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Keywords : chalcogenides ; semiconductors; electrical conductivity; dielectric properties.

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Strictly as per the compliance and regulations of :

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J. Sharma [α] & S. Kumar [σ]

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I. Introduction

In chalcogenide glasses, the studies of structural and chemical disorders which are due to the absence of long-range order as well as various inherent defects [1-3] in the mobility gap are very important for better understanding of transport mechanisms. The hopping conduction can be easily distinguished from that of band conduction by measuring the frequency dependence of conductivity [4], which as expected, is due to conduction in localized states. Therefore, the measurements of ac conductivity of amorphous chalcogenides can be used to obtain information about these states. This led to adapt and elaborate models allowing the electronic properties of these materials to be described [5-9]. Generally, these glasses have poor thermo mechanical properties. In order to enlarge their domain of application, it is necessary to increase their softening temperatures and mechanical strength from application and practical point of view. This leads to the necessity of changing the composition by incorporating the additives to affect the properties of binary systems as Se-Te glassy alloy system [10].

The semi-conducting compounds belonging to the cadmium chalcogenide family such as $CdSe_xTe_{1-x}$ can be advantageously used for various technical applications in particular for the conversion in photovoltaic or photo-electrochemical devices. This material with its near-ideal band gap and a high optical absorbance is a promising material for low-cost terrestrial applications.

Addition of Cd to the Se-Te system is useful in elucidating the transport mechanism in chalcogenide glasses. As well the results obtained by the incorporation of Cd can be discussed in terms of structural transitions in chalcogenide glasses [11]. In Se-Te-Ge, Ge is expected to modify the structure of Se-Te system due to its tetrahedral structure, which is quite stable as compared to chain like structure of Se-Te. Incorporation of Ge in binary Se-Te glassy system results more thermal stability in wide temperature range due to its high melting point [12]. Investigations of the temperature and frequency dependence of conductivity, the effect of impurities on the activation energy, and the effect of high electric field on the conduction mechanism is a subject of great interest, because the result of such studies provide methods to control effectively the conductivity of amorphous semiconductors.

Study of a.c conduction in Se-Te system with addition of different elements has been done by various workers [13-15]. The general frequency behavior in this type of materials is of $A\omega^s$ type over a given frequency range. Temperature dependent exponent s is determined to have a value ≤ 1. Various models have been formulated to explain this behavior and one of the starting points in these models has been formulated by Elliot in which spin pairing is energetically favoured. Hence all defect centers are either positively or negatively charged and bipolarons hop between doubly occupied D^+ states to nearby D^- states over the barrier separating them. The barrier height is correlated with the intersite separation through the Coulombic interaction between the centers. This correlated barrier hopping (CBH) model gives a temperature - dependent exponent s. This behavior is different from that predicted by the quantum mechanical tunneling (QMT) model which assumes that the a.c conduction is due mainly to the tunneling of an electron through a barrier separating

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localized states, and comes up with an exponent s that is not temperature dependent.

The present communication reports some experimental results on ac electrical conductivity and dielectric properties over the range of temperature 300 K–350 K and frequency 1 KHz–5 MHz for aforesaid glassy alloys and discuss these results in terms of the above mentioned transport models.The concept of the CBH model, incorporating the suggestions of Shimakawa, is applied to the present data. The other parameters related to dielectric measurements are also calculated and studied.

II. Experimental

Glassy alloys of $Se_{70}Te_{30}$, $Se_{70}Te_{20}Cd_{10}$ and $Se_{70}Te_{20}Ge_{10}$ systems were prepared by quenching technique. High purity (99.999 %) materials was weighed according to their atomic percentages and were sealed in quartz ampoules (length ~ 5 cm and internal dia ~ 8 mm) with a vacuum ~ 10^{-5} Torr. The ampoules containing the materials were heated to 1000°C and held at that temperature for 10 - 12 hours. The temperature of the furnace was raised slowly at a rate ~ 3 - 4 °C/min. During heating, all the ampoules were constantly rocked, by rotating a ceramic rod to which the ampoules are tucked away in the furnace for the homogeneity of the synthesized compositions. After rocking for about 10 hours, the obtained melts were cooled rapidly by removing the ampoules from the furnace and dropping to ice-cooled water. The quenched samples were taken out by breaking the quartz ampoules. Figure 1 shows the XRD plots of these glassy alloys. Compositional analysis was performed using electron probe micro- analysis (EPMA) technique.

Pellets of diameter ~10 mm and thickness ~ (1-2) mm were prepared by compressing the finely grounded powder in a die in a hydraulic press under a load of ~ 3-4 tons. Measurements were performed after coating the pellets with indium film deposited by vacuum evaporation technique. A specially designed metallic sample holder was used for the measurements of dielectric parameters in a vacuum ~ 10^{-3} Torr. The pellets were mounted in between two steel electrodes of the sample holder. The temperature was measured with the help of a calibrated copper-constantan thermocouple mounted very near to the sample, which could give measurements of temperature with an accuracy of 1^0C. For measuring real and imaginary part of dielectric constant and a. c. conductivity, conductance and capacitance were measured using a "Hioki 3532-50 LCR Hi TESTER" and by applying known relations, all the parameters are calculated. Three terminal measurements were performed to avoid the stray capacitances.

Microsoft Excel programming has been used as sources of all lines drawn on a figure. Method of least square fitting is shown having correlation coefficient (R) of the fit between 0.9 and 1 for almost all the lines obtained in the figures. The values of R^2 of all the lines plotted in the figures have been shown below the lines itself. The error bars on the data in the figures have been shown which has been estimated by the permissible error of the measuring instruments.

III. Results and Discussion

a) Frequency dependence of ac conductivity

A common feature of all semiconductor and some other disordered systems is that ac conductivity is frequency dependent which, as expected, is due to conduction in localized states. The ac conductivity σ_{ac} (ω) was found to obey the following relation [16]

$$\sigma_{ac} = A\,\omega^s \tag{1}$$

where $s \le 1$

An alternate model by Pike [17] and Elliot [6] considers the a.c conductivity as the result of the simultaneous hopping of two carriers between oppositely charged defect centers under the influence of the external electric field. This model known as the CBH model, expresses the a.c conductivity to a first-order approximation as,

$$\sigma(\omega, T) = \Pi^2 N^2 \varepsilon' / 24\,(8e^2/\varepsilon' W_m)^6\, \omega^s / \tau_0^{1-s} \tag{2}$$

where

$$s = 1 - 6kT/W_m \tag{3}$$

According to QMT model, the a.c. conductivity can be expressed as

$$\sigma_{ac}(\omega) = B K_B T [N(E_F)]^2 \alpha^{-5} \omega \{\ln(\nu_{ph}/\omega)\}^4 \tag{4}$$

Where B was found to be equal to be $\Pi/3$ by Mott and Davis and $\Pi/96$ by Pollak. K is the Boltzmann constant, ε' is the dielectric constant, W_m is the maximum barrier height over which the electrons hop, τ_0 a characteristic relaxation time and N the spatial density of defect states. The frequency dependence of σ_{ac} for the investigated compositions is studied in the frequency range 1 KHz- 5 MHz at different temperatures. Figure 2 shows frequency dependence of σ_{ac} (ω) for the aforesaid compositions. It is clear from this figure that σ_{ac} (ω) increases linearly with increasing frequency. The exponent s is calculated from the slope of the curves plotted in Figure 2.

Temperature dependence of s is plotted in Figure 3. It is clearly seen from Figure 3 that the slope of the curves decreases with increasing temperature, indicating that s has temperature dependence. This behavior of s is in contradiction with the QMT model which is based on phonon assisted tunneling of electrons between localized states [18-21]. This model predicts a temperature-independent s value of 0.8. Thus the experiment result agrees with the correlated barrier hopping (CBH) [22], for a critical test of the CBH models comes from the temperature dependence of the a.c conductivity and the frequency exponent. The calculated values of σ_{ac} (ω) and s by CBH and QMT models are given in Table 1.

b) Temperature dependence of ac conductivity

The temperature dependence of ac conductivity was studied for $Se_{70}Te_{30}$, $Se_{70}Te_{20}Cd_{10}$ and $Se_{70}Te_{20}Ge_{10}$ at different frequencies. Figure 4 shows plot of ln σ_{ac} vs 1000/T for the aforesaid glassy alloys. It is clear from this figure that σ_{ac} increase linearly with decreasing the reciprocal of absolute temperature. This suggested that the ac conductivity is the thermally activated process from different localized states in the gap or its tail. The activation energy of conduction ΔE (ω) is calculated from the slopes of lines of lnσ_{ac} vs 1000/T curves by the aid of well- known relation:

$$\sigma(\omega) = \sigma_0(\omega) \exp(-\Delta E(\omega)/ kT) \qquad (5)$$

where σ_0 is the pre-exponential factor. The values of ΔE at different frequencies for various glassy alloys are given in Table 2.

According to CBH model the charge carriers hop across the defects states D^+ and D^- . Each pair of D^+ and D^- is assumed to form a dipole with relaxation, which can be attributed to the existence of a potential barrier over which the carriers must hop [23]. It must be noticed here that the process of hopping of the charge carriers is affected also by the density of localised states $N(E_F)$, which can be calculated using the equation [24]

$$\sigma_{ac}(\omega)=1/3\Pi e^2 K_B T[N(E_F)]^2\alpha^{-5}\omega\{\ln(v_{ph}/\omega)\}^4 \qquad (6)$$

where e is the electronic charge, v_{ph} is the predominant phonon frequency and α is the exponential decay parameter of the localized states wave functions.

Taking the reported values of v_{ph} and α^{-5} [8], the density of localized states N (E_F) was calculated at frequency 1 KHz and temperature 300K. The obtained values of N (E_F) are given in Table 3 for the studied compositions. It is clear from the results obtained that density of states decreases with aforesaid impurity incorporation. Accordingly σ_{ac} (ω) also decreases with the impurity.

c) Temperature and frequency dependence of dielectric constant

Figure 5 declares that ε' increases slowly at lower temperature then increases sharply with the increase of temperature. This behavior was observed in all the three compositions studied at present. Since in chalcogenide glasses, the dielectric properties can be interpreted by considering a set of dipoles as long as the temperature is increased high. Each dipole has a relaxation time depending on its activation energy which is attributed to the existence of a potential barrier over which the carrier can hop. Because of containing dipoles, the contribution due to dipolar or orientational polarization dominates at low frequencies. As the frequency increases high, dipolar or orientational polarization normally removes due to inertia of molecules and the electronic polarization contributes. Thus the dispersion is low at high frequencies.

Since the Orientational or Dipolar polarization is associated with the thermal motion of pair of charges, the orientation of the dipoles increases as the temperature increases, leading to the increase of dielectric constant (ε'). It has also been found that the ε' decreases with increasing frequency. In dielectric spectroscopy, large frequency dependent contributions to the dielectric response, especially at low frequencies, may come from build-ups of charge. This, so-called Maxwell-Wagner polarization occurs either at inner dielectric boundary layers on a microscopic scale, or at the external electrode-sample interface on a macroscopic scale. In both cases this leads to a separation of charges. The charges are often separated over a considerable distance, and the contribution to dielectric response can therefore be orders of magnitude larger than the dielectric response due to molecular vibration which occurs at high frequencies because at high frequencies, the energy is too high to cause rotation, yet too low to effect electrons directly, and is absorbed in the form of molecular vibrations. Thus ε' decreases with increasing frequency. This type of behavior at low and high frequencies comes under interfacial polarization.

d) Temperature and frequency dependence of the dielectric loss

Figure 6 shows the temperature dependence of dielectric loss (ε'') at different frequencies for the studied composition. It is clear from this figure that ε'' increases with increasing temperature. As the temperature increases, $\sigma_{ac}(\omega)$ increases and so the ac conduction loss increases with increasing temperature. At low temperature values, conduction, dipole and vibration losses have the minimum value. However at higher temperatures, As the temperature increases, the hopping process increases and since the conduction is due to hopping from one localized states to the another, thus the conduction increases and so the losses due to conduction also increases. Additionally, dipole and vibration losses also increase. Thus dielectric loss increases with temperature. Figure 7 shows the frequency dependence of ε'' at different temperatures for the studied compositions.

It is clear from the figure that ε'' decreases with frequency. This decrease can be attributed to the fact that the migration of the ions in the glass is the main source of the dielectric loss at low frequencies. Accordingly, the dielectric loss at low and moderate frequencies is characterized by high values of ε'' due to the contribution of ion jump and conduction loss of ion migration, in addition to the ion polarisation loss. However at higher frequencies the ion vibrations may be the only source of dielectric loss because in this case charge carriers vibrate an appreciable distance through a dielectric but which become trapped or localized and thus decreasing vacancies or defects. So ε" decreases at higher values of frequencies. Our results also confirm the same.

e) Impurity dependence of the dielectric parameters

The density of defect states decreases with Cd and Ge incorporation. The lone pairs and the other configuration, which the system might have undergone at the time of quenching, could be responsible for the decrease in the density of localized states. The variation can be explained in terms of charged impurity in the structure of Se-Te bonds. According to Scottmiller et. al. about 40% of Se atoms have a ring structure and 60% atoms are bonded as polymeric chains. An incorporation of Te decrease the Se ring concentration favoring Se-Te polymeric chains and mixed rings [25-26].On addition of Cd and Ge into Se-Te systems, might chains have decreased and rings get increased which decreases the defect states (D+, D-) in the Se-Te rings and chains. The effect of impurities on the dielectric parameters could also be correlated with covalent character of the studied compositions. The degree of covalency of the studied compositions can be estimated according to the following relation [27]:

The proportion of covalent character

$$= 100\% \exp\left[-0.25\,(\chi_A - \chi_B)^2\right] \qquad (7)$$

where χ_A and χ_B are the electronegativities of atoms A and B respectively. The values of covalent characters are listed in Table 4. The incorporation of Cd and Ge in the pure binary $Se_{70}Te_{30}$ glassy alloy leads to decrease the value of the dielectric constant as given in Table 5. This decrease can be understood in terms of the nature of the bonding in the system.

It may be assumed that the incorporation of Cd and Ge in the binary alloy leads to increase the density of stronger bonds Cd-Cd, Ge-Ge and Cd-Te than other bonds in the network structure, i.e, decreases the weaker bond density Se-Cd and Se-Ge in the investigated compositions, which are more responsive to electric field than the stronger bonds. Thus the value of ε' decreases with Cd and Ge incorporation in the studied system. The decrease in the dielectric loss may be supposed due to the decrease in the density of defect states when the third element Cd and Ge as an impurity is incorporated in pure binary $Se_{70}Te_{30}$ glassy alloy. Our calculated data also supports the same.

IV. Conclusions

The temperature and frequency dependence of the ac conductivity and dielectric parameters in various glassy systems in the frequency range (1 KHz-5 MHz) and temperature range (300 K-350 K) have been measured. The ac conductivity seems to be both temperature and frequency dependent through the studied range of temperature and frequency. The conduction mechanism was suggested to be hopping conduction. In addition, the value of the frequency exponent s and its temperature dependence confirmed the applicability of the CBH model to the investigated compositions.

It has been also found that ε' and the ε'' both are highly dependent on frequency and temperature and found to be dependent with the nature of impurity incorporated in Se-Te glassy system. For the frequency and temperature dependence of ε' were attributed to interfacial and orientational polarisation, respectively whereas the temperature and frequency dependence of ε'' is associated with the conduction loss. The decrease in dielectric loss with the impurity is being correlated with the nature of covalent character of the studied composition and with the decrease in density of defect states.

