Saturday 4/7/60 — Gokhale Hall — Bull Temple Road, N.T.R. Colony
6.30 P.M

Abstract Algebra Vol 2. } Vol 1, out of print
Linear Algebra } by B.C.C

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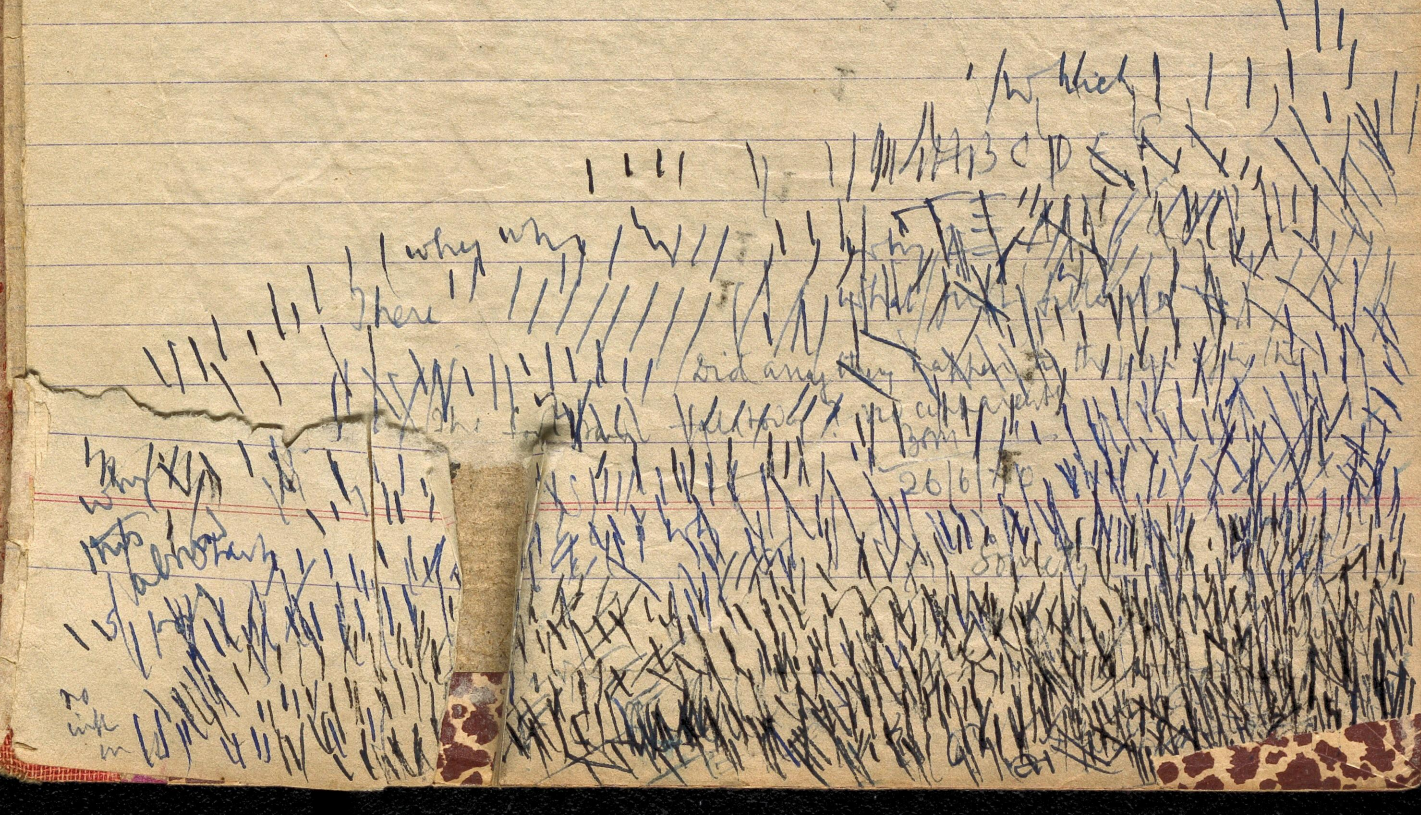
Calcutta-6

Did anything happen?
Luckily no

$$\begin{vmatrix} 1 & 1 \\ 1 & -3 \end{vmatrix}$$

$$\begin{vmatrix} 1-x & 1 \\ 1 & -3-x \end{vmatrix} = 0.$$

$(1-x)(3+x)$
$-x^2-2x+3$
$x^2+2x-3=0$



Waltair — 31/7/70 at 11 A.M.

Leave Waltair at 13.40 hrs on 31/7/70 by 89 - Howrah - Madras Express reach Madras on 1/8/70 at 10.45 A.M. — Waltair to CDM by (115 Madurai - Parcel Passenger) leaving Egmore 22.10 hrs on 1/8

(*) known as superselection rule
Similarly charge conservation is another such rule.

Elementary Particles by W. R. Frazer.

Chap. Preface – No field theory formalism used – Not entered into difficult and lengthy proofs, such as those of dispersion relations, C P T theorem and the connection between spin & Statistics.

Introduction (Ch. I) Quantum numbers; Spin follows from assumption of invariance under rotations; unitary symmetry recently discovered is of more of mysterious origin – I for isotopic spin, ordinary spin labelled by J, and parity P, the less familiar G, C, Y deferred to later chapter – Some table of particles (7 pages) showing for each I, Y, Mass (in MeV), Mean life (in Sec). and principal decay modes – Baryon number B and baryon conservation* ie B is an absolutely conserved additive quantum number ie sum of B's of all particles in initial state of a ~~reaction~~ equals sum of B's in the final state (proton conservation is inappropriate because $n \to p$ in β-decay; also nucleon (N) conservation is inappropriate since one has for eg. $\Sigma^+ \to p + \pi^0$). $B = +1$ for baryons & $= -1$ for their antiparticles. In baryons ~~at least one~~ final decay products include one proton. & $B = 0$ for all other particles

Nucleons & other baryons interact strongly via the nuclear force (by interchange of pions as per Yukawa) just as in electrodynamics the carriers are photons). Hadrons are the strongly interacting particles; A meson is a hadron with $B = 0$. The muon, electron & neutrinos from leptons; they do not participate in strong interactions, but only electromagnetically & weakly.

Quantum electrodynamics (renormalisation theory) – strong interactions not understood quantitatively, because of short range (unlike macroscopic range in electrodynamics). Compton wave length of pion $= \hbar/m_\pi c = 1.41 \times 10^{-13}$ cm, range of force $= \pi\left(\hbar/m_\pi c\right)^2 = 1.63$ mb (mb = millibarn $= 10^{-27}$ cm^2). Cf. $\gamma + N \to \pi + N$ has a cross-section smaller than this by a factor $\alpha = 1/137$ the fine-structure constant. For a typical weak reaction $\nu + n \to p + \mu^-$, the cross-section is 10^{-38} cm^2. Variation in strength of interaction and range of particle life times: 3 groups viz (i) long lived ones (10^{-4} to 10^{-10} Sec) are those decaying via the weak interactions (ii) those decaying via strong interactions have short life times not measurable directly, but only as resonances in reactions for eg $N^*(1238)$ a resonance in pion-nucleon scattering. The ~~not~~ width Γ of the resonance is measured and life time τ & Γ connected by the uncertainty principle as $\Gamma\tau = \hbar$ & thus τ is measured. (iii) Electromagnetic widths are smaller by one or two factors of α, but τ is too short for direct measurement.

Choice of units $\hbar = c = 1$; MeV or BeV (10^9 e.V or GeV in European notation) for

mass, energy, MeV/c = momentum, $1/m_\pi$ = Compton wavelength is in MeV^{-1}, or conveniently using the fermi $= 10^{-13}$ cm.

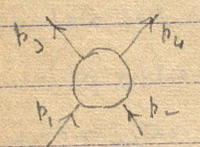
Chapter II - Invariance Principles and quantum numbers.

(1) Relativistic invariance under L.T's a solid foundation ; Lorentz group ; two types (i) rotations $\Lambda = \begin{pmatrix} 1 & 0 \\ 0 & R \end{pmatrix}$, R = 3×3 matrix (ii) with $R^T R = 1$, (ii) pure L.T

$x^{0\prime} = x^0 \cosh u + x^1 \sinh u$, $x^{1\prime} = x^0 \sinh u + x^1 \cosh u$, $x^{2\prime} = x^2$, $x^{3\prime} = x^3$ where $\beta = \frac{v}{c} = \tanh u$ and $\gamma = (1-\beta^2)^{-1/2}$. with $c = \hbar = 1$, $p^0 = E$, $p^i = (\underline{p})_i$; $p_\mu \to i\partial_\mu \equiv i\,\partial/\partial x^\mu$, $\beta = v$.

For a particle at rest, $|\underline{p}| = \gamma m v$, $E = \gamma m$ & hence $v = p/E$.

(2) Relativistic Kinematics of 2-body scattering as eg. of L-invariance



Mandelstam variables s, t, u given by $s = (p_1+p_2)^2$, $t = (p_3-p_1)^2$ $u = (p_4-p_1)^2$ used and simplification obtained by using the C.M. system defined by $\underline{p}_1 + \underline{p}_2 = 0$ (s, t, u are L-covariant or invariant) - Applied to the "associated production" reaction $\pi^- + p \to \Lambda^0 + K^0$

(3) Measurements of elementary particle masses - Exx. of finding masses of π^+, π^- & π^0.

From $\pi^+ \to \mu^+ + \nu$, we get $m_{\pi^+} = p + \sqrt{p^2 + m_\mu^2}$ (assuming $m_\nu = 0$), where p = momentum of μ^+ from π^+ decay at rest. m_μ is known from measurements of its magnetic moments. Hence measuring p gives m_{π^+}. Re m_{π^-} we have $m_{\pi^-} = m_{\pi^+}$ from the CPT theorem. Re m_{π^0} we use reaction $\pi^- + p \to \pi^0 + n$ leading to

$$m_{\pi^-} + m_p = \sqrt{p^2 + m_n^2} + \sqrt{p^2 + m_{\pi^0}^2}$$

where p is the magnitude of momentum of n (or π^0) which can be measured easily. Then taking m_p, m_n & m_{π^-} as known, we get m_{π^0}.

(4) Rotations, spin. - no complete theory yet to derive spin quantum number -

$$R(\hat{\underline{n}}, \theta)|J, m\rangle = \sum_{m'} \mathcal{D}^J_{m'm}(\theta, \hat{\underline{n}})|J, m'\rangle \qquad (\mathcal{D}\text{-matrices})$$

Set of states $|J, m\rangle$ ($2J+1$ in number for given J) is a multiplet or the basis of irreducible representations of the rotation group $R(\hat{\underline{n}}, \theta) = e^{-iH}$ (H unitary ie H is hermitian ie $H = H^+$)* or an elementary system. Spin means an attribute given by existence of an elementary system w.r.t all rotations. - Controversy re. name "elementary particle", a few or a "nuclear democracy" - Rotations are special forms of symmetry operators ie those which leave transition probabilities invariants. only symmetry operators are associated with conservation laws (for eg. rotational symmetry implies conservation of A.M. - No explt. evidence so far found against

(* ie R is unitary) [J = A.M. operator]

this assumption.

(5) Rotational invariance in 2-body collisions; partial wave analysis. — Scattering expts; — Collision of types $A+B \to C+D$ — Instead of using components of spin along z-axes, use of helicity (λ) i.e. component along direction of motion which is invariant under rotations — Case of particle 1 moving along z axis in +ve diren & particle 2 in −ve z-diren leading to

$$\langle p\theta\phi; \lambda_1\lambda_2 \mid JM; \lambda_1'\lambda_2' \rangle = N_J \delta_{\lambda_1\lambda_1'} \delta_{\lambda_2\lambda_2'} \mathcal{D}^{J*}_{M\lambda}(\phi, \theta, -\phi) \quad \text{— (a)}$$

with $|N_J|^2 = (2J+1)/4\pi$. [J Commutes with S] *

Derivation of scattering matrix S (for which $P_{f\leftarrow i} = |\langle f|S|i\rangle|^2$ probability of transition) in the general case

$$\langle p'\theta\phi\lambda_c\lambda_d | \hat{S} | p\theta_0\phi_0\lambda_a\lambda_b \rangle = \sum_{J,M} \frac{2J+1}{4\pi} \mathcal{D}^{J*}_{M\mu}(\phi, \theta, -\phi) \times \langle \lambda_c\lambda_d | S^J(E) | \lambda_a\lambda_b \rangle \mathcal{D}^{J}_{M\lambda}(\phi_0, \theta, -\phi_0)$$

$(\lambda = \lambda_a - \lambda_b,\ \mu = \lambda_c - \lambda_d)$ (b)

where use is made of the relation

$$\langle J'M'\lambda_c\lambda_d \mid S(E) \mid JM\lambda_a\lambda_b \rangle = \delta_{JJ'} \delta_{MM'} \langle \lambda_c\lambda_d \mid S^J(E) \mid \lambda_a\lambda_b \rangle \quad \text{(c)}$$

Derivation of the Jacob-Wicks formula after further simplification; before using this in any practical problem, we must investigate restrictions imposed on the S^J by the unitarity condn, parity invariance and time-reversal invariance — connection between states $|JM; \lambda_1\lambda_2\rangle$ and the customarily employed ones states $|JM; LS\rangle$ formed by adding spins s_1, s_2 to a resultant S, then combining with $\underline{J} = \underline{L} + \underline{S}$. The transformation coefficients are

$\langle JM; LS \mid JM; \lambda_1\lambda_2 \rangle = \left(\frac{2L+1}{2J+1}\right)^{1/2} C(LSJ; 0, \lambda)\, C(s_1 s_2 S; \lambda_1, -\lambda_2)$, where the C's (d) are the Clebsch-Gordan coefficients in the notation of Rose;

$$\langle j_1 j_2 m_1 m_2 \mid j_1 j_2 j m \rangle = C(j_1 j_2 j; m_1 m_2)\, \delta_{m, m_1+m_2} \quad \text{(d')}$$

Derivation of (d) also by Jacob-Wicks [Rotational invariance of collision operator $S \to [R, S] = 0$] *

(6) Parity invariance — Parity valid for strong & e.m. interactions, at least to a very good approximation — Parity operator P leaves spin direction unchanged; thus $P\psi_{\theta\lambda} = \eta\, \psi_{\theta\lambda}$ (η = phase factor ind. of λ) — Evaluation of $P|JM; \lambda_1\lambda_2\rangle$; this $= e^{i\alpha} |JM; -\lambda_1, -\lambda_2\rangle$. Proper specialisation to special case of M & $\theta = \phi = 0$, we find finally

$$P|JM, \lambda_1\lambda_2\rangle = \eta_1\eta_2 (-1)^{J-s_1-s_2} |JM; -\lambda_1, -\lambda_2| \quad \text{(a)}$$

If parity is conserved $\langle f|S|i\rangle = \langle f|P^{-1}SP|i\rangle$ (b)

Applying this to the S matrix in the $JM; \lambda_1\lambda_2$ rep^{n}, we have

$$(-\lambda_c, -\lambda_d | S^J | -\lambda_a, -\lambda_b) = \eta_g \langle \lambda_c\lambda_d | S^J | \lambda_a\lambda_b \rangle \quad \text{(c)}$$

where $\eta_g = (\eta_c\eta_d\eta_a\eta_b)(-1)^{s_c+s_a-s_a-s_b}$ (c')

η_c — are the intrinsic parities of particles A, B, C, D taken equal to ± 1 — In the $JM; LS$ representation ($\underline{S} = s_1 + s_2$, not to be confused with the collision operator S. This

is an unfortunate wrong mixing up of notations in Frazer's book) using (a) and (d') of (5), and the symmetries of the Clebsch-Gordan coefficients, we get

$$P\,|JM;LS\rangle = \eta_1\eta_2\,(-1)^L\,|JM;LS\rangle \qquad --(d)$$

which is more convenient than (a). Using (d) and parity conservation, we have finally

$$\langle JML'S'|S|JMLS\rangle = \langle JML'S'|P^{-1}SP|JMLS\rangle$$
$$= (-1)^{L'-L}\eta_c\eta_d\eta_a\eta_b\langle JML'S'|S|JMLS\rangle \qquad (e)$$

Hence the S-matrix element must vanish unless

$$\eta_c\eta_d\eta_a\eta_b(-1)^{L'-L} = 1 \qquad (e')$$

for eg, if there is no change in intrinsic parities ($\eta_a\eta_b = \eta_c\eta_d$), then

$$\eta_a^2\eta_b^2(-1)^{L'-L} = 1$$

ie L and L' must be both even or both odd.

(7) Time-Reversal – Expt of Cronin-Fitch implying a small violation in weak interactions & no other expts for other interactions. Time reversal reverses both momenta & spins, thus leaving helicities unchanged ($\lambda = \underline{p}\cdot\underline{S}$) and time reversal relates $\langle f|S|i\rangle$ to $\langle i^T|S|f^T\rangle$ {($\langle f|S|i\rangle)^2$ = transition probability from initial to final state & this is reversed to final to initial}. Hence

$$\langle\lambda_c\lambda_d|S^J|\lambda_a\lambda_b\rangle = \langle\lambda_a\lambda_b|S^J|\lambda_c\lambda_d\rangle$$

with phase factor unity. Proof in Jacobi & Wick.

(8) Detailed balancing; spin of the charged pion. – use of time reversal to evaluate cross-sections for $A+B\to C+D$ and $C+D\to A+B$ is called principle of detailed balancy, and applied to the reactions

$$\pi^+ + D \rightleftarrows p + p \qquad \{D = \text{deuteron} = {}_1H^2 (\underline{p} \& \underline{n} \text{ in nucleus}\}$$

leads to $S_\pi = 0$.

(9) Massless particles – Jacob-Wick formalism is available here also, if we remember that for $m = 0$, the only possible states of polarisation are $\lambda = \pm s$. For the neutrino only $\lambda = -s$ is realised in nature. Proof of $\lambda = \pm s$ being generally valid for massless particles given by Wigner. For photon it is customary to take/define the $\lambda = \pm 1$ states as having a vector potential –

(10) Identical particles; Spin and parity of π^0. In (8) we have seen $S_\pi = 0$. The notion of isotopic spin that π^+, π^0, π^- are different charge states of the same multiplet suggests same spin and parity for all the three ie $S_{\pi^+} = S_{\pi^0} = S_{\pi^-} = 0$ – It can however be shown directly that $S_{\pi^0} = 0$ by using the decay mode $\pi^0 \to 2\gamma$, finding the permitted states $|JM;\lambda_1\lambda_2\rangle$ when A and B are identical particles & using the

* (using that the parity factor η_γ for photon $= -1$)

connection between spin & statistics, and analysing the two photon states*, we can deduce $s_{\pi^0} = 0$ or ≥ 2, and the second possibility is discarded (& yet to be proved theoretically, for nature permits higher spins. Next to find parity of π^0, the rare decay process $\pi^0 \to 2e^- + 2e^+$ was observed and it was found that the pion is pseudoscalar ie $P = -1$. Using customary notation J^P for spin & parity, the neutral pion is therefore 0^-. (cont

(11) Spin and parity of π^0: The tensor method – This latter method applicable for more complicated cases for eg decay into three or four particles for which the Jacob-Wick method for 2-body reactions becomes very involved – Explanation of the alternative tensor method illustrated by using the same decay $\pi^0 \to 2\gamma$ used in (10) and showing that the same results are obtained

(12) Parity of the charged pion – This is obtained by using the reaction

$$\pi^- + d \to n + n \qquad (d = \text{deuteron})$$

Analysing the two neutron states, just as for two photon states in (10), we have, however, the difference here that we cannot use the convention like $\eta_\gamma = -1$ since a nucleon cannot decay into two photons. Hence we use the convention $\eta_p = 1$. Next from notion of isotopic spin (charge independence of nuclear forces leads to notion of isotopic spin) we set $\eta_n = \eta_p = 1$. Using these and the analysis of $\pi^- + d \to n + n$, we deduce that the parity of π^- is odd. on the basis of charge conjugation invariance we conclude that parity of π^+ is also odd.

(13) Unitarity of the S matrix – Using notion of probability amplitudes & $\langle i | S^\dagger S | i \rangle = 1$, we can deduce $SS^\dagger = S^\dagger S = 1$ ie the unitary condition playing a fundamental role in the S-matrix theory – discussion, using this, the case in which the elastic scattering $A + B \to A + B$ is the only allowed process.

(14) Isotopic spin – I – n & p are identical w.r.t nuclear forces which are greater than e.m. interactions in a ratio $\simeq \alpha$ ($1/137$); note n & p however differ w.r.t e.m. interactions. Thus there is an approximate symmetry between n & p – p & n form a doublet in the I-spin space (formal) sense ie a spinor & $\frac{1}{2}$ is $\begin{pmatrix} p \\ n \end{pmatrix} \to \begin{pmatrix} p' \\ n' \end{pmatrix} = e^{i \underline{\tau} \cdot \hat{\underline{n}} \theta/2} \begin{pmatrix} p \\ n \end{pmatrix}$ (a)

where τ_i are the usual hermitian traceless ~~hermitian~~ Pauli matrices. (a) comes under general form of rotation operator in (4) – Alternatively, symmetry of n, p w.r.t strong interactions can be stated in the form that the strong interactions should be invariant under a unitary transformation of the p-n doublet

$$\begin{pmatrix} p' \\ n' \end{pmatrix} = Q \begin{pmatrix} p \\ n \end{pmatrix}$$

$\left[\begin{pmatrix} p \\ n \end{pmatrix} \text{ is a spinor} \right]$

where Q is a unitary matrix. The most general such matrix (as derived by Goldstein) is

$$Q = e^{i\varphi}\begin{pmatrix} \alpha & \beta \\ -\beta^* & \alpha^* \end{pmatrix} \qquad (6)$$

with the constrtn $|\alpha|^2 + |\beta|^2 = 1$. The phase factor $e^{i\varphi}$ being irrelevant, the condition of unimodularity is imposed ie $\det Q \equiv |Q| = 1$. Thus (b) is equivalent to (a) since it is easy to show that $\exp(i\underline{\tau}\cdot\hat{n}\theta/2)$ is unitary & unimodular. This unitary unimodular transformation (on two objects) form a group called SU(2), an abbreviation for Special Unitary group in 2 dimensions & this group bears a very close relation to the rotation group. Technically, it is isomorphic to the rotation group in three dimensions – Later a "higher symmetry" SU(3) of the strong interactions will be discussed later – Going back to I-spin, we know from rotation theory that corresponding to a quantum number I (integral or half-integral) there are $2I+1$ multiplets. Thus for the pion-triplet we assign $I = 1$, and $I = \frac{1}{2}$ for the nucleon-doublet.

