IC/82/197

INTERNATIONAL CENTRE FOR
THEORETICAL PHYSICS

GAUGE AND NON-GAUGE CURVATURE TENSOR COPIES

Prem P. Srivastava

INTERNATIONAL
ATOMIC ENERGY
AGENCY

UNITED NATIONS
EDUCATIONAL,
SCIENTIFIC
AND CULTURAL
ORGANIZATION

1982 MIRAMARE-TRIESTE

International Atomic Energy Agency

and

United Nations Educational Scientific and Cultural Organization

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS

GAUGE AND NON-GAUGE CURVATURE TENSOR COPIES *

Prem P. Srivastava **

International Centre for Theoretical Physics, Trieste, Italy.

ABSTRACT

A procedure for constructing curvature tensor copies is discussed using the anholonomic geometrical framework. The corresponding geometries are compared and the notion of gauge copy elucidated. An explicit calculation is also made.

MIRAMARE - TRIESTE

October 1982

* To be submitted for publication.

** Permanent address: Centro Brasileiro de Pesquisas Físicas, R. Xavier Sigaud 150, 22290 Rio de Janeiro, R.J., Brazil.

I. INTRODUCTION

In gauge theories gauge equivalent potentials are very useful in handling certain problems. In connection with Yang-Mills theory ¹⁾, for example, the calculation of topological numbers of the multi-instanton solution can be carried out as an application of the Gauss theorem if we use the 't Hooft solution ²⁾ together with another compact and gauge equivalent solution ³⁾. For the Abelian case gauge copies were used by Wu and Yang ⁴⁾ in their formulation of the Dirac monopole ⁵⁾ theory using overlapping sections into which each monopole divides the space-time. In the non-Abelian case we may also obtain two or more potentials not related by any gauge transformation associated to the same gauge covariant field strength. These field strength copies have been studied in several recent papers ⁶⁾.

For the case of an affine space-time manifold, likewise, the curvature tensor does not determine the space-time connection uniquely. For example, the projective transformation $\Gamma_{\nu\rho}^{\mu} \rightarrow \Gamma_{\nu\rho}^{\mu} - \delta_{\nu}^{\mu} \lambda_{\rho}$, $\delta_{\mu\nu} \rightarrow \delta_{\mu\nu}$ leaves the curvature scale invariant. The importance of eliminating the projective invariance for a consistent theory of gravity interacting with matter was discussed in detail in Ref.7. The curvature tensor is left invariant in the case $\lambda_{\rho} = \partial_{\rho} \chi$. We will discuss in this paper a general procedure to construct curvature tensor copies in analogy to the case of non-Abelian gauge theory. For this purpose we will use the anholonomic geometrical framework (tetrad formulation) which incorporates in it a local (Lorentz) gauge group. The notation is defined in Sec.II. In Sec.III the curvature tensor copies are constructed and the corresponding geometries compared. The notion of gauge copy in the present context is also elucidated. Finally, Sec.IV contains an explicit calculation and describes briefly the procedure to be followed in the case of Weyl-Cartan geometry.

II. NOTATION *): SPINOR CONNECTION

The geometry of the space-time manifold M , labelled by co-ordinates x^{μ} , is described by means of a sufficiently differentiable field of four vectors ⁸⁾ (tetrad frame), $e_a^{\mu} = e^{\mu}_{\alpha} \delta_a^{\alpha}$, and a linear connection Γ at each

*) The anholonomic (tetrad or Lorentz) indices $a, m, \dots$ as well as holonomic (co-ordinate or world) indices $\mu, \nu, \dots$ run from 0 to 3. Also $\eta_{am} = \eta^{\mu\nu} = \text{diag}(1, -1, -1, -1)$.