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Table 1 : Calculated values of σ_{ac} (ω) and s for various glassy alloys at 1 KHz and 350K

Glassy Alloys	QMT σ_{ac} (ω)	QMT *s*	CBH σ_{ac} (ω)	CBH *s*
$Se_{70}Te_{30}$	1.02×10^{-10}	0.81	8.22×10^{-6}	0.53
$Se_{70}Te_{20}Cd_{10}$	1.02×10^{-10}	0.81	6.08×10^{-6}	0.22
$Se_{70}Te_{20}Ge_{10}$	1.02×10^{-10}	0.81	4.69×10^{-6}	0.23

Table 2 : Values of ΔE_{ac} (eV) for various glassy alloys at different frequencies and at 300K

Frequency KHz	$Se_{70}Te_{30}$ ΔE_{ac} (eV)	$Se_{70}Te_{20}Cd_{10}$ ΔE_{ac} (eV)	$Se_{70}Te_{20}Ge_{10}$ ΔE_{ac} (eV)
1	0.450	0.446	0.447
100	0.431	0.425	0.432
500	0.421	0.421	0.417
1000	0.403	0.411	0.413

Table 3 : Values of ac parameters at room temperature for various glassy alloys

Glassy Alloys	$\sigma_{ac}(\omega)(\Omega^{-1}m^{-1})$ (1 KHz, 300K)	N (E_F) (m^{-3})	$\sigma_{o(ac)}(\Omega^{-1} m^{-1})$ (1KHz, 300K)	ΔE_{ac} (ω) (1 KHz,300K)
$Se_{70}Te_{30}$	19.45×10^{-7}	1.23E24	79.51	0.448
$Se_{70}Te_{20}Cd_{10}$	12.78×10^{-7}	9.97E23	37.03	0.446
$Se_{70}Te_{20}Ge_{10}$	10.16×10^{-7}	8.89E23	31.70	0.447

Table 4 : Calculated covalent character of bonds for considered compositions

Bonds for bond type	% covalent character
Se-Se	100.00
Se-Te	97.78
Se-Cd	88.47
Se-Ge	91.39
Te-Te	100.00
Te-Cd	96.08
Te-Ge	79.85
Cd-Cd	100.00
Cd-Ge	99.75
Ge-Ge	100.00

Table 5 : Values of dielectric parameters for various glassy alloys

Glassy alloys	ε' (At 1 KHz, 300 K)	ε'' (At 1 KHz, 300 K)
$Se_{70}Te_{30}$	33.34	34.67
$Se_{70}Te_{20}Cd_{10}$	26.20	23.06
$Se_{70}Te_{20}Ge_{10}$	20.00	18.20

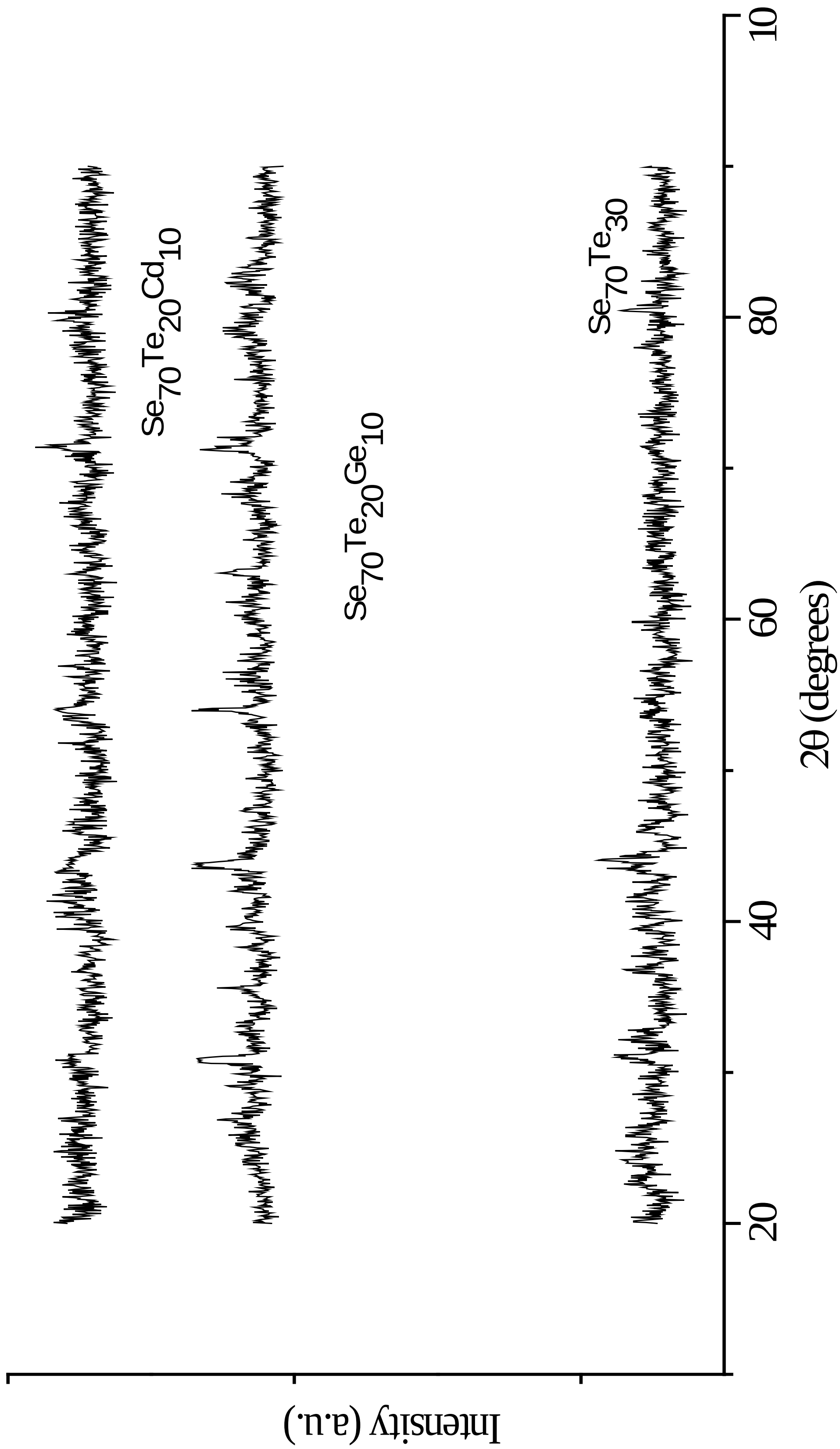

Fig. 1: XRD plots of some binary and ternary glassy alloys

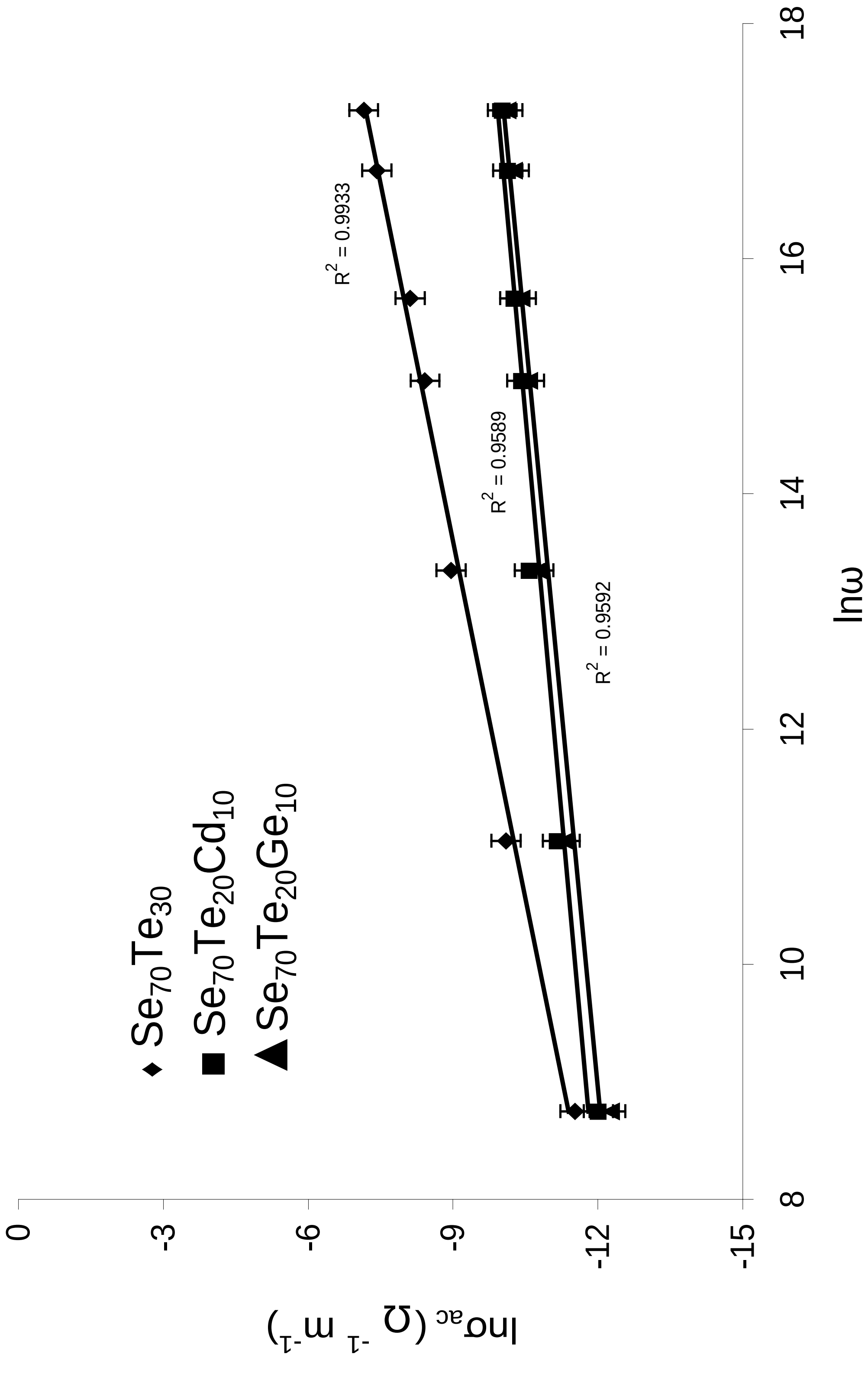

Fig. 2: Frequency dependence of ac conductivity in $Se_{70}Te_{30}$, $Se_{70}Te_{20}Cd_{10}$ and $Se_{70}Te_{20}Ge_{10}$ glassy alloys at 350 K

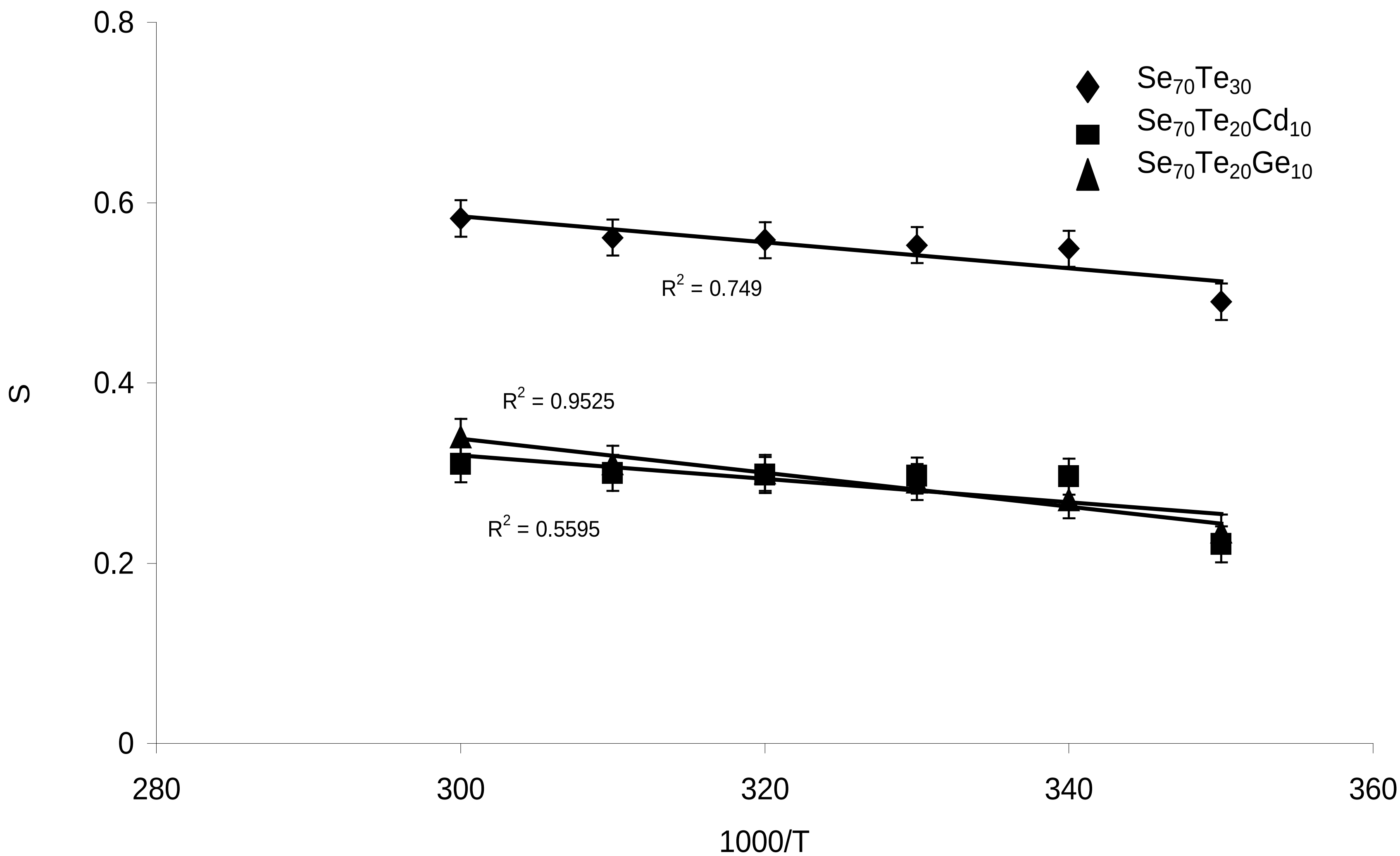

Fig. 3: S vs T curve in $Se_{70}Te_{30}$, $Se_{70}Te_{20}Cd_{10}$ and $Se_{70}Te_{20}Ge_{10}$ glassy alloys.