(15) Charge Conjugation; G parity – C is symmetrical in quantum electrodynamics since laws of motion are independent of C. Pion weak interactions are not invariant under C, but strong interactions are.

C appears as a quantum number for certain particles with $B = 0$ & charge 0. For eg: $C|\gamma\rangle = -|\gamma\rangle$, since C changes sign of charges forming sources of the e-m field. Similarly $C|\pi^0\rangle = +|\pi^0\rangle$ because $\pi^0 \to 2\gamma$. C as a quantum number exists only for neutral particles for eg $C|\pi^+\rangle \propto |\pi^-\rangle$. Such C has no meaning as a quant. no. for a state $B \neq 0$ – Lee & Yang's extension of C by combining it with a rotation by π about the y-axis in I-spin space. The combined operation is denoted by G:

$$G = e^{-i\pi I_2} C$$

& G is conserved if C and I are conserved – We have $G|\pi^{0,\pm}\rangle = -|\pi^{0,\pm}\rangle$. Also

$G|n\pi\rangle = (-1)^n |n\pi\rangle$ – other simple deductions of G-parity viz if initial state of a reaction consists of n_1 pions and final state of n_2 pions, then $n_1 + n_2 =$ even number. The G-parity quantum number also applies to other "non-strange" mesons.

Chapter III – Pion-nucleon scattering (N = nucleon) – $\pi\pi$ scattering expts. still

seem to be far in the future; NN scattering has given much information about nuclear forces, but their analysis is exceedingly complicated; hence πN scattering is chosen here. This was an important proving ground for testing the I-spin hypothesis, and also of the S-matrix theory of the strong interaction.

* $1-\frac{1}{2}$ or $1+\frac{1}{2}$ ($I=1$ for π & $I=\frac{1}{2}$ for N)

(1) Phase-shift analysis of πN scattering – use of the Jacob-Wick formalism – Mentions also the Minami ambiguity – considers the elastic $\pi + N \to \pi + N$

(2) Isotopic spin analysis of πN scattering. – The charge-independence hypothesis or invariance under rotations in I-spin space implies that there are only two independent amplitudes which describe the scattering in all the charge states of πN scattering. These are the $I = \frac{1}{2}$ and $\frac{3}{2}$ amplitudes*. Consider the process $\pi^- p \to \pi^0 n$ or $\langle \pi^- p | f | \pi^- p \rangle$. Using the fact $\langle \pi^- p | I \rangle$ are just the usual Clebsch-Gordon coefficients, one finds

$$\langle \pi^- p | f | \pi^- p \rangle = \frac{1}{3}(2 f_{1/2} + f_{3/2})$$

& similarly $\langle \pi^0 n | f | \pi^- p \rangle = \sqrt{2}/3 \,(-f_{1/2} + f_{3/2})$

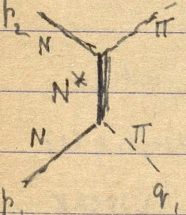
$$\langle \pi^+ p | f | \pi^+ p \rangle = f_{3/2}$$

These are the only three measurable reactions.

$\sigma_T(\pi^- p) = \sum_n |\langle n | f | \pi^- p \rangle|^2$ & defining $\sigma_T(I) = \sum_n |\langle n | f | I \rangle|^2$

we find $\sigma_T(\pi^+ p) = \sigma_T^{(3/2)}$, $\sigma_T(\pi^- p) = \frac{2}{3}\sigma_T^{(1/2)} + \frac{1}{3}\sigma_T^{(3/2)}$

(3) Prominent feature of the scattering data – Fig. showing total cross-sections for π^+ & π^- on protons up to 400 MeV (σ_T in mb plotted again T_L in MeV) – The unstable state in πN scattering has gone by a variety of names: the (3,3) resonance, the "nucleon isobar", the "excited state of the nucleon, the "N^*" and the Δ. The latter two names are currently in fashion among physicists as they have taken to calling resonances as unstable particles. In dynamics of strong interactions stable & unstable particles appear on an equal footing – diagram representing πN scattering via an N^* resonant state – N^* can be considered a peak in the cross-section as an unstable particle only if it has defined quantum numbers. For eg from the last rules of (3) we get isospin for $N^* = 3/2$ & noting the total cross-sections for $\pi^- p$ & $\pi^+ p$ scatterings should be in the ratio 1 : 3 (verified in the diagram for 400 MeV mentioned above.



(4) πN scattering at higher energies – up to 200 MeV, N^* was discovered & at higher energies there were heaps of resonances, nearly 200 in number, called excited states or levels

(5) Polarisation measurements – Consider longitudinal polarisation (as simplest case ie) of the outgoing nucleon ie the difference between the number of nucleons emerging with $+^{ve}$ versus $-^{ve}$ helicity (at a given angle). This number is given by

$$\frac{1}{2}\sum_\lambda \left\{ |f_{+\lambda}|^2 - |f_{-\lambda}|^2 \right\}$$

& since a parity transformation changes $+^{ve}$ helicity into $-^{ve}$ helicity (spin direction is unchanged by ?)

the above expn is zero ie parity invariance forbids longitudinal polarisation — other polarisation measurements yield independent information about which partial waves are contributing to a given process, and this leads to measurements of spins and parities in 2-body reactions.

Chapter IV — K-Mesons and Hyperons.

(1) Empirical facts; Discovery — V-track in cloud chamber expts leading to nickname as "V-particles". In current notation the two types of particles involved were

$$[K^0(?)] \quad K_0 \to \pi^+ + \pi^- \quad \text{and} \quad \Lambda \to p + \pi^- \qquad (\Lambda \text{ a baryon}) \qquad (a), (a')$$

Masses of K_0 & Λ were determined from the kinematics of the decay & life times were found to be $\sim 10^{-10}$ Sec (long-lived upper range). Accelerators producing these new particles & then for eg Σ^+, Σ^- & Σ^0 · mass differences of ~~pions~~ within 5 MeV (thus members of a multiplet). The charged K's were found as well as Ξ^- or "cascade" particle, so named because of its cascade decay viz $\Xi^- \to \Lambda^0 + \pi^-$ (b), with $\Lambda^0 \hookrightarrow p + \pi^-$

These particles were found behaving in a puzzling manner & were dubbed "strange" particles. No more strange than the so-called "non-strange" particles for eg. π — nature of the strange behaviour in terms of cross-sections & life times cf. strong interactions (Eg. lifetime of N^* is $\sim 10^{-23}$ sec)

(2) Associated production; Strangeness:

~~Other~~ Observance of $\pi^- + p \longrightarrow \Lambda^0 + K^0$ (c)

$\pi^- + p \longrightarrow \Sigma^- + K^+$ (d)

and non-observance of $p + n \to p + \Lambda$, led Pais (1952) to predict that strange particles are "associated" in pairs in production via strong interactions. The first two examples of (1) above are examples of weak interactions (10^{-10} sec) ie strange particles are decay via the weak interaction — Some more dilemma not completely solved since the decay $\Xi^- \to \pi^- + \Lambda$ — (e) is a weak interaction, although two particles are involved. Thus the rule appears ad hoc.

Interpretation of Gell-mann & Nishijima (independently) by assuming I-spin conservation ~~for ever~~ for these reactions (with I-spin properly assigned to these particles). For the hyperons (strange baryons): No counterpart of Λ has been observed & hence $I(\Lambda) = 0$. The Σ^+, Σ^- & Σ^0 have all been observed & so $I = 1$. From (c) above I-spin of d.H.S $= \frac{1}{2}$ or $3/2$ & since $I(\Lambda) = 0$, we have $I(K) = \frac{1}{2}$ or $3/2$. The latter would require a K^{++} (not observed, there being only K^+, K^-, K^0 and $\bar{K}^0$) & hence $I(K) = 1/2$. The same follows from (d) & taken with (c) it follows that (K^+, K^0) form a doublet & hence so do must $(\bar{K}^0, K^-)$. Thus

$\bar{K}_0$ is not the same as K_0 unlike π^0 which is its own anti-particle. This situation leads to strange & wonderful consequences – Again (a) is forbidden via strong interactions since a particle of $I = 1/2$ cannot decay into two $I = 1$ particles (Note – It should have been mentioned explicitly that isospin conservation does not hold for weak interactions) These selection rules can be conveniently summarised by introducing

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R(VII)171-Misc./70 13 Feb., 1970.

Dear Sir,

Please indicate the name of the Scheme/s (C.S.I.R., I.C.M.R., D.A.E., N.R.D.C., C.B.I.P., Defence Research, Private etc.,) which will be continued during 1970-1971. This information is required to prepare the pay bills of the Staff Members working in the Scheme/s. On your advice the Director's approval will be taken to prepare and pay the salaries for March, 1970, in anticipation of the continuation of the Scheme/s on the basis of the indications given by you.

Yours faithfully,

REGISTRAR

Head of the Dept. of Inorganic & Physical Chemistry
Head of the Dept. of Organic Chemistry
Head of the Dept. of Biochemistry
Head of the Dept. of Physics
Head of the Dept. of Applied Mathematics
Professor-in-charge: Microbiology & Pharamacology Lab.,
Head of the Dept of Aeronautical Engineering
Head of the Department of Metallurgy
Head of the Dept of Electrical Engineering
Head of the Dept of Civil & Hydraulic Engineering
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The Librarian
Central
Professor-in-charge, Central Instruments & Services Lab.,

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Chitra Prantas, Lunch [illegible]

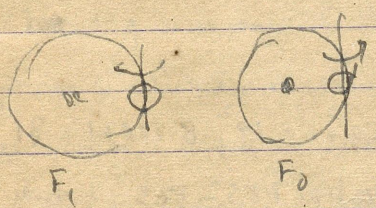
Writing something as usual.

Institute (4/3/70)

Science – 7/11/69 – p. 695 – Some mathematical models in Science by Mark Kac – Models of (1) Hemoglobin (2) An adapting automaton (3) Does ~~not~~ entropy never decrease (4) Condensation in a one-dimensional world.

(6/3/70) – Sc. American 1968 – one issue on light specially lasers (light amplification stimulated by emission of radiation) giving monochromatic coherent light waves – mentions use in Raman effect.

Am. Scientist, 1968 – Maser (Microwave amplification stimulated by emission of radiation i.e. in H-atom falling from state of F_1 to F_0 by use of radiation itself emits radiation which amplifies the radiation used.



(9/3/70) (1) Review of Dirac's lectures on "Quantum field Theory", Academic Press New York, 1966 (151 pp) @ $7.50! by R. L. Ingraham in Amer. Math. Monthly, October, 1969, p. 421 – Not quite a favourable review. – ~~Last paragraph~~ Dirac's lectures given at the Belfer Graduate School of Science. Last paragraph of the review: – "His conviction that field theory must make a choice between yielding finite, sensible numbers ("be a logical theory" as he puts it) and Lorentz invariance (to repeat: prefer no inertial frame over another) is clearly expressed. This pessimistic prejudice is very widely shared today, and goes so deep as effectively preclude further thinking on this vital question. In this reviewer's opinion, it is extremely unfortunate for physics that this view, that a physical cut-off and Lorentz invariance are incompatible, so pernicious because it poses false and desperate alternatives, is allowed to go unexamined and unchallenged. It has, in fact, been demonstrated to be false within the last five years, but these ideas have not yet found their way into ~~currency~~ currency nor been subjected to experimental check."

(2) Quart. J. Math., Oxford, Vol. 20, No. 78, June 69

p. 129: The eqns $3x^2 - 2 = y^2$ and $8x^2 - 7 = z^2$ by A. Baker & H. Davenport. The four numbers 1, 3, 8, 120 have the property that the product of any two, increased by 1 is a perfect square. J. H. van Lint discussed the problem whether

there is any other +ve integer than can replace 120. He also ~~xxxx~~ gave a proof that there is no such integer up to $10^{1780000}$.

An integer N which can replace 120 while preserving the property must have the form $N = x^2 - 1$, and the conditions are equivalent to the two equations

$$3x^2 - 2 = y^2, \quad 8x^2 - 7 = z^2$$

Thus the question is whether these simultaneous equations have any solution in positive integers other than the soln with $x = 1$ (corresponding to $N = 0$) and $x = 11$ (corresponding to $N = 120$). The object of the present note is to prove that there is no other solution.

Longish proof, not at all elegant

[1, 3, 8, 120

$1 \cdot 3 + 1 = 2^2$; $1 \cdot 8 + 1 = 3^2$; $1 \cdot 120 + 1 = 11^2$; $3 \cdot 8 + 1 = 5^2$, $3 \cdot 120 + 1 = 19^2$, $8 \cdot 120 + 1 = 31^2$]

(3) Pacific Journal of Maths – Vol 30, No. 3, Sept. 1969 – pp. 785–803 – Article on "Some renewal theorems concerning a sequence of correlated random variables" by G. Sankaranarayanan & C. Suyambulingom (Annamalai Univ)

(4) Quart J. App. Maths. Vol 27, July 1969 (No. 2), p. 278 – A note on "Decay of the kinetic energy of micropolar incompressible fluids"

(5) Math. Gazette, October 69 – Presidential address on "Liking mathematics" by C. A. Coulson – p. 232. mentions "It was an applied mathematician (or should I say a "natural philosopher"?) Max Born who wrote "I shall never forget the thrill which I experienced when I succeeded in condensing Heisenberg's ideas on quantum conditions in the mysterious equation

$$pq - qp = h/2\pi i$$

which is the centre of the new mechanics and was later found to imply the uncertainty relations"

11/3/70 Physical Review Letters 6/10/69, p. 814

(1) Regge residues in the Veneziano model by Corella Jones & H. W. Wyld Jr (Illinois) – Appears difficult, but may be understood if seriously attempted

(2) Ibid – 20/10/69., p. 843

Spin & Parity analysis of the $\pi\rho$ system produced via a double-Regge mechanism in the reaction $\pi N \to \rho\pi N$ by Froggatt & Ramft (Univ. Coll. London)

(Contd. on p. 7)

Notes from Invariance Principles & Elementary Particles by J. J. Sakurai.

(1) Historical order of fundamental interactions

(a) Gravitational (b) E.m, (c) Weak (d) Strong.

Coupling constants (dimensionless) for (a) viz gravitational repulsion (?) between two protons is $G^2 m_p^2/\hbar c = 2 \times 10^{-39}$; Feynman's ex. of Bohr radius of two π's held by gravitational interaction only would be 10^8 light years; hence (a) neglected.

(b) Characterised by fine structure constant $1/137 \simeq 10^{-2}$

(c) of order 10^{-14} to 10^{-7}.

(d) of order unity.

(2) (c) & (d) of short range of order a few Fermi; energies required to study interactions at this short range of order of 10^2 MeV – No classical analogy for nuclear forces and β-decay – Wigner's remarks re. invariance principles " We may well derive the laws of nature and try to test their validity by means of the laws of invariance, rather than to try to derive the laws of invariance from what we believe to be the laws of nature – Invariance or symmetry considerations playing a fundamental role.

(3) Table for validity of invariance principles.

Conserved quantities	Strong	e.m	Weak
Parity (Space inversion)	yes	yes	no
Charge conjugation	yes	yes	no
Time reversal	yes	yes	? yes
Electric charge	yes	yes	yes
Baryon no.	yes	yes	yes
Isospin	yes	no	no
Strangeness	yes	yes	no

(4) Table of Elementary particles. (Life times $> 10^{-16}$ sec)

	Particle	Spin	Mass (in MeV)	Mean life (sec)
Photon	γ	1	0	Stable
Leptons	ν_e ($\bar{\nu}_e$)	1/2	0 (< 0.2 KeV)	Stable
	ν_μ ($\bar{\nu}_\mu$)	1/2	0 (< 4 MeV)	Stable
	e^- (e^+)	1/2	~ 0.511	Stable
	μ^- (μ^+)	1/2	~ 105.659	$\sim 2.2 \times 10^{-6}$

Mesons	$\pi^{\pm}$	0	139.58 / 135.659	2.551×10^{-8}
	π^0 (π^0)	0	134.97	1.78×10^{-16}
	$K^{\pm}$	0	493.78	1.23×10^{-8}
	K^0, $\bar{K}_0$	"	497.7	50% $\simeq 10^{-10}$
	K_1	"	"	0.91×10^{-10}
	K_2	"	"	5.7×10^{-8}
Baryons	p^+ (p^-)	1/2	938.2	Stable
	n ($\bar{n}$)	"	939.5	1.0×10^{3}
	Λ^0 ($\bar{\Lambda}^0$)	"	1115.5	2.6×10^{-10}
	Σ^+	"	1189.4	0.8×10^{-10}
	Σ^-	"	1192.3	1.6×10^{-10}
	Σ^0 ($\bar{\Sigma}^0$)	"	1197.2	$< 1 \times 10^{-14}$
	Ξ^0 ($\bar{\Xi}^0$)	1/2 (?)	1314.3	3.05×10^{-10}
	Ξ^-	"	1320.8	1.75×10^{-10}
	Ω^-	3/2 (?)	1675	1.3×10^{-10}

Λ, Σ Ξ & Ω^- called hyperons (Baryons = nucleons + Hyperons)

• Baryons + mesons = Hadrons.

Chirality = $\gamma_5 = \gamma_1 \gamma_2 \gamma_3 \gamma_4$ (γ's being Dirac matrices).

(5) Lists of some interactions

(a) Strong:

$$p + n \rightarrow p + n$$

$$\pi^- + p \rightarrow \pi^0 + n$$

$$p + n \rightarrow \Lambda^0 + n + K^+$$ (associated production viz that a strange particle is created only in association with another strange particle)

$$K^- + p \rightarrow \Sigma^+ + \pi^-$$

$$p + \bar{p} \rightarrow \Lambda^0 + \bar{\Lambda}^0$$

(b) Electromagnetic combined with strong

$$\gamma + p \rightarrow \pi^0 + p$$ (photopion production)

$$\pi^- + p \rightarrow n + \gamma$$ (radiative capture of π^-)

$$\gamma + p \rightarrow \Lambda^0 + K^0$$ (associated photoproduction)

$$\pi^0 \rightarrow 2\gamma$$

$$\Sigma^0 \rightarrow \Lambda^0 + \gamma$$

(c) Weak interactions

$\mu^+ \rightarrow e^+ + \nu + \bar{\nu}$ (what ν ?)

$n \rightarrow p + e^- + \bar{\nu}_e$ (Beta decay)

$\mu^- + p \rightarrow n + \nu_e$ (muon capture)

$K^+ \rightarrow \pi^+ + \pi^0$

$\Sigma^+ \rightarrow p + \pi^0$

(A)

Nuclear Physics by Hans von Buttlar (mentain muon capture by nuclei)

p. 203 — Conservation of exchange symmetry; Pauli Principle

Hamiltonian $H = H(1, 2, 3, \ldots N)$ (Coordinates of N particles)

Let P_{ik} be operator exchanging two (identical) particles

$$P_{ik} H(1, 2, \ldots i, \ldots k, \ldots N)$$
$$= H(1, 2, \ldots k, \ldots i, \ldots N) = H(1, 2 \ldots i, \ldots k, N)$$

i.e. $P_{ik} H - H P_{ik} = 0$ (P_{ik} commutes with H)

Thus $P_{ik}\psi$ & ψ describe same physical state & can at most differ by a constant factor i.e. $P_{ik}\psi = \lambda\psi$

$$P_{ik}^2 \psi = \lambda P_{ik}\psi = \lambda^2 \psi \text{ & since } P_{ik}^2 = 1$$

$\lambda^2 \psi = \psi$, $\lambda = +1$ (symmetry

$= -1$ (antisymmetry)

Exptl. result is re. spins of fermions & bosons.

Pauli's Principle — In a system of identical fermions, the probability of finding two particles having an identical set of eigenvalues is zero.

[pn-interactions, muonic atoms, photonuclear reactions, spontaneous nuclear decay (α-decay, γ-decay, β-decay); cross-sections for nuclear reactions, nuclear spins & nuclear moments, nuclear models]

Book on Theoretical nuclear Physics by Blatt & Weisskopff — Nuclear spectroscopy (General theory and special models) — Nuclear reactions (General theory & its applns to expts) — Formal theory of nuclear reactions (S-matrix, conservation & reciprocity theorem, parity conservation, Spontaneous decay of nuclei, interaction of nuclei with e.m. radiation, β-decay; nuclear shell structure (magic numbers : We obtain specially stable nuclei when either the no. of protons Z or the number of neutrons $N = A - Z$ is equal to one of the following numbers viz 2, 8, 14, 20, 28, 50, 82, 126 (magic nos.))

Book on nuclear independent particle model by Green, Sawada & Sanon (1968)

This IPM of the nucleus represents only one facet of nuclear Physics – This makes closer the the relation between nuclear Physics & elementary particle physics

Good features of the IPM model, realistic shell models, Realistic optical models, Recent phenomenological studies, Theoretical basis for IPM model (N–N interaction, N–N one boson exchange potentials)

(B) Solid State Physics

(1) Book on the principles of the theory of solids by J. M. Ziman (Bristol, C.U.P, 65)

Preface – Physics may almost be defined as the intellectual exercise of subsuming the universe to mathematics. (Book about perfect crystalline solids)

Periodic structures, Lattice waves, Electron states (several models), Static properties of solids (Uses Fermi statistics for electrons), Electron–Electron interaction, Dynamics of electrons, transport properties, optical properties, Fermi surface, Magnetism, Super-conductivity (also semi-conductors).

(2) Intro to solid state physics by H. Clark (1968)

one-electron approximation, free-electron model, crystal symmetry, lattice vibrations, Electron transport phenomena, cohesion

(3) 9th Session of the Latin American School of Physics (W. A. Benjamin, 1968) – on Solid State Physics, nuclear Physics and Particle Physics

Part I – Particle Physics – 8 papers

Part II – Nuclear Physics – (i) Some problems in fast neutron physics

Part III – Solid State Physics – (i) Electrodynamics of solids, (ii) The electronic structure and optical properties of insulators, (iii) Electronic optical properties of solids, (iv) measurement of $\hbar \cdot s \cdot c$, $e/\hbar c \simeq 1/137$, (v) Heisenberg models of magnetism.

(C) Spectroscopy

(1) Spectroscopy & structure by R. N. Dixon (Dept of Chemistry, Sheffield, 1965)

Atomic spectra & Atomic Structure, Rotational Spectra, Vibration-rotation spectra of diatomic molecules, Vibrational spectra of polyatomic molecules, Electronic Spectra of diatomic molecules, Do of polyatomic, magnetic resonance

(ii) No of other books on atomic spectroscopy – Plasma Spectroscopy.