point. We also assume the existence of a constant Minkowski metric $\eta_{\lambda m}$ and may choose the tetrad to be orthonormal, $e_\lambda^\lambda e_m^m = \eta_{\lambda m}$. We have the dual frame $e_\lambda^\lambda = e_\mu^\lambda dx^\mu$ and find $e_\mu^\lambda e_\lambda^\mu = \delta_\mu^\lambda$ which implies $e_\mu^\lambda e_\lambda^\mu = \delta_\mu^\lambda$. Let $\Gamma_{\lambda m}^\lambda$ be the anholonomic components $\mathcal{G}_{\lambda m}^\lambda$ of the connection Γ referred to a tetrad basis. We define the mixed components - spinor connection or deformation gauge potential - by

$$\omega_\lambda^\lambda{}_m = e_\lambda^\lambda \Gamma_{m n}^\lambda. \quad (1)$$

and the holonomic components $\Gamma_{\mu\nu}^\lambda$ of Γ by $\mathcal{G}$

$$\Gamma_{\mu\lambda}^\lambda = e_\lambda^\lambda [\partial_\lambda e_\mu^\lambda + \omega_\lambda^\lambda{}_m e_\mu^m]. \quad (2)$$

This implies $\omega_{\lambda m}^\lambda = -e_m^\mu (\partial_\lambda e_\mu^\lambda - \Gamma_{\mu\lambda}^\alpha e_\alpha^\lambda)$. A tensor field may be described either by means of its holonomic or its anholonomic components. It is, however, convenient to use also mixed components, e.g. $\phi_{\mu\nu}^\lambda$, $\phi_{m n}^\lambda$, etc. We may also define (complete) covariant derivative ∇ of such a quantity, for example, as follows:

$$\begin{aligned} \phi_{m\nu;\lambda}^{\lambda\mu} &= \partial_\lambda \phi_{m\nu}^{\lambda\mu} + \omega_\lambda^\lambda{}_n \phi_{m\nu}^n{}^\mu - \omega_\lambda^\lambda{}_m \phi_{n\nu}^{\lambda\mu} \\ &\quad + \Gamma_{\alpha\lambda}^\mu \phi_{m\nu}^{\lambda\alpha} - \Gamma_{\nu\lambda}^\alpha \phi_{m\alpha}^{\lambda\mu} \end{aligned} \quad (3)$$

i.e. anholonomic indices are differentiated by means of $\omega_{\lambda m}^\lambda$ and holonomic ones by means of $\Gamma_{\mu\nu}^\lambda$. Thus Eq.(2) reads $e_\mu^\lambda; \lambda = 0$. The holonomic components of the metric on M are $g_{\mu\nu} = g_{\mu\nu}^\lambda = e_\mu^\lambda e_\nu^\lambda \eta_{\lambda m}$ and **)

*) The derivative property may be verified even when we do not impose $e_\mu^\lambda; \lambda = 0$. We note that $\delta_{m;\lambda}^\lambda = \delta_{\mu;\lambda}^\lambda = 0$.

**) For Dirac spinor field $\psi_{;\lambda} = (\partial_\lambda + \Gamma_\lambda) \psi$. Considering transformation of Γ_λ under Lorentz gauge transformations we can show $\Gamma_\mu = \frac{1}{8} [\gamma_\lambda, \gamma_m] \omega_{\lambda m}^\mu$. On making use of the identity

$$[\gamma_\mu, \gamma^\lambda] = \frac{1}{2} (\omega_{\mu m}^\lambda - \omega_{\lambda m}^\mu) \gamma^m$$

we find $\gamma_{;\lambda}^\lambda = \omega_{\lambda m}^\lambda \gamma_m$. We remark that the definitions above do not impose any symmetry on the indices (λ, m) in $\omega_{\lambda m}^\lambda$ even when $e_\mu^\lambda; \lambda \neq 0$.

$$\begin{aligned} g_{\mu\nu;\lambda}^\lambda &= e_\mu^\lambda e_\nu^\lambda \Gamma_{\lambda m}^\lambda \\ \eta_{\lambda m;\lambda}^\lambda &= -2 \omega_{\lambda m}^\lambda \end{aligned} \quad (4)$$