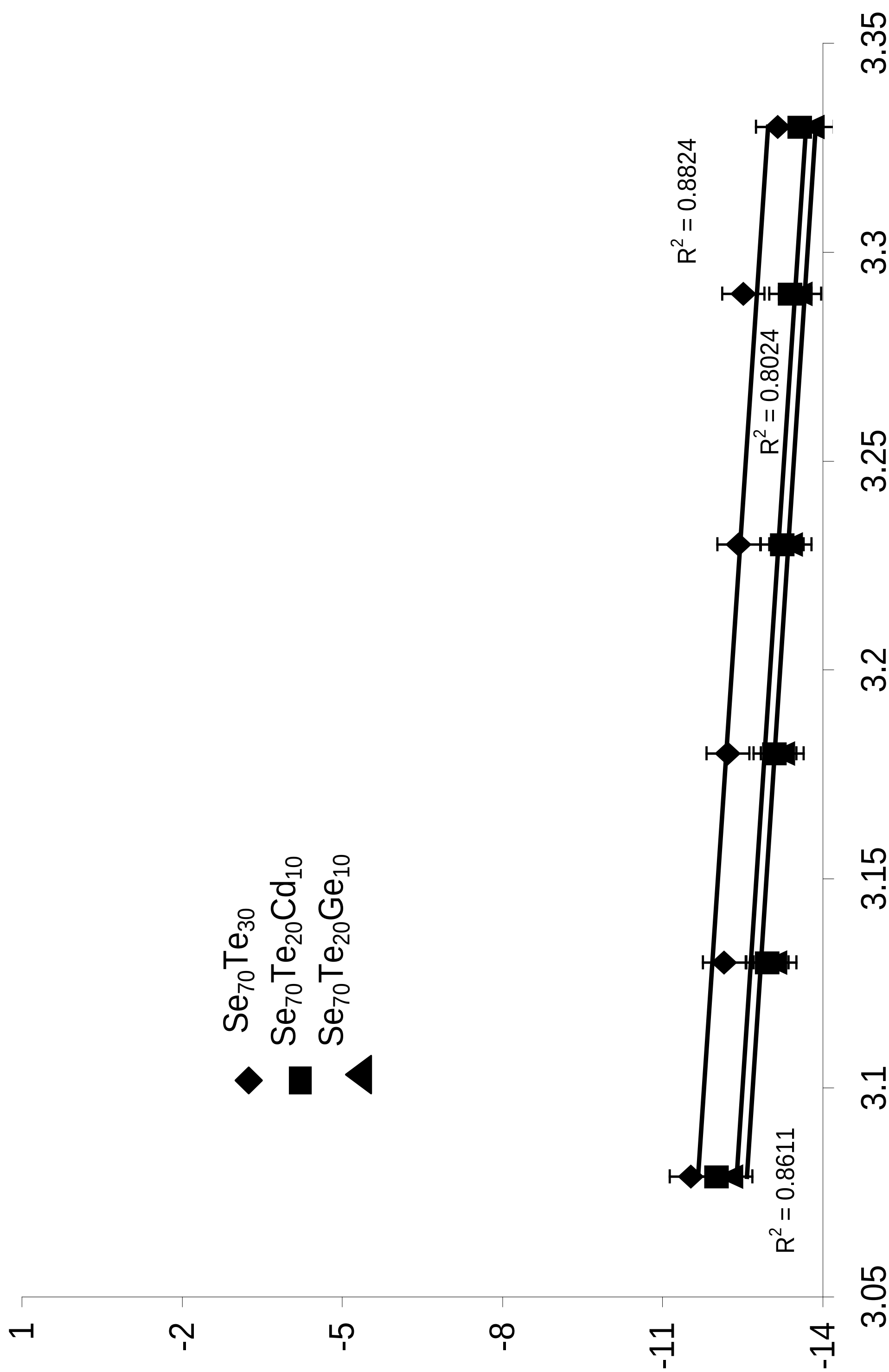

Fig. 4: Temperature dependence of ac conductivity in $Se_{70}Te_{30}$, $Se_{70}Te_{20}Cd_{10}$ and $Se_{70}Te_{20}Ge_{10}$ glassy alloys at 1 KHz.

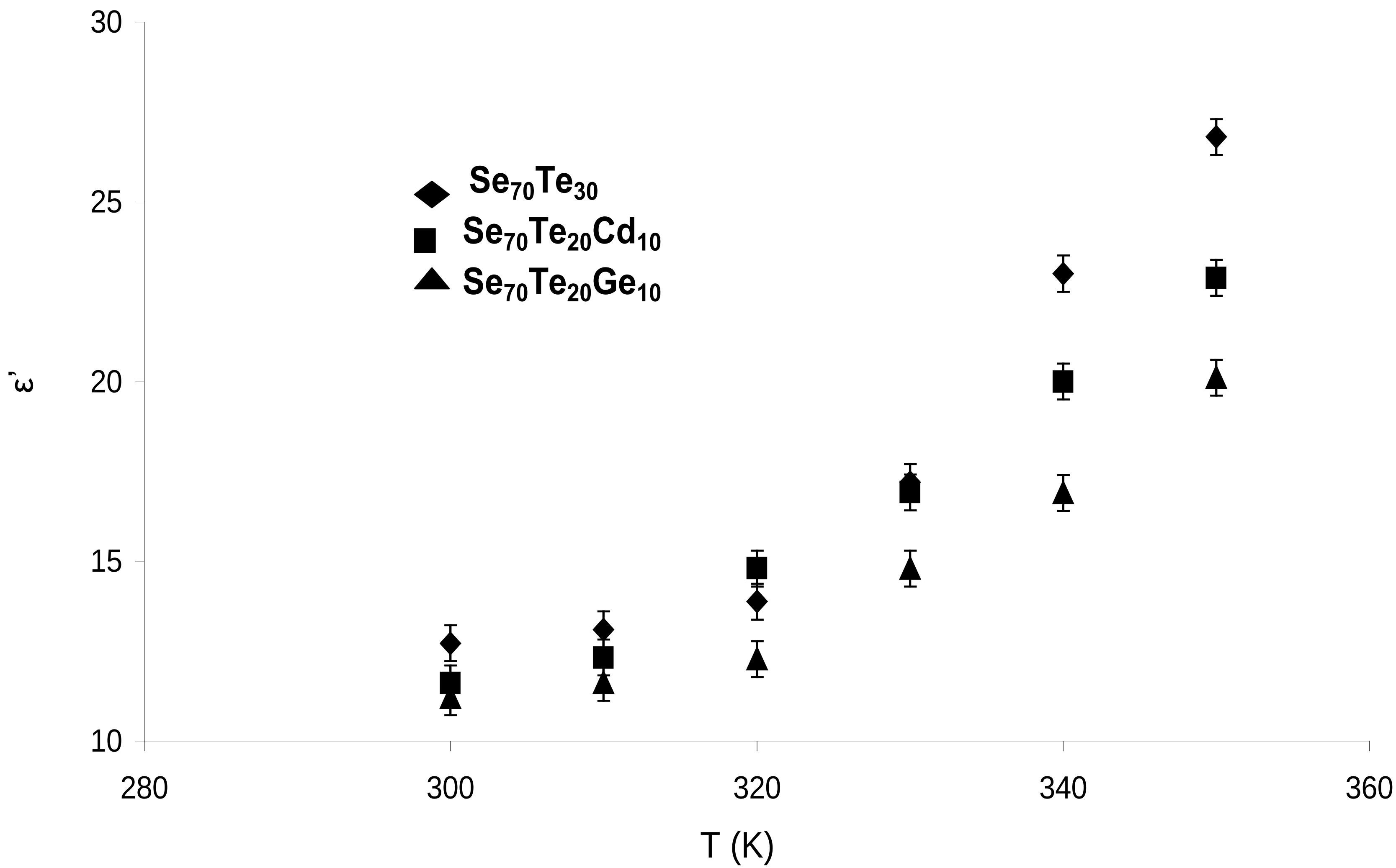

Fig. 5: Temperature dependence of dielectric constant (ε') in $Se_{70}Te_{30}$, $Se_{70}Te_{20}Cd_{10}$ and $Se_{70}Te_{20}Ge_{10}$ glassy alloys at 5 MHz.

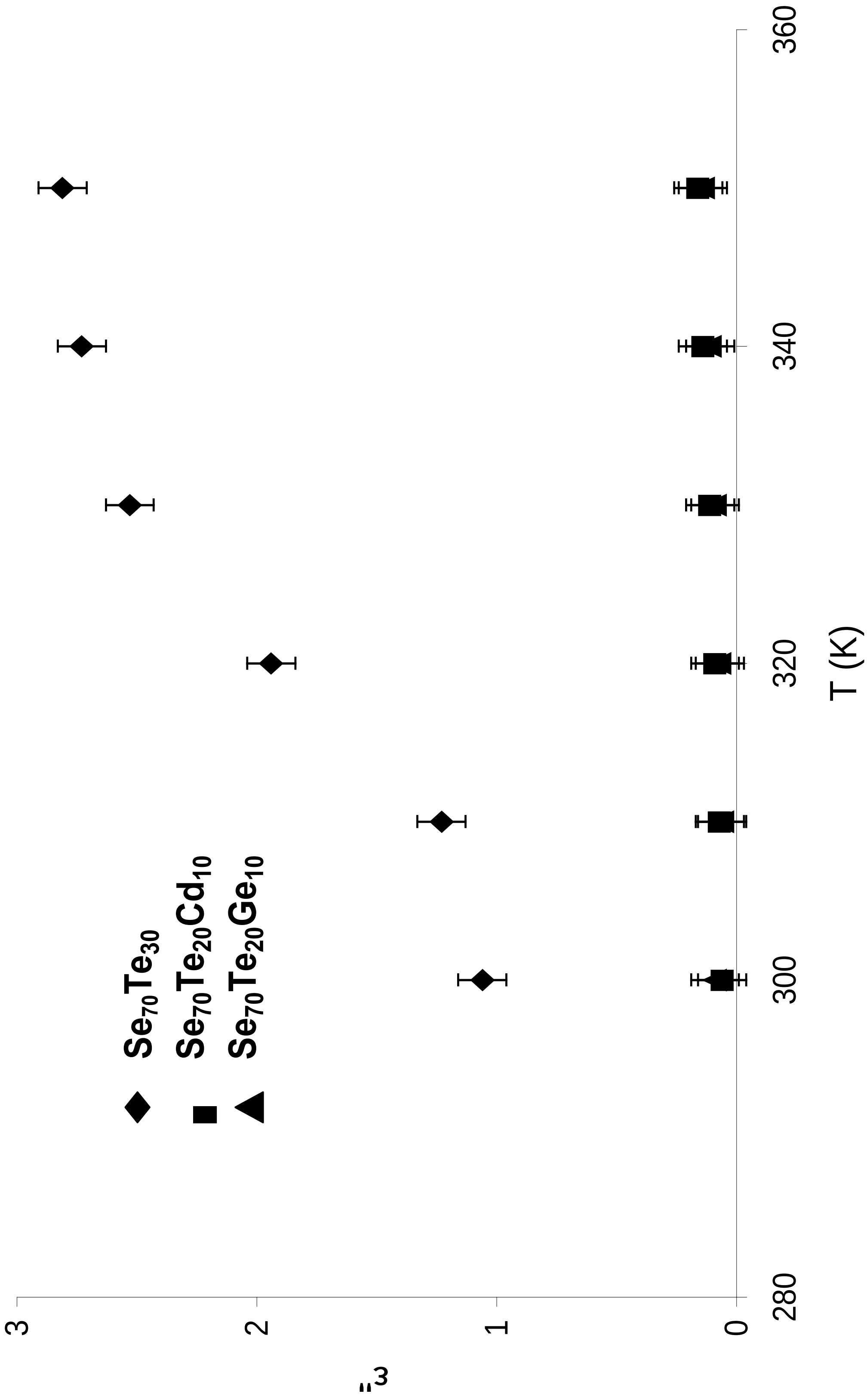

Fig. 6: Temperature dependence of dielectric loss (ε'') in $Se_{70}Te_{30}$, $Se_{70}Te_{20}Cd_{10}$ and $Se_{70}Te_{20}Ge_{10}$ glassy alloys at 5 MHz.

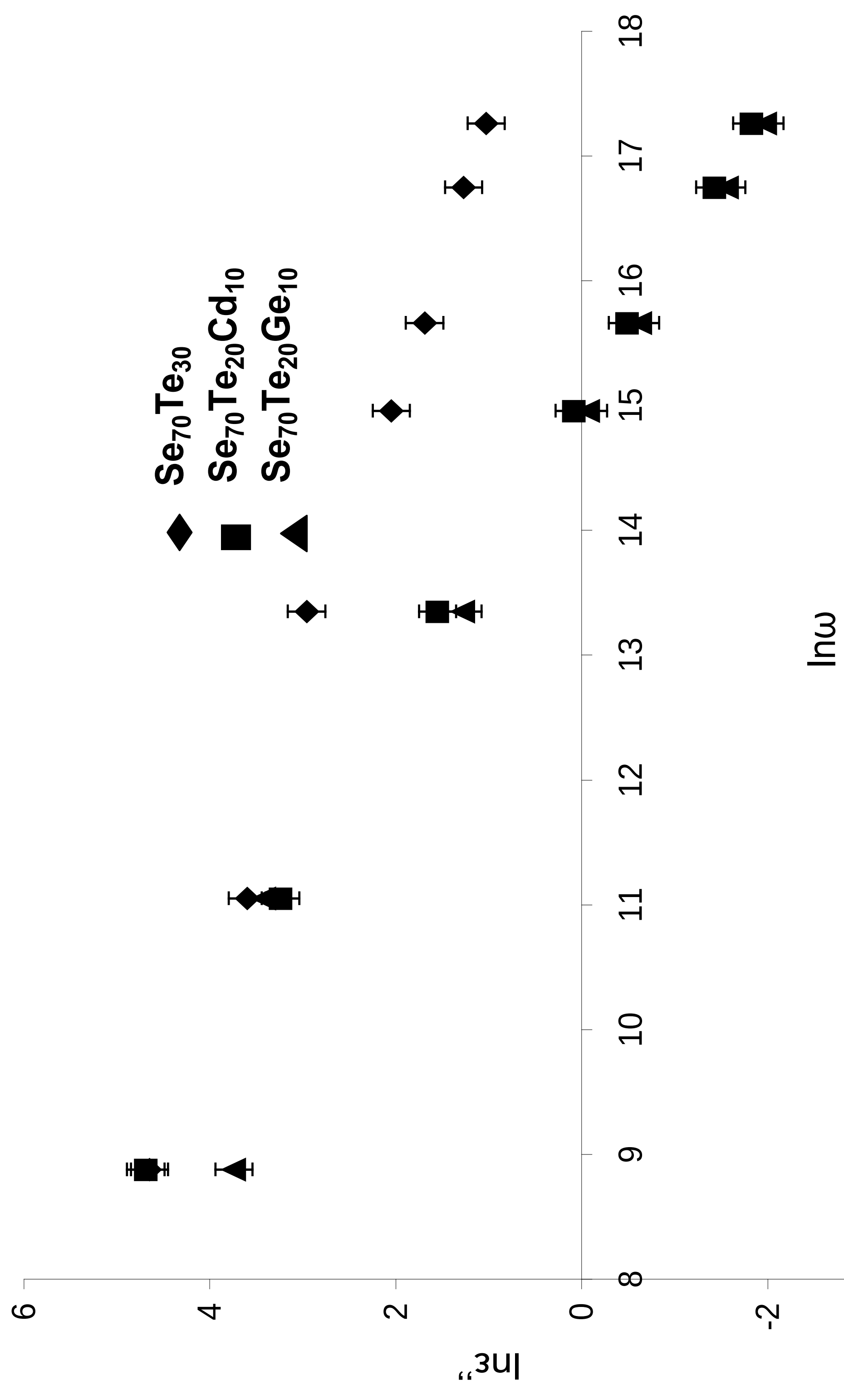

Fig. 7: lnε'' versus lnω curves in $Se_{70}Te_{30}$, $Se_{70}Te_{20}Cd_{10}$ and $Se_{70}Te_{20}Ge_{10}$ glassy alloys at 350K.

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By Ajadi, D. A & Sanusi, Y. K.
Ladoke Akintola University

Abstract - Among other atmospheric factors, relative humidity of the air plays an important role in the drying by solar radiation. The effect of relative humidity over oven temperature was investigated in this work. This study reveals that is a relationship between relative humidity and temperature.From the work done it has been found out that the higher the temperature the lower the relative humidity and hence the faster the drying rate of the material. It was also observed that the time, at which the maximum temperature was obtained, the relative humidity was minimum. Throughout the period of the research the oven temperature was higher than the ambient temperature while the ambient relative humidity is higher than the oven relative humidity.

Keywords : relative humidity, oven temperature, solar dryer, drying rate, atmospheric factors.