(D) Electronics (Electrons) – Heaps of books on all kinds of topics (lasers?)

Physics (D) – plasma?

– Saw a book on Solid state Electronics combining (B) and (D).

E8 P3

Slater's classic on Quantum Theory of matter.

(3) Explosive plasma instabilities by J. Fukai, S. Krishnan & E. G. Harris – The Univ. of Tennessee, Knoxville, Tennessee, 37916 (Is this Ananda University).

(4) Ibid – 27/10/69, p. 987

Lepton ~~non-~~ Conservation and the early universe by Ludwig Oster (Colarado)

Abstract – It is pointed out that the existence of a neutrinoless β-decay process would provide a basis for the customary assumption that the number of neutrinos and antineutrinos is equal in the universe.

✓ III – must be read carefully & if possible the converse proved

Read in the library below a book by "Roy & Reed" on some ideas about lepton conservation, where a reference is given to Kallen's book.*

(5) Ibid, p. 998

Are Regge trajectories straight lines? by Kelemen, K. Y. Lee & Pick (Indiana)

[* Chap. 12 of Roy & Reed's book "Interaction of photons & leptons with matter" p. 252

The conservation of leptons seems to hold universally for particles participating in weak interactions (Ref. to Källen, Ch. 13). This conservation law assigns a quantum number λ to the ~~negative~~ negative electron & muon e^- & μ^-, and to the associated neutrinos, ν_e & ν_μ. The quantum number $-\lambda$ is assigned to the antiparticles of the foregoing viz. e^+, μ^+, $\bar{\nu}_e$ and $\bar{\nu}_\mu$; and Zero is assigned to all other particles. The law of conservation of leptons then requires that this quantum number be ~~additive~~ additively conserved [for the other alternative of multiplicative conservation laws see Feinberg & Weinberg, Nuovo Cimento, 14, 571 (1959). As an example, the conservation of leptons would allow reactions of the form

$$\pi^+ \rightarrow \mu^+ + \nu_\mu \qquad (12.1, a)$$

$$\nu_\mu + n \rightarrow p + \mu^- \qquad (12.1, b)$$

$$\mu^\pm \rightarrow e^\pm + \gamma \qquad (12.1, c)$$

and forbid reactions of the type

$$\pi^+ \rightarrow \mu^+ + \bar{\nu}_\mu \qquad (12.2, a)$$

$$\nu_\mu + p \rightarrow n + \mu^+ \qquad (12.2, b)$$

In fact (12.2, a) & (12.2, b) have not been observed and (12.1, a) & (12.1, b) have been observed, thus indicating that the lepton quantum number is a good quantum number. On the other hand (12.1, c) is allowed by the conservation of leptons, but has never been observed. The absence of experimental verification observations of muon-electron

transition accompanied unaccompanied by neutrinos, of the type (12·1, C) has led to the formulation of a second Conservation law : the law of conservation of muons [Ref. to Feinberg & Weinberg, Phys. Rev. Letters, 6, 381 (1961). In analogy to the lepton conservation law, a quantum number M is assigned to the μ^- and ν_μ and $-M$ is assigned to μ^+ and $\bar{\nu}_\mu$ (?) & $M = 0$ for all other particles. Thus, reactions of type (12·1, C) transgress the law of conservation of muons & the lack of their observation is thereby reconciled. The conservation of lepton number and the conservation of muon number are sufficient to account for the observed reactions involving charged lepton pairs, and to forbid the unobserved reactions]

(13|3|70) Wolf-Rayet Stars (on the new book series) – Symposium held at Colorado, June 10–14, 1968 at JILA (Joint Inst. for Lab. Astro Physics).

Opening remarks by R. N. Thomas, JILA, Univ. of Colorado, Boulder, Colorado. – X

Abstract – The Wolf-Rayet stars represent the most extreme example studied of an interaction between aerodynamic motions and a radiative field to produce a high temperature, large scale plasma in a steady but non-equilibrium state. As such these stars provide a perfect example of the kind of gaseous ensemble that JILA was created to study. In order to understand them, we require a knowledge of gases with temperatures between 10^4 and 10^7 K, and differential velocities between 0 and 10^3 km/sec. In particular, we need information on radiative and collisional atomic cross-sections for a wide range of ions, on collective interactions of ions and photons, on methods of diagnostic spectroscopy, and on velocity fields generated by convective, gravitational, nuclear, ~~cost~~ radiative, rotational, thermal and other instabilities

p. 7. Prologue by C. S. Beals, Manotick, Ontario, Canada.

Considerable length of time elapsed that has elapsed since my active participation in research on Wolf-Rayet stars. I am naturally sensitive to a comparison with Rip van Winkle who slept for 20 years, waking up to experience difficulties in communicating with his friends & relatives who had outgrown him. Perhaps a kinder assessment of my ~~not~~ present relation to Wolf-Rayet stars would be an analogy with the semi-hibernators or dormers of which the black bear is the most notable example. Unlike the true hibernator who falls into a deep sleep in the autumn and spends many months in a state of complete unconsciousness, the bear sleeps lightly during the winter, is easily disturbed and on occasion wakes up,

emerges from his den and investigates the state of the outside world.

In a similar way, due to the force of circumstances I have spent considerable periods of time in a state of mental somnolence induced by the performance of non-scientific tasks, but have wakened up from time to time and used the nearest library to see what was going on in the scientific world. During these excursions I have become aware that work on the WR stars has been going forward and the progress has been such that keeping in touch and catching up is a major problem for any one with limited time on his hands. I have therefore welcomed this symposium as an aid in the catching-up process and can only hope that my talk, necessarily concerned mainly with the past, will not only have some value as history but may also have some relevance to the problems of the present day — Talks of Phases I, II & III and under II mentions quasi-stellar objects or quasars ~~wherein are found~~ regarded by many as the most important astronomical discovery of the 20th century. All kinds of interesting observations have been made of them, everybody is interested in them and, whenever possible, everybody wants to get in on the act. Certainly, I cannot claim any special knowledge of them and I have no desire to rush in where angels such as William Fowler, Thomas Gold, Fred Hoyle and Martin Schmidt fear to tread ..... I only wish to suggest that the presence in this object of Wolf-Rayet and P-Cygni characteristics may well influence the conclusions on the nature of quasars, if they are indeed a homogeneous group of light sources. It might, for example, give some inkling whether these objects are small, bright galaxies or some sort of gigantic star-like ~~orbits~~ objects.

Part A – The features of the system of Wolf-Rayet Stars – Introductory speaker: Lindsey P. Smith, Deptt. of Astronomy, Univ. of California at Los Angeles

Chairman – ~~Cecil~~ Cecilia Payne-Gaposchkin (Smithsonian Astrophys. ~~Lab~~ observatory & Harvard College Observatory) – Name suggests it is a woman (?)

Discussion from pp. 65 onwards – Quite interesting. Each person addressing a participant ~~is~~ not by surname but actual name as "Anne" referring to Anne B. Underhill (Sterrewacht "Sonnenborgh", Der Ruksuniversiteit, Servaas Bolwerk 13, Utrecht, Holland), and so on

p. 82 – Hanbury Brown's remark that Miss Underhill has kindly drawn his (?) attention to the paper by Ganesh and Bappu (?) giving the period as ~~78~~. 78.5 days.

(B) A book "Lectures on the numerical solution of linear, singular and non-linear differential eqns by Donald Greenspan, (Prentice Hall series in automatic

computation – Gives 486 references – Indian names being

(i) R.D. Bhargava & H.C. Radhakrishna – Proc. Nat. N.I.S.I., A, 29, 1963, 283-93

(ii) Greenspan & P.C. Jain

(iii) M.K. Jain – D.Sc. Thesis, I.I.T., Kharagpur, 1963.

(iv) M.K. Jain & M.M. Chawla – I.I.T, New Delhi

(v) V. Pitchaiah (?) Ph.D. Thesis, Minnesota, 1965.

(vi) R.V. Viswanathan, M.T.A.C

(C) The Universe and its origin – Edited by H. Messel and S.T. Butler (Macmillan & Co 1964

Contributors (i) G. Gamow, Deptt of Physics, Univ. of Colorado, Boulder U.S.A

(ii) B.J. Bok, Deptt of Physics, Australian National Univ, Canberra

(iii) T. Gold, Centre of Radiophysics & Space Research, Cornell Univ, New York U.S.A

(iv) C.B.A. Mc Custer – Observ. of Sydney, Australia.

Chaps 1 to 5 by Gamow, (i), Chaps 6-8 by (ii), 9-13 to (iii) & Last Chap. to (iv)

These are merely summer school type series of lectures to bring the science teachers up to date in Australia. – Also date is 1964(?)

16/3/70

Physical Review Letters

(6) 3/11/69.

(7) 10/11/69.

p. 1128 – Electric fields in rotating, magnetic, relativistic stars by x & y.

Pulsars are now believed to be rotating neutron stars [T. Gold, Nature, 218, 731 (1968) and 221, 25 (1969)] – Ref. to critical review by Chiu [Paper presented at the Proc. Crab Nebula Meeting, Proc. Pacific Astronomical Soc. 1969 (to be published)] – The emission is believed to take place on the very surface of the star & Consequently the magnetic laser device appears to be the only one available today for investigation of the highly non-thermal emission regn (if a reasonably superficial magnetic field of 10^{12} G is allowed) – So far electric fields in pulsars have been obtained from a L.T by postulating a relative motion between matter and magnetic field – The author tries to show that the built-in

General-relativistic ~~modal~~ conditions already imply, in a straight forward way from Maxwells eqns, the existence of an electric field — Gives a develop^t based on Maxwells eqns in general relativity (Ref. to books by Synge & others)

p. 1137 — Cabibbo angle and self-consistency condition by Tanaka & Tarjanne — Looks quite a simple paper worth studying.

17/11/69.

p. 1184 — Essential singularities in General Relativity by S. Deser & J. Higgle

Looks Greek at present, but shall persevere to understand the thing.

p. 1195 — Possible additional tests of Charge-Conjugation invariance in other than weak interactions by Saul Barshay (Niels Bohr Inst.)

Refers to CP-violation in $K^0 - \bar{K}^0$ system, and ~~explains~~ possible expts to test C-non conserving effects outside weak processes. — Quite obstruse.

24/11/69

p. 1264 — Duality and non-leptonic hyperon decay by Nussinov & Rosner

Duality reproduces most current algebra results & Leads to octet enhancement for S-wave non-leptonic decays of baryons. Reasons for ~~the~~ its inapplicability to P-wave decays is given.

1/12/69.

p. 1310 — Physical realisation of non-compact dynamical symmetries by Kabrat and Adam.

✓ The dynamical symmetry of a charged spinless harmonic oscillator in a constant magnetic field is identified .. for low fields it is SU(3), for high fields SU(2,1) and for a certain definite intermediate field SU(2) ⊗ H. ~~Why~~?

[H is the non-compact Heisenberg group (Ref. to the book by R. Herman on Lie Groups for Physicists, Benjamin N.Y. 1966., p. 137)]

8/12/69.

p. 1355 — Analysis of some results of quark searches by Adair & Kasha.

Nothing definite or of interest

15/12/69.

p. 1412 — Continuous breaking of chiral symmetry by Okubo & V.S. Mathur

✓ Continuity arguments for transitions between various subgroups of the chiral-symmetry group are presented. Some interesting sum rules are obtained in this way

p. 1415 – Very high-energy collisions of hadrons by R.P. Feynman

✓ Proposals are made predicting the character of longitudinal-momentum distributions in hadron collisions of very high energies

Uses the Regge-trajectory function $\alpha(t)$ – Ref. to his article on Proc. 3rd. ~~Int. Conf~~ Topical Conf. on high energy collision of hadrons, Stonybrook (to be published)

p. 1417 – Gauge-invariance, duality and $N_\alpha - N_\gamma$ exchange degeneracy in photoproduction by D.P. Roy

✓ 29 29/12/69 – Search for chemically bound neutrons by a, b, c, d (p. 1475)

Negative expt. results shown.

✓? p. 1510 – Tensor fields, generators of the Poincaré group and the Dirac-Schwinger condition by Dirac & Woo.

5/1/70 : —

12/1/70 :

p. 37 – Editorial on "Relaxation in expt. only" is more allotment of pages for expt. work – Regular recommendation to authors : "If you really want people to read your Letters, make them short by making them simple.

✓ p. 76 – General cosmological solution of the gravitational equations with a singularity in time by Khalatnikov & Lifschitz

– Quite interesting and of a general nature.

(18/3/70) – Looked into Proc. Nat. Acad. Sci. U.S.A from 1968–64 – Some interesting article by T.Y. Thomas that the Universe would come finally to its initial static space (like one before the at the stage of the exploding universe)

Also some articles by Brillouin criticising $E = Mc^2$ as not ~~correctly~~ representing mass corresponding to potential energy.

Also "epochal cosmology" by T.Y. Thomas to ~~which~~ which I made no reference either at my Madurai or Annamalai lectures.

(3/4/70) Physics Today. – Jan. 1970.

Pp. 27–32 – An age change by H. William Koch – Discusses changes in Physics –

p. 61 · Search and Discovery

(1) Reports on deep inelastic electron-proton scattering made ~~at~~

by the SLAC experimenters in mid-1968 support data challenging the views of the high energy community — 20 GeV beams used by the SLAC-MIT group — Many models proposed — R. P. Feynman of Caltech & others have supported a "parton" model in which the electron scatters incoherently from many pointlike constituents inside the proton. They argue that such point-like behaviour implies scaling. — Partons like quarks do not seem to be in immediate agreement with the picture of hadrons in which one visualises the hadron as a cloud of virtually strongly interacting particles, this clouds extends over a large region, about a fermi in size; all known stable hadrons appears to have this fundamental dimension. However, Sidney Drell & etals (at SLAC) (Paper to be published in Phys. Rev) have derived a ~~model~~ parton model from conventional field theory.

Also attempts using Regge exchange ideas have been made (Ref given) ~~Also~~ As re. elastic data diffraction models (?) of C. N. Yang et als have been incorrect in explanation

Also mention a vector-dominance model proposed by J. J. Sakurai

(2) Bubble chambers are ready to study neutrinos.

(3) Interview with Peter Kapitza who has come to Columbia to receive an Hon. Degree It was his first visit to the U.S and at 75, even after a hectic month of travel his eyes were sparkling & conversation lively — He is to publish a paper 135 pages long in the JETP on controlled thermonuclear emission — In the Columbia meeting, a mention was made of a paper of his when he was 22 about an exptl. det. of the mag. moment of e, which made excellent sense half a century later — His enforced stay in the Soviet Union (?) began in 1934 & he was Director of Inst. of Phys. Problems (except except when he was in disfavour from 1946-54) & Lev Landau & many others were his students) — In his reply Kapitza mentions how he was happy to be in a Univ. where Fermi, Rabi & Leo Szilard worked.*

(4) NAS panel details advantages of a large telescope in space.

(5) New spectrometer to measure 10^{13} eV cosmic ray events. — Hadrons from ~~the~~ cosmic rays

(6) NSF extends Deep-sea drilling project for another 3 years — Possibility of there being large petroleum deposits under the Gulf of Mexico.

p. 83. Murray ~~Goldmann~~ Gell-mann wins Nobel Prize for Physics (with a portrait of Gell-man — Gives an interesting historical career — Also a short of the important work done by him

Refers is made to the postulate of existence of three fractionally

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* Also mention of observer in USSR of a man like Feynman, after the death of Landau nobody has been able to take his place.

(14)

charged quarks as the fundamental basis of SU(3) [A point missed in R.S. Pandit's article in Science Today [given to me by Ashok to read yesterday] - Mentions a horrible unsuccessful detection attempt of quarks & refers to Science Today, October 1969, p.55 p.87] - Ref. to Oak Ridge National Laboratory & the A.E.C extending ~~their~~ cooperation for ~~6 negro students~~ six predominantly Negro Colleges in Washington & the Smiths, to train 6 students in each school to graduate & get jobs at Nuclear Division of Oak Ridge - What a commentary on attitude towards negros in U.S? X

(6/4/70) New Books Section (1) A book on Mathematical Analysis by T.M. Apostol Sc.D [to ref. only.

Examples Collected: (1) p. 59, 2.18. Prove that if $c_1, \ldots c_N$ are non-negative real numbers, then

$$\left(\sum_{n=1}^{N} c_n\right)^3 \leq N^2 \sum_{n=1}^{N} c_n^3 \quad \text{with equality if and only if } c_1 = c_2 = \ldots = c_N$$

[In Cauchy's inequality $\left(\sum a_n b_n\right)^2 \leq \left(\sum a_n^2\right)\left(\sum b_n^2\right)$

take first $a_n = c_n^{3/2}$, $b_n = c_n^{1/2}$ and then $a_n = c_n$, $b_n = 1$.]

(2) The real valued fn f has a derivative at each point of $[a, b]$ and $f'(a) = f'(b)$. Show that there exists at least one $\xi \in]a, b[$ such that

$$\frac{f(\xi) - f(a)}{\xi - a} = f'(\xi).$$

[Reduce to the case $f'(a) = f'(b) = 0$ by considering $x \to f(x) - x f'(a)$ and then for this case consider the fn ψ given by

$$\psi(a) = 0, \quad \psi(x) = \frac{f(x) - f(a)}{x - a} \quad (x > a).$$

Evidently ψ is continuous on (a, b), and

$$\psi'(x) = -\frac{(f(x) - f(a))}{(x-a)^2} + \frac{f'(x)}{x-a} \quad (a < x < b)$$

we have therefore to prove that there exists $\xi \in]a, b[$ such that $\psi'(\xi) = 0$. If $\psi(b) = 0$, the result follows from Rolle's theorem. If $\psi(b) > 0$, then $\psi'(b) < 0$ whence we can find $x_1 \in]a, b[$ such that $\psi(b) < \psi(x_1)$. Since $\psi(a) < \psi(b)$, we can therefore find $x_2 \in]a, b[$ such that $\psi(x_2) = \psi(b)$ and hence $\psi'(\xi) = 0$ for some $\xi \in]x_2, b[$ by Rolle's theorem. A similar argument applies to $\psi(b) < 0$.

(3) Prove that if f, g are real-valued fns continuous on $[a, b]$ which have first derivatives at each $x \in]a, b[$, then there exists at least one $\xi \in]a, b[$ such that

$$\{f(b) - f(a)\} g'(\xi) = \{g(b) - g(a)\} f'(\xi)$$

[Apply Rolle's theorem to the function given by

$$\phi(x) = \begin{vmatrix} f(x) & g(x) & 1 \\ f(a) & g(a) & 1 \\ f(b) & g(b) & 1 \end{vmatrix}$$

$$= \{f(b)-f(a)\}\{g(x)-g(a)\} - \{g(b)-g(a)\}\{f(x)-f(a)\}.\ ]$$

(4) Cauchy's mean value theorem

$$\frac{f(b)-f(a)}{g(b)-g(a)} = \frac{f'(\xi)}{g'(\xi)}$$

[use the mean value theorem to prove $g(b) \neq g(a)$; then use above Ex]

(5) Give an example of a function f defined and possessing continuous derivatives of all orders on $[1, \infty[$ such that the integral $\int_1^{+\infty} f(x)\,dx$ exists and that $f(x)$ is unbounded on every neighbourhood of $+\infty$.

[Take e.g. $f(x) = \frac{d}{dx}\left(x^{-1}\sin(x^3)\right)$]

(6) Prove that if X is a topological space, and there exists a connected subset E of X such that $\bar{E} = X$, then X is connected. Deduce that if E is a connected set in a topological space X, and if $E \subset F \subset \bar{E}$, then F is connected.

[To prove 1st part, note that if A, B are disjoint open sets in X with union X, then since E is connected, either $A \cap E$ or $B \cap E$ is empty. If the first, then $E = E \cap B \subset B$, when $X = \bar{E} \subset \bar{B}$. But B is closed in X, so that $X = B$ and therefore $A = \phi$ ~~$\emptyset$~~. Similarly if $B \cap E = \emptyset$, then $B = \phi$

For the second part, note that the closure of E relative to F is $\bar{F}$.]

(*) (8/4/70) – The Scientist Speculates by I. J. Good

p. 115 – Re. Cig. smoking – R. A. Fisher's argument that smoking of cigarettes may not be a cause of lung cancer – Recently suggested that inhaling might indirectly, in some populations, tend to prevent lung cancer since it might encourage the smoker to throw away a long cigarette butt – certain chemical constituents become more concentrated the further down the cigarette is smoked viz. the polycyclic polycylic hydrocarbons including benzpyrene which can in large quantities cause skin cancer in animals – The conjecture then is that inhaling is positively correlated with butt-length. Even if this conjecture be true the extra damage from inhaling the first part of the cigarette would more than counterbalance the avoidance of the last part . . . . . It gives support to the recommendation that, whether he inhales or not, the smoker should avoid

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making cigarettes to the filter end. Perhaps a very small amount of explosive should by law be inserted in the butt in order to encourage smokers to adopt this recommendation (!!)

pp. 281-83 - Taste differences by Fred L. Whipple

Actually represent inherent differences in the taste sensitivity of a physiological nature - Statistical data required to determine genealogical patterns involved in taste differences - Editor comments that the subject be called "Saporology" - Rep. to Nature Vol 191, p. 1328, 23 Sept. 1961

p. 284 - Remarks on the mind-body question by E. P. Wigner - very interesting using quantum mechanics and dealing with speculative questions.

9/4/70 - Smithsonian Inst. Reports Vol I (Treasury of Science), p. 278 - Article by Einstein on Newton - ✓

13/4/70 - The Mathematical Sciences - A Report - National Academy of Sciences, Washington D.C, 1968 - ✓✓

The Report authors of this Report feel that there are too few distinguished applied mathematics groups in American Universities, and that special encouragement is needed for building such groups. Whatever place applied mathematical sciences find in the academic structure, however, it is essential to maintain a strong and continuing interaction between these sciences and pure mathematics - an interaction in which ideas and people must move in both directions.

(i) Reports on undergraduate education;

(ii) Collection of 22 essays by distinguished mathematical scientists, brings together, in a form accessible to a wide range of readers, expositions of the achievements, traditions and prospects in a rich variety of mathematical fields

p. 9. The theory of Lie groups, for instance, was developed for many years because of its intrinsic mathematical interest. It seems now to be the ? || natural way of describing symmetries in elementary particle physics

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Saw in some book references to Harish-Chandra's thesis about Lie groups.