Consider local Lorentz transformations $\Lambda(x) = (\Lambda^\lambda_\mu(x))$, i.e. $\eta_{\lambda m}^\lambda \Lambda^\lambda_\mu \Lambda^m_\nu = \eta_{\mu\nu}$. The rotation of the tetrad at x^μ by $\Lambda(x)$, e.g. $e_\mu^\lambda = \Lambda^\lambda_\mu e_\mu^m$, $e_\lambda^\mu = \Lambda^\mu_\lambda e_\lambda^m$ does not affect the metric structure. Since by definition $\phi_{;\lambda}^\lambda$ transforms as $\phi_{;\lambda}^\lambda$ we obtain the transformation rule of the connection $\omega_\lambda = (\omega_{\lambda m}^\lambda)$ under Lorentz gauge transformations $\Lambda(x)$ to be

$$\omega_\mu \xrightarrow{\Lambda} \Lambda \omega_\mu \Lambda^{-1} - (\partial_\mu \Lambda) \Lambda^{-1}. \quad (5)$$

The holonomic components $\Gamma_{\mu\nu}^\lambda$ of Γ are then seen to be unaltered under tetrad rotations. The geometry of the system is thus invariant under local gauge transformations.

III. CURVATURE TENSOR COPIES. GAUGE COPIES

The space-time curvature tensor is given by

$$R_{\nu\lambda\rho}^\mu = \partial_\nu \Gamma_{\lambda\rho}^\mu - \Gamma_{\lambda\nu}^\rho \Gamma_{\rho}^\mu + \Gamma_{\lambda\rho}^\nu \Gamma_{\nu}^\mu - (\lambda \leftrightarrow \rho). \quad (6)$$

It is clear from Eq.(5) that, in analogy with the case of Yang-Mills theory, we may define a gauge covariant field strength $P_{\lambda\rho}(\omega)$ - spin curvature tensor - by

$$\begin{aligned} P_{\lambda\rho}(\omega) &= \partial_\lambda \omega_\rho - \partial_\rho \omega_\lambda + [\omega_\lambda, \omega_\rho] \\ P_{\lambda\rho}(\omega) &\xrightarrow{\Lambda} \Lambda P_{\lambda\rho}(\omega) \Lambda^{-1} \end{aligned} \quad (7)$$

The indices in $R_{\mu\lambda\rho}^\lambda(\omega) \equiv (P_{\lambda\rho}(\omega))_{\lambda m}^\lambda$ are all tensorial and it is easy to

verify using Eq.(2) that *)

$$R^{\alpha}_{\mu\lambda\rho}(\tau) = e^{\mu}_m e^{\alpha}_l R^l_{m\lambda\rho}(\omega) \quad (8)$$

The curvature tensor copies arise if we have a connection $\bar{\omega}_{\lambda}$ such that

$$P_{\lambda\rho}(\bar{\omega}) = P_{\lambda\rho}(\omega) \quad (9)$$

Writing $\bar{\omega}_{\lambda} = \omega_{\lambda} + \kappa_{\lambda}$ we obtain

$$P_{\lambda\rho}(\kappa) + [\omega_{\lambda}, \kappa_{\rho}] - [\omega_{\rho}, \kappa_{\lambda}] = 0 \quad (10)$$

This copy is called a gauge copy if $\bar{\omega}_{\lambda}$ and ω_{λ} are connected by a Lorentz gauge transformation, e.g.

$$\kappa_{\lambda} = -\omega_{\lambda} + \Lambda \omega_{\lambda} \Lambda^{-1} - (\partial_{\lambda} \Lambda) \Lambda^{-1} \quad (11)$$

for some $\Lambda(x)$. On substituting in Eq.(10) this leads to $\Lambda P_{\lambda\rho}(\omega) \Lambda^{-1} = P_{\lambda\rho}(\omega)$.

The holonomic connection $\bar{\Gamma}^{\alpha}_{\mu\lambda}$ corresponding to $\bar{\omega}_{\lambda}$ follows to be (Eq.(2))

$$\bar{\Gamma}^{\alpha}_{\mu\lambda} = \Gamma^{\alpha}_{\mu\lambda} + \kappa^l_{\lambda} e^l_m e^m_{\mu} e^{\alpha}_l \quad (12)$$

and

$$g_{\mu\nu;\lambda}(\bar{\Gamma}) = e^l_{\mu} e^l_{\nu} \eta^m_{lm;\lambda}(\bar{\omega}) \quad (13)$$