GJSFR-A Classification : *FOR Code: 020504*

EFFECT OF RELATIVE HUMIDITY ON OVEN TEMPERATURE OF LOCALLY DESIGN SOLAR CARBINET DRYER

Strictly as per the compliance and regulations of :

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Keywords : relative humidity, oven temperature, solar dryer, drying rate, atmospheric factors.

I. Introduction

Drying is used to remove water from foods for two reasons: to prevent (to inhibit) micro – organisms and hence preserve the food and to reduce the weight and bulk of food to cheaper transport and storage. When carried out correctly, the nutritional quality, colour, flavor and texture of dehydrated foods are slightly less than fresh food but, for most people, this has only minor nutritional significance as dried foods from one component in the diet. However if drying is carried out incorrectly there is a greater loss of nutritional and eating quantities and more seriously, a risk of microbial spoilage and possibly even food poisoning (Practical Action).

Tropical countries are characterized by relative high ambient temperature, relative humidity and rainfall. In these countries agricultural products are harvested all year round and must be dried immediately to reduce mass losses and prevent spoilage. These losses might occur as a result of microbial activities, especially mould (Ndukwu, 2009).

For effective drying, air should be hot, dry and moving. These factors are inter – related and it is important that each factor is correct: for example cold moving air or hot, wet moving air is unsatisfactory. The dryness of air is termed humidity – the lower the humidity, the drier the air. There two ways of expressing humidity (or Relative Humidity, RH) the most useful is a ratio of the water vapour in air to air which is fully saturated with water vapour. The temperature of the air affects the humidity (higher temperatures reduce the humidity and allow the air to carry more water), (Practical Action). Rapid dehydration is desirable: The higher the temperature and the lower the humidity, the more rapid the rate of dehydration will be. Humid air slows down evaporation. If drying takes place too fast, however, 'case hardening' will occur.This means that the cells on the outside of the pieces of food give up moisture faster than the cells on the inside. The surface becomes hard, preventing the escape of moisture from the inside (Drying Food).

The review of literature revealed some limited work on this area; however post – harvest machine designed with their data cannot function effectively because of the peculiar agro climatic conditions of a particular area (Ndirika and Oyeleke, 2006). Various studies on the drying of biomaterials indicate that drying constant and drying rate are important factors in predicting the drying time of biomaterials (Brooker et al. 1992). The importance of drying constant in relation to handling processing and design of post harvest machine is justified.

In this work the effect of relative humidity on oven temperature of a locally designed solar cabinet dryer was studied with the main chamber that supplying heat energy required by the drying chamber of the dryer.

II. Materials and Methods

The solar dryer used in this work was designed by Ajadi and Adelabu (2003). The distance between the glass cover and the absorber plate was fixed for 4 cm (Ajadi, 2007). This region is known as absorption region which allows maximum absorption and emission of the sun radiation, and thus the absorber plate acts as a perfect blackbody. The solar dryer was positioned in an open space and protected against all obstruction of shades to allow maximum sun radiation to fall on the surface of the glass through out the day between 8.00 am and 6.00 pm local time. The dryer was cleaned from dust effect (Ajadi et al, 2007) before each day readings are recorded.

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The experiment was performed during the hammattan season for a period of 21 days in the month of January 2009. Electronic digital multi-meter which is of 5 in 1 Auto Ranging Digital Multi-meter with number MS 8209, was used to determine the humidity for ambient (Ha) and oven (Ho). The same instrument was used to determine the temperature of the ambient (Ta) and oven (To) respectively. The readings were taken at an interval of 30 minutes for each day. The results are tabulated below.

III. Results and Discussion

Table 1 : Oven Relative Humidity and Oven Temperature

Time	Ho(%)	To(°C)
8.0	70.2	26.4
8.5	66.5	27.1
9.0	62.8	27.5
9.5	60.2	28.1
10.0	57.1	28.7
10.5	55.2	29.1
11.0	52.7	29.7
11.5	49.8	30.2
12.0	48.1	31.6
12.5	45.2	32.1
13.0	40.6	32.6
13.5	39.8	32.9
14.0	39.0	33.5
14.5	37.1	34.2
15.0	37.6	35.0
15.5	38.9	34.6
16.0	40.4	34.0
16.5	43.1	33.6
17.0	44.5	32.2
17.5	45.1	30.8
18.0	44.9	29.5

Table 2 : Ambient Temperature and Oven Temperature

Time	Ta(°C)	To(°C)
8.0	26.0	26.4
8.5	26.7	27.1
9.0	27.0	27.5
9.5	27.6	28.1
10.0	28.2	28.7
10.5	28.4	29.1
11.0	29.9	29.7
11.5	29.8	30.2
12.0	30.8	31.6
12.5	31.5	32.1
13.0	31.9	32.6
13.5	32.2	32.9
14.0	32.8	33.5
14.5	33.7	34.2
15.0	34.2	35.0
15.5	33.7	34.6
16.0	32.4	34.0
16.5	31.8	33.6
17.0	30.0	32.2
17.5	29.7	30.8
18.0	27.4	29.5

Table 3 : Ambient Relative Humidity and Oven Relative Humidity

Time	Ha(%)	Ho(%)
8.0	70.8	70.2
8.5	68.1	66.5
9.0	64.6	62.8
9.5	62.3	60.2
10.0	59.4	57.1
10.5	57.0	55.2
11.0	54.6	52.7
11.5	51.3	49.8
12.0	50.6	48.1
12.5	47.8	45.2
13.0	44.3	40.6
13.5	40.7	39.8
14.0	39.5	39.0
14.5	38.8	37.1
15.0	38.9	37.6
15.5	40.7	38.9
16.0	42.8	40.4
16.5	43.9	43.1
17.0	45.2	44.5
17.5	45.8	45.1
18.0	46.1	44.9

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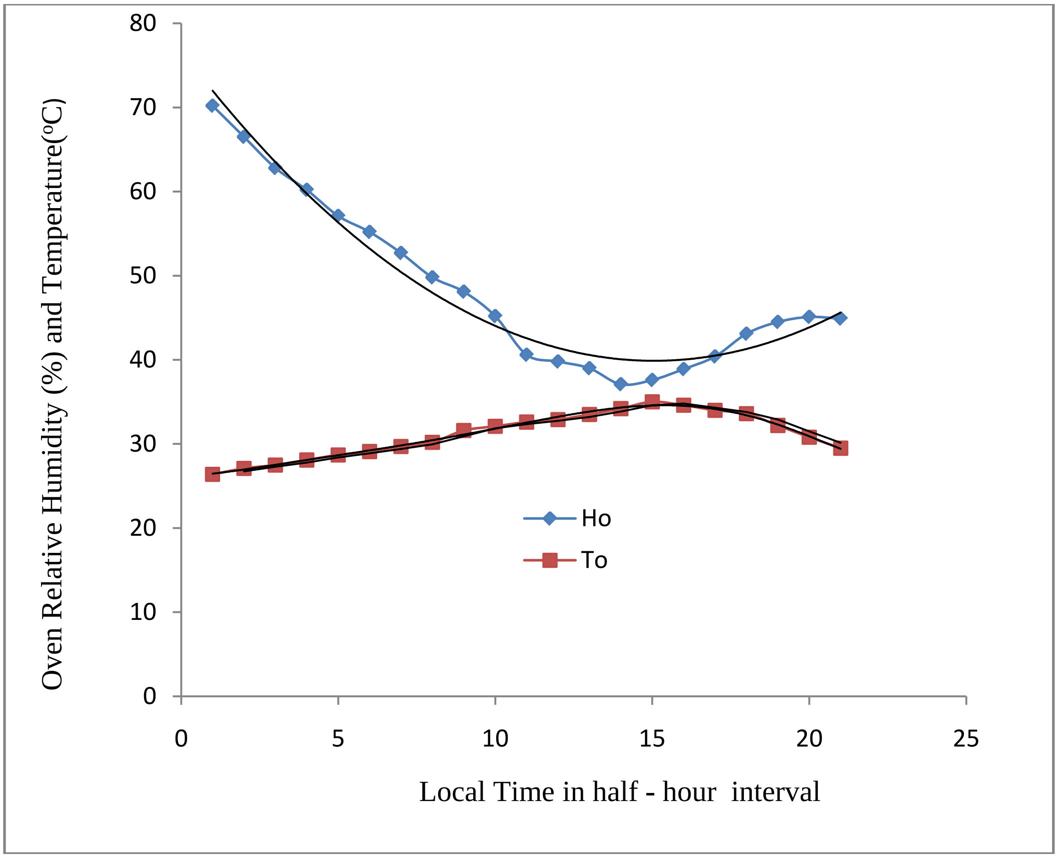

(7)

Figure 1 : Oven Humidity and Oven Temperature aganist Time

Figure 1 display the graph showing the average daily variation of the relative humidity and temperature with time as obtained from Table 1 above. Both graphs follow the normal polynomial curve of degree five with $R^2 = 0.99$. The curves show that at about 14 hour local time, the humidity shows minimum point while the temperature shows maximum point. From this graph it could be observed that the higher the temperature recorded the lower the relative humidity before the minimum/maximum point and vice versa after the point. This can be explained from the expression for relative humidity given as:

$$\text{RelativeHumidity} = \frac{\text{Actual Vapoure Pressure}}{\text{Saturated Vapoure Pressure}} \qquad (1)$$

This is because increase in temperature raises saturated vapour pressure, which leads to reduction in the relative humidity as seen in Equation 1 above. Hence the higher the temperature observed the lower the relative humidity.

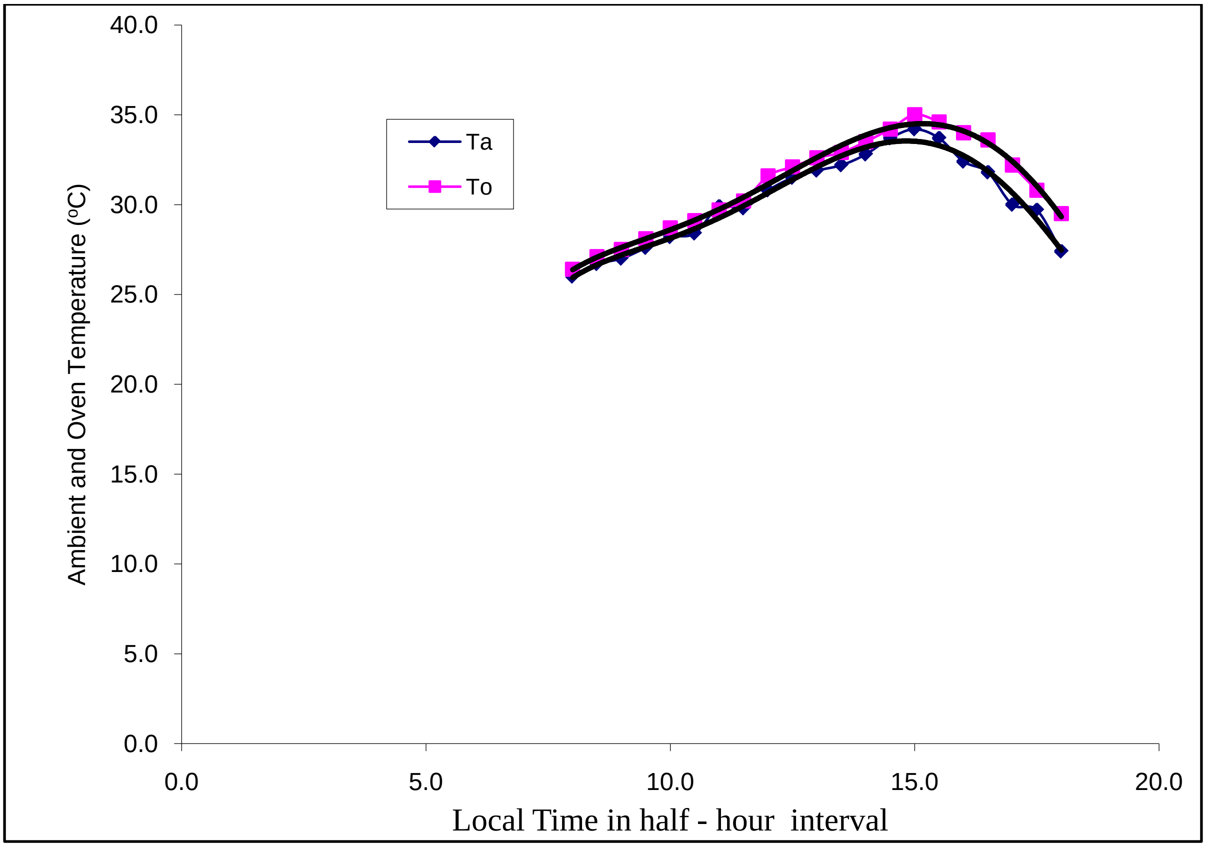

Figure 2 : Ambient temperature and Oven Temperature aganist Time

Figure 2 display the graph showing the average daily variation of the ambient and oven temperature with time as obtained from Table 2 above. Both curves follow the normal polynomial curve of degree five with R^2 = 0.99. The curves also show that at about 14 hour local time, both curves are at maximum point. It is observed that the temperature of the oven is always higher than the temperature of the ambient (environment), this shows that drying in the oven will be faster than that in the open air drying.

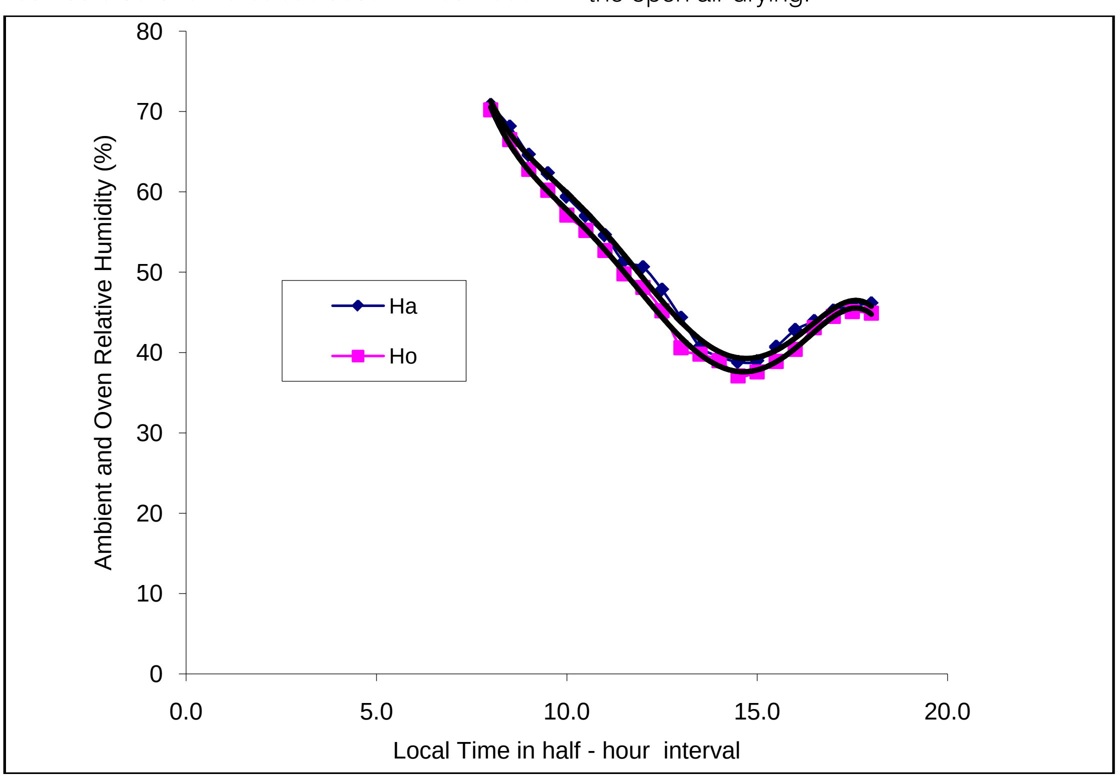

Figure 3 : Ambient Humidity and Oven Humidity aganist Time

Figure 3 display the graph showing the average daily variation of the ambient and oven relative humidity with time as obtained from Table 3 above. Here it is observed that the relative humidity of the oven is always lower than the relative humidity of the ambient (environment) which in turn favours the drying rate or reduce the drying time of the dryer for better dried products. The twocurves follow the normal polynomial curve of degree five with $R^2 = 0.99$. The curves also show that at about 14 hour local time, both curves are at minimum point.