EL 3

p. 10. International Congresses of mathematicians, meeting at roughly 4 year intervals, were inaugurated around the turning the century. The earliest such Congress in 1897 in Zurich was attended by only 200, whereas the recent Moscow Congress of 1966, the attendance was approximately 4300. An invitation to a mathematician to address an international congress evidences world wide recognition of his contribution to mathematical discovery at the highest level.

(29/5/70) Science (9/1/70)

p. 126 – Indian agriculture – Modern methods produce good harvests by Robert B. Davis (Boreya Road, Kanke, Ranchi-7, Bihar, India) – gives 6 agricultural principles to be followed & not mere mechanical farming blindly

p. 139 – Mission to an Asteroid by H. Alfvén and G. Arrhenius – Suggest this as an intermediate step towards Mars.

p. 141 – In defense of Science by Alvin. M. Weinberg – out of basic science comes technology – job and purpose of science & technology remain overwhelming: to create a more livable world, to restore man to a state of balance with the environment, to resolve the remaining elementary and suffering of man – hunger, disease, poverty, and war.

p. 147 – Turmoil in Japanese Universities appears to be colossal.

Science (30/1/70) – A huge big volume especially devoted to the Apollo successful mission to the moon. = The whole volume contains different aspects of stories of the moon sample – In Section on Age measurements, we find the names of K. Gopalan & S. Rajan on p. 471. – E. V. Gangadharan on p. 505 in tracer elements – P. Ramdohr on p. 615 in special mineral stories – N. R. Mukherjee on p. 743 in other physical properties – C. Ponnamperuma on p. 760 in organic chemistry

Ibid – 6/2/70

" – 13/2/70 – p. 935 – The need for basic research – A short article by V. F. Weisskopf, Deptty Physics, M. I. T – A small fine article supporting the promoting basic research ✓

p. 960 – Japan; A crowded nation wants to boost its birth rate by P. M. Boffey – Japan is the most crowded

nation in the world. It has 102 million people – half as many as U.S – all crammed into a string of narrow islands that are smaller in area than Montana + Moscow 85% of Japanese territory is mountainous – Sato's statement about increasing Japan's population! – Some justification made out for this?

Ibid – 20/2/70

p. 1075. (1) Should college applicants be selected by a lottery? – A letter

p. 1076 – A letter by E. P. Wigner on Civil Defense

p. 1083 – Some 3-body atomic systems by J. William MacGow – The climb to the first major plateau in our understanding of the 3-body atomic problem has been very exciting, but the climb yet to come promises to be even more thrilling.

p. 1110 – Bertrand Russell (1872-1970): The constant centre (News & Comments by John Walsh.

p. 1114 – Review of a book "The Oppenheimer case Security on trial by Philip M. Stern.

Ibid – 27/2/70.

p. 1203 – The case for a hierarchical cosmology by G. de Vaucouleurs

✓ Recent observations indicate that hierarchical clustering is a basic factor in cosmology

p. 1237 – Gravitational waves – the evidence mounts by C. L. Wreck

1/6/70 New Books Section.

(1) Book "Science in India's fortune" – some rubbish with first article by Atma Ram.

(2) Beyond the Milky Way – Galaxies, Quasars and the new Cosmology. Number of small articles by several people. – Section 7 on Cosmology – On p. 303 is mentioned "the late George Gamow" (in the epilogue) Mention is made of Olbers's paradox (ie no of stars increase as R^2 & luminosities as $1/R^2$ & so at night the small amount of light from all these should be of a amount or at least a finite sizable amount at night. Bondi explains Olbers's paradox by expansion of the Universe [Galaxies 1 million light years away recede at 100 miles per sec, at 5 million light years, the recession is at 500 miles a sec, at 25 million light years, it is 2500 miles a second, at 100 million light years, the rate of recession has a value of 10,000 miles per sec; at 250 million light years, it is more than one eighth the speed of light

12 ["law of redshifts": $V = HD$, H = Hubble's constant, is now considered to be 18 miles per million l. years (or 100 km/sec per million parsecs)]

This increase is limited at 2 billion light years, receding > c. But this is impossible according to special theory of relativity - Mount Palomar Observatory new telescope may test this & if true some other explanation of red shift has to be obtained]

(3) Scientific American – Feb, 1970

p. 68. Particles that go faster than light – They have not been discovered, but there are reasons to ~~be~~ believe that they exist by Gerald Feinberg.

Called tachyons. Contrary to common beliefs, however, their existence would not be inconsistent with the theory of relativity – Shows at great length the consistency, but not very convincing, expts re. cerenkov radiation to discovery of tachyons not successful – Long/ish article to be read ~~later~~ later more carefully – The author's own conclusions appear to contradict existence of tachyons; one argument in favour of this view is that if charged tachyons exist, the photon would not be a stable object but instead would decay within some time period into a pair of charged tachyons. We know that photons can travel for billions of years across intergalactic space without so decaying. This means square of tachyons is $\simeq 0$ ie difficult to distinguish from – mentioning other difficulties.

(4) Physics Today, Jan 1970

p. 123 – We hear that – Sudarshan formerly at Syracuse University has joined the Univ of Texas as a Professor.

p. 125 – Short article on L. Brillouin; Theoretical Physicist was also a Radio Engineer by L. H. Thomas.

(5) Physics Today, Feb. 1970.

(i) p. 34. Cosmology – A search for two numbers by Allan R. Sandage.

3/6/70 ~~Nature~~ Science (16/1/70)

p. 249 – The genetics of schizophrenic and schizoid disease by L. L. Heston – Establishment of the genetic relation proved. – Read nothing whatsoever.

5/6/70 New Books Section.

(1) A book on Herman Hesse, his mind and art by Mark Boulby. Cornell Univ Press, Ithaca, New York, 1967

Chap 4 – entitled Siddhartha, p. 121, – Hesse's learning from Bhagavad Gita.

Chap 7 – The journey to the East & the Glass Bead game p. 245

Chap 4 is very interesting, as also Chap 7 – In the selected bibliography there is a reference to "Bhagavad Gita" by Prabhavananda Swami & Christopher Isherwood

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8/6/70 New Books Section

(1) Quantum Statistical Mechanics by P. H. E. Meijer – Gordon & Breach, 1966 in the Documents of modern physics series – I noticed another book in this series (i) viz. Applns of distns in theory of elementary particles by L. Schwartz and also (ii) Neutrino astrophysics by H. Chiu, (iii) Quark model for elementary particles by R. H. Dalitz, (iv) Lectures on Group theory by H. Bacry, (v) Dynamical theory of groups and fields by Bryce S. DeWitt, (vi) Th. Symposium of exp. Relativity by R. H. Dicke (vii) Laws of symmetry theorem of TCP by M. Gourdin (~~[illegible]~~

Contains 5 articles by 5 different people.

(2) Quantum Mechanics by A. S. Davydov – translated, edited & with additions by D. Ter Haar – Addison Wesley, 1965 – Seems quite a good book dealing ~~exh~~ exhaustively with several topics

(3) The propagation of gamma quanta in matter by Leipunskii, Novozhilov and Sakharov translated by Prasenjit Basu (?); translation edited by K. T. Spinney, J. Butler, and J. B. Sykes being Vol. 6 of International series of of Monographs on nuclear energy (Gen. Editor: J. V. Dunworth) – Division X Reactor Design Physics [K. T. Spinney seems to have died recently

(4) Elements of number theory by I. M. Vinogradov – Translated from the 5th revised edition by Saul Kravetz – Dover Publications. Inc. 1954

From the Preface: – Talks very big of Russian work on theory of nos. & the Petersburg School of the theory of Nos (Peterburgskaya shkola teorii chisel) & refers to Delone's book of 1947 with this title – great tradition of their predecessors, creating powerful new methods, obtaining first-class results – refers to "Maths in USSR after 30 years" a report in Russian of 1948

In the present book, a systematic exposition of the fundamentals of number theory within the scope of a University course is presented. A large collection of problems introduces the reader to some of the new ideas in number theory – Also answers to problems are given

Quite a nice beautiful book easy to understand.

(5) Mathematical methods in the theory of queueing by A. Y. Khintchine – Vol 7 of Griffin's Statistical monographs & courses, Griffin, London, 1969 (2nd Edn)

(6) The World of Science by Sherwood Taylor (3rd Edn) – Heinemann – Popular Book

(7) The wonderful world of medicine by Ritchie Calder – Macdonald & Co, Lond – 21^s net – Popular book on medicine beautifully illustrated

This series "The wonderful world books" consists of "The wonderful world of mathematics" by Lancelot Hogben & Others etc.

(8) Complex variable methods in Science & Technology by John Cunningham – D. van Nostrand Co. Ltd, 1965.

(9) The theory of random functions by A. Blanc-Lapierre and R. Fortet, Univ of Paris – Translated from the French by J. Gani (?) of Michigan State Univ. – Gordon and Breach, 1967. – Preface in Vol 1. by G. Darmois (Mentions this as joint work with Kampé de Fériet) – Chap XIV of Vol 2, (complete by itself and consisting of five subdivisions) deals with Random functions and the statistical theory of turbulence by J. Kampé de Fériet.

[Section 2, p. 255 of this chapter dealing with the statistical mechanics of a linear oscillator should be studied later]

(10/6/70) – Classical Mechanics by Herbert Goldstein.

(12/6/70) – Solutions to Calcutta Paper I

2.1(a) B.C.C – pp. 23-24

(b) Perhaps in B.C.C.

2.9(b)

Elements of linear algebra & matrix theory by John. T. Moore.

p. 291, ~~Examples~~

Ex. If λ_1 & λ_2 are the eigen values of the matrix $A = \begin{pmatrix} 1 & 1 \\ 3 & -1 \end{pmatrix}$, determine a non-singular matrix P such that $P^{-1}AP = \text{diag}\{\lambda_1, \lambda_2\}$

Soln. The characteristic polynomial of A is easily found to be $(x-2)(x+2)$ so that its eigenvalues are ± 2. If we now think of A as a repn of a linear operator T on V_2, a simple computation shows that the eigen vectors belonging, respectively to 2 and -2 are (a, a), and $(a, -3a)$ for any $a \in R$. A suitable eigen-vector basis of V_2 is thus $\{(1,1), (1,-3)\}$ and so $P = \begin{pmatrix} 1 & 1 \\ 1 & -3 \end{pmatrix}$ is the corresponding matrix of transition. We find that $P^{-1} = \begin{pmatrix} 3/4 & 1/4 \\ 1/4 & -1/4 \end{pmatrix}$ and a simple check shows that

$$P^{-1}AP = \begin{pmatrix} 3/4 & 1/4 \\ 1/4 & -1/4 \end{pmatrix}\begin{pmatrix} 1 & 1 \\ 3 & -1 \end{pmatrix}\begin{pmatrix} 1 & 1 \\ 1 & -3 \end{pmatrix} = \begin{pmatrix} 2 & 0 \\ 0 & -2 \end{pmatrix}$$

(7) The wonderful world of medicine by Ritchie Calder – Macdonald & Co, Lond – 21^s net – Popular book on medicine beautifully illustrated

This series "The wonderful world books" consists of "The wonderful world of [illegible]" by Lancelot Hogben & Other names.

$$\begin{pmatrix} z & \omega \\ -\bar{\omega} & \bar{z} \end{pmatrix} \cdot \begin{pmatrix} z' & \omega' \\ -\bar{\omega}' & \bar{z}' \end{pmatrix} = \begin{pmatrix} zz' - \omega\bar{\omega}' & z\omega' + \omega\bar{z}' \\ -\bar{\omega}z' - \bar{z}\bar{\omega}' & -\bar{\omega}\omega' + \bar{z}\bar{z}' \end{pmatrix}$$

$$\left.\begin{aligned} \overline{zz' - \omega\bar{\omega}'} &= \bar{z}\bar{z}' - \bar{\omega}\omega' \\ \overline{z\omega' + \omega\bar{z}'} &= \bar{z}\bar{\omega}' + \bar{\omega}z' \end{aligned}\right\}$$ to link now? Yes! too much.

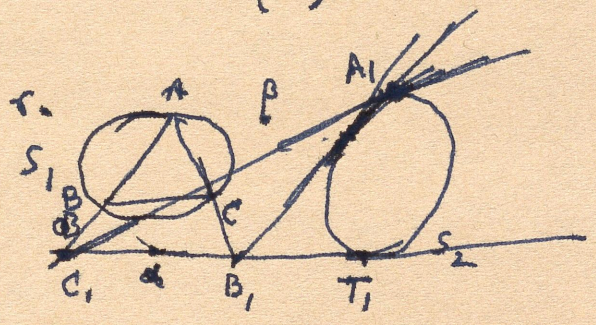
~~$a \cdot ab = aa \cdot b = b$~~

$a \cdot ba = ab \cdot a$ $\quad a^{-1} = a$:

$ab = a^{-1}b^{-1} = (ba)^{-1} = ba.$

Page 3.

$(ba)^{-1}$



$$P^{-1}AP = \begin{pmatrix} 3/4 & 1/4 \\ 1/4 & -1/4 \end{pmatrix}\begin{pmatrix} 1 & 1 \\ 3 & -1 \end{pmatrix}\begin{pmatrix} 1 & 1 \\ 1 & -3 \end{pmatrix} = \begin{pmatrix} 2 & 0 \\ 0 & -2 \end{pmatrix}$$

Ex. 2. If $A = \begin{pmatrix} -1 & 2 & 2 \\ 2 & 2 & 2 \\ -3 & -6 & -6 \end{pmatrix}$

as the matrix of an operator T on V_3, it is not difficult to discover that $(1, 0, -1)$, $(0, 1, -1)$ and $(2, -1, 0)$ are three linearly independent eigenvectors of T in the space. The matrix P whose transformation whose columns are these eigenvectors is

$$P = \begin{pmatrix} 1 & 0 & 2 \\ 0 & 1 & -1 \\ -1 & -1 & 0 \end{pmatrix} \quad \text{with} \quad P^{-1} = \begin{pmatrix} -1 & -2 & -2 \\ 1 & 2 & 1 \\ 1 & 1 & 1 \end{pmatrix}$$

An elementary matrix calculation shows that $P^{-1}AP = \text{diag}\{-3, 0, -2\}$ a diagonal matrix that lists the eigenvalues of T along its main diagonal.

p. 283 - Proof of the Cayley-Hamilton Theorem

(22/6/70) New books Section

(1) Cargese Lectures in Th. Phys - Applns of Maths to problems in Th. Phys
Gordon & Breach, 1967

Part I - Quantum field theory and related problems

p. 83 - Quantum field theory on the Poincaré group by F. Lurçat
Faculty of Science de Faculté des Sciences, Univ. de Paris, Orsay, France
Le sujet traité dans ce cours (F. Lurçat, Phys I, 95, 1964) a évolué depuis l'été 1965, de telle sorte qu'il n'est pas possible d'en donner en 1966 une version satisfaisante.
Un article sera publié ultérieurement en collaboration avec Nghiem Xuan Hai (!!).

Part II - Group theory and applications

p. 453 - The SU(6) model of elementary particles by L.A. Radicati
[with lots of references]

√√ || p. 491 - Applns of Current algebras by N. Straumann

(2) The Structure of matter by Rice & Teller - Many topics dealt with - The book was meant to serve as an introduction -

(26/6/70) - New Books Section

√√ || (1) Battelle Rencontres - 1967 Lectures in Mathematics & Physics
edited by Cecile M. DeWitt and John A. Wheeler (Princeton Univ)
(a) Introduction by the above two entitled "Babel and Battelle"
Compares and contrasts the different viewpoints in Maths & Th. Phys

and also deals with many other topics.

(4) Contains 33 interesting articles on many topics of Mathematics & Physics. — It is mentioned that most articles are of a pedagogical nature.

In the first article on Lie Groups & Symmetry Spaces by Sigurdur Helgason, there is a reference in the bibliography to an article by S. Bhanu-murthy in Dokl. Akad. Nauk U.S.S.R., 135 (1960), 1027-30. and three articles by Harish-Chandra

(2) Solution of non-linear systems by S. Vajtasek & Janac. — In Appendix 2 on Special Concepts deals with matrices also

p. 206 — Elementary divisors.

p. 208 - Ex. A. 2.1

Consider matrix $A = \begin{pmatrix} 2 & 0 & 0 \\ 1 & 2 & 0 \\ 0 & 0 & 2 \end{pmatrix}$, $A - \lambda E = \begin{pmatrix} 2-\lambda & 0 & 0 \\ 1 & 2-\lambda & 0 \\ 0 & 0 & 2-\lambda \end{pmatrix}$

The characteristic eqn is $(2-\lambda)^3 = 0$ is a triple Ch. root with multiplicity $\bar{K} = 3$

The matrix $A - \lambda E$ yields altogether four non-zero minors viz $(2-\lambda)^3$, $(2-\lambda)$, $(2-\lambda)^2$, $(2-\lambda)^2$. Their G.C.D is $(\lambda - 2)$ so that $K_1 = 1$. The first order minor (1) is no longer divisible by the binomial $(\lambda - 2)$, so that $K_m = K_1 = 1$. Thus $m = 1$, $l_{m+1} = l_2 = K_1 = 1$, $l_1 = 3 - 1 = 2$. The elementary divisors are therefore $(\lambda - 2)^2$, $(\lambda - 2)$.

Consider a characteristic root λ_1 with the multiplicity $\bar{K}$ corresponding to the determinant $\Delta(\lambda)$ of an $n \times n$ matrix $A - \lambda E$. Thus $\Delta(\lambda)$ is divisible without remainder by the expn $(\lambda - \lambda_1)^{\bar{K}}$. Let us consider all the minors $\Delta_1(\lambda)$ of order $n-1$. Let all of them be divisible by the expn $(\lambda - \lambda_1)^{K_1}$, but let at least one of them not be divisible by the expn $(\lambda - \lambda_1)^{K_1+1}$. Let us consider all the minors $\Delta_2(\lambda)$ of order $(n-2)$ and let all of them be divisible by $(\lambda - \lambda_1)^{K_2}$, but at least one of them not be divisible by the expn $(\lambda - \lambda_1)^{K_2+1}$, etc. Thus we arrive at the minors $\Delta_m(\lambda)$ of order $n-m$, all of which are divisible by $(\lambda - \lambda_1)^{K_m}$, but at least one of which is not divisible by $(\lambda - \lambda_1)^{K_m+1}$. Simultaneously, let at least one minor of order $n-m-1$ no longer be divisible by the linear binomial $(\lambda - \lambda_1)$. Let us then determine the integers l_j defined by the formulae

$$l_1 = \bar{K} - K_1,\ l_2 = K_1 - K_2,\ \ldots\ l_m = K_{m-1} - K_m,\ l_{m+1} = K_m$$

for which $\sum_{j=1}^{m+1} l_j = \bar{K}$; $K_1 \geq K_2 \geq \ldots \geq K_m > 0$.

The expressions $(\lambda - \lambda_1)^{l_1}$, $(\lambda - \lambda_1)^{l_2}$, $\ldots (\lambda - \lambda_1)^{l_{m+1}}$, $l_j > 0$

are then the regd. elementary divisors corresp. to the characteristic root λ_1.

Elementary divisors permit us to setup special types of matrices with the aid of which it is possible to find, relatively quickly and in a useful form, the solution of linear diff. eqns with const. coefficients & also with periodic coefficients]

p. 208. Ex. A. 2.2

$$A = \begin{pmatrix} 2 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 2 \end{pmatrix}$$

Characteristic eqn $(2-\lambda)^3 = 0$. with $K = 3$. Here there are altogether three non-zero minors of 2nd order, $(2-\lambda)^2$, $(2-\lambda)^2$, $(2-\lambda)^2$. Their G. C. D is $(\lambda-2)^2$. Thus $k_1 = 2$. The first order minors $(2-\lambda)$ are no longer divisible by the expn $(\lambda-2)^2$ so that $k_2 = 1$. Since zero can be divided by any non-zero expn, and the remaining minors $(2-\lambda)$ are no longer divisible by $(\lambda-2)^2$, we set $m = 2$, $l_{m+1} = l_3 = K_3 = K_2 = 1$. Therefore $l_1 = 3-2-1$, $l_2 = 2-1-1$. In this way we obtain the elementary divisors : $(\lambda-2)$, $(\lambda-2)$, $(\lambda-2)$

p. 209. Ex. A. 3.3

$$A = \begin{pmatrix} -1 & 1 & 1 \\ 1 & -1 & 1 \\ 1 & 1 & -1 \end{pmatrix}$$

Here the ch. roots are $\lambda_1 = 1$, $\lambda_2 = \lambda_3 = -2$. So the root $\lambda_1 = 1$ the corresponds the linear elementary divisor $(\lambda-1)$. The multiplicity of λ_2 is two, so that $K = 2$. All the 2nd order minors are divisible by the binomial $(\lambda+2)$ but none of them is divisible by $(\lambda+2)^2$, so that $K_2 = 1$. None of the first order minors is divisible by the binomial $(\lambda+2)$, so that $m = 1$, $K_m = k_1 = 1$. We thus set

$l_1 = 2-1 = 1$, $l_2 = l_{m+1} = K_1 = 1$ & so the remaining two elementary divisors are $(\lambda+2)$, $(\lambda+2)$]

General defn of elem. divisors p. 206

Let $A - \lambda E = \begin{pmatrix} a_{11}-\lambda & & a_{1n} \\ & \ddots & \\ a_{n1} & & a_{nn}-\lambda \end{pmatrix}$

Called a λ-matrix. The symbol $D_i(\lambda)$ denotes the largest common divisor of all the polynomials obtained by expanding the corresponding minors of the ith-order. Let $D_0(\lambda) = 1$. It is known that the largest common divisor can be uniquely determined apart from a non-zero numerical factor. We therefore choose $D_i(\lambda)$ such that

the coefficients accompanying the highest power should be unity. At the same time, it can be shown that $D_i(\lambda)$ is divisible by $D_{i-1}(\lambda)$. The quotients

$$\frac{D_i(\lambda)}{D_{i-1}(\lambda)} = E_i(\lambda)$$

which are polynomials are called the invariant factors of the matrix A. Evidently $D_1(\lambda) = E_1(\lambda)$. These factors are invariant because they do not undergo any change when the matrix A is transformed into a similar matrix (The constant matrices square matrices B and C are said to be similar if there exists a regular const. matrix S such that $S^{-1}BS = C$). The matrices have equal characteristic roots.

From the above, it follows that

$$D_i(\lambda) = E_1(\lambda)\, E_2(\lambda) \ldots E_i(\lambda)$$

Let us decompose the invariant factor $E_i(\lambda)$ into a product

$$E_i(\lambda) = (\lambda - \lambda_1)^{m_{i1}} (\lambda - \lambda_2)^{m_{i2}} \ldots (\lambda - \lambda_s)^{m_{is}}$$

where s denotes the number of characteristic roots and λ_j & m_{ij} are positive integers. If the multiplicity of λ_j is k_j and the matrix is of order n, then

$$\sum_{i=1}^{n} m_{ij} = k_j, \qquad \sum_{j=1}^{s} \sum_{i=1}^{n} m_{ij} = n$$

The individual expressions $(\lambda - \lambda_j)^{m_{ij}}$ for $m_{ij} \geq 0$ are said to be elementary divisors and the linear binomials $(\lambda - \lambda_j)$ are the linear elementary divisors of the matrix $A - \lambda E$.

29/6/70 New books Section (A)

(1) Graph Theory & Theoretical Physics by eds – Ch. 12 is given as Heawood's May coloring problem in the title page, but are given inside the correct words "Map coloring". Such an error is surprising

(2) Symmetry Principles at high energy by (5th Coral Gables Conference) Jan 24-26, 1968

Very interesting articles & discussions on several topics by Feller, Pais, Michel, Radicati, one by O' Raifeartigh on recent algebraic approaches to particle physics, Kursunoglu, Hurst, Nishijima, Lipkin, Wightman, P. T. Matthews, Cabibbo, Y. Ne'eman & others with interesting discussions – in 5 sessions.

p. 278: In article by Lipkin on "Quarks, symmetries and Groups", he talks of the "broom and rug" model in which one use a broom to sweep all aspects of the problem which one does not understand under a rug!

(26)

p. 291 – In Wightman's paper on the Poincaré group, there is no reference to my work at all, only a reference to Harish-Chandra's Roy. Soc. paper of 1947. – The whole article deals with spin 3/2 particles – Send him reprints

(Prof A. S. Wightman, Princeton University).

p. 355 – Review of all the five Coral Gables conferences on symmetry principles at high energy by Y. Ne'eman (Tel-Aviv University) – Very interesting historical document.

(B) Scientific American, Feb. 1970, p. 68 – Particles that go faster than light by Gerald Feinberg. – Shows that such existence of such particles is consistent with the special theory of relativity – Should examine this more closely in view of Pauli's "cause & effect" relation being reversed if $v > c$. – I feel there is a mistake in the argument by Feinberg.

(C) Physics today – April, 1970

1/7/70 – New Books Section

(1) Modern Quantum Mech. with applns to elem. particle physics by John S. Eisele, Naval Research Laboratory, Washington D.C.

(Wiley Interscience, 1969)

Part II – Chapter 2 on the Dirac wave equation and specially Sections B to F dealing with Dirac algebra (Section B) contain no references to my work – most disgraceful – should send him my reprints.

(2) Old & new problems in Elementary particles – Collection of articles – Academic Press 1968 – dedicated to Bernardini on his 60th birthday

p. 156 – Prospects for the muon-electron problem by L. M. Lederman – gives 24 references.

Conclusion – Few problems in the frontier of physics have survived the number of technologically weighted man-years as has the muon-electron problem. The last 10 years have certainly been disappointing, but the facilities becoming available will provide many opportunities so that some physicist, perhaps now in high school will suddenly see the solution at present hidden from all of us

$\left(\frac{m_\mu}{m_e} = 206.765 \pm 0.003\right)$ – Calls this the most uselessly precise number in particle physics. ν_e known to be < 200 eV & $\nu_\mu < 2$ MeV.

(3) Book on Muons by Weissenberg, North-Holland, 1967, 10 references &

(4) Italian Physical Society – Enrico Fermi Course 32 ed by T. D. Lee, 1966

(a) p. 96 – Theoretical survey of muon physics by H. Primakoff.

Calls it one of the "superfluous" – gives a curious numerological fact is mentioned viz. $\frac{3}{2}(1/\alpha) = 206!$ $(\alpha = ?)$ $\left[(m_\mu - m_e)/m_e = 205.8\right]$ – The mass difference between p and n is attributed to their different electric charges (1 vs 0) and therefore to their different e.m. interactions. one can indeed speculate that the μ-e mass difference is also sometimes caused by the e.m. interactions, but the complete forbiddenness of reactions such as $\mu \to e + \gamma$ is hard to reconcile with this concept.

(b) p. 122 – Muon Physics by L. M. Lederman – Part I Weak interactions & Part II – e.m. interactions.

(a) gives a reference to an excellent general review by Feinberg & Lederman in Ann. Rev. Nucl. Sci. 13, 432 (1963); (b) gives no reference to Primakoff!

(5) Annual Review of nuclear science, Vol 13, p. 432 – Article by Feinberg and Lederman – Containing 230 references!

(6) Ibid, 1967 – There is an article on Current Algebra.

3/7/70 – New Books Section

(1) 1968 Jawaharlal Memorial Lecture, 1968 by S. Chandrasekhar on "Astronomy in Science & Human Culture" – Introduction by Karan Singh Secretary and closing speech by Zakir Hussain – Lecture of 18 pages – Very interesting remarks on Ancient Indian Astronomy of North & South India (Greek & Babylonian sources respt) – Refers to work of Penrose and Dicke – concluding speech also interesting

(2) The mathematical approach to biology and medicine by Norman T. J. Bailey, John Wiley & Sons, 1967 (Very interesting)

Part I – General principles & techniques (1) The necessity of mathematics (2) The role of probability & statistics (3) The process of scientific research (4) The scope of operational research (5) The influence of automatic computers (6) Teams, projects and organisations

Part II – Special applications: (1) Numerical taxonomy. (2) Population growth and ecology (3) Theory of epidemics (4) General linkage and chromosome maps (5) Mathematical method of medical diagnosis (6) O.R. in medicine.

6/7/70 – New Books Section

(1) Course of Th. Physics – Vol I – Mechanics by Landau & Lifschitz – 2nd Edn Pergamon Press – No extensive revision made – Deals classical mechanics).

(2) Group Theory and unitary symmetry by T. S. Santhanam – Math Science Report 61 (No date mentioned) – All kinds of things brought up together without an appropriate aim

(3) Bhagavantham Volume (in honour of his 60th birthday) – 4/10/69 Editors: S. Balakrishna, Asst. Director, N. G. R. D. Hyderabad, Dr M. Krishna murthy, Dy Director (Tech), Cabinet Secretariat, New Delhi & Dr B. Ramachandra Rao, Head of Physics Dept, A. U, Waltair – Foreword by G. Herzberg, Ottawa, Canada, which is mostly rubbish (Saying that he was active with scientific research while he was an administrator!) — Appreciation by B. Ramachandra Rao, a student of Bhagavantam; highly exaggerated and absurd — Dedication by K. R. Ramanathan of Ahmedabad (also of the Raman group); I never thought Ramanathan would descend so low as this. — Series of dedicated papers of low standard specially on p. 53 by two people of the Annamalai Phys. Dept —

(4) Springer Verlag – Grundlehren Series No. – Bd 119 – The theory of branching processes by Theodore E. Harris, 1963 – Probability theory, the Galton & Watson model in treating the problem of extinction of family names – This model now finds useful for study of population of such objects as genes, neutrons and or cosmic rays – Pure mathematical except Chapter III – p. 201, martingale property of energy (5) Ibid – Bd 125, 1965 – Diffusion processes and their sample paths – Brownian motion and allied topics

– In the cover are mentioned 2 other Grundlehren series 121, & 122 on Markov processes.

(6) Documents on Modern Physics — Published by Gordon & Breach — Neutrino astrophysics by Hong-yee Chiu (Nasa Inst. of Space Studies & Columbia University – Very interesting editors' preface by E. Montroll, G. H. Vineyard & Maurice Levy – specially the remark that "Today the dramatic phase of a new branch of physics spans less than a decade, and subsides before the definitive treatise is published"

(7) The Origins of the Infinitesimal Calculus by Margaret. E. Baron.

Chap. 2 – Contains references to Hindu Mathematics & some parts interesting

(8) Progress in elementary particle and cosmic ray physics – Vol. V, 1960 – Edited by J. G. Wilson, and S. A. Wouthuysen – North Holland Publishing

Chap 1 – Weak interactions

Chap 2 – Nucleon–Nucleon interaction

Chap. 3 – Theory of antinucleons – Chap IV 4 – Cosmic ray "jet" interaction

Chap 5 – Absorption and decay of negative muons.

(9) Ibid, Vol 4 (1958)

Chap 1 – Strong interactions of new particles

" 2 – Properties & production of K-mesons

" 3 – Interactions of μ-mesons with matter

" 4 – Primary cosmic rays & time variation

(10) " 5 – Origin of cosmic variation

(10) The 1965 Brandeis Univ Summer Inst in Th. Physics – Vol 2 – Particle symmetries (Gordon & Breach) – Contributors; Cabibbo, Coester Cutkosky, Epstein, Hepp, B. W. Lee, T. D. Lee, F. E. Low, L. Michel, R. G. Newton, D. H. Robinson and A. H. Rosenfeld.

– Reference to Vol 1. of the same

(11) Radhakrishnan Reader – Anthology – Bharatiya Vidya Bhavan, Bombay-7 – Editors, Murthi & Srivastava – Radakrishnan's tribute to Rabindranath Tagore pp. 29–34 is most interesting – Also Tagore's words on p. 33 accepting the degree of Doctor of Letter honoris causa by Oxford Univ at Shantiniketan.

Re. Max Born

Date of death. 5|1|70

Ency. Britannica – 3 – p. 903.

" – 16 – p. 477.

" – 11 – p. 346

" – 18 – p. 814.

" – 20 – p. 947.

World's Who is Who in Science, p. 213.

Asimov's Biographical Encyclopaedia, p. 430.

Mc Graw-Hill modern men of Science pp. 54

Encyclopedia Americana Vol. 20, p. 392

" 12, p. 613

09

Ency. Americana, Vol 4, p. 276.

8/7/70 Details re. Max Born

(1) World's Who is who in Science, p. 213 - Colossal amount of information - Born. Breslau, Germany (now Poland), Dec. 11, 1882 - married Hedwig Ehrenberg, 2/8/1913 - Children - Irene (Mrs. Newton John), Margaret (Mrs. Pryce) - Home. Marcardstr. 4, Bad Pyrmont, Germany.

Found that Dirac is still alive & address: 7, Cavendish Av. Office: St Johns College, Cambridge, England

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10/7/70 New books Section

(1) Enrico Fermi Course XL - Nuclear structure and nuclear reactions (1969)

11 Lessons and 14 seminars - Colossal amount of information on all sorts of topics, which I had never heard of.

(2) Differential Geometry - by J. J. Stoker - Has something about general relativity also.

(1) one of the lectures by M. Baranger, p. 511 has something about Feynman diagrams, Feynman-Goldstone diagrams, Goldstone theorem, disregarding the Pauli principle at intermediate states.

(3) Theoretical and mathematical biology Ed by Waterman & Morowitz. Blaisdell Pub. Co. N.Y, Toronto & London - 1965 (1st Edn)

- A series of 20 articles on different topics.

Section I - Introduction - The problem by Talbot H. Waterman is a very simple & popular - This chapter originally published as in slightly different form in American Scientist, Vol. 50, pp. 548-569, 1962 as "Revolution in Biology"

13/7/70 New Books Section

(1) Springer-Verlag - Grundlehren Series Vol. 145

Semigroups of operators and approximations by Butzer & Berens.

- Refer in the introduction to a monumental treatise by Hille & Phillips (1957) - Chap I contains the fundamentals - Bibliography has a reference to

S. Minakshisundaram (T. Madras Univ) – Work of Hille & Phillips referred to is "Functional Analysis and Semi-groups – Amer. Math. Soc. Coll. Publ. Vol. 31, Providence R.I, 1957]

(2) Mixed boundary value problems in potential theory by Ian N. Sneddon (Glasgow), North-Holland, 1966 – It is only since 1945 that there have been attempts to develop the theory of dual integral eqns (Chap. IV) – No attempt to treat methods of Muskhelishvili which have played a decisive role in the development of potential theory & theory of elasticity – Book meant for a general class of readers & rigour not absolute – References (fifty) to R. P. Srivastav.

(3) Phase-space dynamics of particles by A. J. Lichtenberg (John Wiley) – All kinds of things like accelerators, applns to plasmas, phase-space transformations, adiabatic invariants (p. 53) – p. 80 has an example of the asymptotic method of adiabatic invariance the case of the harmonic oscillator.

(4) Exploring the Universe by H. C. King (The story of astronomy from the astrolabe to the radio telescope – Looks to be a popular book.

(5) Fundamentals of Electrodynamics by Podolsky & Kung (Marcel Dekker, N. Y. & London, 1969). Also treats relativity & relativistic mechanics in a simple way. For eg. on p. 76 deals with the twin paradox of a traveller (speed v c) returning younger than a person who was born at the same time & remained in our coord system – Interesting in view of tachyons problem

(15/7/70) New Books Section

(1) Symmetry Principles and fundamental particles – prepared and edited at Centre of Theoretical Studies, Univ. of Miami, Coral Gables, Florida ~~Istanbul~~ held at Istanbul, Turkey August 1–19, 1966 – with 4 Chapters

Chap I – Non compact groups & dynamical applications (5 articles)
" II – Quark models (3 articles)
" III – Current Algebra, weak interactions & Chiral symmetries (4 articles)
" IV – Recent developments in field theory and S-matrix theory (2 articles)

– In the first Chapter, & in the first article Coleman speaks of a famous and beautiful theorem of O'Raifeartaigh (CC).

(2) Lectures on particles and field theory – Brandeis Summer Institute in Th. Phys., Vol. 2. 1964 – Contents.

(a) Foreword
(b) K. Johnson on Quantum Electrodynamics
(c) D. Lichtenberg on Spectroscopy of strongly interacting particles
(d) J. Schwinger – Field theory of particles

(e) S. Weinberg on the quantum theory of massless particles.

Science – 20/3/70.

p. 1569. Particles that travel faster than light by R. G. Newton – Discusses the cause & effect idea which I had in mind and says it is not against tachyons. – His conclusion is that it is not impossible for superluminal particles to exist, but that if they were found and meaningfully identified as such, the consequences for physics would be far reaching. Either relativity theory or basic rules of quantum mechanics would have to go by the board, or else some very fundamental assumptions of essential controllability of events would have to be abandoned. The final answer, of course, rests with the experimentalist – Lots of references

p. 1601 – Research topics – Galaxies and quasars: Puzzling observations and bizarre theories by Robert W. Holcomb. Very interesting with a good bit of cosmology too.

17/7/70 – New Books Section.

(1) Compendium of meteorology – Containing 25 sections (including one by S. K. Mitra on the upper atmosphere.

(2) Comparitive studies in philosophy in honor of Radakrishnan's 60th birthday (with a portrait when he must have been young) (London: George Allen & Unwin Ltd, 2nd impression 1968) – Editorial Board: The very Rev. W. R. Inge, (*Mys. Univ) Principal L. P. Jacks, Prof M. Hiriyanna*, Prof E. A. Burtt, & Prof P. T. Raju – 21 articles with an Introduction by the Editors in praise of Radhakrishnan

[Heard the sad news of the death of Devanathan (only 36 years old) yesterday due to heart failure. It appears his wife Dr. Ratna was a student of mine. There was a condolence meeting yesterday at which the Director spoke nothing, but left weeping.]

Proc. Nat. Acad. Sci. U.S.A. Jan 1970 (Vol 65, No. 1)

p. 250 – Symposium on chemical and biological warfare).

20/7/70 – New books Section

(1) Volumes of Encyclopaedia Americana about 30

(2) Topics in non-linear physics – Springer-Verlag – Proc. Phys. Session of International School of non-linear mathes & Phys (Munich, 1966)

(a) p. 1 – Non linear problems in Physics by W. Heisenberg (This article also appeared in Physics Today 20, 27 (May, 1967) – The present conclusion is

that we do not know whether finally the fundamental problem in the quantum theory of elementary particles will be a non-linear or a ~~not~~ linear problem. – Other articles by Truesdell, Prigogine, M. Baus, Bloembergen, P. G. Saffmann and a last one of the bizarre geometrodynamics type by J. A. Wheeler.

(b) The last entry by Saffmann is "Lectures on homogeneous turbulence" pp. 485-614. in which the final remark is "Finally, it would seem that turbulence theory to date can be summarised by the quotation from Macbeth "full of sound and fury signifying nothing". It is hoped that future work will render this quotation inappropriate."

(c) Wheeler's ~~last sentence~~ "Conclusion" "There is nothing that is foreign and 'physical' immersed in space. Everything that is, is constructed out of geometry. This is the dream. Is the dream coming to life?"

p. 709 – Some remarks on "quanta" by wheeler

(3) Proc. on Computation of Turbulent boundary Layers – 1968 – AFOSR-IFP-Stanford Conference held at Stanford University, California, August 18–25, 1968 Vols I and II

(4) A history of the Maratha people by C. A. Kincaid & Rao Bahadur D. B. Parasnis 1964 – S. Chand & Co.

Frontispiece contains a picture of "Raja Shivaji, founder of the Maratha Empire (A.D. 1627–1680)

29/7/70 – New Books Section

(1) Applications of group theory in quantum mechanics by M. D. Petrashen and E. D. Trifonov (Translated by & revised by two Englishmen of King's College London) – no reference to any work of mine.

~~(2)~~ Math. Gazette – May, 1968, p. 162 – In mathematical notes No. 3206 on "Through the light barrier" by J. G. Gibson, Mathematics Dept., Queen Mary College, London, E.1 – The author states that a generalisation of the Lorentz transformation gives a means of working with values of the velocity parameter in excess of the velocity of light – To be read carefully later

5/8/70 – New Books Section

(1) Recent progress in combinatorics – Proc. 3rd Waterloo Conference on Combinatorics, May 1968 – Edited by W. T. Tutte, Univ. of Waterloo, Waterloo

Ontario (Canada) — Academic Press, N.Y. & Lond, 1969.

Preface by W. T. Tutte: Study of families of finite subsets of a given set or sets ie graph theory is included since a graph is often defined by a set of "vertices" and a family of pairs of vertices called "edges" — and originally combinatorics was considered a refuge for few eccentrics but now a field of activity for respectable mathematicians; we have watched with mingled awe & pleasure its development into a major field of mathematics generated as the spin-off of the 4-colour problem & is now applied to practical questions of transportation theory, communications theory, linear programming & electrical engineering — Eg. Orystein Ore tells us something of this recent work in showing that a 5-chromatic planar map must have at least 40 regions. But his death a few months later (X) was a heavy blow to combinatorics — Consists altogether 4 instructional courses & related papers, 15 invited papers, 18 contributed papers, 3 abstracts and one on unsolved problems ie 41 papers in all by several contributors; many short ones.

Ex. (a) How to win at football pools? p. 37)

(b) Enumeration of tree-shaped molecules by N. G. de Bruijn, p. 59
(Is this the man who gave complete references to all my papers?)

(c) Simple proofs for the Ramanujan congruences $p(5m+4) \equiv 0 \pmod 5$, and $p(7m+5) \equiv 0 \pmod 7$ by A. M. Gandhi?, p. 221

(d) A survey of thickness, p. 255

(e) Bricicity and cubicity of a graph, p. 301 (3)

(f) Brooks' 2 x 1 simple perfect rectangle, p. 338.

(2) Summary of terms frequently used in quantum mechanics — published by American Inst. of Physics (only 27 pp. found on the table of the library)

Some definitions (i) Anomalous magnetic momentum. — That part of the magnetic moment of a particle in excess or deficiency of the appropriate magneton (ie a unit of magnetic moment $= eh/2\pi mc$)

(ii) antiparticle — identical to the original in mass & spin, but having all its electric and magnetic properties, its strangeness (a property ascribed to certain elementary particles whose lifetimes are abnormally long relative to their rates of production; particles with a normal relationship between rate of production and rate of decay are said to have zero strangeness), and (for a fermion) its baryon number or lepton number opposite in sign from those of the original.

(iii) Born approximation — A system of successive approximations for treating

Scattering problems. It is based on the assumption that the effect of the scattering process on the wave function is small.

(iv) Degeneracy – Several states differing in many properties, but having same energy.

(v) Exchange energy – difference between energies of two states of a system of two or more interacting identical particles, arising from the fact that it is impossible to tell whether particle No. 1 is in state A & No. 2 in B or 1 in B and 2 in A. This is a purely quantum effect without a classical analogue.

(vi) Feynman diagrams – A means of representing by means of diagrams terms in an expansion of S-matrix elements. (S-matrix represents the operator which relates the final state of a process to the initial state. Many physicists regard it as the fundamental entity in quantum theory, but no complete formalism for basing dynamics of the system on it (rather than vice-versa) has been obtained)

Elements

(vii) Spin – that part of A.M. independent of how the particle is moving

(viii) Isospin or isotopic spin – a quantum number arising by regarding particles which differ only in their charges, such as p & n, as different states of a single particle

(ix) Renormalisation – A systematic technique for dealing with the infinite quantities that appear in calculations on the quantisation of fields. It is equivalent to replacing the "bare" coupling constant and mass, in these ∞-quantities by multiples of themselves equated to the actually observed coupling constant & mass.

(x) Rest energy – $E = mc^2$

(xi) Second quantisation – quantisation (in the broader sense) of fields, especially the fields which arise from quantisation of particle dynamics

(xii) Tunnel effect – The phenomenon in which a particle initially on one side of a potential "barrier" which, classically it could not cross, has a non-zero chance of being found, at a later time, on the other side of the barrier.

(xiii) Virtual state (1) any intermediate state whether the transition to it from the initial state would violate some conservation law (usually of energy) (2) virtually bound state is a state of fairly well-defined energy, which is not truly bound but remains localised for a fairly long time ("fairly long" depends on system involved)

(xiv) Resonance – Probability or the cross-section usually depends on energy of collision; when this probability is high over a small range of energy, the system of colliding particles is said to have a resonance at that energy. For eg. the absorption of neutrons by

is hyd only for a definite energy in each nucleus. Atoms absorb only certain energies (wave lengths) of light but not others.

[Reference to Stark effect, but no reference to Raman effect ?]

[Gives 14 names of Nobel Laureates, but no name of poor Raman!

[mention of "the profound meaning of the Pauli principle not yet fully understood]

(3) Advanced Mathematics for Scenice by W. L. Ferrar — A sequel to Mathematics for Scenice) — Clarendon Press, Oxford, 1969.

Part I — Diff. eqns (ordinary)

" II — Matrices & determinants

" III — Convergence, Fourier Series, orthogonal functions

" IV — Solid Geometry, Nexus in and partial diff eqns

(with lots of examples)

(4) Maharaja — Lives and loves and intrigues of Indian princes by Dewan Jarmani Dass — Very interesting book (Rs 18.00)

7/8/70 — New Books Section

(1) Mathematics in the modern world — Readings from Scientific American with introduction by Morris Kline.

An article on Ramanujan also.

Science — 9/1/70, p. 126 — An interesting article on Indian agriculture: Modern methods produce good harvests. by Robert. B. Davis, Boreya Road, Kanke, Ranchi-7, Bihar, India.

30/1/70 — Moon issue — Introduction by Philip. H. Abelson — relating to the successful Apollo 11 mission — Huge big volume with colossal amount of information.

6/2/70 — Reference to Egyptian Pyramids Research Organisation — joint U.A.R & U.S.A.

13/2/70 — p. 935 — The need for basic research by V.F. Weisskopff — Pleads vigorously for its need & points out opposition to it from two fronts — Interesting article.

p. 963 — A geneticist quitting science & going to politics, since research by scientists is put to evil use by politicians —

Quite interesting as showing views of the younger scientists (as for eg. towards CBW in Vietnam).

2 20/2/70, p. 1110 – Bertrand Russell the constant critic by John Walsh – mentions his four marriages – 4 turbulent years during World War II in the U.S.A which culminated in the annulment of his appointment of a professorship at City College in New York. In an opinion upholding a tax-payer's suit against Russell, the Judge cited "immoral and salacious 'opinions' contained in Russell's works. After the war, he had qualified his pacificism in support of the war against the fascicists & returned triumphant to Cambridge & was made Earl Russell & given O.M.

p. 1114 – Review of the book "The Oppenheimer Case" by P. M. Stern by Harry Calven. – Relating to Oppenheimer's opposition to the H-bomb. Oppenheimer was under during his entire government career under steady surveillance; the intransigent hostility to him of the U.S. Air Force

27/2/70, p. 1203 – 1211 – A case for a hierarchial cosmology by G. de Vancouleurs.

p. 1237 – Gravitational waves: the evidence mounts by G. I. Wick. – mentions Brans-Dicke – Jordan scalar-tensor theory (?)

10/8/70 – New Books Section

(1) The analytical Calculus – Vols I – IV by E. A. Maxwell – C.U.P

(2) Linear algebra by Mary Kopper – Many examples

✓ (3) 1967 Tokyo Summer ~~School~~ Lectures in Th. Physics – Fundamental particle Physics edited by Takeda & Hara – Benjamin, 1968.

Articles (1) Universality and symmetry principles in Hadron Physics by Peter G. O. Freund.

(2) Chiral Dynamics by Y. Yamaguchi

(3) Soft pions and current algebra by S. M. Berman

(4) Algebra of the observed current operators by T. D. Lee

✓ (5) C, P, T, symmetries by T. D. Lee

(6) A model of CP violation by K. Nishijima

(7) TCP invariance, Time-reversal invariance & K-meson decay by M. Gourdin

(8) Daughter trajectories and Bethe-Salpeter ghosts by N. Nakanishi

✓(4) Contributions to Functional Analysis – Springer Verlag, 1966 – Collection of articles
Nearly 45 articles published in Math. Annalen Vols 162 and 163 have been collected &
published & dedicated to Prof. Gottfried Köthe on his 60th birthday.

Some articles (a) G. Krabbe – Math. Ann. 162, 237–45 (1966) – Ratios of Laplace
transforms, Mikusinski operational calculus.

(b) On general integral transformations by Aronszajn and Szeptycki –
Ibid Math. Ann, 162, 127–154 (1966).

Science – 6/3/70

p. 1325 – Preliminary examination of lunar samples from Apollo 12 by
Lunar Sample Preliminary exam. team! (pp. 1325–1339)

✓ p. 1354 – Korean Institute for Science & Technology (KIST) built by help
of Americans (ie S. Korea) – Very interesting article

13/3/70 —

20/3/70 – p. 1569 – Particles that travel faster than light by
R.G. Newton – To be read more carefully later – Anyway
a preliminary reading did not convince me

✓ p. 1601 – Galaxies and quasars: Puzzling observations and
bizarre theories by R.W. Holcomb – Very interesting

27/3/70. p. 1688 – Student unrest: Sources & consequences by Leon Eisenberg
Starts with a quotation from Socrates as quoted in Plato's "Republic"
and ends with the sentence "But he who ~~has~~ does not lose his mind
over certain things has no mind to lose"

p. 1693 – Fourier analysis & structure of DNA – three papers
being comments on an article with the above heading in Science, 165
-1091 (1969) & the fourth a reply

p. 1704 – Science in Italy – Remarks of Mario Ageno, Head of the
physics Dept at the Institute for 11 years. On 25th July Ageno's
laboratory was invaded by a group demonstrating on the issue of
greater equality in salaries. Ageno himself, it is agreed by all, was
as holy as any of them on this issue. But he decided at that point that
he had enough. He walked out of the Institute and has never
returned. He said in an interview "I resigned because it became

impossible to work. Today we have a lot of people who call themselves scientists but who don't know anything about science. Profesors no longer teach, students get degrees without having done any research. We have enough money for research. What we lack is organisation and people who are interested in research, rather than social and political struggles. I was going to quit anyway."

p. 1707 – Stragetic arms limitation talks (SALT) between U.S. & U.S.S.R. – What is negotiable by Andrew Hamilton

p. 1751 – Report on physiological effects of transcendental meditation by R. K. Wallace –

✓ | Number of references to meditation as taught by Maharishi Mahesh Yogi in the text & also references to his books – Concludes that this might have practical therapeutic value.

B/4/70. (Vol. 168, No. 3927).

12/8/70 – Read C. P. Snow's foreword to Hardy's "A Mathematician's apology" – greatly struck by Hardy's playing Tennis & his intense love of cricket & his atheism.

14/8/70 Vol. 168. No. 3927 – B/4/70 of Science.

p. 104 – Parity violating nuclear forces by G. L. Wick

(i) Lee & Yang – 1950 – Theoretical studies based on K-meson decay.

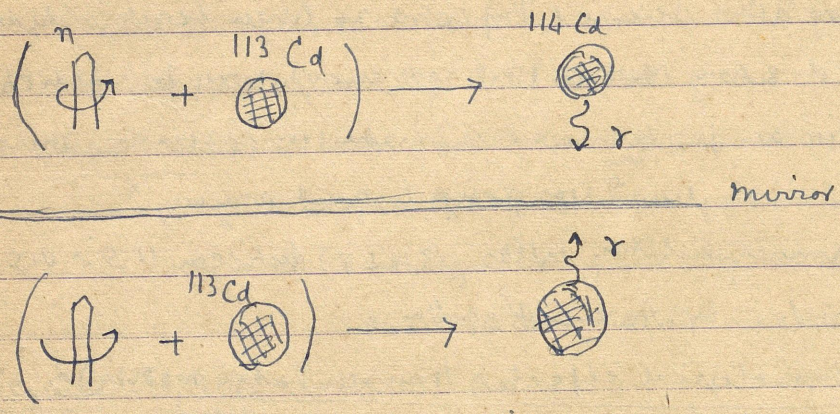
(ii) Expt. by C. S. Wu & her collaborators verified parity violation in β-decay of Cobalt-60. (almost immediately after Lee & Yang)

(iii) Immediately afterwards two other groups verifying this in μ-meson decays.

(iv) Later the parity-violating theory of weak interactions was generalised by Feynman & Gellmann (Phy. Rev. 109, 193, 1958), showing possibility of a parity-violating interaction of nucleons by a weak force, in case besides the parity-conserving strong force between nucleons. Their theory called the "Universal theory of weak interactions" was based on analogy with electromagnetic theory, where e.m. processes can be understood as the interaction of two currents. Thus weak nuclear phenomena could also proceed by way of current-current interaction. Nuclear β-decay can be described as the phenomena interaction of a nucleon current with a lepton (electron & neutrino) current.

Further describes expts to confirm this F & G's current-current

— Gives a figure for ^{113}Cd interacting with a thermal neutron → $^{114}Cd + \gamma$



The nuclear reaction and its mirror image are not identical. This situation constitutes parity violation.

10/4/70 — not available in the journal stack.

17/4/70. p. 315 — Letters on Frontal attack on radiation — radiation attack due to exposure

p. 316 — The University is not a highway Dept. by B. Liebermann

p. 319 — Editorial on overeducation.

p. 351 — Pill warning modified

p. 354 — Review of "Essays in the history of Mechanics" by C. Truesdell — Springer Verlag N.Y; 1968 by J. L. Synge [School of Th. Phys., Dublin Institute of Advanced Studies, Dublin, Ireland] — Very interesting specially the 6th para.

24/4/70. p. 420 — Two letters stating that schizophrenia is not necessarily of genetic origin

p. 428 — Editorial on "The threat of impatience" (referring to survival of a University)

1/5/70. — p. 525 — Editorial on "Troubled time for academic science" by F. H. Abelson — Quite interesting.

p. 544 — Ecological effects of the war in Vietnam. — Describes the horrors of use of defoliants by American & how Vietnamese farmers nothing growing in their lands for 3 years at a stretch due to this, thereby giving rise to a natural hatred towards Americans.

8/5/70. p. 664 — Origins of molecular biology by Eugene L. Hess

(*) on p. 917 – Attack on U.S. South East Asian policy by a member of California Univ. (41)

p. 669 – Language, name & concept by J. Bronowski & Ursula Bellugi

p. 674 – Traffic & highway research by B. D. Greenshields – Very interesting using mathematics.

p. 679 – Hiroshima / Nagasaki – Atomic Bomb Casualty Commission perseveres in sensitive studies

p. 681 – Among new members selected for the U.S. National Academy the only familiar names are A. S. Wightman of Princeton Univ, ~~and~~ Nathan O. Kaplan, Univ of California, San Diego, Harold Grad N.Y. Univ & Courant Inst., Cronin of Princeton

p. 685 – NAS says no to Shockley (N.L) (who feels that U.S. population is declining in quality due to reproduction of large number of negroes of low I.Q. & so wants excessive multiplication of white population)

p. 687 – Review of two books on melodramatic questions.
(i) Towards century 21, (ii) The children of Frankenstein

p. 691 – Review of book on the "Case for population growth" – General theory of population by ~~Af~~ Alfred Sauvy

p. 695 – The inexorable atom – Review of Vol 2 of a history of U.S. A.E.C named "the atomic shield"

15/5/70. p. 777 – Population growth and extremism

p. 811 – Astrophysical model proposed for galactic magnetic field

p. 878 – South pole reaches the Sahara – A problem for the paleomagneticists.

22/5/70.* p. 923 – Physics in the twentieth century by Victor. F. Weisskoff

(pp. 923–930) to be read carefully later.

17/8/70

Relativity, quantum theory, atomic physics, molecular physics, the physics of the solid state, nuclear physics, astrophysics, plasma physics, particle physics – all these are children of the 20th century.

A remarkably fine article treating with all the above topics with some emphasis (but not too much) on particle physics. In fact, barring the nucleons, electron, muon, no other particles (even the pion) are mentioned.

~~Some concepts~~

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19/8/70 News books Section.

(a) Glossary of terms frequently used in nuclear physics

Introduction: Within the last ten years, nuclear physics has split clearly into two parts, one being the older field of low energy nuclear physics, concerned with nuclear structure, and the other being the field of high energy physics or the field of elementary particles

In the field of low energy nuclear physics the structure and motion of the nucleus as a whole are studied, considering the nucleus as a collection of neutrons and protons held together by the strong but short range force between them - theories of radioactive nuclei, nuclear reactions of all kinds, the scattering of nucleons by nucleons at various energies, the systematic variation of nuclear masses and even the effect of various nuclear properties on the behaviour of the atomic electrons which move about outside the nucleus.

Particle physics, on the other hand, is concerned with the understanding of the subnuclear particles themselves including p & n, which are believed to be the constituents of the nuclei, and the mesons and hyperons which can be created in high energy collisions of one particle with another. one might say arbitrarily define "high" energies as those above the energy required to produce mesons.

The glossary is a collection of terms drawn from both fields, with special emphasis on the low energy side.

(1) Absorption coefficient - Quantity used to describe the ability of various materials to attenuate radiation of various kinds - for eg. the linear absorption coeffn of a particular material for gamma rays (high energy electromagnetic quanta (photons) similar to X-rays or visible light) of a certain energy measures the probability that the gamma ray will interact in any way in passing through unit thickness of the material. The intensity of a beam of gamma rays of one energy decreases exponentially with the thickness of the absorber.

(2) Alpha decay - Decay uranium, radium etc which are radioactive decaying by emitting an alpha-particle (nucleus of He-atom composed of 2 neutrons

and 2 protons) ie α-decay → nucleus of atomic number two less and a mass number four less than original nucleus.

(3) Annihilation – eg. $e^+ + e^- \xrightarrow{2\gamma \text{ or } 3\gamma}$ (energy conserved including rest energy of $e^+ + e^-$) p^+ and p^- usually produce π-mesons when they annihilate

(4) Antiparticle – If a particle has charge, antiparticle has opp. charge. If particle has no charge, then antiparticle has no charge and may or may not be identical to it. Particle and antiparticle have the same mass, same spin and same mean life and same magnitude of magnetic moment (ie μ of the particle determining the torque (μH) which the particle experiences when its spin axis is ⊥r to a magnetic field of strength H) but with opposite sign

(5) Atomic mass – actual mass of an atom or an element in atomic mass units

(6) Atomic mass unit – Equal to 1.66×10^{-24} gms (amu), this value being chosen so that the isotope O_{16} will have a mass exactly 16.000 amu.

(7) atomic number – no of $\underline{p}$ in nucleus or no of orbital $\underline{e}$

(8) Barn – unit of cross-section (a measure of probability that a reaction will occur). one barn = 10^{-24} cm^2.

(9) Baryon – All free baryons heavier than $\underline{p}$ eventually decay into end products one of which is a $\underline{p}$

(10) Beta ray – e^- or e^- given off in beta decay

(11) BeV = 10^9 = one billion eV (= GeV)

(12) Binding energy – amount of energy needed to remove that nucleon from the (of a nucleon in nucleus) nucleus against the attractive forces that hold it there – varies from nucleus to nucleus, but is about 7 or 8 MeV.

(13) Bohr magneton – magnetic moment of electron = $e\hbar/4\pi mc = 0.92 \times 10^{-29}$ erg/gauss.

(14) Bound level – Energy levels in a nucleus which are so close to the ground state that they can only decay by gamma emission in contrast to virtual levels which can decay by particle emission

(15) Bragg scattering – A term used in work with slow neutrons (or X-rays) to describe the selective scattering process in which particles of a given de Broglie wave length ($\lambda = \hbar/mv$) are scattered with high intensity from the regular planes of a single crystal at only very definite angles.

(44)

The Bragg law governing this process is: $n\lambda = 2d \sin\theta$ (n an integer, λ = wave length of the particle, d = spacing of crystal planes & θ = angle at which particles hit the plane.

(16) Breit-Wigner formula – A theoretical formula giving, in the simplest form, the value of the cross-section for a nuclear reaction in the vicinity of a single resonance level in the compound nucleus.

(17) Bremstrahlung – "breaking radiation", when a charged particle is accelerated electromagnetic radiation is emitted. The term is used ~~when~~ to describe continuous x-rays emitted when high energy electrons such as those from betatrons or synchrotrons are accelerated at a target.

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(18) Cascade particles – particles (mesons, photons etc) which arise from the collision of a ~~nucleon~~ nucleon with matter

(19) Charge conservation – No one has ever observed a reaction in which total electric charge is not conserved.

(20) Chopper – A rotating shutter used in neutron physics for producing short bursts of neutrons of many energies (which can be separated) from range 5 millivolts to a few thousand volts.

(21) Cloud – term used to describe those ~~neutrons~~ nucleons in the nucleus not in closed shells.

~~(22)~~ 21/8/70 – The above continued

(22) Cloudy crystal ball model – A model of the nucleus which predicts the total ~~no~~ elastic scattering (a scattering process in which the outgoing particles are the same kind as the incident particles, and in which no K.E. has been lost) cross section for neutrons averaged over resonances that may be present. This cross-section and the angular distribution of the neutrons show systematic variations with mass number suggesting that they are related to large scale property of the nucleus rather than the details of the arrangement of the nucleons. The nucleus is considered mathematically as a spherical potential well with a real and imaginary part, the real part resulting in the scattering of the neutrons while the imaginary part leads to attenuation or absorption of the neutrons. The nucleus is

therefore only partly transparent resulting in the name "cloudy crystal ball model)

(23) Coincidence circuit – An electronic circuit used to determine when two or more particles pulses from separate counters occur within a given time interval. This is done to determine whether the pulses were produced by the same particle or whether they correspond to the same event.

(24) Cold neutrons – Very low energy neutrons (a few millivolts) obtained by using only a small fraction (the low energy tail of the Maxwellian distribution) of the neutrons coming from a reactor or by moderating the more energetic neutrons produced in a reactor in a special low temperature moderator. These cold neutrons are very useful tools in learning about the motions of atoms in solids and liquids when used with a neutron chopper. The cold neutrons can be scattered off the material of interest and in the process they can gain energy from the atoms of this material. A study of the energy distribution of these scattered neutrons that have picked up energy reveals much about the behaviour of the atoms.

(25) Collective model – A model of the nucleus combining many of the aspects of the shell model of the nucleus, and the liquid drop model. The nucleus is thought of as having a shell structure with its characteristic individual particle states upon which is superimposed the collective or liquid drop type motions. It was devised to explain the quadrupole moments of nuclei and still preserve the shell model characteristics.

(26) Complex potential model – Vide (22)

(27) Compound nucleus – A theory of nuclear reactions devised by Niels Bohr in 1936 to explain and interpret nuclear reactions. Nuclear reactions are assumed to take place in two steps. First an incident particle is absorbed by a nucleus to form a compound nucleus. The energy of the incident particle is shared amongst all the other particles in the nucleus so that the nucleus "forgets" how it was formed, and the decay of the compound nucleus, step two, is independent of the manner in which it was formed.

(28) Compton scattering – A gamma ray with energy large compared to the energy with which an energy bound to the atom "hits" an electron, and knocks it out of the material, the γ-ray coming off with less energy

such that energy and momentum are conserved in the process.

(29) Compton wave length – used in elem. part. physics = $\hbar/2\pi mc$, and is a measure of the force "carried" by the particle – Compton wave length for π-meson (exchange force between nucleons) is about 10^{-13} cm – $2\hbar/mc$ gives the largest possible wave length change for a γ-ray which is Compton scattered.

(30) Control rod – Rods which are inserted in nuclear reactors which can be adjusted to control the rate at which fission processes go on.

(31) Core – That part of the nucleus containing particles in closed shells. The Collective model of the nucleus treats excitations of this core as well as those of the cloud composed of nucleons in non-closed shells

(32) Cosmic rays – Earth constantly bombarded by very high energy protons and some bare nuclei (no electrons) of light elements. These "primary" cosmic rays strike the atmosphere and produce many other particles. These secondary ones consist mostly of muons, γ-ray and electrons hitting the surface of the earth at the rate of about one particle per cm^2 per minute.

(33) Coulomb scattering – The scattering that takes place when charged particles passing through matter are scattered by the electrostatic force exerted on them by the other charged particles – Coulomb's law ee'/r^2.

(34) Critical assembly – assembly of sufficient fissionable materials (U etc) and moderator material (water, heavy water, graphite) which is capable of sustaining a fission chain reaction at a low power level.

(35) Crystal spectrometer – A device used in neutron physics consisting of a single crystal of perhaps Al or Cu which utilizes Bragg scattering to obtain a beam of monoenergetic neutrons from a more intense beam containing many energies coming from a nuclear reactor. – Many energies can be selected by changing angles at which the beam from the reactor strikes the crystal to study the manner in which these monoenergetic neutrons interact with matter.

(36) Curie – A unit of radioactivity – one curie is the amount of radioactive material giving 3.7×10^{10} disintegrations per second.

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(37) Delayed neutrons – In the fission process, most of the neutrons released are emitted in a very short length of time ie 10^{-13} or 10^{-14} sec. after the splitting takes place.

A small fraction however (less than 1%) is emitted over a period of up to a few minutes after the fission. These are called delayed neutrons. It is believed that that the compound nucleus formed by the neutron and the fissionable nucleus splits into two parts each of which has too many neutrons for stability. The delayed neutrons are given off by these unstable fission fragments.

(38) Delta ray – An electron which is hit by an energetic charged particle in passing through matter will sometimes acquire energy to be detached. Such an electron is called a δ-ray

(39) Deuteron – nucleus of heavy hydrogen (isotope of H of mass no. 2) consisting of a neutron and proton – Its binding energy is 2.2 MeV. Since it is the simplest nucleus with more than one nucleon, this particle has been the object of much study to learn about the force between proton & neutron.

(40) Differential cross-section – probability of emission at a particular angle w.r.t particle inducing the nuclear reaction. Total cross-section = sum of diff. cross-sections over all angles.

(41) Diffusion – the process by which particles such as molecules in a gas or neutrons in a moderator move about and mix up as a result of their thermal motions.

(42) Diffusion length – Distance in a moderator in which the neutron density decreases by a factor 1/e.

(43) Dispersion theory – A theory of nuclear reactions analogous to dispersion of light. The compound nucleus is pictured as a damped oscillator which readily absorbs a neutron, for eg, at a resonance energy and then gets rid of the energy it has acquired by emitting γ-rays, resulting in a small probability of the neutron being re-emitted. The Breit-Wigner formula is a result of dispersion theory.

(44) Double beta decay – A possible transition between two stable even Z (atomic number) even N (no. of neutrons) isobars (nuclides having the same mass number) in which two β-rays are emitted at the same time. Double beta decay has been of interest because the magnitude of the half life (time necessary for half of a large sample of decaying particles [such as radio-active nuclei] to decay) for such a process is one indication of the existence or lack of existence of distinguishable neutrinos and anti-neutrinos.

24/8/70 New books Section

(1) British scientists of the 20th century by J. G. Crowther

About Rutherford: (a) There are some scientists who have earned a noble memory by creating opportunities for others, besides contributing discovering the discoveries themselves [Mention about Born in letter to Hedi Born]

(b) Giving immemorable special lectures and presidential addresses. His stamina was very remarkable.

(c) Rutherfords interest in helping German scientists persecuted by Hitler

(d) Russia insisting on Kapitza going back to U.S.S.R & Rutherford did not attack the Soviet Union, but negotiated a fair settlement. The Soviet Govt. undertook to purchase Kapitzas apparatus for £ 30,000.

(e) He accepted an invitation to deliver the Presidential address of the Indian Science Congress in Jan. 38. But on Oct 14th, 37, he became ill, owing to a slight hernia & he died on Oct. 19th departing suddenly in the midst of a healthy, happy, triumphant and glorious life (1837-1871-1937) – Great believer in British Empire saying it is U.K. He declined all help from U.S.A & refused all posts there

(f) He was born to play with particles; every α-particle was one of his personal friends, as Hardy had said of Ramanujans acquaintance with integers.

(g) He was still young in spirit when he died, and those whom the Gods love die young.

(2) A book on Intro to Quant. Mech

(3) Boolean algebra & Math. logic.

Continuation of Glossary of terms in nuclear physics

(45) Electric quadrupole moment – A term used to describe the football shaped distribution of electric charge in some nuclei

(46) Electron – Lighter particle with non-zero rest mass (9.1×10^{-28} gm or 0.511 MeV) found in nature. It is a fermion undergoing only weak, electromagnetic and gravitational interactions.

(47) Electron capture – (Sometimes called K capture) occurs when the orbital electrons, usually the K electrons nearest the nucleus are "captured" by the new nucleus, resulting in a new nucleus with same mass no. but atomic no. one less than original nucleus. No charged particle is emitted and the process is only observed by the x-rays given off as an electron from an outer shell fills the vacancy in the K-shell. In an

[Obituary of Max Born by Heisenberg in Nature of 17/2/70 read today]

electron capture to be energetically possible the atomic mass of the original atom must be > atomic mass of the product atom.

(48) Electron volt (eV) = Energy = 1.6×10^{-16} erg or energy gained by an electron in being accelerated through a potential difference of one volt.

(49) Elementary particle – not a composite of two or more others

(50) Emulsion; nuclear – Similar to photographic emulsions but thicker and less sensitive to light. A charged particle passing through the emulsion ionises the grains along its track and these grains become black when the emulsion is developed. Interactions and decays can be studied with great accuracy by examining the tracks formed by the developed grains using a microscope.

(51) Energy conservation – No violations of this law have ever been found.

(52) Energy level – Particular value of the energy which a system like the nucleus can maintain for a reasonable length of time – restriction due to quantum mechanics

(53) Equivalence of mass & energy – $E = mc^2$. The K.E of a particle of mass m and rest mass m_0 is given by $E_k = (m - m_0)c^2$ being just its increase in mass multiplied by c^2. A particle accelerated to an appreciable fraction of the c is an example of conversion of energy into mass, while the fission and fusion processes are examples of conversion of mass into energy

[Rest mass – mass of a particle having zero velocity. The term is used to specify what we would normally think of the mass of an object since all objects that are moving experience an increase in mass according to special theory of relativity. The effect becomes only significant when the velocity is an appreciable fraction of c. Particles with velocities close to c are commonly encountered in nuclear physics. For eg. a 20 MeV electron has a mass which is about 40 times its rest mass.]

(54) Exchange force – eg. of π-mesons exchanged by nucleons – Similar sort of thing occurs in the covalent bonding of molecules in which electrons are exchanged between atoms.

(55) Excited state – Energy level of a higher level from a lower one when given sufficient energy. Usually such an excited nucleus will only exist in this state for a short time after which it gives off a particle of some sort and returns to the ground state.

(56) Exclusion principle – Statement that two identical fermions cannot exist in the same state at the same time – due to Pauli

(57) Expectation value – Probability obtained from quantum mechanics for the result of a particular physical measurement or the average of a large number of measurements.

(58) Fertile material – An element which is not fissionable but which can be made so usually in a nuclear reaction initiated by a neutron. For eg. Thorium 232 + a neutron → Thorium 233 which is radioactive with a half life of 23 minutes. This goes by Beta decay (ie $e^- + \bar{\nu}_e$ or $e^+ + \nu_e$) to Protoactinium 233 which is also undergoes beta decay (half life 27 days) to Uranium 233 which is fissionable.

(59) Fission – Splitting of a heavy nucleus into two or more parts. Although fission can occur spontaneously, it is usually caused by a neutron hitting the nucleus. Considerable energy (about 200 MeV) is given off per fission, and much of this goes into the kinetic energy of the fission fragments. Also more than two neutrons are given off, on the average, during each splitting so that if enough fissionable material is present a chain reaction can take place. In a nuclear reactor the chain reaction is controlled, the reactor being a source of heat energy or of neutrons. The reaction is uncontrolled, after it starts, in an atomic bomb.

(60) Flux – In nuclear physics the term flux means the product $n\underline{v}$, where n is the no. of particles per unit volume and $\underline{v}$ is their average velocity. For eg. the thermal neutron flux at a particular place in a reactor might be 10^{12} neutrons per sq. cm. per second.

(61) Fusion – The process of combining two light nuclei to form a heavier nucleus. For eg. two deuterons might be combined to form an alpha particle. Since the sum of the masses of the two deuterons is greater than the mass of the alpha particle (ie the binding energy per nucleon is greater for the alpha particle) energy must be released in the process. The fusion process is used in the so called hydrogen bomb, and is also a principal source of the energy given off by the stars.

(62) Gamma rays – e.m. quanta (photons). The final or product nuclei resulting from β or α-decay often emit γ-rays as they change from an excited state to a lower state.

(66) Gaseous diffusion – A process for separating isotopes of the same element which uses the fact that gases will be enriched in the molecules of lower molecular weight as they flow, under pressure, through the very small holes in a porous material. This process repeated many times, is used to separate U_{235} from U_{238} both being in the gaseous compound uranium hexafloride.

(67) Geiger counter – A detector designed to detect ionising particles

(68) Gyromagnetic ratio – The magnetic moment of a particle can be written as $g = eS/mc$ [S = intrinsic A.M (spin)], and g a dimensionless number known as the g-factor or gyromagnetic ratio. For fermions which have no strong interactions (leptons), g is very close to 2.

(69) Half life – Characteristic of exponential decay.

(70) Helicity – If a particle is spinning about an axis ∥ to its direction of motion, it is said to possess helicity. If its motion is like that of right handed screw, it has right handed helicity, otherwise left handed.

(71) Hyperfine structure – The splitting (slight) of atomic spectral lines caused by the fact that atoms of the same element may have different isotopes as nuclei, and by the fact that the nucleus may have A.M & therefore a magnetic moment which interacts with the orbital electrons

(72) Inelastic forces – K.E of outgoing particles is not same as that of incoming particles. Such a process would occur, for eg, if some of the incoming K.E. is converted into the mass of a new particle or if the incoming particle stays in the compound nucleus raising it to an excited state as in the so called (n, γ) reactions in which the compound nucleus is formed by an incident neutron, the nucleus then gives off an energetic gamma ray.

(73) Interactions (i) strong (range 10^{-13} cm), forces holding nucleus together of great strength. Primary forces in most reactions involving π-mesons, K-mesons and hyperons (> nucleons). Leptons not affected by the strong interactions

(ii) e.m – All reactions involving photons or gamma rays are of this type.

(iii) weak - responsible for β-decay, π-decay, K-decay and decays of Λ, Σ and Ξ particles; many orders of magnitudes smaller than (i)

(iv) gravitational

(74) Internal conversion. - often after a nucleus has undergone beta decay the resultant nucleus is left in an excited state. often it goes to the ground state by giving off one or more gamma rays, but sometimes there is an interaction between the excited nucleus and one of the orbital electrons, usually the K or L electrons closest to the nucleus. The electron given off in this process is called an internal conversion electron. The energy of this conversion electron is the same as the γ-ray instead of which it was emitted, if one includes the binding energy of the electron in the atom. These conversion electrons all have the same energy and are superimposed on the continuous β-spectrum.

(75) Ionisation chamber - A chamber containing a gas through which ionising particles pass.

(76) Isobar - Nuclides having same mass number.

(77) Isomer - Sometimes a nucleus in an excited state will remain in this state for a long time, the half lives being as large as several years. It is therefore possible for two nuclides to be identical in all respects except that one is an excited state and will eventually decay by giving off a gamma ray. Such nuclides are called isomers and the transition in which the gamma ray is given off is called an isomeric transition.

(78) Isotopic spin - nuclear quantum number (nuclear ~~phenomena~~ forces do not distinguish between $\underline{p}$ & $\underline{n}$) considering $\underline{p}$ & $\underline{n}$ as states of same particle ie $+\frac{1}{2}$ for $\underline{n}$ and $-\frac{1}{2}$ for $\underline{p}$. The isotopic spin for a nucleus is the sum of the isotopic spins of the constituent $\underline{n}$ and $\underline{p}$ & is zero if no. of $\underline{n}$ = no. of $\underline{p}$

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(79) Klein - Nishina formula - An expression for the differential scattering cross section for the Compton effect ie scattering of a gamma ray by an electron at rest.

(80) K-Mesons, K^+, $\underbrace{K^0, K^{-0}}_{\text{anti}}$ and K^- - All have masses equal to about 970 electron

anti

masses. The K^+ & K^- decay with mean life of 1.2×10^{-8} sec in one of several

ways. The K^0 and K^{-0} can decay in two different ways one having mean life of 10^{-10} sec & the other a mean life of 10^{-7} sec.

(81) Kurie plot – A graph of $\sqrt{N(p)/p^2}$ vs K.E. for the beta particles given off by a radioactive sample. $N(p)$ = no. of particles per unit momentum interval, and p = momentum. According to the fermi theory of β-decay this graph should be a straight line for certain classes of beta emitters.

~~(15)~~ 26/8/70 New Books Section

✓ (1) Atomic energy by Glasstone – Has at the end a small but up to date chapter on elementary particles

(2) Precious stones Vol I, by X – Describes the Panna mines of diamond and the Kohinoor. (Stolen by the British scoundrels)

(3) A history of the Sikhs – Gives an account of the Sepoy Mutiny

Glossary contd.

(82) Lambda particle – A hyperon with spin ½ and mass about 2188 electron masses, decays with mean life of 2.5×10^{-10} sec. into either $\pi^- + p$ or $\pi^0 + n$.

(83) Liquid drop model of nucleus – A model of the nucleus which treats it as analogous to a drop of incompressible fluid of very high density. Using this idea and consideration of such things as surface tension and coulomb repulsion of the protons, the semi-empirical mass-formula can be obtained giving the binding energies & and therefore the masses of all the nuclides. The liquid drop model is also quite successful in explaining the fission process.

(84) Magic numbers – The name given to certain numbers of neutrons or protons in the nucleus which result in that nucleus being more stable than its neighbours in the periodic table. These numbers correspond to closed shells in the nucleus. Values of Z or $N = A - Z$ (no. of neutrons) of 2, 8, 20, 28, 50, 82 and 126 have come to be called magic numbers. The stability is indicated not only by high binding energy but also by high natural abundance of isotopes for eg. tin, with 50 protons and 10 stable isotopes.

(85) Mass number – A = no. of p + no. of n in nucleus. For most atoms it is fairly close to the atomic mass expressed in (amu). For eg. lead 208 has 82 p & 126 n. Its mass no. is 208. Its atomic mass is 208.0422 (amu)

(86) Mass spectrograph – Instrument for measuring the masses of atoms – Ionised atoms accelerated in an electric field & then deflected in a magnetic field or a combination of both fields – atoms of different mass are deflected by different amounts and recorded, for eg, on a photographic plate. – Separation of images on plate → mass difference.

(87) Maxwellian distribution – Distn of velocities of molecules in a gas at given temp. The term is also used in nuclear physics to describe the distn of velocities of neutrons in a moderator in which the neutrons bounce around and come to thermal equilibrium with the atoms of the moderator behaving much like molecules in a gas.

(88) Mean life – The average or mean time of decay for a large no. of particles of the same kind – The mean time is equal to 1.44 times the half life

(89) Mesons – mass > m_e & < m_p or m_n (MeV = 10^6 electron volt ie million e.v.)

(90) Microwave spectroscopy – Many gas molecules give off radiation as a result of the decay of quantised rotational energy levels in the wave length region from 1 mm to about 30 cm. Radiation passed through samples of these gases will be absorbed preferentially at the same wave lengths, permitting a study of these levels. The magnetic field produced by the nucleus may split these levels (hyperfine structure) so that their study provides a means of determining the magnetic moments and spins of nuclei

(91) Mirror nuclei – A name given to a pair of nuclides such as $_6C^{11}$ and $_5B^{11}$ which have the same number of nucleons but one of the pair has one less proton than the other and also one more neutron. Each of the pair would be changed into the other if its protons were changed into neutrons, and if its neutrons were changed into protons. The study of mirror nuclei has provided information about the charge independence of nuclear forces.

(92) Moderating ratio – a term used to describe the effectiveness of a moderator. It is defined as the quantity $\xi \sigma_s/\sigma_a$ where ξ is the average decrease per collision in the logarithm of the neutron energy and σ_s and σ_a are the scattering and absorption cross-sections respectively. The moderating ratio is a measure of the relative ability of a

moderator to slow down neutrons as opposed to absorbing them. Deuteron has a very high modrating ratio (12,000) as compared with 72 for water, and 170 for graphite.

(93) Moderator – A substance such as water, deuterium, graphite or paraffin which is used to slow down neutrons to thermal energies as they collide with the atoms of the moderator. A good moderator should absorb very few neutrons, should provide frequent chances for collision, and should be as close in mass number to the neutron as possible, to permit as much energy loss as possible per collision.

(94) Molecular beam – beams of neutral atoms which are passed through non-uniform magnetic fields in order to obtain a measure of the magnetic moment of their nuclei

(95) Momentum conservation – In an isolated system momentum is always conserved

(96) Multi-channel pulse height analyser – An electronic device which takes pulses from various kinds of counting equipment and records them according to their size.

(97) mu-meson (muon μ) – $m_\mu \simeq 207\, m_e$. Results from decay of π-meson and decays into an electron and two neutrinos with mean life of 2.2×10^{-6} sec. As cf. with π, μ interacts weakly with matter.

(98) Neutrino – an uncharged fermion with zero rest mass. originally postulated by Pauli and Fermi to explain energy and momentum in β-decay of radioactive nuclei. It is also believed to play the same role in the decay of π-mesons into μ-mesons. Despite the fact that the neutrino has negligible probability of interacting with matter it was finally detected by Reines and Cowan in 1956 using the high flux of neutrinos from a nuclear reactor.

(99) Neutron (n) – $m_n = 1838\, m_e$ – It is stable in the nucleus – Free neutrons as found for eg. in a reactor as the result of fission are radioactive and decay $\rightarrow e + p + \nu$ with a half life of about 12 minutes.

(100) Nuclear force – Force between two nucleons – strong interaction. Nuclear forces are characterised by the term saturation because the binding

per nucleon is constant ie the binding energy of a nucleus is nearly proportional to the number of particles in the nucleus and not to the number of possible interacting pairs of nucleons indicating that a given nucleon does not interact with all the others in the nucleus and that the force between nucleons is one of short range.

(101) Nuclear magnetic resonance - When a particle such as a proton which acts as a small magnet is put in a steady magnetic field it will precess, much as a gyroscope precesses, with a frequency which depends on its magnetic moment (eg the p) and the strength of the field. If an alternating magnetic field is applied at right angles to the steady field with a frequency just equal to the precession frequency of the proton, it can be flipped over. This flipping at the proper resonance frequency can be detected and the technique provides a method of measuring the magnetic moment of such particles as the photon or of accurately measuring magnetic fields if the alternating field frequency and the proton magnetic moment are known. The protons in the hydrogen atoms in a sample of water work well for this purpose because they are relatively free of the other nucleons.

(102) Nuclear reaction - A process in which a particle hits a nucleus often forming a compound nucleus which can decay by giving off the same particle with the same or less energy, or by giving off another particle. The resultant or product nucleus is sometimes radioactive. The notation sometimes used to describe nuclear reactions is illustrated below for the case of an alpha particle interacting with an aluminium nucleus resulting in a proton being given off

$$_{13}Al^{27} + _{2}He^{4} \rightarrow \left[_{15}P^{31}\right] \rightarrow _{14}Si^{30} + _{1}H^{1} + Q.$$

This is often abbreviated as $_{13}Al^{27}(\alpha, p)_{14}Si^{30}$. The number to the lower left of the chemical symbol is the atomic number, and the number to the upper right of the symbol is the atomic mass number. Q represents the Q value or energy balance. The square brackets enclose the compound nucleus.

(103) Nucleus - radii in the range 10^{-12} to 10^{-13} cm - Roughly equal no. of n & p in light elements & n increasing for heavier elements.

(104) Nuclide – Almost a synonym for nucleus : one distinguishes different nuclides by the no. of n and p in each and by their energy content. For example two isomers would be considered different nuclides

(105) Pair production – A process in which a gamma ray with energy greater than 1·02 MeV can produce a positron and an electron, the so called e^+e^- pair, if it gets close enough to a nucleus. The gamma ray disappears and its energy is converted into the rest energy and K.E of the electrons. Along with the Compton effect and the photoelectric effect, pair production is one of the principal methods by which gamma rays interact with matter.

(106) Parity – Refers to symmetry properties of wave fns in quant. mech. If parity is conserved, as in the case of strong interactions, no experiment can differentiate between the behaviour of a system and its mirror image. In weak interactions ~~just~~ such as beta decay it is found that parity is not conserved, with the result that the decay particles may be assigned a definite (L·H or R·H) helicity.

(107) Photoelectric effect – one of the principal methods by which gamma rays interact with matter. A gamma ray interacts with an atom and disappears (as in pair production) and an electron comes off with all the energy of the gamma ray (unlike in Compton effect) except that required to remove it from the atom. The interpretation of the photoelectric effect by Einstein was an important step in the development of the idea that e.m. radiation is quantised ie that it ~~be~~ behaves ~~like~~ as a particle as well as a wave.

(108) Photomultiplier tube – A vacuum tube which converts light signals into electrical pulses. The tube consists of a light sensitive surface or photocathode which gives off photoelectrons when light is incident on it. These electrons are directed and focused using electric fields so that they strike perhaps 10 or 14 successive stages or dynodes at each of which the number of electrons is increased or multiplied by a process called secondary emission. The result is that a single photon incident on the photocathode can result in several million electrons at the other end of the tube which can produce electrical pulses big enough to be amplified and recorded. Such tubes are very useful in recording the scintillations produced by charged particles in passing through scintillating materials such as

Sodium iodide crystals. They are thus an essential part of a modern scintillation counter.

(109) Photon – e.m. radiation such as light, X-rays and gamma rays (all in diff ranges of energies) can be thought of as waves of frequency ν or as particles or photons of energy $h\nu$.

(110) Pi-meson – π^+ π^- Charged π has mass = $273 m_e$ and π^0 has mass = $264 m_e$. Believed to be the exchange particles between nucleons resulting in nuclear force holding the nucleus together. Charge π-mesons usually decay into a mu-meson and a neutrino with a mean life of 2.86×10^{-8} sec. π^0 decay into two gamma rays with mean life of 10^{-14} sec.

(111) Planck's constant – $h = 6.6 \times 10^{-27}$ erg. sec. determining basic quanta of energy $h\nu$ and of angular momentum $h/2\pi$.

(112) Polarisation – A sample of material in which the magnetic moments and therefore the spin directions, of all the nuclei are aligned in the same direction is said to be polarised. This can be done by cooling the sample to temperatures close to absolute zero to minimise thermal motions and applying a magnetic field to align the "atomic magnets". Beams of polarised particles can also be produced by Bragg reflection from crystals.

(113) Positron – when they encounter electrons they annihilate usually producing two gamma rays.

(114) Potential well – Notion rather complicated – the nucleons are thought of as existing in a potential well which is analogous to the macroscopic gravitational potential well experienced by a golf ball after it rolls into the hole on the green.

(115) Proportional counter – A gas filled radiation counter designed to count charged particles.

(116) Proton – $m_p = 1836 m_e$ (Cf. $m_n = 1838 m_e$) – Is stable.

(117) Quantum mechanics – named after quanta of energy. A Mode.

(118) " number – integral or half-integral multiples of the fundamental quanta.

(119) Q value – The Q value or energy balance in a nuclear reaction can be defined as either the difference between the K.E of the initial particle and/or nuclei, and the K.E of the products, or the difference in

mass between the initiating reacting particles and the products. If the Q value is positive the reaction is said to be exothermic and energy is released. If Q is negative the reaction is endothermic and energy must be supplied by the original reacting particles in order to make the reactions go.

(120) Radiation length – The average distance in a substance required to reduce the energy of a relativistic charged particle to 33% of its initial energy (factor 1/e). The energy loss occurs mainly by bremsstrahlung. The radiation length for relativistic electrons in lead is about half a centimeter.

(121) Radiative capture – The name given to a nuclear reaction in which a particle is captured by the nucleus followed by the emission of a gamma ray from the nucleus. The term is usually used to refer to neutron capture, but the process occurs for other particles such as p and α-particles as well.

(122) Radioactivity – Spontaneous decay of certain so-called radio-active nuclides by the emission of β rays, α-particles & γ-rays. It is possible to make radioactive nuclides using nuclear reactions initiated by neutrons in a reactor or by various particles from an accelerator. Some naturally occurring radioactive elements exist because of their long half life or because they are continuously produced by the decay of a naturally occurring nuclide with a long half life.

(123) Range – Range of a charged particle in a given substance is the distance that that the particle will travel before being brought to rest as the result of ionization losses. The range depends on the energy of the particle.

(124) Reactor – A device which maintains a controlled fission reaction for the purpose of producing large quantities of neutrons or heat. In general, a reactor consists of some arrangement of a fissionable fuel, such as Uranium 235, and a moderator such as deuterium, water or graphite to slow down the fast neutrons produced originally in the fission process. The reaction is held in check by movable control rods usually containing substantial amounts of cadmium or boron which have large cross-sections for the absorption of thermal neutrons. A reactor produces intense beams of neutrons for use with choppers and crystal spectrometers. High internal neutrons fluxes permit the manufacture of strong radioactive samples for experimental use.

(125) Resolving time – of a coincidence circuit is the time interval within which two or more pulses can arrive at the circuit, and still be recorded as occurring at the

same time. The term is also used with counting systems to specify the shortest time that can elapse between successive events and still have them counted.

(126) Resonance - just as the weight on the end of a spring has a certain natural or ~~natural~~ resonant frequency of vibration, nuclei also exhibit ~~no~~ resonance behaviour. The cross section for the formation of the compound nucleus by, for eg, a neutron is much greater for some neutron energies than for others. The sudden increases in the cross-section are called resonances and correspond to the addition of just the right amount of energy to the nucleus to raise it from one energy level, usually the ground state, to the next

(127) Roentgen - A unit of dose acquired as a result of exposure to ionising radiation. It is strictly defined as that amount of X or Gamma radiation sufficient to produce ions carrying one electrostatic unit of charge in one cm^3 of air - Loosely applied only to gamma rays.

(128) Rutherford scattering - Is Coulomb scattering by a nucleus. Rutherford first discovered the nucleus as pictured today by studying the scattering of α-particles by the nuclei of gold atoms.

(129) Saturation of nuclear forces - A term used to describe the fact that the nucleons seem to interact with only a few of their neighbours, because of the short range of nuclear forces. This results in the binding energy of the nuclei being $\propto$ to the no. of particles in the nucleus and not to the number of possible pairs of interacting particles. This also means that the binding energy per nucleon is roughly the same for all nuclei

(130) Scintillation counter - A device for detecting charged particles and gamma rays and neutrons indirectly by using a photomultiplier tube. One advantage of this counter is that they are very fast ie have very small resolving time.

(131) Semi empirical mass formula - A formula based on the liquid drop model of the nucleus which predicts the masses of all nuclides. It consists of a series of terms which account for the various factors which affect the binding energy of the nucleus. These terms are weighted by constants determined both by theory and experiment. Since the binding energy is directly proportional to the number of nucleons the principal term is one $\propto$ to the mass number A. Other factors considered are the Coulomb repulsion of the protons, the surface tension effect, analogous to a liquid drop, and a symmetry effect related to the fact that

nuclei tend to be more stable if the no. of n = no. of p if the Coulomb effect is neglected.

(132) Shell model – A model of the nucleus in which it is assumed that each nucleon moves about, independent of the others, in a potential well determined by the average interaction with the other nucleons. The nucleons are assumed to be arranged in shells in analogy with atomic electrons. Shells of neutrons and protons are full when the number of either reaches a so-called magic numbers. The shell model has been useful in predicting the total A.M. of nuclei

(133) Sigma particle – A hyperon with mass about 2330 m_e & $\Sigma^{\pm}$ or Σ^0. The charged sigmas decay into a nucleon and a pi-meson with a mean life of about 10^{-20} Sec. The neutral sigma decays into a lambda particle a gamma ray ~~which is~~ with a mean life expected to be about 10^{-20} Sec.

(134) Slowing down power – Term used to describe the behavior of moderators and defined as the product of the average decrease per collision in the logarithm of the neutron energy, the no. of atoms per c.c, and the scattering cross-section.

(135) Sodium iodide crystal – often used as scintillator in a scintillation counter. Sodium iodide is particularly good for detecting gamma rays by means of photoelectrons and compton electrons they produce in the crystal because it has a high density and therefore a high probability of getting a gamma ray interaction and because it produces pulses of light.

(136) Spin – Term used to describe the total A.M of elem. particles or nucleides. It is given by $(n/2)\hbar$, where n is a small integer and $\hbar$ is Planck's constant divided by 2π. Sometimes the spin is called merely $n/2$, the $\hbar$ being understood.

(137) Stripping reaction – Term usually used to refer to reactions in which the bombarding particle is a deuteron. It is possible for either the n or p to hit a nucleus before the other and be "stripped" off leaving the other particle to proceed alone. This is particularly easy to do with deuterons because of their low binding energy (2.2 MeV)

(138) Tau-meson – Original name given to a K-meson which decays into three pi-mesons

(139) Thermal column – A term used for a large piece of graphite very close to a reactor. Neutrons from the reactor are slowed down in the graphite and become thermal neutrons. A thermal column is therefore a source of large numbers of thermal neutrons for experimental use.

(140) Thermal neutrons – Neutrons which have come to thermal equilibrium with the atoms of a moderator ie they have bounced around off moderator atoms until it is just as likely that they will gain energy as lose energy in subsequent collisions. They have a Maxwellian velocity distribution and energies about the same as the thermal energies about the same as the thermal energies of vibration of the moderator atoms.

(141) Theta-meson – Original name given to a K-meson which decays into two pi-mesons.

(142) Threshhold – The K.E of a bombarding particle just enough to make an endoergic (or endothermic) nuclear reaction go is called the threshhold energy

(143) Transmission – A term often used in connection with the measurement of total cross-sections. The transmission is just the number of particles in a beam passing through a given sample of material in a certain time divided by the number passing the same point in the beam with no sample or absorber in place.

(144) Triton – The nucleus of the hydrogen isotope of mass number three. It consists of two neutrons and a proton. It is radioactive with a half life of about 12 years.

(145) Velocity of light – no particle can acquire a velocity $> c$ ($= 3 \times 10^{10}$ cm/sec)

(146) Velocity selector – A mechanical monochromator for slow neutrons consisting perhaps of several cadmium discs (high thermal neutron cross section) mounted coaxially at intervals along a rotating shaft. Slots are cut in the discs which are offset in angle for each successive disc such that only neutrons with a small range of velocities can pass through all the slots at a given speed of rotation. The result for such a device would be a pulse of monoenergetic neutrons once each revolution. The velocity sector is not to be confused with a Chopper.

(147) Virtual level – An excited energy level of the compound nucleus which can decay by the emission of a particle as compared to a bound level which can decay only the emission of a gamma ray.

(148) Wave fn – used in quant. mech. to determine probability or expectation value of a given event or measurement

(149) Wave length – In many situations involving the de Broglie wave length of

particles, one can consider the wave length of a particle as a measure of its size.

Masses & decay properties of the elementary particles (A table)

Particle		Spin	Mass eq. in Mev.	Decay modes	mean life (in Sec)
Photon $-\gamma$		1	0	—	stable
Leptons	ν	$1/2$	0	—	stable
	$\bar{\nu}$	$1/2$	0	—	stable
	$e^{\pm}$	$1/2$	0.511	—	stable
	$\mu^{\pm}$	$1/2$	105.7	$\mu^{\pm} \to e^{\pm} + \nu + \bar{\nu}$	2.2×10^{-6}
Mesons	$\pi^{\pm}$	0	139.6	$\pi^+ \to \mu^+ + \nu$; $\pi^- \to \mu^- + \bar{\nu}$	2.6×10^{-8}
	π^0			$\pi^0 \to 2\gamma$	$\sim 10^{-16}$
	$K^{\pm}$	0	493.9	$K^{\pm} \to \pi^{\pm} + \pi^+ + \pi^-$; $\pi^{\pm} + 2\pi^0$; $\pi^+ + \pi^0$; $\mu^{\pm} + \{\nu, \bar{\nu}\}$	1.2×10^{-8}
	K^0, $\bar{K}^0$, K_1^0, K_2^0	0	497.8	$K_1^0 \to \pi^+ + \pi^-$, $2\pi^0$; $K_2^0 \to \pi^+ + \mu^- + \bar{\nu}$; $\pi^- + \mu^+ + \nu$; $\pi^+ + e^- + \bar{\nu}$; $\pi^- + e^+ + \nu$; $\pi^+ + \pi^- + \pi^0$	10^{-10}; $\sim 10^{-7}$
Baryons	p	$1/2$	938.2	—	stable
	n	$1/2$	939.5	$n \to p + e^- + \bar{\nu}$	10^3 sec
	Λ^0	$1/2$	1115.4	$\Lambda^0 \to \pi^- + p$; $\pi^0 + n$	2.5×10^{-10}
	Σ^+	$1/2$	1189.4	$\Sigma^+ \to \pi^+ + n$; $\pi^0 + p$	0.8×10^{-10}
	Σ^-	$1/2$	1196.0	$\Sigma^- \to \pi^- + n$	1.6×10^{-10}
	Σ^0	$1/2$	1191.5	$\Sigma^0 \to \Lambda^0 + \gamma$	$\sim 10^{-20}$
	Ξ^-	?	1318.4	$\Xi^- \to \Lambda^0 + \pi^-$	1.3×10^{-10}
	Ξ^0	?	1311.0	$\Xi^0 \to \Lambda^0 + \pi^0$	$\sim 10^{-19}$

31/8/70 — New Books Section

(1) Lectures on weak interactions astrophysics and weak interactions — Gordon & Breach.

Contents (a) The origin of cosmic rays by S. Hayakawa.

(b) Neutrino astrophysics by H.Y. Chiu, NASA

(c) Theory of weak interactions at high energy by G. Feinberg (Columbia)

(d) The existence and significance of parastatistics

from (b), pp. 208 - 209 etc. At zero temperature matter must be in a crystalline form. This may be seen from the third law of thermodynamics that at $T = 0$ matter must be ordered. At $T = 0$, moreover, the free energy must be a minimum. Consequently the Coulomb energy must also be a minimum. ____ "Madelung" sum. — The configuration is a lattice of $+^{ve}$ ions, with each ion surrounded by a lattice of electrons.

At high density the Coulomb energy will cause zero point motion leading to reactions even without thermal motion. Moreover, electron concentration will raise the Coulomb energy level of the protons. Hence even at zero temperature the ions will have some energy due to the electrical properties of the medium. Nuclear reactions thus can proceed at zero temp. and high density. Such reactions are called pycnonuclear or pressure induced nuclear reactions.

Photo-neutrino process: $\gamma + e^- \longrightarrow e^- + \bar{\nu}_e + \nu_e$

~~Conclusion~~ - Pair annihilation process — Is the annihilation of an electron-positron pair into neutrinos.

Plasma process — A free photon cannot decay into neutrinos because the decay of a zero mass particle into two particles is forbidden by energy-momentum conservation. In an electron gas photons may appear to have a rest mass. The relation between the frequency ω and the wave-vector k is, for $\omega > \omega_0$ (ω_0 is the plasma frequency)

$$\hbar^2\omega^2 = \hbar^2\omega_0^2 + k^2c^2$$

In this case a photon may be decay into a neutrino - antineutrino pair

Summary, p. 229 — The pair-annihilation process is the one most likely to responsible for the neutrino process of stellar collapse, and the plasma process is most likely responsible for the creation of White dwarfs.

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p. 243 – Neutron stars – For discussion of these some knowledge of general relativity is necessary – Schwarzschild exterior solution has a singularity at $r = 2m$. Does this singularity have a physical significance? At this radius

$$1 = \frac{2m}{r} = \frac{2GM}{rmc^2} \quad (m = \text{mass of test particle})$$

$$= \frac{2GM}{r} \Big/ Mc^2$$

At the Swarzschild radius $r_s = 2GM/c^2$, the gravitation self energy of the body is the same as its rest energy i.e a mass m would have to convert all its self energy to propel itself ballistically away.

$$\text{For a proton } r_s = \frac{2 \times 6 \times 10^{-8} \times 1.7 \times 10^{-24}}{(3 \times 10^{10})^2} \simeq 10^{-52} \text{ cm}$$

$$\text{For the sun, } r_s = 1.3 \times 10^{-28} \times 2 \times 10^{33} = 2.6 \text{ km}$$

The density of the sun, if it were all collapsed inside the Schwarzschild radius would be $= \frac{2 \times 10^{33}}{4/3 \times 27 \times 10^{15}} \simeq 10^{16} \text{ gm/cc}$

This gives the order of magnitude of density for which relativity becomes very important inside a star.

The galaxy has a mass of about 10^{10} Suns; $M_g = 10^{43}$ gm.
The universe has about 10^{10} galaxies. This gives $M_u = 10^{53}$ gm, and the no. of protons in the universe is $N_u = 10^{77}$. Then for the universe $r_s = 10^{25}$ cm. Radius of universe is about 10^{28} cm. Hence if all the matter of the universe is contained in galaxies, relativity is not important in cosmology. However a large portion of the mass of the universe may be in the form of intergalactic matter without being detected – –. Thus a Schwarzschild singularity can be felt but not seen

(c) p. 313 – Discusses the ψ-meson ie that the interaction between currents used to describe weak interactions is mediated by a virtual particle.

p. 319 – Field theory of the IVM (intermediate vector meson)

p. 369 – Muon decay discussed $[\mu^- \to \nu_\mu e^- \bar{\nu}_e]$

p. 373 – outlook (Conclusion) – Discussion of four outstanding problems of the new theory of higher order weak interactions.

(d) (i) The problem & its background (ii) The proofs of the non-existence of parastatistics (iii) The formal construction of parastatistics, (iv) Physical aspects of parastatistics – Are there para-particles? – Statistics which is

(66)

Which is between F-D & E-B statistics – States that permutation invariance (invariance of enumeration of particles) taken with quantum mech. does not lead to the result that the F-D & E-B are the only possible ones.

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(2) Lectures on strong and electromagnetic interactions – Vol I – Gordon & Breach

(a) Strong interactions of elementary particles. by P. T. Matthews, Imp. Coll, London

(b) Topics in quant. elec. dynamics by D. R. Yennie, Univ of Minnesota

(c) Unitary symmetry of strong interactions by M. E. Mayer, Brandeis Univ

(4) A modern algebra for biologists by Howard M. Nahikian – University of Chicago Press (1964). – Introduction in 1954 by Rashevsky of what he then called "topological biology" and now known as "relational biology". This branch developed further by Rosen and others uses extensively not only topology and set theory but even such a special branch as the theory of categories

Chap 1 – Elementary theory of sets. Ch. 2 – * Applns of set theory to biology – Ch. 3. General algebraic systems – Ch. 4 – Intn to theory of groups – Ch. 5. Vector spaces and matrices – Ch. 6 – Determinants – Ch. 7 – Matrix applns to biology *

(* appear to be the only useful Chapters for biologists)

(5) The Character of Physical Law by Richard Feynman – M. I. T. Press, 1965 (First published by B. B. C). [Lectures delivered extempore as claimed by R. F]

(a) Foreword (b) Intn by Provost of Cornell Univ.

Ch (1) – The law of gravitation, an example of Physical Law.

Ch. 2 – The relation of mathematics to Physics

Ch. 3 – The great Conservation Principles

Ch. 4 – Symmetry in Physical Law

Ch. 5 – The distinction of past and future

Ch. 6 – Probability & uncertainty – the quant. mech. view of Nature

Ch. 7 – Seeking new Laws.

(6) The Mathematical Sciences – A collection of Essays – Edited by M. R. C & published by U. S. A. National Academy of Sciences (M. I. T), 1969

– A number of 22 essays by different people with interesting short photographed notes of each author.

p. 116 – Analytic fns & elem. particles by A. S. Wightman

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p. 217 – Mathematics & the biomedical sciences by Hirsh Cohen

p. 153 – The algebraisation of mathematics by Samuel Eilenberg – mentions 'Categories' & their applications.

p. 72 – Functional analysis by J. T. Schwartz.

(7) Nuclear and Particle Physics by E. B. Paul – North-Holland, 1969

(8) Elementary Particle Theories – Edited by Paul Urban – Springer Verlag 1966. Who chose based the photomechanical method working quicker & cheaper – Nearly 20 contributions from different people.

1/9/70 Looking at Rev. Mod. Physics I saw in Vol 21, 1949, p. 463, saw an article by Max Born on Reciprocity theory of elem. particles (viz invariance under $x_k \to p_k$ & $p_k \to -x_k$) & found a reference to my name in the body of the paper on p. 465 [Proc. Ind. Acad. A. 15, 139 (1942). & 26, 221 (1947)]

(1) stating that myself Bhatia & others have attempted (?) similar generalisations of the ordinary wave eqn without obtaining more than interesting formal results.

In same on p. 447 I saw an article by Kurt Gödel (Princeton I. A. S.) on a new type of cosmological solns of Einstein's field eqns of gravitation

(2) Article by Harish-Chandra on infinite irreducible representations of the Lorentz group (Proc. Roy. Soc. A. 189, p. 372, 1947 (Gonville & Caius College, Cambridge – comm. by Dirac) – talks of exponents – nothing to do with my work.

(3) Dirac – ibid – Vol. 183, p. 284 (1945) – Talks of ∞ unitary representations of the L. G – Says all finite reps dealt with by spinor & tensor analysis are known & none of them is unitary (ie matrices of the repn)

(4) Kemmer – P. R. S. A. 173, p. 91. (comm. by S. Chapman) – mentions Duffin's commutation rules for the β's in $\partial_\mu \beta_\mu \psi + k\psi = 0$ viz

$$\beta_\mu \beta_\nu \beta_\rho + \beta_\rho \beta_\nu \beta_\mu = \beta_\mu \delta_{\nu\rho} + \beta_\rho \delta_{\nu\mu} + \beta_\nu \delta_{\nu\mu} \quad -(2)$$

$\left(k = \frac{mc}{\hbar},\ \partial_\mu = \frac{\partial}{\partial x_\mu},\ x_4 = ict \right)$

[Refers to Pauli's Hd. der. Physik article of 1933, 24, 2nd ed, Pt. 2, Leipzig, Springer]

Also uses $t_{\mu\nu} = \beta_\mu \beta_\nu - \beta_\nu \beta_\mu = i S_{\mu\nu}$ [$\psi' = S\psi$, $(\psi^+)' = \psi^+ S^{-1}$ where $\psi \to (1)$

$S = 1 + \frac{1}{2} \epsilon_{\mu\nu} t_{\mu\nu}$ & $t_{\mu\nu} = -t_{\nu\mu}$ for $x'_\mu = x_\mu + \epsilon_{\mu\nu} x_\nu$ $(\epsilon_{\mu\nu} = -\epsilon_{\nu\mu})$

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The wave eqn can be readily seen to be invariant if the $t_{\mu\nu}$ are connected with the β_μ by the relations

$$\beta_\mu t_{\nu\rho} - t_{\nu\rho}\beta_\mu = \delta_{\mu\nu}\beta_\rho - \delta_{\mu\rho}\beta_\nu$$

Eqn (1) suggests $t_{\mu\nu} = \beta_\mu\beta_\nu - \beta_\nu\beta_\mu = i S_{\mu\nu}$ is an adequate choice. This is indeed the case as can be proved directly by interchanging ν and ρ in eqn (2) & subtracting from the original eqn:

$$\beta_\mu(\beta_\nu\beta_\rho - \beta_\rho\beta_\nu) - (\beta_\nu\beta_\rho - \beta_\rho\beta_\nu) = \delta_{\mu\nu}\beta_\rho - \delta_{\mu\rho}\beta_\nu$$

Algebraic properties of the β_μ — Thankfully Pauli — finds 3 inequivalent reps of degrees 10, 5 & 1 so that $10^2 + 5^2 + 1^2 = 126$ & there are no further ones

Gwies spurs of the three reps and explicit forms of the matrix irreducible reps of the three reps, the last one being $\beta_1 = \beta_2 = \beta_3 = \beta_4 = (*)$ (* stands for zero)

— Gwies 27 references two relating to Bhabha (viz P.R.S. 1938, A.166, 501 and ibid 1939, (in Press) †

Duffin, 1938, Phys. Rev. 54, 1114

Fierz & Pauli — P.R.S. 1939 & 3 more papers of his

[† These both refer to meson theory, the first one mentioning that proton & neutron are diff. forms of the same particle (isospin — due to Heisenberg, but no mention made of this) and about short range force through π-mesons.]

(5) Phys. Rev. Vol 54, 1938 — Duffins note in Letters to the Editor on p. 1114 — This note is not at all clear — He mentions that the symbols β_j in Proca's eqn tensor wave eqn [J. de. phys. et le rad. 7, 347 (1936)]

$$\left.\begin{aligned} \eta_{ijkl}\,\beta_l\,\phi_m &= \mu f_{jk} \\ \beta_j f_{jk} &= \mu\phi_k \end{aligned}\right\} \qquad (1)$$

where $\eta_{jklm} = (\delta_{jl}\delta_{km} - \delta_{jm}\delta_{kl})$, $p_k = \frac{h}{i}\frac{\partial}{\partial x_k}$ & $\mu = m_0 c/i$

Let ψ be a single column matrix whose elements are the components of the vector ϕ_j and the distinct components of the tensor f_{jk}. Then eqn (1) may be written $\Sigma\,\beta_j p_j \psi = \mu\psi$ (2)

The symbols β_j are 10-row Hermitian matrices which are found to satisfy

the following identities

$$\left.\begin{aligned} &\beta_j^3 = \beta_j \\ &\beta_j \beta_k^2 + \beta_k^2 \beta_j = \beta_j \quad (j \neq k) \\ &\beta_j \beta_k \beta_\ell + \beta_\ell \beta_k \beta_j = 0 \quad (j \neq k,\ \ell \neq k) \end{aligned}\right\} \qquad (3)$$

It is easy then to deduce this theorem: A necessary & sufficient condition for the existence of eqns (3) is that

$$\sum_{j,k,\ell} \beta_j \beta_k \beta_\ell C_{jk\ell} = \sum_{j,k} \beta_j C_{jkk} \qquad (4)$$

for every $C_{jk\ell}$ such that $C_{jk\ell} = C_{\ell kj}$. The application of this theorem to eqn (2) gives the relations $\sum \beta_i^2 \psi = \mu^2 \psi$ and $\sum s_{jk} \beta_k \psi + \beta_j \psi = \mu \beta_j \psi$. Here s_{jk} is the matrix $\beta_j \beta_k - \beta_k \beta_j$ and it satisfies the identities

$$\left.\begin{aligned} &s_{jk}^2 = -s_{jk} \\ &s_{jk}\beta_\ell - \beta_\ell s_{jk} = \begin{cases} 0, & k \neq \ell \\ \beta_j & k = \ell \end{cases} \end{aligned}\right\} \qquad (5)$$

— Gives some quantum-mechanical significance which is very vague — Finally we shall give an example of a tensor wave equation with characteristic matrices abstractly isomorphic to the Dirac matrices. This is given by eqns (1) if $\eta_{jk\ell m}$ now signifies the tensor $(\delta_{j\ell}\delta_{km} - \delta_{jm}\delta_{k\ell} + \delta_{jk}\delta_{\ell m} + \epsilon_{jk\ell m})$. Here $\epsilon_{jk\ell m}$ is $+1$ or -1 depending on whether or not $jk\ell m$ is an <u>even</u> or <u>odd</u> permutation of 1234 and is zero otherwise. Because $\epsilon_{jk\ell m}$ is not invariant in sign under certain reflections, there is an equipollent set of equations with $-\epsilon_{jk\ell m}$ replaced by $-\epsilon_{jk\ell m}$. The matrices have eight rows & columns.