*) When $e^l_{\mu;\lambda} \neq 0$ we use the identity

$$\begin{aligned} e^l_{\mu;\lambda\rho}(\tau, \omega) - e^l_{\mu;\rho\lambda}(\tau, \omega) + (\Gamma^{\alpha}_{\lambda\rho} - \Gamma^{\alpha}_{\rho\lambda}) e^l_{\mu;\lambda}(\tau, \omega) \\ = R^{\alpha}_{\mu\lambda\rho}(\tau) e^l_{\rho} - R^l_{m\lambda\rho}(\omega) e^m_{\mu} \end{aligned}$$

The curvature tensor copies may be discussed by setting $e^l_{\mu;\lambda} = -\kappa^l_{\lambda} e^l_m e^m_{\mu}$.

The case of curvature scalar copies may also be discussed with appropriate modifications.

It is worth pointing out that the last term in Eq.(11) is always antisymmetric and that ω_{λ} may be decomposed into its irreducible symmetric and antisymmetric components. Thus, if ω_{λ} is antisymmetric (Einstein-Cartan geometry), a symmetric κ_{λ} cannot correspond to a gauge copy. A copy with antisymmetric κ_{λ} corresponds to E.C. geometry.

IV. ILLUSTRATIONS OF SOME CURVATURE TENSOR COPIES

Eq.(10) is similar to that encountered in the study of field strength copies in non-Abelian gauge theory ⁶⁾. We will only consider here some simple solutions as illustrations.

An obvious symmetric solution is $\kappa_{\lambda} = -I(\partial_{\lambda} X)$, $\text{Tr } \kappa_{\lambda} = -4(\partial_{\lambda} X)$ where $X(x)$ is a scalar function. We get from Eqs.(12) and (13)

$$\begin{aligned} \bar{\Gamma}^{\alpha}_{\mu\lambda} &= \Gamma^{\alpha}_{\mu\lambda} - \delta^{\alpha}_{\mu} \partial_{\lambda} X \\ g_{\mu\nu;\lambda}(\bar{\Gamma}) &= g_{\mu\nu;\lambda}(\Gamma) + 2g_{\mu\nu} \partial_{\lambda} X \end{aligned} \quad (14)$$

For $(\partial_{\lambda} X)$ replaced by a vector field φ_{λ} (projective transformation) we get only a curvature scalar copy ⁷⁾.

Another simple solution is obtained by making the ansatz

$$\kappa_{\lambda} = a(x) \partial_{\lambda} X \quad (15)$$

where $a(x) = (a^l(x))$ may correspond to a symmetric or antisymmetric solution. Eq.(10) leads to ^m

$$\partial_{\lambda} a(x) + [a(x), a(x)] = 0 \quad (16)$$

Consider, for an illustration, the metric space defined by the following line element ¹⁰⁾:

and verify by direct calculation that $R_{\mu\lambda\rho}^{\alpha}(\bar{r}) = R_{\mu\lambda\rho}^{\alpha}(\bar{r})$.

An antisymmetric solution is found to be $a(t) = \left(\frac{A}{C}\right) \omega_1$ and corresponds to

$$\bar{r}_{\nu\lambda}^{\mu} = \left\{ \nu_{\lambda}^{\mu} \right\} + \left[\frac{A}{C} \delta_{\nu}^{\mu} \delta_{\lambda}^0 - C \delta_{\lambda}^{\mu} \delta_{\nu}^1 \right] (\partial_{\lambda} x)$$

$$g_{\mu\nu;\lambda}(\bar{r}) = 0. \quad (21)$$

However, this case can be shown to correspond to a gauge copy. We find

$P_{\lambda\rho} = \left[-\frac{C}{C} + \frac{A}{A} \right] \left[\delta_{\rho}^0 \omega_1 \delta_{\lambda}^1 + \omega_2 \delta_{\lambda}^2 \right] - (\lambda \leftrightarrow \rho)$ so that in order to satisfy $AP_{\lambda\rho}(\bar{\omega}) \Lambda^{-1} = P_{\lambda\rho}(\bar{\omega})$ we require $\Lambda_{1,2}^0 \Lambda^{-1} = \omega_{1,2}$ apart from the restrictions that Λ be a Lorentz matrix. Adding to these the restrictions arising from Eq.(11) a tedious calculation shows that the Lorentz gauge matrix $\Lambda(x)$ is given by