IV. Conclusion

The relative humidity plays an important role in solar drying to achieve good quality dried products. In view of this, the effect of relative humidity on oven temperature of a locally designed solar cabinet dryer was experimentally studies. Based on the results obtained, it has been found that out the higher the temperature the lower the relative humidity and hence the faster the drying rate of the material. Also it was observed that the time, at which the maximum temperature was obtained, the relative humidity was minimum. Throughout the period of the research the oven temperature was higher than the ambient temperature while the ambient relative humidity was higher than the oven relative humidity.

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Appraisal of Wind Energy Potential in Zaria Metropolis

By Olatunji S & Sanusi, Y.K.
University of Ilorin

Abstract - Daily wind speed and directions obtained using wind vane and anemometer for a period of ten years (1995- 2004) were acquired from meteorological station located at longitude 07 ° 41′ E and latitude 11°08′ W, altitude of 686 m in Nigerian college of aviation technolog Zaria. The readings were usually taken twice in a day, at 10.00 am and at 4.00 pm. The results showed a relative dominance of N-E. With 7251 direction counts recorded throughout the years N-E windhas3317 direction counts representing 45.75%, S-W 33.4%, N-W, 11.75% S-E 7.94% E, 0.68%; W, 0.30% S, 0.08% and N, 0.07%. The maximum wind speed of 3 m/s was obtained at a height of 10 m above the earth surface. There is an evidence of speed increase with height above the earth surface. The average extractable wind power per unit area wasnot less than 9 w/m^2 in the area . It was also observed that dry season (N-E wind period), normally runs from the month of November to February whereas the rainy season (S-W wind period), and runs from the month of May to September.

Keywords : wind, extractible, energy, speed, power, anemometer, cold, warm.

GJSFR-A Classification : FOR Code: 660202

APPRAISAL OF WIND ENERGY POTENTIAL IN ZARIA METROPOLIS

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I. Introduction

Wind was seen by a Greek philosophers-Anaximander as a current of air produced when air is stirred or melted by the sun (Brown, 1962)Atmospheric pressure varies from day to day and from place to place.So air flows from a high atmospheric pressure towards a low area.Thus, the process of equalisation taking place between a region of rarefied air and one that is denser tends to initiate air flow/current. Energy extracted from the wind is in the form of rotary, translational, or oscillatory mechanical motion (Cheremisnaff, 1978)

In consequence, wind results from the movement of air masses and arises primarily due to unequal heating of the earth's surfaces by the sun. The air over oceans and lakes remains relatively cool during the days since much of the sun's energy is consumed in the evaporating water or is absorbed by the water itself (Fig. 1) Over land, the air is heated more during the day, since land absorbs less sunlight than waters and evaporation is less. The heated air overland expands, becomes lighter and rises. The cooler, heavier air from over the water moves in to replace it. Local breezes on a shoreline are thus created in this way (Eldridge, 1979). These local seashore breezes reverse themselves during the night, since land cools more rapidly than water, and so does the air above it (Fig. 2). The warm air that rises from the surface of the water is replaced by this cool air from over the land as it blows sea ward. (Eldridges, 1979) Thus, the sea shore line becomes wormer at night. Similar breezes occur on mountain sides – during the day as the heated air rises along the warm slopes that face the sum (Fig. 3). During the night, the relatively heavy cool air on the slope flows down into the valleys (Fig. 4). (Eldridges 1979). Thus, mountain sides (valley) are cooler at night.

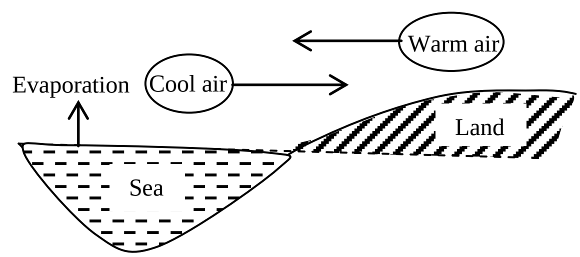

Figure 1 : Formation of Seashore Breeze during the Daytime

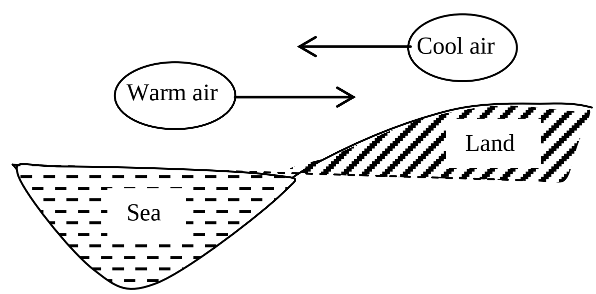

Figure 2 : Formation of Local Offshore Breeze during the Night time

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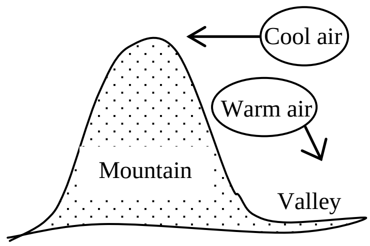

Figure 3 : Formation of Mountain Breeze During the Daytime

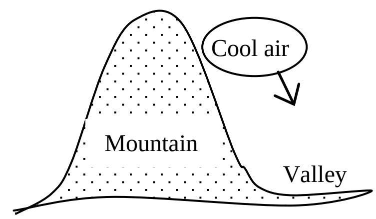

Figure 4 : Formation of Valley Breeze During the Night time

Circulating planetary winds are likewise caused by the greater heating of the earth's surface near the equator than near the poles. This causes cold surface winds to blow from the poles to the equator to replace the hot air that rises in the tropics and moves in the upper atmosphere towards the poles (Fig. 5). However, the rotation of the Earth also affects these planetary winds, which makes-wind a much more complex phenomenon (Fig. 6) The inertia in the cold air moving near the surface towards the equator tends to twist it to the west, while the warm air moving in the upper atmosphere towards the poles tends to be turned to the east. This causes large counter – clockwise circulation of the air around, low pressure areas in the northern hemisphere, and clockwise circulation around such areas in the southern hemisphere. Since the Earth's axis of rotation is reclaimed at an angle of 23.5° to the plane in which it moves around the sun, seasonal variations in the heat received from the sun result in seasonal changes in the strength and direction of the winds at any given location on the Earth's surface (Eldridge 1979).

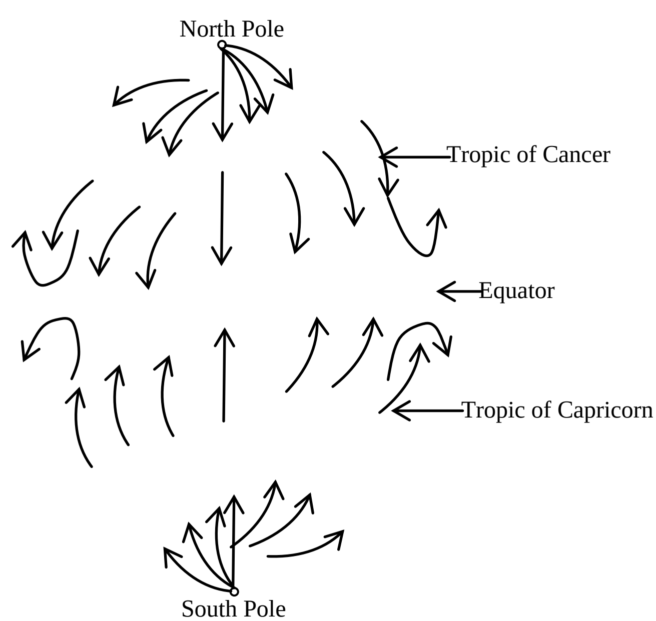

Figure 5 : Hypothetical Wind Nature, Were the Earth not rotating

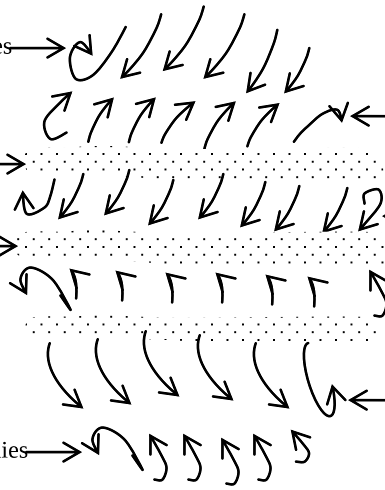

Figure 6 : Effects of Earth's Rotation on the Wind Shape

II. Related Literatures

In Zaria, Elegba, (1982) found that high average wind speed is observed during the months of November and December and low average wind speed during the months of January to October. It was also found that the long-term average wind speed for Zaria is 3.2m/sec. It was observed that wind speeds in the area are generally high quantity between the months of November and June (Inglis,1978 and Swena, 2000) This is of very important significant because irrigation periods fall between the months of November and March in the area. Wind mills could therefore be used to advantage by matching the high water requirements with the high wind speeds in the period.

III. Materials and Methods

a) *Instrumentation*

The wind's direction was measured with wind vane. The vane or arrow points to the direction from which the wind is blowing so that wind is named from the direction it blows e.g. south-west wind blows from south-west direction. The wind vane is located in an exposed position on the field, at Nigerian College of Aviation Technology Zaria premises.

Anemometer was used to monitor the speed of windat a height of 2.5m above ground levelby calibrator on the support.

b) *Theories*

i. *Available Wind Energy*

The power available in a free flowing wind of a given cross – sectional area is given by

$$P_a = \frac{\rho V^3 A}{2} \tag{1}$$

Where $\rho = density, V = velocity\ and\ A = area$

All the available energy in the wind cannot be extracted because of the continuity constraint. It has been proved by (Cheremisinaff, 1978) that an ideal wind machine is capable of extracting only 59.3% of the energy available in the wind. One method of characterizing the potential wind energy of various sites of interest is through their average available wind power per unit area (Justus, 1978). That is

$$\frac{P_a}{A} = \frac{\rho V^3}{2} \tag{2}$$

ii. *Extractable Wind Energy*

The amount of power which can be extracted from a wind stream depends on the available wind energy and on the operational characteristics of the wind machine. The average power extracted during the programme - Wind Energy Conversion Systemof U. S. A. in the year 2000 given by

$$P_e = \frac{C_p \rho V^3 A}{2} \tag{3}$$

Where P_e = extractable power and C_p is the power coefficient and equal to 0.593
(Justus, 1978)

iii. *Average Wind Speed*

The monthly and yearly average wind speeds are converted from 2.5m height to 10m height using

$$\frac{V_H}{2.5} = \frac{V}{2.5} \tag{4}$$

Where V_H = wind speed at a desired height and V = wind speed at reference height e.g. 2.5 m

iv. *Wind Energy Flux*

The available wind power per unit area is given as

For instance ρ = 1.16 kg/m^3 at 30°C (Dewinkel, I.E.S.; report 104)$\frac{P_a}{A} = 0.58\mathrm{V}^3$, and assuming maximum machine efficiency, then $C_p = 0.593$ and

$$\frac{P_e}{A} = 0.3344\,V^3.$$

c) *Data Acquisition*

Data was obtained from meteorological stationlocated at longitude 07° 41′E and latitude 11°08′W, and at an altitude of 686m in Nigerian college of aviation technolog Zaria.Daily wind speed and directions obtained from wind vane and anemometerfora period of ten years (1995-2004) were acquired. The readings are usually taken twice in a day, at 10.00am and at 4.00 pm. Average daily wind speeds for duration of ten years were collected for Zaria, 1995-2004 inclusive. Ten year period is considered adequate for any peculiar climatological and seasonal variations as recommended by (Ishaku 1982)

IV. Results and Discussions

a) *Wind Speed*

Wind speed of 2m/sec is considered to be the minimum threshold speed for any meaningful small scale wind power application (Elegba *et.al.*, 1982). Average wind speed in the area is enhanced by the altitude increase (Tables 1-3) The maximum average wind speed of 3 m/s was observed from the month of January through Julyand low average wind speed period is observed from August to December (Fig. 7) The fact that high average wind speed period is observed between January to July is of domestic and economic important. This is because it is the period when irrigation is carried out and supply of domestic water from other sources is low.

The variation of wind speed over the years is not much pronounced. It can be seen in figure 8 that wind speed was fairly steady from 1995 to 1999 after which if fluctuates. The average wind speed over the ten years was seen to be 2.1 m/s (Table 3) There exists 9 W/m^2 extractable wind power per unit area in the metropolis (Fig. 9)

Table 1 : Wind Speed for 1995 - 2004 at 2.5 m Height

	1995 (m/s)	1996 (m/s)	1997 (m/s)	1998 (m/s)	1999 (m/s)	2000 (m/s)	2001 (m/s)	2002 (m/s)	2003 (m/s)	2004 (m/s)	Average (m/s)
Jan.	1.25	1.50	1.83	1.47	2.93	1.59	1.65	1.59	1.35	1.47	1.70
Feb.	1.25	1.90	1.94	1.75	2.01	1.66	2.29	1.42	1.26	1.60	1.71
Mar	1.53	1.78	1.53	1.88	2.28	1.72	2.15	1.54	1.74	1.92	1.82
Apr	2.04	1.92	2.19	2.32	1.79	2.14	1.72	2.38	2.01	2.16	1.81
May.	2.16	2.60	2.08	2.39	2.78	2.61	2.94	2.40	2.28	2.13	2.07
Jun.	1.84	2.32	2.24	2.28	2.67	2.42	2.74	2.80	2.00	2.15	2.35
Jul	1.49	1.67	2.03	1.94	2.16	1.86	2.03	2.39	1.82	1.98	1.94
Aug	1.53	1.30	1.47	1.53	1.35	1.66	1.59	1.56	1.26	1.61	1.49
Sep	1.14	1.60	1.32	1.22	1.13	1.04	1.27	1.36	1.14	1.30	1.20
Oct	0.84	1.12	1.02	1.17	1.09	0.71	096	0.95	1.00	0.80	0.97
Nov	099	1.17	1.64	1.30	0.86	1.01	0.98	1.09	0.91	0.93	1.09
Dec.	1.53	1.64	1.31	1.61	1.05	1.61	1.67	1.65	1.15	1.20	1.44
Average	1.50	1.67	1.72	1.74	1.84	1.67	1.83	1.76	1.49	1.61	

Table 2 : Monthly Average Wind Speed at 10m Height

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
Speed (m/s)	2.12	2.13	2.25	2.58	3.05	2.93	2.42	1.86	1.50	1.21	1.36	1.80	2.10

Table 3 : Yearly Average Wind Speed at 10m Height

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Average
Speed (m/s)	1.87	2.08	2.15	2.17	2.30	2.08	2.28	2.20	1.86	2.01	2.10

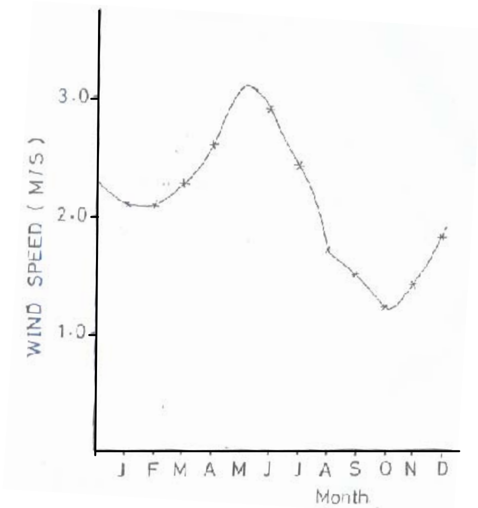

Figure 7 : Monthly Average Wind Speed Distribution

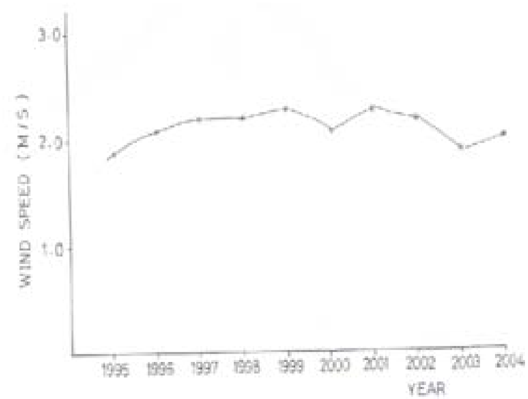

Figure 8 : Yearly Average Wind Speed Distribution

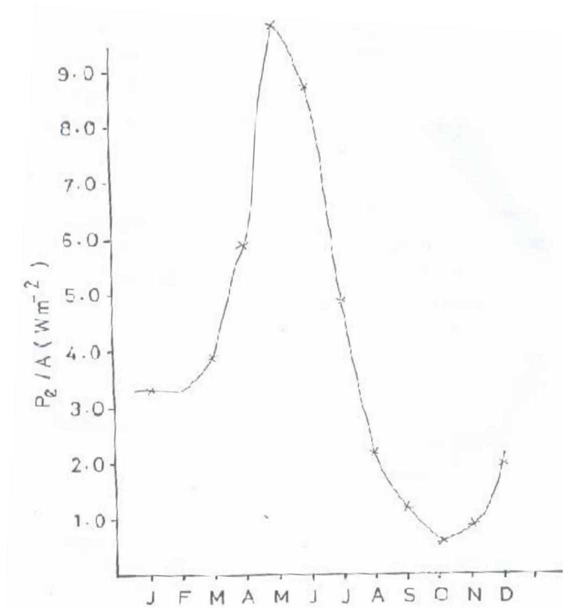

Figure 9 : Extractible Wind Power perunit Area Distribution

Table 4 : Monthly Extractable Wind Power per Unit Area Wind Directions

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pa(W/m^2)	5.53	5.60	6.61	9.96	16.46	14.59	8.22	3.73	1.96	1.03	1.46	3.38

Table 5 : Monthly Extractable Wind Power per Unit Area

Month	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pe/m^2	3.28	3.32	3.92	5.91	9.76	8.65	4.88	2.21	1.16	0.61	0.87	2.00

b) Wind Directions

In order to prepare table 6, the wind direction data for each month and for each of the prevailing directions are counted (direction count) over the period under study. To plot a graph of monthly and yearly (Figures 10 and 11) total direction count for each month and for each wind direction over the period Table 6a-b are summed up to obtain table 7 and table 8.

Throughout the ten years under study, the NE wind direction is found to be the most predominant

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(3317 counts, 47.75%) out of 7251 counts recorded for the period. This is then followed by the SW wind direction (2424direction counts, representing 33.43%)

Figure 10 shows that NE wind direction count dominates over all other wind directions and the fact that NE wind is cold and dry wind reveals the tropical nature of Zaria. Hence, NE wind is predominant wind in Zaria.

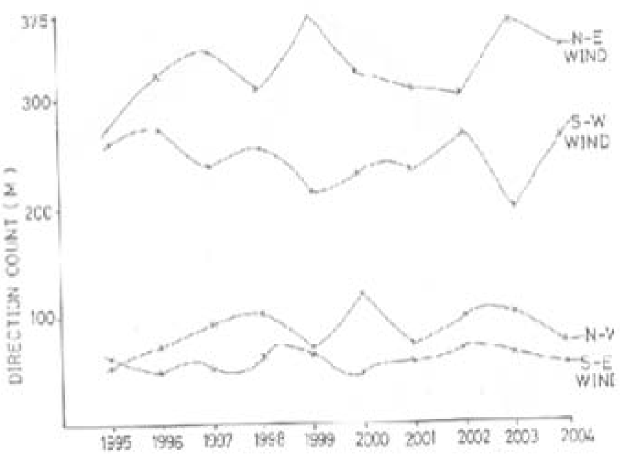

Figure 10 : Yearly Total Direction Count Distribution

c) Direction Count Distribution

When the sun heats the air molecules on the surface of the earth, theygain kinetic energy and move upward with higher kinetic energy (higher direction counts) and lower potential energy until maximum kinetic energy is attained. At this point, the molecules start to drift downward with increasing potential energy and decreasing kinetic energy (lower direction count) until maximum potential energy is attained. The process continues as confirmedin figure 11.This agrees with the assertion that atmospheric heating is converted into average kinetic energy during the rising of masses of warm air Hidy (1967) Further, since wind direction is velocity dependent, it can be seen from fig.11 that the higher the direction count, the higher the kinetic energy and the lower the potential energy and vice – versa. This implies that all the crests in fig. 11 represent points of maximum kinetic energy and all the troughs represent points of maximum potential energy.

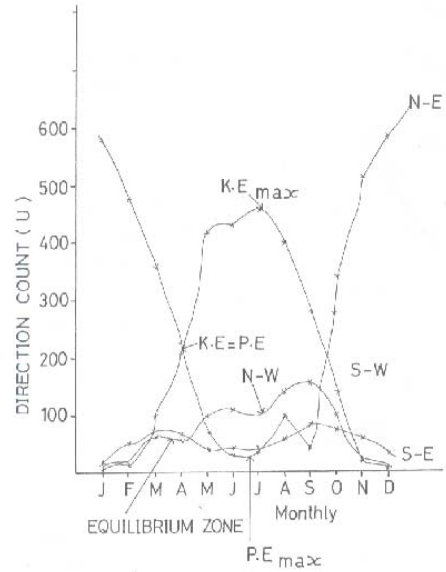

Figure 11 : Monthly Total Direction Count Distribution

The NE wind is characterised by dry and cold naturewhileSW wind ischaracterisedby wet and warm nature. This can be seen from fig. 11 in that NE wind has maximum potential energy. But along the paths of motion of these two winds, there is a point where the kinetic energy of one wind is equal to the potential energy of the other wind (equilibrium point). These pointsare where the effects of these two winds are mixed; thisliegenerally between the month of February and May, so also between September and November (Fig. 11) These points where the SW wind (warm) slips over the NE wind (cold) are the points of interchange of energy.

Hidy (1967) stated that rising of warm air and sinking of cold airis a direct circulation that heads to the release of potential energy to the kinetic energy of fluid motion. He furthered that when cool air over takes warmers air and drifts underneath it, a cold front develops; warm air slipping over retreating cold air gives rise to a warm front.

The nature of fig. 11 confirmed that when the NE wind (cold) slips over the SW wind (warm) cold front develops. This cold front generally stretched from the month of October to March. Also,when the SW wind (warm) slips over NE wind (cold) warm front develops. This warm front generally stretches from the month of April to September. Coincidentally, April-September marks the wet/rainy session, October-March marks the dry and coldest (hazy) period; and partly March - April usually witness extremelyhot weather.

Distribution of wind direction monthly directing count is shown in table 6a-j.

Table 6a : 1995 Monthly Directing Count

1995		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WIND DIRECTION COUNT	NW	0	0	0	3	14	66	2	9	7	8	5	0
	NE	60	46	30	3	2	4	4	4	7	18	37	27
	SW	0	0	1	6	42	46	52	46	37	23	5	0
	SE	0	0	0	0	4	4	3	3	9	13	12	5
	N	0	0	0	0	0	0	0	0	0	1	0	0
	W	0	0	0	0	0	0	0	0	0	0	0	0
	S	0	0	0	0	0	0	1	0	0	0	0	0
	E	2	10	23	0	0	0	0	0	0	0	0	0

Table 6b : 1996 Monthly Directing Count

1996		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WIND DIRECTION COUNT	NW	0	1	2	6	8	5	7	9	16	12	3	1
	NE	57	54	33	20	1	1	3	6	11	23	54	57
	SW	0	1	12	24	50	57	3	38	25	22	1	0
	SE	5	0	8	5	2	1	47	4	6	5	2	4
	N	0	0	0	1	0	0	4	0	1	0	0	0
	W	0	0	0	1	1	2	0	3	1	0	0	0
	S	0	0	0	0	0	0	1	2	0	0	0	0
	E	0	2	7	2	0	0	0	0	0	0	0	0

Table 6c : 1997 Monthly Directing Count

1997		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WIND DIRECTION COUNT	NW	2	2	7	5	12	12	9	16	18	7	0	2
	NE	59	52	45	22	4	0	0	1	7	34	58	60
	SW	0	0	2	23	45	45	50	40	30	14	0	0
	SE	1	2	8	20	3	3	3	5	5	7	2	0
	N	0	0	0	0	0	0	0	0	0	0	0	0
	W	0	0	0	0	0	0	0	0	0	0	0	0
	S	0	0	0	0	0	0	0	0	0	0	0	0
	E	0	0	0	0	0	0	0	0	0	0	0	0

Table 6d : 1998 Monthly Directing Count

1998		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WIND DIRECTION COUNT	NW	0	1	7	17	12	16	9	12	14	13	1	1
	NE	60	42	45	19	3	3	2	2	16	21	48	58
	SW	2	3	4	31	43	38	46	43	23	21	0	1
	SE	0	10	6	3	4	3	5	5	7	7	11	2
	N	0	0	0	0	0	0	0	0	0	0	0	0
	W	0	0	0	0	0	0	0	0	0	0	0	0
	S	0	0	0	0	0	0	0	0	0	0	0	0
	E	0	0	0	0	0	0	0	0	0	0	0	0

Table 6e : 1999 Monthly Directing Count

1999		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WIND DIRECTION COUNT	NW	0	1	4	1	7	12	9	17	18	4	1	0
	NE	62	44	43	32	8	2	4	2	12	51	56	59
	SW	0	1	7	11	45	37	44	38	22	4	1	1
	SE	0	10	0	16	2	9	5	4	8	3	2	2
	N	0	0	0	0	0	0	0	0	0	0	0	0
	W	0	0	0	0	0	0	0	0	0	0	0	0
	S	0	0	0	0	0	0	0	0	0	0	0	0
	E	0	0	0	0	0	0	0	0	0	0	0	0

Table 6f : 2000 Monthly Directing Count

2000		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WIND DIRECTION COUNT	NW	2	6	10	7	12	16	12	19	18	15	0	0
	NE	59	48	35	20	20	5	6	2	2	27	50	60
	SW	0	1	12	31	41	35	37	31	31	18	0	0
	SE	1	3	5	0	5	2	5	7	7	2	8	1
	N	0	0	0	0	0	0	0	0	0	0	1	0
	W	0	0	0	1	3	2	2	2	2	0	0	0
	S	0	0	0	0	0	0	0	0	0	0	0	0
	E	0	0	0	1	0	0	0	0	0	0	0	1

Table 6g : 2001 Monthly Directing Count

2001		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WIND0 DIRECTION COUNT	NW	4	0	6	2	12	7	11	12	11	6	0	1
	NE	55	55	28	36	5	3	5	6	13	45	55	6
	SW	3	0	22	13	44	35	44	34	21	4	2	1
	SE	0	1	6	9	1	5	1	9	15	7	2	0
	N	0	0	0	0	0	0	0	0	0	0	0	0
	W	0	0	0	0	0	0	0	0	0	0	0	0
	S	0	0	0	0	0	0	1	1	0	0	0	0
	E	0	0	0	0	0	0	0	0	0	0	1	0

Table 6h : 2002 Monthly Directing Count

2002		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WIND DIRECTION COUNT	NW	1	2	0	6	7	5	18	11	19	14	6	0
	NE	54	47	26	18	7	2	1	3	9	30	44	59
	SW	0	2	16	30	43	47	40	41	29	12	4	0
	SE	7	5	10	6	5	6	3	7	3	6	6	3
	N	0	0	0	0	0	0	0	0	0	0	0	0
	W	0	0	0	0	0	0	0	0	0	0	0	0
	S	0	0	0	0	0	0	0	0	0	0	0	0
	E	0	0	0	0	0	0	0	0	0	0	0	0

Table 6i : 2003 Monthly Directing Count

2003		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WIND DIRECTION COUNT	NW	1	4	13	4	4	15	11	13	21	14	0	0
	NE	59	41	32	47	19	7	2	6	7	35	57	57
	SW	0	1	11	3	36	37	45	34	21	8	0	1
	SE	2	10	6	6	3	1	4	9	11	5	3	4
	N	0	0	0	0	0	0	0	0	0	0	0	0
	W	0	0	0	0	0	0	0	0	0	0	0	0
	S	0	0	0	0	0	0	0	0	0	0	0	0
	E	0	0	0	0	0	0	0	0	0	0	0	0

Table 6j : 2004 Monthly Directing Count

2004		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WIND DIRECTION COUNT	NW	1	0	8	1	9	14	7	15	12	2	1	3
	NE	57	50	42	17	12	1	2	1	8	49	53	52
	SW	1	3	7	34	39	42	52	44	32	5	1	1
	SE	3	5	9	8	2	3	1	2	8	5	5	6
	N	0	0	0	0	0	0	0	0	0	0	0	0
	W	0	0	0	0	0	0	0	0	0	1	0	0
	S	0	0	0	0	0	0	0	0	0	0	0	0
	E	0	0	0	0	0	0	0	0	0	0	0	0

Table 7 : Yearly Total Wind Direction Count

WIND DIRECTION COUNT	Year	1995	1996	1997	1998	1999	200	2001	2002	2003	2004
	N-E	272	320	342	209	375	219	300	300	369	344
	S-E	61	46	51	63	69	46	56	67	64	53
	N-W	54	70	92	103	74	117	72	97	100	73
	S-W	258	271	239	255	212	233	232	266	197	261

Table 8 : Monthly Total Wind Direction Count

		Ja▶	Fe	Ma	Apr	Ma	Ju	Jul	Au	Se	Oc	Nov	De	TOTAL	%
WIND DIRECTION COUNT	N-E	582	479	359	224	62	28	29	97	32	333	513	580	3317	45.75
	E	2	12	30	3	0	0	0	0	0	0	0	1	49	0.68
	S-E	19	46	70	63	33	37	34	55	79	60	53	27	576	7.94
	S	0	0	0	0	0	0	2	3	0	0	1	0	6	0.08
	S-W	6	12	96	206	418	423	457	386	271	131	14	4	2424	33.43
	W	0	11	0	2	4	4	3	5	3	1	0	0	22	0.30
	N-W	11	17	65	52	97	108	95	133	154	95	17	8	852	11.75
	N	0	0	0	1	0	0	0	1	1	0	2	0	5	0.07
Total		620	566	620	551	614	600	620	620	600	620	600	620	72510	100

V. Conclusion

The fact that wind parameters vary with seasons and topography of the side considered, a careful assessment of wind energy potential in Zaria was carried out with wind data obtained therefore. This is in order to have an in sight into the feasibility of harnessing wind energy in Zaria for various developmental purposes. There is a relative dominance of N-E wind direction. This is because out of 7251 direction counts that have been recorded throughout the years N-E wind accountedfor 3317 direction counts, which represent 45.75%. Others are:S-W 33.4%, N-W, 11.75% S-E 7.94% E, 0.68%; W, 0.30% S, 0.08% and N, 0.07%. It was also observed that dry season (N-E wind period), normally runs from the month of November to February whereas the rainy season (S-W wind period), runs from the month of May to September. The maximum wind speed of 3 m/s was obtained at a height of 10 m above the earth surface. There is an evidence of speed increase with height above the earth surface. The average extractable wind power per unit area was not less than 9 w/m^2 in the area.

Though average annual wind speed in Zaria metropolis (2.1 m/s) is not very high, butcan still be harnessed for wind power generation, though at high altitudes as the result here depicts positive dependence of speed on altitude. This is because some wind machines (e.g. one designed by U.S.C. NIG.L.T.D) have a start – up wind speed of 1.5m/s.

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Study of Noise Pollution During Pre-Carnival, Carnival and Post-Carnival Festivals in Calabar Municipality, Calabar, Cross River State, South-South Nigeria

By Aniefiok O. Akpan, Ubon E. Asuquo & Augustine A. Umoh
University of Calabar

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Keywords : noise pollution, carnival, noise levels, health hazard, hearing loss.

GJSFR-A Classification : *FOR Code: 889804*

STUDY OF NOISE POLLUTION DURING PRE-CARNIVAL, CARNIVAL AND POST-CARNIVAL FESTIVALS IN CALABAR MUNICIPALITY, CALABAR, CROSS RIVER STATE, SOUTH SOUTH NIGERIA

Strictly as per the compliance and regulations of :

Study of Noise Pollution During Pre-Carnival, Carnival and Post-Carnival Festivals in Calabar Municipality, Calabar, Cross River State, South – South Nigeria

Aniefiok O. Akpan [α], Ubon E. Asuquo [σ] & Augustine A. Umoh [ρ]

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Keywords : noise pollution, carnival, noise levels, health hazard, hearing loss.

I. Introduction

Noise pollution is a significant environmental problem in many urban areas that has not been properly recognised despite the fact that it is steadily growing in developing countries (Jamrah et al ,2006). At present, noise pollution is considered as one of the key problems of urban communities that has numerous hazardous effects on the urban environment and may result in a great deal of costs on the society. (Martin et al., 2006; Chien & Chien, 2007). There is no question that noise is both a public health hazard and an environmental pollutant as well. It is present in every human activity and is classified as either occupational noise ie. noise in workplace, or as environmental noise, which includes noise in all other settings, whether at community, residential or domestic level when assessing its impact on human well-being (Concha-Barrientos et al.,2004). Vehicles, musical instruments, small scale industries, urbanization and human activities are the main sources of noise pollution. (Gangwar, 2006).Traffic noise levels increase with increasing density of traffic composition, the road slope, width and surface structure distance to cross road. (Williams and McCrae,1995). Studies have also attributed vehicular noise pollution to large scale migration, increase in number of vehicles (Escap, 1990), traffic jams, defective roads and vehicles and above all the human factor which in our society is reflected by inherent impatience under social pressures giving rise to such acts as blowing of horns unnecessarily. (Sharikh and Rizvi, 1990; SEPA, 1994; Ahmad,1994; Mehdi et al., 2002; Dev and Singh, 2011.) These attributes are well pronounced during festive periods.

Study of noise pollution in Kolhapur city, India during Deepawali festival showed an average noise level of 74.24 dB(A), 62.52 dB(A), 58.88 dB(A), and 50.02 dB(A) at industrial, commercial, residential and silent zones respectively. The result showed that there was an enhanced pressure of noise at all sites due to increase in number of vehicles and facilities of transportation. All the sites under study showed higher sound level than the prescribed limits of the Central Pollution Control Board (CPCB).(Mangalekar et al., 2012).

Noise levels of ten sites were found to be above permissible limit during Diwali festival weeks in Sangamner city in Maharashtra. The noise level was higher in the morning and evening but lower at noon. Pre-diwali showed 0.1% to 20.6%, diwali revealed 2.7% and post-diwali showed 0.4% to20.3% higher sound level limit. The combination of various types of vehicular noise was found to be minimum 70.2 (0.3% higher) and maximum 90.0 (29% higher). The contributions of individual levels were found to be more than the traffic noise limit of 70dB (A) and varied from vehicle to vehicle (Dhembare et al, 1999).

The blowing of horns increased alarmingly and was up to 30 – 35 dB(A) above the tolerance limits in

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Karachi, the largest city in Parkistan (SEPA, 1994). The most noticeable sources of noise pollution here are the auto rickshaws, trail motorbikes and fag horns of public transports (Zaidi, 1990). The problem caused by noise pollution is more aggravated during celebration, festival, marriage or religious functions (Vijayalakshmi et al., 2003). Noise from fire crackers is one of the most important environmental problems mainly during festive occasions.

Thirty seven sampling sites were selected to measure the noise levels at three main streets in Alexandra city. The minimum noise levels recorded at Elgish street, Horreya Avenue and Circular Highway were 58.4 , 48.6 and 42.2 dB respectively while the maximum values were close to 101 dB. The noise levels exceeding 10% of the measured time (L_{10}) were 92, 88 and 97 dB at Elguish Street, Horreya Avenue and Circular Highway respectively. The noise levels exceeding 90% of the measured time (L_{90}) were 67, 62 and 57 dB at the same streets. The noise level at three streets in the day and evening times were higher than the permissible limits according to Egyptian Environmental Law 4/94. The levels at horreya and Circular Highway at night time were lower than the permissible limits.(Ghatass, 2009)

II. About the Study Area and the Carnival Festival

Calabar is the capital of Cross Rivers State in the coastal South-Eastern Nigeria. For the purpose of administration, the city is divided into Calabar Municipality and Calabar South local government areas. Calabar has an Area of 406 Km^2 and a population of 371022 as at 2006 census. Calabar Municipality is a local government area in Cross River State with it's headquarters in the city of Calabar. The municipality has an area of 331.551 km^2 and a population of 17932 at the 2006 census. It lies between latitude 04^0 15' and 5^0 N and longitude 8^0 25' in the north and is bounded by Odukpani local government area in the north east and by the great Kwa River. It's southern shores are bounded by the Calabar River and Calabar South local government area.

The Cross River State annual Christmas festival which started in 2004 and since then holds every year attracts thousands within and beyond Nigeria. The festival which includes music performance from both local and international artists, the annual Calabar carnival, boat regatta, fashion shows, Christmas village activities, traditional dances and annual Ekpe festival is a yearly event that brings in thousands of tourists at that time of the year. The carnival which begins on every 1st of December and lasts till 31st December has boosted the cultural mosaic of Nigerian people while entertaining the millions of spectators within and outside the state and boosting industry for all stakeholders. (http://en.wikipedia.org/wiki/calabar)

Table 1.0 : Climate data for Calabar

Climate data for Calabar													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C (°F)	28 (83)	29 (85)	29 (85)	28 (83)	28 (82)	27 (80)	26 (78)	25 (77)	26 (78)	26 (79)	27 (81)	28 (83)	27.3 (81.2)
Average low °C (°F)	27 (80)	28 (83)	28 (83)	27 (81)	27 (80)	26 (78)	25 (77)	24 (76)	25 (77)	26 (78)	26 (79)	27 (80)	26.3 (79)
Precipitation mm (inches)	41 (1.6)	69 (2.7)	157 (6.2)	216 (8.5)	292 (11.5)	394 (15.5)	445 (17.5)	394 (15.5)	409 (16.1)	310 (12.2)	175 (6.9)	51 (2)	2,951 (116.2)
Source: Weatherbase													

III. Materials and Methods

With digital sound level meter S- 100 (Voltcraft product) set at fast time evaluation and frequency evaluation filter (weighting) set at A, sound level measurements were carried out at site location shown in table 1.1. The meter was set at fast time evaluation because the measured sound from horns, drums, human voices, knock-outs, etc were such that changed rapidly, the filter was set at A since this represents the characteristics curve of the human ear. Measurements were done with meter set at Hi – range which for this meter is 60 to 130 dB. The meter was hand held at 1.3 to 1.5m above the ground level and at a distance of 6m away from the road side. Sound level measurements were carried out for ten (10) days at intervals of two (2) day in a month in ten (10) different locations during the Pre-carnival (November, 2011,), Carnival (December, 2011) and Post- carnival (January, 2012) periods. These measurement were made between the hours 7.00am to 8.00am when people were busy going to work and carrying their children to school, 1.00pm to 2.00pm when the children were back from school and parents going on break and 7.30pm to 8.30pm when people were out to the city for relaxation, these were all busy hours. The measurement days in December included the day the carnival train sailed round the city, this is always accompanied by competing carnival bands operating at full blast on top of moving trucks round the city and followed by mammoth crowd all chanting and dancing. People with different types of cars and with different types of motorcycles form part of the moving carnival train.The five competing bands this time were seagull, Passion 4, Master Blaster, Bayside and Freedom bands. Apart from this day, noise measured were mostly from road traffic.

Table 1.1 : Measurement locations and codes

S/N	LOCATIONS	CODES
1	Eta Agbo by Goldie junction	SITE 1
2	Eta Agbo by Akim road junction	SITE 2
3	Akim Road by Marian road junction	SITE 3
4	Effio-ette junction	SITE 4
5	MCC by Calabar road junction	SITE 5
6	Stadium (Calabar road)	SITE 6
7	Mary Slessor by Calabar road junction	SITE 7
8	Mary Slessor by Marian road junction	SITE 8
9	Watt Market roundabout	SITE 9
10	Cultural Centre	SITE 10

IV. Results

Table 1.2 : Noise levels in dB(A)

S/N	Measurement Locations	Pre-carnival Period			Carnival Period			Post-carnival Period		
		Morning	Afternoon	Evening	Morning	Afternoon	Evening	Morning	Afternoon	Evening
1	Site 1	84.2	80.3	84.9	92.3	87.6	95.4	85.2	81.2	83.5
2	Site 2	82.5	75.9	86.1	94.1	85.2	96.8	77.5	76.4	81.6
3	Site 3	77.4	72.7	78.3	96.5	81.5	95.6	76.9	72.5	79.5
4	Site 4	84.5	81.5	83.2	96.2	90.2	102.2	85.5	80.1	86.6
5	Site 5	80.1	77.2	85.1	92.6	89.5	98.5	84.1	76.1	83.2
6	Site 6	83.5	70.7	87.1	94.5	79.6	89.8	77.2	70.5	79.9
7	Site 7	80.0	73.2	83.5	98.1	81.8	97.6	74.5	71.2	78.2
8	Site 8	81.5	82.6	85.2	95.5	87.1	96.5	86.9	80.5	87.5
9	Site 9	75.9	74.1	77.8	97.2	80.1	99.1	79.1	72.8	79.8
10	Site 10	78.5	71.2	80.1	92.4	77.4	89.4	80.5	75.4	81.6

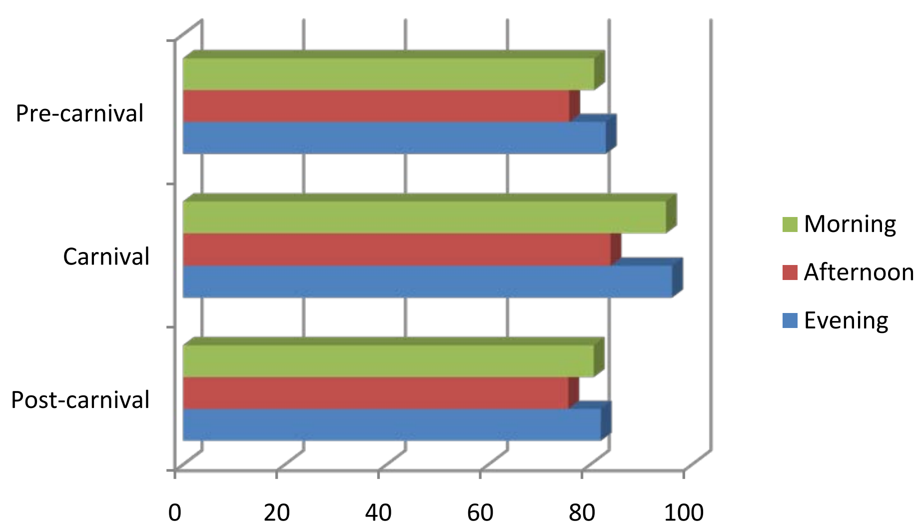

Figure 1.0 : Average noise levels in dB(A)

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V. Discussion of Results

The study of noise levels in Calabar municipality during pre-carnival, carnival and post-carnival periods was aimed at comparing the noise levels during these periods and to find out whether the noise levels are within the recommended standards. The Calabar carnival is the greatest festive period of the year that attracts many from far and near thereby increasing human activities in the Municipality during the period. Ten sites were selected for the measurements as shown in table 1.2.

It is observed that noise level of 87.1 dB(A) in the evening hours at the stadium (site 6) was the highest during the pre-carnival period as compared to 87.5 dB(A) obtained at Mary Slessor by Marian road junction (site 8) in the evening of the post-carnival period. Though this is slightly higher than that of the pre-carnival, the difference is not significant, these are all non festive periods. These two levels when compared to the highest noise level of 102.2 dB(A) obtained at Effiotte junction (site 4) during the carnival period really shows that there is a high increase in noise levels in the Municipality during this festive period. To further confirm this, one can see that the noise levels at each site and at the same measurement hours are higher during carnival periods than during pre and post-carnival periods. This is in line with the findings of Mangalekar et al (2012) in the study of noise pollution in Kolhapur city, India during Deepawali festival. This can be attributed to increase in human activities such as drumming, trumpeting, throwing of knock outs and shouting, increase in number of vehicles and facilities of transportation etc. During this period a lot of tourists visit the Municipality thereby increasing the population and vehicular movements. People are compelled to stay out-doors to witness the different activities that take place as compared to the non festive period. The lowest noise levels were in the afternoons when comparing these three investigating periods, 70.7 dB(A) at site 6 in pre-carnival, 77.4 dB(A) at site 10 in carnival and 70.5 dB(A) at site 6 at post-carnival. The number of vehicular and other human activities during the day time reduced tremendously because parents retire to their offices for the days work after having dropped their children in school. Again transporters and many others get tired and retire home for relaxation in preparation for the evening outing. Figure 1.0 shows that the average noise levels in the Municipality during the carnival period was higher during pre and post carnival. Average noise levels of 94.9 dB(A) in the morning, 84.0 dB(A) in the afternoon and 96.1 dB(A) in the evening were for the carnival period while 80.8, 75.9 and 83.1dB(A) , 80.7, 75.7 and 82.1dB(A) were average levels for morning, afternoon and evening of pre and post carnivals respectively.

Though the festive period is time of merriment and income is being generated through foreign exchange from tourists, how healthy is the noise generated during this period to the well being of the people? In Nigeria, noise regulations usually specify a minimum out-door noise level of 60 to 65 dB(A) (Agbo et all 2012). Noise levels during the carnival period far exceed the maximum outdoor permissible level (Table 1.2). Vidyasagar and Rao (2006) observed that noise has adverse effects on citizens, auditory disorders are on the rise among city dwellers and considered noise as a major threat to human wellbeing. It has been scientifically proven that noise more than 85 dB(A) can cause hearing impairment. (Ogbo, 2012). The multi-dimensional concept of quality of life which include aspects of emotional, functional, physical, mental and social well being as perceived by individuals offer wide possibility to look at health related outcome of noise. (Akpan et al, 2012). Health include physical, psychological and social well being of an individual (WHO, 2011).

The organisers of this yearly carnival in Calabar municipality should not therefore look at merriment and income generation only but should also look at the damaging effects of the noise on the citizenry after the festival who may be ignorant of this problem.

VI. Conclusion

Study of noise pollution during pre-carnival, carnival and post-carnival festival in Calabar municipality has been investigated. This study has shown that the noise level in the municipality during the carnival period is higher than the pre and post- carnival periods and far exceed the recommended 60 to 65 dB(A) permissible outdoor noise level. Though this is a time of merriment and income generation, the people stand the risk of endangering their health physically, psychologically and socially due to excessive noise.

VII. Recommendation

The organisers of this festival are therefore advised not to look at the merriment and income generation aspect of this festival only but should also consider the damaging effect of noise generated during this period on the well being of the people which includes hearing loss. Alternative ways of organising the festival without excessive noise in the municipality should be sought for.

VIII. Acknowledgement

We strongly acknowledge Mr Donald Duke, the then governor of Cross River State who had the vision of starting this carnival show in 2004 which has today made the state the hub for tourism in Nigeria and in Africa. We also acknowledge the Cross River State government for sustaining this festival.

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Temperature Dependence of Relaxation Rate in KH_2PO_4 above T_c

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Abstract - With the help of the modified four-particle cluster model Hamiltonian [GJSFR, 10, 18(2010)], the theoretical expressions for the relaxation rate of polarization fluctuation have been evaluated and discussed for the KH_2PO_4 (KDP)- type crystals by using the double-time thermal dependent retarded Green's functions techniques and Dyson's equation treatment. The correlations appearing in the dynamic equation have been evaluated using double-time thermal dependent retarded Green's functions techniques and Dyson's equation treatment. Without any decoupling the higher order correlations have been evaluated using the renormalized Hamiltonian. By fitting model values in the theoretical expressions, temperature dependence of relaxation rate is calculated for the KH_2PO_4 (KDP)-type crystals. Theoretical results are compared with experimental result of Garland and Novotny [1969 *Phys Rev.* 177 971]. A good agreement has been found.

Keywords : *Retarded Green's Functions, Dyson Equation Treatment, Relaxation Rate, Lattice Anharmonicity, Stochastic Motion.*

GJSFR-A Classification : *FOR Code: 029999*

TEMPERATURE DEPENDENCE OF RELAXATION RATE IN KH2PO4 ABOVE T

Strictly as per the compliance and regulations of :

Temperature Dependence of Relaxation Rate in KH_2PO_4 above T_c

V. S. Bist [α] & N. S. Panwar [σ]

Abstract - With the help of the modified four-particle cluster model Hamiltonian [GJSFR, 10, 18(2010)], the theoretical expressions for the relaxation rate of polarization fluctuation have been evaluated and discussed for the KH_2PO_4 (KDP)-type crystals by using the double-time thermal dependent retarded Green's functions techniques and Dyson's equation treatment. The correlations appearing in the dynamic equation have been evaluated using double-time thermal dependent retarded Green's functions techniques and Dyson's equation treatment. Without any decoupling the higher order correlations have been evaluated using the renormalized Hamiltonian. By fitting model values in the theoretical expressions, temperature dependence of relaxation rate is calculated for the KH_2PO_4 (KDP)-type crystals. Theoretical results are compared with experimental result of Garland and Novotny [1969 *Phys Rev.* 177 971]. A good agreement has been found.

Keywords : Retarded Green's Functions, Dyson Equation Treatment, Relaxation Rate, Lattice Anharmonicity, Stochastic Motion.

I. Introduction

The KH_2PO_4(KDP)-type crystals are interesting hydrogen-bonded materials undergoing structural phase transitions accomplished by ferroelectricity or antiferroelectricity. In these crystals, it is known that protons in the double well potentials on the hydrogen bonds are involved in a phase transition accompanied by displacements in the heavy atoms (K, P, and O) structure. KDP undergoes the ferroelectric phase transition at $T_C = 123$. Above T_C the excitation spectrum shows relaxation character and is centered around $\omega = 0$. Only below T_C, a mode of finite frequency $\omega \neq 0$ is found (as for spin waves in ferromagnets). On the other hand, in displacive systems a mode of finite frequency exits even above T_C, and tends to freeze out on approaching T_C from above[1]. This soft mode was found extremely fruitful both for experimental and theoretical researches in structural phase transitions of displacive ferroelectrics[2]. The soft mode concept has been extended to order-disorder relaxational system[3], wherein a mean field $2\pi/\tau = \omega_{relax} \propto (T - T_C)$; whereas $\omega_{soft} \propto (T - T_C)^{1/2}$ However, if soft mode is overdamped its temperature dependence cannot be distinguished from a relaxational response[4].

Peercy[5] has measured the pressure and temperature dependence of the soft-mode Raman spectra of KDP in both paraelectric (hereafter referred to as PE) and ferroelectric phases. At low pressure where the soft-mode is over damped, the relaxation rate (τ^{-1}) was found more reliable parameter than the individual parameters, i.e., the acoustic mode frequency $(\tilde{\tilde{\omega}}_{\pm}^{2})$ and width (Γ_P). Experiments using the Brillouin scattering[6,7] resonance vibration[8,9] and pulse-echo techniques[10] for attenuation studies in these materials reflect the substantial asymmetry in the temperature dependence of the polarization relaxation rate in the PE phases analogous to that of susceptibility[11,12]. Also the attenuation is found strongly frequency dependent and becomes so large to measure close to T_C [11,12]. Many workers[13,14] have experimentally studied the dielectric properties of KDP type ferroelectrics. Formulae were developed to explain ferroelectric transitions in order-disorder[15,16] type crystals.

At first, Pak[17] employed Green's function methods in the order-disorder type ferroelectrics, who however, did not consider the anharmonic interactions. Pak's theory was further developed by Ramakrishanan and Tanaka[18], who calculated the excitation spectrum of the system, but did not consider the anharmonic interactions. Their attempt, however, established the superiority of Green's function method over the other methods. Ganguli[19] et al modified Ramakrishanan and Tanaka theory by considering anharmonic interaction. Their treatment explains many features of order-disorder ferroelectrics. However, due to insufficient treatment of anharmonic interactions, they could not explain quantitatively good results and could not describe some very interesting properties, like dielectric properties, acoustic attenuation, relaxation rate etc.

In our previous studies[20] {hereafter referred to as I (2010), II (2011), and III (2012)} we have designed the Blinc's Hamiltonian in terms of lattice anharmonicity upto fourth order for the stochastic motion of $H_2PO_4^-$ groups. Applying Green's functions techniques and Dyson's equation the higher order correlations have been evaluated using the renormalized Hamiltonian. The

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proton renormalized frequency of the coupled system and collective proton wave half widths have been evaluated in I, Relaxation processes and ultrasonic attenuation in KDP-type ferroelectrics in II, and Di-electric Properties of Order-Disorder Type Crystals in III.

In the present study, we use same Hamiltonian as in previous studies. Expression for the relaxation rate of polarization fluctuation have been evaluated and discussed for the KH_2PO_4 (KDP)-type crystals by using the double-time thermal dependent retarded Green's functions techniques and Dyson's equation treatment and model Hamiltonian. By fitting model values in the theoretical expressions, temperature dependence of relaxation rate is calculated for KH_2PO_4 crystal. Theoretical results are compared with experimental result of Garland and Novotny[12]. A good agreement has been found.

II. RELAXATION RATE

The relaxation rate is obtained as[18]:

$$\tau_p^{-1} = \tilde{\tilde{\omega}}_{\pm}^2 \times (2\Gamma_p)^{-1}. \tag{1}$$

Where for resonant interaction $(\Omega = \omega_q)$ $\tilde{\tilde{\omega}}_-$ is the collective phonon mode frequency {represented by equation (6) in II} and for small q limit, we obtain the collective proton mode frequency width (Γ_q),for $\omega << \tilde{\tilde{\omega}}$., from equation (20) in I, by using a four cluster model Hamiltonian {represented by equation (3) in I}, and Green's function technique and Dyson's equation as:

$$\Gamma = (2\bar{V}_q^2 \omega_q^2 < S_q^x > \tau_p) \times \left\{\tilde{\tilde{\omega}}_q^2 \,\Omega\left(1+\omega_q^2 \tau_p^2\right)\right\}^{-1} + (\pi b c^2)\times(2\tilde{\Omega})^{-1}\left[\delta(\omega-\tilde{\Omega})-\delta(\omega+\tilde{\Omega})\right]$$
$$+ (\pi a^2 \tilde{\Omega})\times(2b)^{-1}\left[\delta(\omega-\tilde{\Omega})-\delta(\omega+\tilde{\Omega})\right] \tag{2}$$

III. NUMERICAL CALCULATIONS AND RESULT

By using model values of physical quantities given by Ganguli[19] *et al* (Table 1 in III), from calculated values of $< S^x >$, Γ_P and $\tilde{\tilde{\omega}}_-$,(Table 1, and 2 respectively in II),and ultrasonic attenuation coefficient $\alpha(q)$ given by Litov and Garland[21] for KDP .The calculated value of temperature dependence of relaxation rate (τ_P^{-1}) in PE phase for KDP crystal have been calculated and summarized in Table (1). The values of relaxation rate in PE phase are plotted against temperature in figure 1. The theoretical results of present study are compared with the experimental result of Garland and Novotny[12], which shows good agreements.

Table 1 : Temperature dependence of the relaxation rate in PE phase for KDP crystal

Temperature (K)	125	130	135	140	145	Reference
$\alpha\,(cm^{-1})$	0.106	0.0553	0.0468	0.0382	0.034	*21*
$\tau_p^{-1} \times 10^{11} (\sec^{-1})$	4.09	7.93	11.11	11.90	12.50	*Present study*
$\tau_p^{-1} \times 10^{11} (\sec^{-1})$	1.3	3.55	5.5	-	-	*12*

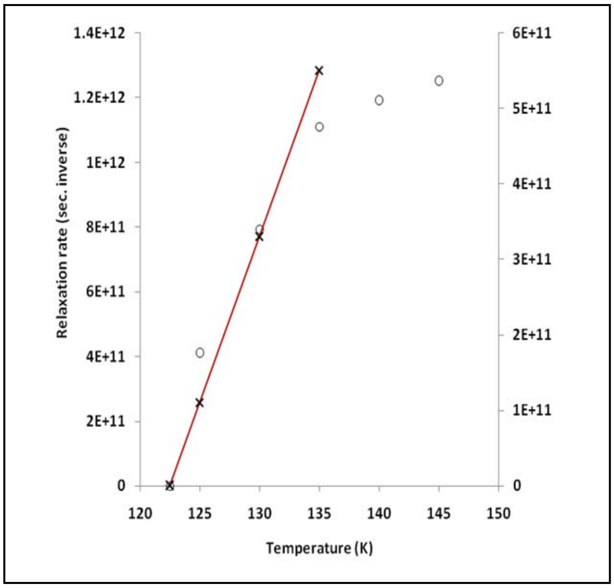

Figure 1 : Temperature dependence of the relaxation rate (τ_p^{-1}) in KH_2PO_4 above Tc. The solid line represents the experimental result of Garland and Novotny[12] (shown by ×××) and theoretical result of present calculation (shown by o o o).

IV. Discussion and Conclusions

The polarization relaxation rate τ_p^{-1} has been calculated from the elastic constants and attenuation data[18] for KH_2PO_4 and KD_2PO_4. It is seen that[11] the temperature dependence of τ_p^{-1} can be given by $\tau_p^{-1} = b\left|T - T_c\right|$ where b is the polarization relaxation rate parameter. In Table (2), the value of b by fitting $b\left|T - T_c\right| = \tau_p^{-1}$ with experiments, for several KDP-type crystals been summarized:

Table 2 : Polarization relaxation rate parameter (b) in the expression $\tau_p^{-1} = b\left|T - T_c\right|$

Compound	$b\times10^{10}$ $Sec.^{-1}K^{-1}$ $(T > T_C)$	$b\times10^{10}$ $Sec.^{-1}K^{1}$ $(T < T_C)$	References
KD_2PO_4	0.40 0.27 0.36 0.24	3.0 - - -	11 22 23 24
KH_2PO_4	4.2 2.8 1.5 -	- 1.6 - 400	12 25 26 27
CsH_2AsO_4 KH_2AsO_4	1.6 3.6	- -	28 29

It is observed that in KD_2PO_4 ,b is about 7.5 times larger for $T < T_c$ than for $T > T_c$ .When one compares KH_2PO_4 with KD_2PO_4 ,it is found that the b values are quite similar below T_c ,but are almost an order of magnitude larger in KH_2PO_4 than the KD_2PO_4 ,for $T > T_c$. In CsH_2AsO_4 and KH_2AsO_4 , for $T > T_c$, b has values similar to that of KH_2PO_4 .The very large b value for the ferroelectric phase of the KDP reported by Harnik and Shimshoni[27] was derived from the study of longitudinal ultrasonic wave propagating along the ferroelectric axis. The reason for the large discrepancy between these values and those obtained from shear measurements by Litov and Garland[18] has not been resolved. It may due to the fact that the relational formulism discussed by them does not apply to this case.

The transition temperature (T_c) and the critical relaxation rate inferred from an analysis of the ultrasonic attenuation is very sensitive to deuteration table 2. It is observed that the ratio b_H *to* $b_D \cong 8.3$ for KDP. Furthermore, dielectric relaxation measurements on CsH_2AsO_4 (CDP) and CsD_2PO_4 yield the ratio CsD_2PO_4 of at all values of[30] $(T\text{-}Tc)$ also these crystals have a chain like structure which is quite different from that of KDP. The qualitative explanation of isotope effect was proton tunneling[9].

The data on temperature and pressure measurements[5] show that $T\tau_a^{-1}$ is linear with temperature dependence for measurements at high pressure. This behaviour is similar to the temperature depend previously found [28, to 31] for the relaxation rate τ_a^{-1}. From these studies, it is observed that $T\tau_a^{-1}$ extrapolates to zero$\sim 4^0$ below T_c , which agree within experimental uncertainty with the result for $\tilde{\tilde{\omega}}^2$ by Ramakrishna and Tanaka[18].

From equation (1), one would expect τ_p^{-1} to be linear in T and to vanish at $T = Tc$, the straight line shown in figure (1), is given by:

$$\tau = (2.44\times10^{-12})\times(T - T_C)^{-1} \qquad (3)$$

Such short relaxation time (2.44×10^{-12} sec.) can only be determined from acoustic measurement at $10^7 - 10^8$ Hz, because of the large value of $(\tilde{\tilde{\omega}}_-)^{-1}$ near T_c . In view of the very rapid variation with temperature in both α and $(\tilde{\tilde{\omega}}_-)^{-1}$ for KDP, it is not surprising that the temperature dependence of τ_p is somewhat difficult to measure. The above results for KH_2PO_4 can be compared with those of ultrasonic investigation[12] in KD_2PO_4 , in which it was found that

$\tau = (24.4 \times 10^{-11}) \times (T - T_C)^{-1}$, where $T_C = 205.6\,K$ for the incompletely deuterated samples. This tenfold increase in relaxation time on deuterated seems quite reasonable in view of stochastic motion of $H_2(D_2)PO_4$ over a potential barrier which seems an intrinsic feature of this ferroelectric transition. By fitting model values in the theoretical expressions, temperature dependence of relaxation rate is calculated for KH_2PO_4 crystal. Theoretical results are compared with experimental result of Garland and Novotny[12]. A good agreement has been found

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Reference Frame and Lorentz Transformation

By Aleks Kleyn

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A reference frame in event space is a smooth field of orthonormal bases. