. This paper reports progress in the group-theoretic description of such systems, suggesting that more may be possible than first meets the eye--for example, unusual statistics for quantum dipoles in $\mathbf{R}^2$ is proposed. Then θ-and para-θ-statistics as well as unusual multipole statistics in $\mathbf{R}^2$ or S^2, all correspond to representations of Diff(M) induced by braid groups or their subgroups.

H3

The Diamond Lie Group and Path Integrals. WALTER SCHEMPP, University of Siegen. The diamond solvable Lie group $D(\mathbf{R})$ is the semi-direct product of the one-dimensional compact torus group $\mathbf{T}$ and the three-dimensional real Heisenberg 2-step nilpotent Lie group $\tilde{A}(\mathbf{R})$. The irreducible unitary linear representations of $D(\mathbf{R})$ which restrict to the linear Schrödinger representation U_1 of $\tilde{A}(\mathbf{R})$ are classified in terms of the Maslov index and a Feynman path integral via the oscillator representation of the metaplectic group $Mp(1,\mathbf{R})$. Extensions to 3-step nilpotent Lie groups and applications to multimode parabolic-index optical waveguides and the Franck-Condon principle are briefly indicated.

H4

Levi-Civita, Kustaanheimo-Stiefel and other transformations. D. LAMBERT, Universite Catholique de Louvain and M. KIBLER, Universite Claude-Bernard Lyon-1. Nonbijective quadratic transformations which generalize the LC transformation and the KS transformation are defined in an algebraic framework based on the use of Cayley-Dickson algebras of dimension $n \leq 8$. Compact and noncompact transformations are described in terms of Clifford algebras for $n = 2$, 4 and 8. The general algebraic framework developed here allows us to generate other (nonbijective) quadratic transformations besides the LC- and KS-like transformations. The KS-like transformations are also investigated from a geometrical viewpoint. Indeed, they are connected to Hopf and pseudo-Hopf fibrations. Some differential aspects of the KS-like (and to a less extent the LC-like) transformations are briefly discussed.

H5

Linear Realization of Non-compact Symmetries. Yuan K. Ha, The Rockefeller University. The non-linear sigma model based on the non-compact manifold SO(M,N)/SO(M)xSO(N) is formulated. A number of dynamical issues involved in the use of non-compact symmetries, such as physical Hilbert space, positivity of energy, unitarity and mass generation, are examined in a non-perturbative analysis.

H6

Iwasawa and Langland decompositions, Satake Diagrams and graded Lie algebras. K.C. Tripathy and V. Sharma, University of Delhi. Kac's classification of Z_2-graded Lie super algebras are briefly reviewed. Possible Satake diagrams are constructed which yield the involutive automorphisms for such algebras. The Iwasawa and Langland decomposition of Lie super algebras are consequently carried out. The computation of parabolic and minimal parabolic algebras, it is hoped, will yield representation of super Lie groups by prescribing the Scmidt induction techniques.

H7

A folk theorem revisited. The degenerate case, R. T. Sharp and Y. Giroux, McGill University, Montreal.

H8

Progress report on the study of asymmetry parameters for elastic scattering of electrons by H and He atoms. N.S. RAO, Physical Research Laboratory, Theoretical Physics Area, Ahmedabad 380 009, India. Born and Ochkur approximations are used to obtain the direct and exchange scattering amplitudes for elastic scattering of electrons by hydrogen (H) and helium (He) atoms. Present scattering amplitudes are used to obtain the asymmetry parameters and collision cross sections for $\bar{e}$-H and He interactions. Mathematical techniques used in the present study and the final results will be discussed at the conference.

POSTER SESSION

Explicit expression for the product of the class of transpositions with an arbitrary class of the symmetric group J. KATRIEL and J. PALDUS, Waterloo. The product of any two class operators is a linear combination of class operators. A full knowledge of the corresponding coefficients is equivalent to a full knowledge of the character table, and has far reaching applications. An expression for the product of the class operator $[2]_N$, consisting of a sum of the $N(N-1)/2$ transpositions of S_N, with an arbitrary class $[2^{\ell_2} 3^{\ell_3} \ldots]$ consisting of ℓ_i i-cycles ($i \geq 2$) and $N - \sum_{i=2}^{N} i\ell_i$ 1-cycles is derived. The derivation is purely combinatorial and uses no information from character theory.

An Algebraic Approach to Molecular Electronic Spectra. R. LEMUS*, A. FRANK* AND F. IACHELLO†, University of Mexico* and Yale University†. The use of algebraic methods has proved to be a fruitful approach for the description of rotation-vibration spectra in nuclei and molecules. In the latter case the inclusion of the electronic degrees of freedom is fundamental for a complete description of the systems under consideration. We show that it is possible to construct a general algebraic framework including bosonic and electronic variables, which may provide feasible ways for treating complex situations, such as those arising in polyatomic molecules and electron-molecule scattering.

Particle Masses and Force Constants in Spin(8) Gauge Theory

Frank D. (Tony) Smith, Jr., P. O. Box 1032, Cartersville, GA. 30120

As calculated from Spin(8) gauge field theory (Smith, Int. J. Theor. Phys. 25 (1986) 355), lepton masses and quark constituent masses are:

e - 0.51 Mev;	u - 313 Mev;	d - 313 Mev;	$\nu_e \approx 0$ Mev;
μ - 104.8 Mev;	c - 1.99 Gev;	s - 523 Mev;	$\nu_\mu \approx 0$ Mev;
τ - 1.88 Gev;	**t - 130 Gev;**	b - 5.63 Gev;	$\nu_\tau \approx 0$ Mev;

for the first generation, W+ and W- have mass 81 Gev and W^0 has mass 99 Gev;

for the second generation, W+ and W- have mass 329 Gev and W^0 has mass 403 Gev;

for the third generation, W+ and W- have mass 17.5 Tev and W^0 has mass 21.5 Tev;

the effective force strength constants for characteristic distances for each force are:

$\alpha_E = 1/137.03608$ for electomagnetism;

$G_W m_{proton}^2 = 1.03 \times 10^{-5}$ for the weak force;

$\alpha_C = 0.6286$ for the color force;

$G_G m_{proton}^2 \approx 3.4\text{-}8.8 \times 10^{-39}$ for gravitation;

Kobayashi-Maskawa-Chau-Keung parameters are: $\Phi = 90^\circ$; $\sin(x) = 0.239 \approx V_{us}$; $\mathbf{\sin(y) = 0.0188 \approx V_{cb}}$; $\sin(z) = 0.0046 \approx V_{ub}$;

and

the bottom quark lifetime is : $\boldsymbol{\tau_b \approx 1.86 \times 10^{-12}}$ **sec.**

Field Theory & High Energy Particle Physics Manifestations of Universal Anderson Localization-DeLocalization Transition With 1/f Noise Signature/ "Echo"Critical Phenomena. EDWARD SIEGEL, S.S.R.L., 183-14th Avenue, San Francisco, CA. 94118. Static Synergetics[1] identification of universal Anderson localization-delocalization transition with 1/f noise and 1/f susceptibility polarization catastrophe signatures/ "echos" critical phenomenon, is extended to field theory/high energy physics[2]: Higgs-Goldstone transition for bosons(massive-massless), infra-red divergence, hadronic jets equivalent to light localization, Cerenkov radiation effect, superconducting Meissner effect, collapse of electromagnetism in $d \lesssim 4$, collapse of gravity in $d \lesssim 4$,..., even RF-EM skin effect. Weinberg's[2] emphasis of the curious analogy between field theory and hydrodynamics Navier-Stokes equation, equivalent to classic Brillouin $w \cong \underline{k}^2/S(\underline{k})$ in classical limit, motivates understanding of analogies!

1. E. Siegel, IBM Conf. Comp. & Math., Stanford(1986); XXIII Intl. Conf. High Energy Phys., Berkeley(1986) 2. S. Weinberg-ibid.

POSTER SESSION

Self-Similarity & Self-Affinity : Simultaneous Global(Homogeneous) Symmetry-Restoring But Local(Heterogeneous)Symmetry-Breaking:Can Groups Be Scale Dependent ? EDWARD SIEGEL, S.S.R.L., 183-14th Avenue, San Francisco, CA. 94118. Self-similar(isotropic) and self-affine(anisotropic) scaling-invariance, generators of $\underline{r}$-& t-space fractals and $\underline{k}$-& w-space diffractals, are a unique group of generators:globally symmetry-restoring(homogeneity) but locally symmetry-breaking(heterogeneity) present a unique group:globally versus locally! Can groups be scale-dependent? This seemingly paradoxical dichotomy of self-similar and self-affine groups(SS(3) & SA(3)), that generate fractals and their diffractals, global symmetry versus local asymmetry, is examined. The question of scale-dependence versus scale-invariance of continuous Lie groups T(3), S(3) (and discrete groups) under SS(3) and SA(3) generators, and just how, why and where scaling cut-offs exist between global symmetry versus local asymmetry, the global-local cut-off, and how to define it, is examined.

How Fractal Is Fractal?:How Many of What Measures Are Both Necessary & Sufficent To Define A Fractal As Fractal? EDWARD SIEGEL, S.S.R.L., 183-14th Avenue, San Francisco, CA. 94118. Fractals, and their("waves that encounter fractals")diffractals, have a plethora of measures, qualities and quantities associated with them(sometimes paradoxically antithetical):depressed dimensionality, upper and lower scaling cut-offs, homogeneity(vs. heterogeneity), isotropy(vs. anisotropy), lacunarity(vs. alacunarity), succloarity(vs. asuccolarity), ramification(vs. unramification), ... How many of what measures(and qualities and quantities) than can and do characterize fractals (and their diffractals) are both necessary and sufficent to define a fractal as fractal? Even depressed fractal dimensionality is shown to depend upon both upper- and lower-scaling cut-offs: $d^{connectivity}_{topological} \leq D(\varkappa^{upper}, \varkappa^{lower}) \leq d_{geometric\ embedding}$. Questions such as these are mandatory to ask and answer with the overwhealming advent of fractals in physics![1] [1] L. Kadanoff, Physics Today, p.6(Feb., 1986)

Nonlinear Dynamics Manifestations of Universal Anderson Localization-DeLocalization Transition With 1/f Noise Signature/"Echo". EDWARD SIEGEL, S.S.R.L., 183-14th Avenue, San Francisco, CA. 94118. The identification, via Static Synergetics[1], of the universality of the Anderson localization-delocalization transition with 1/f noise and 1/f susceptibility polarization catastrophy signatures/"echos", is extended to nonlinear dynamics:intermittency, period doubling(=fractal quantized frequency-halving), collapse to center manifold two-time-scale dynamics, ..., routes to chaos. All can be understood as universal Anderson localization-delocalization transition critical phenomena in w-space, via the common Lyapunov exponent, spatial localization length or temporal localization time(in phase space). As well, anomalous diffusion and intermittency, both exhibiting 1/f noise and "somehow" caused by fractal self-similar group scaling-invariance are identified. 1.E.Siegel, I.B.M.Conf.on Comp.&Math., Stanford(86); ICM'86, Bkly(86); Statphys-16, Boston(86) 2.Toulouse&Pfeuty, p.173!

"RoughStoffe"= Irrational Numbers + Their Fractals + Their Diffractals : "Functals" EDWARD SIEGEL, S.S.R.L., 183-14th Avenue, San Francisco, CA. 94118. Irrational numbers are identified as the orgin of fractals, and the fractals of their diffractals, generically named "RoughStoffe"[1]. Aside from the ubiquity of irrational transcendental numbers e, π and G(Golden mean) as fixed points of Mandelbrot, Julia, ... sets, if fractal patterns in Nature originate from thermodynamic second law entropy extremization(under arbitrary constraints, now always maximization), to minimize free energy, $S=k_B \ln_e W$ bimodally means that in addition to $S=S(W)$, also $k_B=k_B(e)$. Similarly $w=(h/2\pi)\underline{k}^2/S(\underline{k})$ means $w=w(\underline{k})$, but as well $h=h(\pi)$. These cross-equalities, termed "Functals"[1], are not independent, being related by Euler's formula $e^{i\pi}+1=0$, $e=e(\pi)$. The equations of physics are not just about about how the dependent variables are functions of the independent variables, but about how and why the constants of physics are irrational and functions of irrational numbers. 1.E.Siegel, ICM'86(Bkly)&Comp.Stanf(86)

POSTER SESSION

Scattering of electrons from the excited states of helium atom at E = 1000 eV. N.S. RAO, Physical Research Laboratory, Theoretical Physics Area, Ahmedabad 380 009, India. Collision processes involving atoms initially in an excited state are very important to the study of gaseous discharges, plasma physics, excimer laser and other phenomena where excitation from the excited states represents one of the major channels for the absorption of electron energy. In view of the importance of this process, here I made an attempt to study the scattering of electrons by He atom for the transition 2^3S-3^3S in the Born and GES approximations. Collision cross sections are studied at E = 1000 eV. Mathematical techniques used in the present work will be discussed at the time of conference.

Effect of core interaction in the study of electron-alkali atom scattering at intermediate and high incident energy regions. N.S. RAO, Physical Research Laboratory, Theoretical Physics Area, Ahmedabad 380 009, India. Scattering of electrons from alkali atoms (Li,Na) has been studied by a variety of approximations. Most of these approximations have neglected the core interaction in the calculation of scattering parameters for alkali atoms like lithium (Li) and sodium (Na). Recent studies on the scattering of electrons by Li atom show that the contribution coming from the core potential to the scattering parameters is considerable even at intermediate incident energy region. In view of this, an analytical study is made to obtain the scattering amplitude, by considering the core potential for Li and Na atoms. Born and Ochkur approximations are used for the present study. Total cross sections (TCS) are calculated for Li and Na at E = 1000 eV. Differential cross sections (DCS) are in progress. Present TCS and DCS results will be discussed at the time of conference.

Role of excitation energy in the elastic scattering of electrons by Lithium atom. N.S. RAO, Physical Research Laboratory, Theoretical Physics Area, Ahmedabad 380 009, India. The study of electron collisions with atomic systems was attracted a considerable amount of interest in recent years. Firstly, there is an increasing demand for collision cross sections in other fields such as astrophysics, laser physics and plasma physics. Secondly, a number of advances have occurred on the experimental side. These experiments provide very stringent tests of the theory and have stimulated the development of new theoretical approaches. Motivated to this, an analytical study is made to obtain elastic collision cross sections for scattering of electrons by lithium atom through the Born and static field approximations. Two types of excitation energies (DE's) are used to obtain the cross sections for $\bar{e}$-Li interaction. The best choice of DE to obtain the accurate cross sections and the effect of DE on second and third Born terms will be discussed at the time of conference.

Quasicrystals:Self-Similar Scaling-Relations Interpolate Between Microscopic Fractal Molecules And Macroscopic Quenched-In Vortices. EDWARD SIEGEL, S.S.R.L., 183-14th Avenue, San Francisco, CA. 94118. Pauling's microscopic view of quasicrystals as fractal molecules[1] versus other views of quasicrystals as quenched-in liquid vortices[2] during quasicrystal freezing from the liquid state, can be reconciled by performing self-similar scaling-relations(dilation-symmetry,scale-invariance) transformations from micro-scale fractal molecules to macro-scale quenched-in vortices. Thus,these seemingly paradoxical dichotomous views of quasicrystals are in reality just different scale interpretations of the same paradigm for how and why seemingly impossible symmetries of quasicrystals can and do form in Nature. Mandelbrot's[3] fractals[4] can and do provide a common language to describe quasicrystals,self-similarity the key.

1.L.Pauling,Am.Crystall.Assn.Mtg.,Stanford(1985) 2.E.Siegel-ibid. 3.B.B.Mandelbrot,Fractal Geometry of Nature(83) K.Falconer,Geom.of Fractal Sets(1985)

J1

Gauge theory of string models, T. Curtright, University of Florida, Gainsville.

J2

A new construction of exceptional Lie groups, P. Cvitanovic, Nordita.

J3

Hierarchies of Symmetries and Conserved Functionals of the Federbush model. PAUL H.M. KERSTEN, University of Twente, The Netherlands

The Lie algebra of Lie-Bäcklund transformations of the Federbush model is discussed. First of all the Lie algebra of infinitesimal symmetries and the associated conserved functionals is given. Then, relying on the grading of the model, first, second and third order (x,t)-independent Lie-Bäcklund transformations are obtained. The construction of four creating and annihilating Lie-Bäcklund transformations, which turn out to be local, is given. These transformation, which are polynomial of degree one in x and t, generate four hierarchies of Lie-Bäcklund transformations. Finally, due to the construction of two Lie-Bäcklund transformations, which are polynomials of degree two in x and t, we obtain an infinite number of hierarchies of Hamiltonian vector fields. The corresponding Hamiltonian densities are given. All results are obtained by **symbolic computation**, using REDUCE 3 and developed software packages.

J4

Spin Structure, Projection Operators, and Bose-Fermi Equivalence for Simply Laced Groups, A. N. Redlich*, Howard J. Schnitzer† and K. Tsokos†, Brandeis University

Bosonic and Fermionic partition functions on the two-dimensional torus are explicitly calculated to establish a bose-fermi equivalence for each fundamental representation of every simply-laced group G. A one-to-one correspondence exists for bosons with momenta generated by the root lattice of G shifted by the element w_k, where w_k is a minimal weight of G, i.e., an element of the center of the covering group of G, and fermions with generalized boundary conditions $\psi \rightarrow (\exp\theta_k)\,\psi$ (under rotation around the torus) where $\exp i\theta_k$ is the same element of Z as is w_k. The non-orthogonal weight lattices of G are converted into orthogonal lattices with constraints. It is shown that only for spin (2N) can these constraints be written as projection operators, which correspond to sums over spin structure in fermion language. For SU(N), E_6 and E_7 the appropriate constraints are imposed by coupling the fermions to U(1) gauge field which act as Lagrange multipliers. Explicit modular invariant partition function are presented for closed strings compactified to simply-laced groups associated to Kac-Moody algebras with central charge K=1

*Supported by the U.S. National Science Foundation under Contract No. 82-01094

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J5

Highest weight vectors in Virasoro modules, G. J. ZUCKERMAN, Yale University. The extended state space of the first quantized bosonic string is an indefinite Hermitian module over the Virasoro algebra. If the dimension of Minkowski space-time is D and the slope is α, then the physical states of the string are highest weight vectors, of weight (α, D), in the extended state space. We present a formula for the rank and signature of the restriction of the Hermitian form to the space of physical states. A prominent role in the formula is played by the irreducible Virasoro module of highest weight $(1-\alpha, 26-D)$. The no-ghost theorem for weight $(1, 26)$ is a special case of our formula--thus, the formula is an extension of recent results obtained jointly with I. Frenkel and H. Garland at Yale. A further extension of our results relates modified string modules for $D=2$ to the irreducible modules of highest weight (h,c), with $0 < c < 1$. This relationship refines an observation by C. Thorn of a connection between no ghost theorems for modified strings and the unitarity theorems of D. Friedan and S. Shenker, (and of D. Olive and P. Goddard.)

J7

3-Cocycles in the Monopole Sector of Gauge Theories. I. BAKAS and D. MCMULLAN, University of Utah. The 1 and 2-cocycles of gauge group cohomology have played a fundamental role in anomalous theories. It is natural to inquire whether there are field theoretic examples that allow the occurrence of 3-cocyles, thus leading to (possible) breakdowns of associativity. We show that in the monopole sector of gauge theories such a possibility may arise, due to the boundary conditions imposed on the fields at infinity. Using the Christ-Jackiw interpretation of Yang-Mills dyons, it is found that a non-trivial 3-cocycle of the space gauge group results when the defining 3-simplex is not entirely confined in one connected component of the gauge orbit (and hence has no infinitesimal analogue). The 3-cocyle is a globally defined gauge invariant quantity obtained from a generalization of the "descent" tower of gauge cocyles to manifolds with boundaries. For an SU(2) gauge theory, explicit calculation shows its relation with the Callias index theorem for the Dirac operator in a dyon field.

J6

INFINITE DIMENSIONAL LIE ALGEBRAS ACTING ON THE SOLUTION SPACE OF VARIOUS σ MODELS. M. JACQUES, Université Catholique de Louvain, Belgique, Y. SAINT- AUBIN†, Université de Montréal, Canada

We investigate infinite dimensional Lie algebras of infinitesimal transformations acting on the solution space of various 2-dimensional σ models: (i) principal σ models (σ models with values in a group), (ii) σ models with values in a Riemannian symmetric space and (iii) σ models with a Wess-Zumino term. Using Takasaki's approach, we recover, for the principal G-models, the algebra found earlier by Dolan and Wu. This algebra has the structure of the loop algebra $\mathfrak{g} \otimes R[t, t^{-1}]$ where $\mathfrak{g}$ is the Lie algebra of G. The σ models with a Wess-Zumino term are also considered; the algebraic structure is found to be the same. For σ models with values in a Riemannian symmetric space G/H which is not a Lie group, the algebra is a subalgebra of the loop algebra found for the principal models but it does not seem to be graded. However it contains two graded infinite dimensional subalgebras with the following structure: if $\mathfrak{h}$ and $\mathfrak{m}$ are the two eigenspaces of the involution σ defining the RSS G/H, these two graded subalgebras are $\mathfrak{h} \otimes R[t]$ and $(\oplus_{i \in N} \mathfrak{h} \otimes t^{2i}) \oplus (\oplus_{i \in N} \mathfrak{m} \otimes t^{2i+1})$.

† Supported in part by the Natural Sciences and Engineering Research Council of Canada and the "Fonds FCAR pour l'Aide et le Soutien à la Recherche"

J8

The Virasoro symmetry of the Ernst equation, Bo-Yu Hou, Xibei University.

K1

Physical Interpretation of the Spinor, Adjoint, and Vector Representations of Spin(8). F. D. SMITH, JR., Georgia Institute of Technology. The 8-dimensional (left-handed) irreducible half-spinor representation of Spin(8) corresponds to the 8 first-generation lepton and quark particles. The mirror image half-spinor representation corresponds to antiparticles. The 28-dimensional adjoint representation of Spin(8) corresponds to gauge bosons: 8 gluons; 10 graviton polarizations; 4 photon polarizations; and 6 for weak Spin(4). The 8-dimensional vector representation of Spin(8) corresponds to a space-time base manifold. A geometric Higgs mechanism reduces the 8-dimensional base manifold to 4-dimensional space-time and also reduces the weak gauge group Spin(4) to SU(2).

K2

Orthornormal Gauge and Affine Geometry in String Theory B.H.Cho and Y.S.Myung, Korea Advanced Institute of Science and Technology. We discuss the relationship of particle field theory to string theory. The orthonormal gauge is derived, as a natural extension of the arc-length gauge ($x^2=1$) in the point particle theory. Also it is shown that the residual reparametrization invariance after the gauge fixing is identified with the affine invariance.

K3

SU(9) Grand Unification Model of Subquarks. Xiao-Zhou Xue, Henan Teachers University. An improved version of the grand unification, composite model proposed earlier is suggested. Under the hypothesis of partly broken global chiral symmetry, we give the four family of Fermions at low energies to realize unification of four family of Fermions. Neutrino may acquire naturally the Dirac Mass. Proton lifetime and Weak Neutral Current at low energy are consistent with experimental results.

K4

The Announcement: The Solution for the Measurement Problem in Quantum Mechanics. Jin Yoshimura, S.U.N.Y.-E.S.F. at Syracuse. -- I introduce the notion of subjective probability space based on the definition of probability space function. From this notion, the interpretation of probability in quantum mechanics can be viewed as follows. The quantum probability space is the human information concerning the properties of elementary particles, which is built from the past experiences. It infers the result of measurement, i.e. the value of observables. The reduction of wave packet is the artifact of the Copenhagen interpretation of probability. EPR paradox and Schrodinger's cat paradox does not occur in my theory. The resulting quantum mechanics is not the description of the physical nature of elementary particles, but that of human prediction theory about the result of an experiment of elementary particles.

1. J. Yoshimura, K. Yoshimura, Probability definition: the mathematical foundation of statistics. Unpublished (1986).

K5

Broken $SU_6 \times O_3$ and the rare decay $\rho \to 4\pi$

D. PARASHAR, University of Delhi. The Lorentz invariant structure of the hadron couplings deduced within the general framework of a broken version of the $SU_6 \times O_3$ quark model is exploited to compute the rare four-body decay channel $\rho \to 4\pi$. The decay amplitude is assumed to be dominated by the $(\pi, \omega, A_1, A_2)\pi$ and $\rho\ \rho$ intermediate states. The calculated estimates for the $\rho \to 4\pi$ decay rate are found to be consistent with the available experimental evidence.

K6

Supersymmetric Strings on Grassmann Manifolds, GARY L. DUERKSEN, AT&T Bell Laboratories. One of the fundamental problems in string theory is understanding the geometry of the underlying space or "target space" on which the string dynamics are formulated. In conventional string theory, attempts are made to identify this initially undetermined space via consistency and phenomenological arguments A new string model and its supersymmetric generalization are proposed in which the world-sheet coordinates of the string represent the Stiefel coordinates of a Grassmann Manifold, G_k, the set of all k-dimensional linear subspaces of the embedding space. In this formulation the intrinsic geometry of the model is made manifest in the initial formulation of the Lagrangian.

K7

Integral-Spin Fields on 3+2 de Sitter Space. J.P. GAZEAU, LPTM, Université Paris 7. Irreducible or non-decomposable representations of the de Sitter group SO(3,2) are extensively studied. Corresponding carrier states and invariant two-point functions are built through recurrence formula. The problems of light-cone propagation and "reverberation" phenomenon are examined. A particular emphasis is given on the so-called massless nondecomposable representations with arbitrary spin, with the following result : for a certain choice of the gauge-fixing parameter, the carrier states propagate only on the light-cone.

K8

On Different Symmetries Of Mesons And Baryons.
B.J.Bhattacharjee;St.Anthony's college.
Particle symmatries are expressed mathematically by special algebras. GellMann -Okubo mass formulae , Y Q and Y I_3 etc symmatries predicted successfully some elementary particles .But the formulae and symmatries do not seems to hold for many cases.Even quark- anti quarks triplet symmatries Q Y I_3 could not solve the problem of finding how many particles may exist in nature.It will be discussed how E,J,P symmatries can solve this particulr problem.

L1

Color Space Groups in the Analysis of the Phase Transitions, J.N.Kotzev, D.A.Alexandrova, Sofia University. An algorithm for derivation of all the P-type permutational color space groups $G^{(p)}$, isomorphic to the 230 cristallographic space groups G, is found/1/. The full list of the color space groups, belonging to 10 chromomorphic classes, is given together with appropriate classification. The color space groups application in the Landau theoty of phase transitions is discussed/1,2,3/ and a comparison with results of other authors is given.

1. J.N.Kotzev, D.A.Alexandrova, Proc.III Int.Seminar, Yourmala, 85, Ed.by M.A.Markov, "Nauka", Moskow(1986); Proc X European Cryst.Meeting, Wroclaw, 1986. 2. D.B.Litvin, J.N.Kotzev, J.L.Birman, Phys.Rev.B, 26, 6947(1982). 3. J.N.Kotzev, D.B. Litvin, J.L.Birman, Physica 114A, 576(1982).

L2

Physical applications of compatibility relations for space group Clebsch-Gordan-Coefficients. R. DIRL, TU Wien, Austria; B.L. DAVIES, University College of North Wales, Bangor, UK. Compatibility relations for multiplicities and for space group CG-matrices are presented. These relations prove to be useful and necessary when applying the Wigner-Eckart's theorem for space groups and when varying continuously q-vectors. Continuous parameter variations are essential in physical applications and may lead to discontinuous changes in selection rules. This discontinuity is governed by the compatibility relations for space group CG-matrices. We analyze the implications of parameter variations in terms of a characteristic class of irreducible tensor operators that arise in scattering processes. We show that irreducible tensor operators may cease to be irreducible when their defining q-vectors are varied continuously to q-vectors of higher symmetry. Finally to illustrate the utility and applicability of compatibility relations we treat various examples in detail.

L3

Various classification schemes for irreducible space group representations. B.L. DAVIES, University College of North Wales, Bangor, UK, R. DIRL, TU Wien, Austria; Due to the existence of infinitly many different labelling schemes for space group irreps we use this ambiguity to standardize induced space group irreps in a specific way. We analyze the implications of changing the shape of representation domains from standard to non-standard ones and discuss the merits and drawbacks of them. To achieve this standardization the little co-group irreps and the coset decompositions of space groups with respect to their little groups are unified within classes of space groups. Finally to demonstrate the variety of possible labelling schemes, 'alternative' classification schemes /1/ based on chain adaptations with respect to different space groups are also sketched.

/1/ R. Dirl, R.W. Haase: "Alternative classification schemes for energy bands" in Proceedings of the XIIIth International Colloquium on Group Theoretical Methods in Physics

L4

Q-Reducible Space Groups. V. Kopsky and D.B. Litvin, Penn State-Berks. If a point group G of a space group $\mathfrak{G}$ is Q-reducible, then the group $\mathfrak{G}$ has the following properties: (1) The point group G is a direct or subdirect product of point groups H_1 and H_2 which act on G-invarient subspaces V_1 and V_2. (2) The translation subgroup T_G splits into a direct or subdirect product of its projections T_1 and T_2 onto V_1 and V_2. (3) The subgroups $T_1^o = T_G \cap V_1$ and $T_2^o = T_G \cap V_2$ are normal in $\mathfrak{G}$ and the corresponding factor groups $\mathfrak{G}/T_1^o$ and $\mathfrak{G}/T_2^o$ have the structure of subperiodic groups. (4) The group $\mathfrak{G}$ itself is a direct or subdirect product of space groups of lower dimensions. These properties can be used either for the analysis of spce groups with Q-reducible point groups or for the construction on the basis of the knowledge of lower dimensional ones. These points are illustrated by an example of groups of Laue class D_4.

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XV INTERNATIONAL COLLOQUIUM
ON
GROUP THEORETICAL METHODS
IN
PHYSICS

Monday, October 20, 1986

Algebraic Methods in Physics

- 8:00 Registration
- 9:00 Opening Remarks
- 9:20 R. F. Casten — Dynamical symmetries in nuclear structure
- 10:10 W. G. Harter — Spin phase space and rotational symmetry for molecular rovibrational dynamics
- 11:00 coffee
- 11:20 F. Iachello — Review of recent developmentsin the use of symmetries in reactions
- 12:10 R. D. Amado — Algebraic methods in medium energy scattering from nuclei and molecules
- 1:00 lunch
- 2:30 J. E. Marsden — The dynamics of rotating structures
- 3:20 R. D. Levine — Algebraic method for molecular structure and dynamics
- 2:30 Parallel Sessions A and B

Tuesday, October 21, 1986

Quasicrystals

- 9:00 P. Kramer — "Das Pentagramma nacht dir Pein?" Violation of periodic symmetry in Quasicrystals
- 9:50 M. Duneau — Title to be announced
- 10:40 coffee
- 11:00 V. Elser — The growth of quantum crystals
- 11:50 P. J. Steinhardt — Introduction to the physics of Quasicrystals
- 12:40 lunch
- 2:30 Hao Bai Lin — Number of periodic windows in one-dimensional mappings and group theory
- 3:20 L. C. Biedenharn — The group theoretical approach to scattering
- 1:30 Parallel Sessions C, D, and E

Wednesday, October 22, 1986

Nonlinear Dynamics

- 9:00 P. Cvitanovic — Renormalization approach to chaos
- 9:50 M. Gutzwiller — Chaos in the transition from classical to quantum mechanics
- 10:40 coffee
- 11:00 A. J. Libchaber — Quasiperiodicity, chaos and turbulence in mercury and helium experiments
- 11:50 M. J. Feigenbaum — Characterization of strange sets
- 12:40 lunch
- 2:00 sightseeing in Philadelphia
- 5:00 Wigner Medal Award
- 6:00 Reception
- 7:00 Banquet

Thursday, October 23, 1986

Differential Equations

- 9:00 P. Olver — Generalized symmetries
- 9:50 A. Deprit — Title to be announced
- 10:40 coffee
- 11:00 P. Winternitz — New results in the applications of group theory to differential equations
- 11:50 C. L. Wu — Dynamical symmetries in collective nuclear structure physics
- 12:40 lunch
- 2:30 Parallel Sessions F, G, and H

Friday, October 24, 1986

Fundamental Physics

- 9:00 E. Witten — Title to be announced
- 9:50 H. Georgi — Approximate global symmetries of the electroweak interactions
- 10:40 coffee
- 11:00 L. Sulak — Title to be announced
- 11:50 C. N. Yang — Title to be announced
- 12:40 lunch
- 2:30 Parallel Sessions J, K, and L

Parallel Session A

Monday, October 20, 1986 — MacAlister 2023

A1	2:30	Hans E. DeMeyer	Dynamical group approach to certain anharmonic oscillator and perturbed Coulomb potentials, H. E. DeMeyer
A2	2:45	S. K. Kim	Theorem on the Schwinger representation and its application to the algebraic Hamiltonian for diatomic molecules, S. K. Kim
A3	3:00	J. P. Draayer	Algebraic foundation for the triaxial rotor, J. P. Draayer and Y. Leschber
A4	3:15	Hans E. DeMeyer	Classification of symmetry-preserving cubic interactions in the Interacting Boson Model, H. E. DeMeyer
	3:30		coffee
A5	3:45	Guido van den Berghe	Symmetry conserving higher-order interaction terms in the IBA model: the O(6) limit, G. van den Berghe
A6	4:00	George Rosensteel	The U(6,1) model of pairing and quadrupole collectivity, G. Rosensteel
A7	4:15	A. B. Balantekin	Dynamical symmetries for Odd-Odd Nuclei, A. B. Balantekin
A8	4:30	J. N. Ginocchio	Spin quenching in the SO(8) and Sp(6) fermion models of collective motion, J. N. Ginocchio
A9	4:45	Y. Alhassid	Algebraic approach to dissociation from bound states, Y. Alhassid

Parallel Session B

Monday, October 20, 1986 — MacAlister 4014

B1	2:30	Jacob Katriel	Group theoretical applications of generalized Bose operators: fractional boson squeezed states for SU(2) and SU(1,1), J. Katriel, M. Rasetti, and A. I. Solomon
B2	2:45	Christopher Gerry	SU(1,1) coherent states and squeezed light interacting with an anharmonic oscillator, C. Gerry
B3	3:00	Marcos Moshinsky	Representation of the generators of Sp(6,R) in a monomial basis asssociated with a given irrep of this group, M. Moshinsky
B4	3:15	C. Quesne	SU(n) represeentation theory in terms of pseudo-unitary groups, C. Quesne
	3:30		coffee
B5	3:45	R. LeBlanc	A new perspective on the Wigner-Racah calculus, R. LeBlanc and K. T. Hecht
B6	4:00	James D. Louck	Symmetries of some hypergeometric series, W. A. Beyer, L. C. Beidenharn, and J. D. Louck
B7	4:15	A. B. Balantekin	On coherent states for ortho-symplectic supergroups, A. B. Balantekin and H. Schmitt
B8	4:30	Joris van der Jeugt	On principal subalgebras of Lie superalgebras and unimodality, J. van der Jeugt
B9	4:45	Antonino Sciarrino	Representations of Lie algebra G(3), A. Sciarrino

Parallel Session C

Tuesday, October 21, 1986 — MacAlister 4014

C1	2:30	Rudolph Haag	Generally covariant quantum field theory and scaling limits, K. Fredenhagen and R. Haag
C2	3:00	Alfred Rieckers	On the covariance representations of global quantum dynamics and its symmetries, A. Rieckers
C3	3:15	Y. S. Kim	Unitary representations of photon polarization vectors, Y. S. Kim, D. Han, and M. E. Noz
	3:30		coffee
C4	3:45	B. J. Dalton	New geometric symmetries via nonlinear realizations, B. J. Dalton
C5	4:00	G. D. Rideau	Nonlinear representations of the Poincare group, G. Rideau
C6	4:15	R. R. Aldinger	Quantized deSitter structured connection and an example: the quantum relativistic rotator, R. R. Aldinger
C7	4:30	C. J. Papachristou	Isogroups of differential ideals of vector valued differential forms: application to the classical Yang-Mills equations, C. J. Papachristou and B. K. Harrison
C8	4:45	Howard E. Brandt	Differential geometry and gauge structure of maximal acceleration invariant phase space, H. E. Brandt
C9	5:00	Philip Yasskin	The space-time diffeomorphism group as a doubly semi-direct product, P. Yasskin

Parallel Session D

Tuesday, October 21, 1986 — MacAlister 4016

D1	2:30	S. Deonarine	Symmetry and subgroups of the regular tetrahedron in 4-dimensions, S. Deonarine and J. L. Birman
D2	2:45	J. P. Lu	Symmetry of quasiperiodic lattices in 2-D as subsymmetries of 4-D crystallographic symmetery, J. P. Lu and J. L. Birman
D3	3:00	R. W. Haase	Quasi lattices associated with the icosahedral and dihedral groups, R. W. Haase and P. Kramer
D4	3:15	S. Y. Goshen	Tensorial properties which distinguish icosahedral symmetry from cubic or SO(3) symmetry, S. Y. Goshen and J. L. Birman
	3:30		coffee
D5	3:45	Charles Radin	The unstable chemical structure of quasicrystal alloys, C. Radin
D6	4:00	Marko V. Jaric	Group theory and elasticity of Quasicrystals, M. V. Jaric
D7	4:15	Daniel B. Litvin	Symmetry and phase transitions in decagonal quasicrystals, D. B. Litvin, J. L. Birman, and V. Kopsky

Parallel Session E

Tuesday, October 21, 1986 — MacAlister 2023

E1	2:30	Raphael D. Levine	Implementing an algebraic, maximal entropy approach to molecular collisions, M. Berman and R. D. Levine
E2	2:45	Chau Chin Wei	Scaling Law of a space charge flow, C. C. Wei, R. J. Yeh, and C. Y. Wang
E3	3:00	Ren Jye Yeh	Lie operators of nonlinear Schrodinger equation, C. C. Wei, R. J. Yeh, and C. Y. Wang
E4	3:15	Z. Papadopolos	Symplectic decomposition of reaction channels, P. Kramer and Z. Papadopolos
	3:30		coffee
E5	3:45	Alejandro Frank	Group deformations and the algebraic approach to scattering, A. Frank
E6	4:00	G. Vitiello	Group contraction and the algebraic approach to scattering, E. Celeghini, F. Iachello, M. Tarlini, and G. Vitiello
E7	4:15	Jim Stasheff	Constrained Hamiltonians, BRS and Homological algebra, J. Stasheff
E8	4:30	D. A. Sparrow	Properties of the strong factor in dynamically generated S-matrices, R. D. Amado, D. A. Sparrow, Y. Alhassid, F. Iachello, and J. Wu
E9	4:45	Joseph. L. Birman	Unified model of superconductivity and density waves with SO(4)xSO(4) dynamical symmetry, J. L. Birman and A. I. Solomon
E10	5:00	Allan I. Solomon	Dynamical SU(8)- a laboratory for phase coexistence, A. I. Solomon and J. L. Birman
E11	5:15	A. Bohm	The algebraic method for relativistic systems: spectrum and radiative transitions, A. Bohm
E12	5:30	R. Perline	Stereographic projection in hyperbolic space and the Kepler problem, R. Perline

Parallel Session F

Thursday, October 23, 1986 — MacAlister 4014

F1	2:30	Randall D. Morris	SU(2)xSU(2)xU(1) charge symmetric, color electroweak model, R. D. Morris and F. Reifler
F2	2:45	Freydoon Mansouri	Interacting parastring theories, F. Mansouri
F3	3:00	M. Spiegelglas	QBRST cohomology- a mechanism for getting rid of negative norm states, with an application to the bosonic string, M. Spiegelglas
F4	3:15	K. C. Tripathy	Representation theory of BRS algebras, M. K. Patra, K. C. Pati, and K. C. Tripathy
	3:30		coffee
F5	3:45	Ugo Bruzzo	Noether theorems on superspace field theories, U. Bruzzo
F6	4:00	Dominique Dehin	N=2 superconformal quantum harmonic oscillator, D. Dehin, J. Beckers, and V. Hussin
F7	4:15	Sultan Catto	Effective quark-diquark supersymmetry and splitting of Regge trajectories, S. Catto and S. Kuyucak
F8	4:30	Chang Kuen Jue	The chiral transformation and invariant interactions of superfields, S. K. Choi, D. Son, and C. K. Jue
F9	4:45	Luc Vinet	Subvariant chiral and vector fields, L. Vinet
F10	5:00	Pankaj Jain	Bag formation in a chiral model, P. Jain
F11	5:15	Fred Cooper	Exactly soluble supersymmetric potentials and shape invariance, F. Cooper, J. N. Ginocchio, and A. Khare
F12	5:30	Gerald Kaiser	Quantized fields in complex superspace, G. Kaiser

Parallel Session G

Thursday, October 23, 1986 — MacAlister 2023

G1	2:30	K. B. Wolf	Symmetry in Lie optics, K. B. Wolf
G2	2:45	A. Gonzalez Lopez	Symmetries of linear Newtonian systems, A. Gonzalez-Lopez
G3	3:00	Langis Gagnon	Nonlinear differential equations with superposition law for the osp(1,2) superalgebra, L. Gagnon, P. Winternitz, V. Hussin, and J. Beckers
G4	3:15	Daryl D. Holm	Hall magnetohydrodynamics: conservation laws and Lyapunov stability, D. D. Holm
	3:30		coffee
G5	3:45	Hernan Cendra	Clebsch potentials, Lin constraints, and gauged Lie Poisson structures, L. A. Ibort and H. Cendra
G6	4:00	Jair Koiller	Nonholonomical systems with symmetry, J. Koiller
G7	4:15	D. David	Symmetry reduction for the Kadomtsev-Petviashili equation and its Backlund transformation, D. David
G8	4:30	G. F. Helminck	Construction of solutions of the multi-component KP hierarchy, G. F. Helminck
G9	4:45	Dorian M. Hatch	Little groups for reducible representations of space groups, D. M. Hatch and H. T. Stokes
G10	5:00	M. Grundland	The exact solution of multidimensional classical ϕ^6 field equations

Parallel Session H

Thursday, October 23, 1986 — MacAlister 4016

H1	2:30	Hans Doebner	Title to be announced, H. Doebner
H2	2:45	Gerald A. Goldin	Unitary representations of diffeomorphism groups and unusual particle statistics, G. A. Goldin
H3	3:00	Walter Schempp	The diamond Lie group and path integrals, W. Schempp
H4	3:15	Maurice Kibler	Levi-Civita, Kostaanheimo-Steifel and other transformations, D. Lambert and M. Kibler
	3:30		coffee
H5	3:45	Yuan K. Ha	Linear realization of noncompact symmetries, Y. K. Ha
H6	4:00	K. C. Tripathy	Iwasawa and Langlands decompositions, Satake diagrams and graded Lie algebras, K. C. Tripathy and V. Sharma
H7	4:15	R. T. Sharp	A folk theorem revisited. The degenerate case, R. T. Sharp and Y. Giroux
H8	4:30	N. S. Rao	Progress report on the study of the asymmetry parameters for elastic scattering of electrons by H and He, N. S. Rao

Poster Session

Thursday, October 23, 1986 — Living Arts Lounge

Jacob Katriel	Explicit expression for the product of the class of transpositions with an arbitrary class of the symmetric group
Alejandro Frank	Algebraic approach to molecular electronic spectra
E. Siegel	Self-similarity and self-affinity RoughStoffe Nonlinear dynamics Field Theory & Quasicrystals: How Fractal is Fractal?

Parallel Session J

Friday, October 24, 1986 — MacAlister 2023

J1	2:30	Thomas Curtright	Group theory of string models, T. Curtright
J2	2:45	P. Cvitanovic	A new construction of exceptional Lie groups, P. Cvitanovic
J3	3:00	P. H. M. Kersten	Hierarchies of symmetries and conserved functionals of the Federbush model, P. H. M. Kersten
J4	3:15	Norman Redlich	Spin structure, projection operators, and Bose-Fermi equivalence for simply laced groups, A. N. Redlich, H. J. Schnitzer, and K. Tsokos
	3:30		coffee
J5	3:45	Gregg Zuckerman	Highest weight vectors in Virasoro modules, G. J. Zuckerman
J6	4:00	Yvan Saint-Aubin	Infinite dimensional Lie algebras acting on the solution space of various S models, M. Jacques and Y. Saint-Aubin
J7	4:15	I. Bakas	3-cocycles in the monopole sector of gauge theories, I. Bakas and D. McMullen
J8	4:30	Bo-Yu Hou	The Virasoro symmetry of the Ernst equation, Bo-Yu Hou

Parallel Session K

Friday, October 24, 1986 — MacAlister 4014

K1	2:30	F. D. Smith	Physical interpretation of the spinor, adjoint, and vector representations of spin(8), F. D. Smith
K2	2:45	Byung Ha Cho	Orthonormal guage and affine geometry in string theories, B.-Y. Cho
K3	3:00	Xiao-Zhou Xue	SU(9) grand unification model of subquarks, X.-Z. Xue
K4	3:15	Jin Yoshimura	The Announcement: the solution for the measurement problem in Quantum Mechanics, J. Yoshimura
	3:30		coffee
K5	3:45	D. Parashar	Broken SU(6)xO(3) and the rare decay r-->4p, D. Parashar
K6	4:00	Gary Duerkson	Supersymmetric strings on Grassman manifolds, G. L. Duerkson
K7	4:15	J. P. Gazeau	Integral spin fields on 3 + 2 deSitter space, J. P. Gazeau
K8	4:30	B. J. Bhattacharjee	On different symmetries of mesons and baryons, B. J. bhattacharjee

Parallel Session L

Friday, October 24, 1986 — MacAlister 4016

L1	2:30	Joseph N. Kotzev	Color space groups in the analysis of phase transitions, J. N. Kotzev and D. A. Alexandrova
L2	2:45	Rainer Dirl	Physical applications of compatibility relations for space group Clebsch-Gordan coefficients, R. Dirl and B. L. Davies
L3	3:00	B. L. Davies	Various classification schemes for irreducible space group representations, B. L. Davies and R. Dirl
L4	3:15	Daniel B. Litvin	Q-reducible space groups, V. Kopsky and D. B. Litvin
	3:30		coffee
L5	3:45	M. I. Aroyo	The auxiliary group approach to the reduction of multiple Kronecker products and to the chain-adapted subduction matrices, M. I. Aroyo, J. N. Kotzev, R. Dirl, P. Kasperkovitz, and B. L. Davies
L6	4:00	H. Bacry	What group theory tells us about bands in solids, H. Bacry, L. Michel, and J. Zak
L7	4:15	M. N. Angelova	On the 6-D symbols for corepresentations of antiunitary magnetic groups, M. N. Angelova, M. K. Peev, M. I. Aroyo, and J. N. Kotzev
L8	4:30	Hao Bai Lin	GRAPE- Group representation and Application in Physics Environment, Çui Zhan, Gao Jun-ming, and Hao Bai Lin