$$\Lambda(x) = \begin{pmatrix} 1 + \frac{1}{2}\psi^2 & -\psi & 0 & -\frac{1}{2}\psi^2 \\ -\psi & 1 & 0 & \psi \\ 0 & 0 & 1 & 0 \\ \frac{1}{2}\psi^2 & -\psi & 0 & 1 - \frac{1}{2}\psi^2 \end{pmatrix}, \quad (22)$$

where $\psi = A(t) \chi(x)$.

The case of Weyl-Cartan geometry may also be discussed. The geometry is characterized by $g_{\mu\nu;\lambda}(\bar{r}) = 2g_{\mu\nu}\phi_{\lambda}$ where ϕ_{λ} is a Weyl field. Since we require $e_{\mu;\lambda}^{\lambda} = 0$ it follows that $\eta_{\lambda m;\lambda}(\omega) = 2\eta_{\lambda m}\phi_{\lambda}$, $\omega_{\lambda}(\lambda m) = -\eta_{\lambda m}\phi_{\lambda}$. We may assume $\omega_{\lambda} = (\omega_{\lambda}^0 - I\phi_{\lambda})$ and $\Gamma_{\mu\nu}^{\lambda} = \left\{ \begin{smallmatrix} \lambda \\ \mu\nu \end{smallmatrix} \right\} - \delta_{\mu}^{\lambda}\phi_{\nu}$ and proceed along similar lines.

ACKNOWLEDGMENTS

The author would like to thank Professor Abdus Salam, the International Atomic Energy Agency and UNESCO for hospitality at the International Centre for Theoretical Physics, Trieste, where this work was completed. Thanks are also due to Professor P. van Nieuwenhuizen for his comments and for conversations with Professors J. Niederle, J. Tiomno, M. Novello, C.G. de Oliveira and I. Damiao Soares. This work has been partially supported by CNPq of Brazil.

$$ds^2 = dt^2 - 2A(t) dz dt - C^2(t)(dx^2 + dy^2). \quad (17)$$

We have for the non-vanishing element $g_{00} = 1$, $g_{11} = g_{22} = -C^2$, $g_{03} = g_{30} = -A$, $g_{03}^3 = -A^{-1}$, $g_{11}^{11} = g_{22}^{22} = -C^{-2}$ and $\sqrt{-g} = AC^2$. A set of tetrad fields is found with the non-vanishing elements given by

$$e_0^{(0)} = 1, e_1^{(1)} = e_2^{(2)} = C, e_3^{(3)} = e_3^{(0)} = -A,$$

$$e_0^{(0)} = -e_3^{(0)} = 1, e_3^{(3)} = -A^{-1}, e_1^{(1)} = e_2^{(2)} = C^{-1}, \quad (18)$$

where the indices inside the brackets are the anholonomic indices. We also assume, for definiteness' sake, Γ^{λ} to be Christoffel connections, $\Gamma_{\mu\nu}^{\lambda} = \left\{ \begin{smallmatrix} \lambda \\ \mu\nu \end{smallmatrix} \right\}$. The internal spin connections determined from $e_{\mu}^{\lambda}(\Gamma^{\lambda}) \omega_{\lambda} = 0$ are antisymmetric and found to be $(\omega_{\lambda}^{\lambda} \equiv \omega_{\lambda}^{\lambda})$

$$\dot{\omega}_3 = 0, \dot{\omega}_1 = \dot{C} \begin{pmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & -1 \\ 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix}, \dot{\omega}_2 = \dot{C} \begin{pmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & -1 \\ 0 & 0 & 1 & 0 \end{pmatrix},$$

$$\dot{\omega}_0 = \dot{A} A^{-1} \begin{pmatrix} 0 & 0 & 0 & -1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 \end{pmatrix}, \quad \dot{\omega}_1 \dot{\omega}_2 = \dot{\omega}_2 \dot{\omega}_1 = 0. \quad (19)$$

A traceless symmetric solution is found to be $a(t) = A^2 M$ where the non-vanishing elements of M are $M_0^0 = +M_3^3 = -M_3^0 = -M_0^3 = -1$. Since ω_{λ} are antisymmetric this cannot correspond to the case of a gauge copy. We find

$$\bar{r}_{\nu\lambda}^{\mu} = \left\{ \nu_{\lambda}^{\mu} \right\} + A(\partial_{\lambda} x) \delta_3^{\mu} \delta_{\nu}^0$$

$$g_{\mu\nu;\lambda}(\bar{r}) = 2A^2(\partial_{\lambda} x) \delta_{\mu}^0 \delta_{\nu}^0 \quad (20)$$

REFERENCES

- 1) C.N. Yang and R. Mills, Phys. Rev. 96, 191 (1954).
- 2) G. 't Hooft in Deeper Pathways in High Energy Physics, Eds. A. Perlmutter and L.F. Scott (Plenum Press, N.Y. 1977);
R. Jackiw, C. Nohl and C. Rebbi, Phys. Rev. D15, 1642 (1977).
- 3) P.P. Srivastava, Phys. Rev. D17, 1613 (1978).
- 4) T.T. Wu and C.N. Yang, Phys. Rev. D12, 3845 (1975); D13, 437 (1976).
- 5) P.A.M. Dirac, Proc. Roy. Soc. A133, 60 (1931); Phys. Rev. 74, 815 (1948).
- 6) S. Deser and F. Wilczek, Phys. Letters 55B, 391 (1976);
S. Roskies, Phys. Rev. D15, 1731 (1977);
M. Calvo, Phys. Rev. D15, 1733 (1977);
M.B. Halpern, Phys. Rev. D15, 1798 (1977); D19, 517 (1979);
C.G. Bollini, J.J. Giambiagi and J. Tiomno, Phys. Letters 83B, 185 (1979).
- 7) F.W. Hehl, E.A. Lord and L.L. Smalley, Gen Rel. Grav. 13, 1037 (1981)
and references cited therein.
- 8) See for example, F.W. Hehl in Cosmology and Gravitation, Eds.
P.G. Bergmann and V. De Sabbata (Plenum Press, N.Y. 1980) and the
earlier references contained therein.
- 9) J.A. Schouten, Ricci Calculus (Springer, Berlin-Heidelberg, N.Y. 1954);
See also E.A. Lord, Phys. Lett. 65A, 1 (1978).
- 10) See for example, M. Novello and I. Damião Soares, Phys. Lett. 56A,
431 (1976).

IC/82/63	N.S. CRAIGIE, V.K. DOBREV and I.T. TODOROV - Conformal techniques for OPE in asymptotically free quantum field theory.
IC/82/64	A. FRYDRYSZAK and J. LUKIERSKI - $N = 2$ massive matter multiplet from quantization of extended classical mechanics.
IC/82/65	TAHIR ABBAS - Study of the atomic ordering in the alloys Ni-IR using diffuse X-ray scattering and pseudopotentials.
IC/82/66	E.C. NJAU - An analytic examination of distortions in power spectra due to sampling errors.
IC/82/67	E.C. NJAU - Power estimation on sinusoids mounted upon D.C. background: Conditional problems.
IC/82/68	E.C. NJAU - Distortions in power spectra of signals with short components.
IC/82/69	E.C. NJAU - Distortions in two- and three-dimensional power spectra.
IC/82/70	L. SCHWARTZ and A. PAJA - A note on the electrical conductivity of disordered alloys in the muffin-tin model.
IC/82/71	D.G. FAKIROV - Mass and form factor effects in spectrum and width of the semi-leptonic decays of charmed mesons.
IC/82/72	T. MISHONOV and T. SARIISKY - Acoustic plasma waves in inversion layers and sandwich structures.
IC/82/73	T. MISHINOV - An exactly averaged conductivity in a disordered electronic model.
IC/82/74	S.M. MUJIBUR RAHMAN - Structural energetics of noble metals.
IC/82/75	E. SEZGIN and P. van NIEUWENHUIZEN - Ultraviolet finiteness of $N = 8$ supergravity, spontaneously broken by dimensional reduction.
IC/82/76	JERZY RAYSKI and JACEK RAYSKI, Jr. - On a fusion of supersymmetries with gauge theories.
IC/82/77	A. BOKHARI and A. QADIR - A prescription for n-dimensional vierbeins.
IC/82/78	A. QADIR and J. QUAMAR - Relativistic generalization of the Newtonian force.
IC/82/79	B.E. BAAQUIE - Evolution kernel for the Dirac field.
IC/82/80	S. RAJPOOT AND J.G. TAYLOR - Broken supersymmetries in high-energy physics.
IC/82/81	JAE HYUNG YEE - Photon propagators at finite temperature.
IC/82/82	S.M. MUJIBUR RAHMAN - Roles of electrons-per-atom ratio on the structural stability of certain binary alloys.
IC/82/83	D.K. SRIVASTAVA - Geometrical relations for potentials obtained by folding density dependent interactions.
IC/82/84	C.A. MAJID - Glass forming tendencies of chalcogenides of the system $(As_2 Se_3)_{1-x} (Te_2 Se)_x$.
IC/82/85	C.A. MAJID - Surface photoconductivity in amorphous $As_2 Se_3$.

THESE PREPRINTS ARE AVAILABLE FROM THE PUBLICATIONS OFFICE, ICTP, P.O. Box 586, I-34100 TRIESTE, ITALY.

* (Limited distribution).

- IC/82/86 FAHEEM HUSSAIN and A. QADIR - Quantization in rotating co-ordinates revisited.
- IC/82/87 G. MUKHOPADHYAY and S. LUNDQVIST - The dipolar plasmon modes of a small metallic sphere.
- IC/82/88 A.P. BAKULEV, N.N. BOGOLUBOV, Jr. and A.M. KURBATOV - The generalized Mayer theorem in the approximating Hamiltonian method.
- IC/82/89 R.M. MOHAPATRA and G. SENJANOVIC - Spontaneous breaking of global B-L symmetry and matter-anti-matter oscillations in grand unified theories.
- IC/82/90 PRABODH-SHUKLA - A microscopic model of the glass transition and the glassy state.
- IC/82/91 WANG KE-LIN - A new vacuum structure, background strength and confinement.
- IC/82/92 G.A. CHRISTOS - Anomaly extraction from the path integral.
- IC/82/93 V. ALDAYA and J.A. DE AZCARRAGA - Supergroup extensions: from central charges to quantization through relativistic wave equations.
- IC/82/94 ABDUS SALAM and E. SEZGIN - Maximal extended supergravity theory in seven dimensions.
- IC/82/95 G. SENJANOVIC and A. SOKORAC - Observable neutron-antineutron oscillations in SO(10) theory.
- IC/82/96 Li TA-tsein and SHI Jia-hong - Global solvability in the whole space for a class of first order quasilinear hyperbolic systems.
- IC/82/97 Y. FUJIMOTO and ZHAO Zhi Yong - Avoiding domain wall problem in SU(N) grand unified theories.
- IC/82/98 K.G. AKDENIZ, M. ARIK, M. HORTACSU and M.K. PAK - Gauge bosons as composites of fermions.
- IC/82/100 M.H. SAFFOURI - Treatment of Cerenkov radiation from electric and magnetic charges in dispersive and dissipative media.
- IC/82/101 M. OZER - Precocious unification in simple GUTs.
- IC/82/102 A.N. ERMILOV, A.N. KIREV and A.M. KURBATOV - Random spin systems with arbitrary distributions of coupling constants and external fields. Variational approach.
- IC/82/103 K.H. KHANNA - Landau's parameters and thermodynamic properties of liquid He II.
- IC/82/104 H. PUSZKARSKI - Effect of surface parameter on interband surface mode frequencies of finite diatomic chain.
- IC/82/105 S. CECOTTI and L. GIRARDELLO - Local Nicolai mappings in extended supersymmetry.
- IC/82/106 K.G. AKDENIZ, M. ARIK, M. DURGUT, M. HORTACSU, S. KAPTANOGLU and N.K. PAK - Quantization of a conformal invariant pure spinor model.
- IC/82/107 A.M. KURBATOV and D.P. SANKOVIC - On one generalization of the Fokker-Planck equation.
- IC/82/108 G. SENJANOVIC - Necessity of intermediate mass scales in grand unified theories with spontaneously broken CP invariance.
- IC/82/109 NOOR MOHAMMAD - Algebra of pseudo-differential operators over C^* -algebra.
- IC/82/111 M. DURGUT and N.K. PAK - SU(N)-QCD₂ meson equation in next-to-leading order.
- IC/82/112 O.P. KATYAL and K.M. KHANNA - Transverse magneto-resistance and Hall resistivity in Cd and its dilute alloys.
- IC/82/113 P. RACZKA, JR. - On the class of simple solutions of SU(2) Yang-Mills equations.
- IC/82/114 G. LAZARIDES and Q. SHAPI - Supersymmetric GUTs and cosmology.
- IC/82/115 B.K. SHARMA and M. TOMAK - Compton profiles of some 4d transition metals.
- IC/82/116 M.D. MAIA - Mass splitting induced by gravitation.
- IC/82/117 PARTHA GHOSE - An approach to gauge hierarchy in the minimal SU(5) model of grand unification.
- IC/82/118 PARTHA GHOSE - Scalar loops and the Higgs mass in the Salam-Weinberg-Glashow model.
- IC/82/119 A. QADIR - The question of an upper bound on entropy.
- IC/82/122 C.W. LUNG and L.Y. XIONG - The dislocation distribution function in the plastic zone at a crack tip.
- IC/82/124 BAYANI I. RAMIREZ - A view of bond formation in terms of electron momentum distributions.
- IC/82/127 N.N. COHAN and M. WEISMANN - Phonons and amplitudons in one dimensional incommensurate systems.
- IC/82/128 M. TOMAK - The electron ionized donor recombination in semiconductors.
- IC/82/129 S.P. TEWARI - High temperature superconducting of a Chevrel phase ternary compound.
- IC/82/130 LI XINZ HOU, WANG KELIN and ZHANG JIANZU - Light spinor monopole.
- IC/82/131 C.A. MAJID - Thermal analysis of chalcogenides glasses of the system $(As_2 Se_3)_{1-x} (Te_2 Se)_x$.
- IC/82/132 K.M. KHANNA and S. CHAUBA SINGH - Radial distribution function and second virial coefficient for interacting bosons.
- IC/82/133 A. QADIR - Massive neutrinos in astrophysics.
- IC/82/134 H.B. GHASSIB and S. CHATTERJEE - On back flow in two and three dimensions.
- IC/82/137 M.Y.M. HASSAN, A. RABIE and E.H. ISMAIL - Binding energy calculations using the molecular orbital wave function.
- IC/82/138 A. BREZINI - Eigenfunctions in disordered systems near the mobility edge.
- IC/82/140 Y. FUJIMOTO, K. SHIGEMOTO and ZHAO ZHIYONG - No domain wall problem in SU(N) grand unified theory.
- IC/82/142 G.A. CHRISTOS - Trivial solution to the domain wall problem.
- IC/82/143 S. CHAKRABARTI and A.H. NAYYAR - On stability of soliton solution in NLS-type general field model.
- IC/82/144 S. CHAKRABARTI - The stability analysis of non-topological solitons in gauge theory and in electrodynamics.
- IC/82/145 S.N. RAM and C.P. SINGH - Hadronic couplings of open beauty states.
- IC/82/146 BAYANI I. RAMIREZ - Electron momentum distributions of the first-row homonuclear diatomic molecules, A_2 .
- IC/82/147 A.K. MAJUMDAR - Correlation between magnetoresistance and magnetization in Ag Mn and Au Mn spin glasses.
- IC/82/148 E.A. SAAD, S.A. EL WAKIL, M.H. HASSAG and H.M. MACHALI - Pade approximant for Chandrasekhar H function.
- IC/82/149 G.A. EL WAKIL, M.T. ATIA, E.A. SAAD and A. HENDI - Particle transfer in multiregion.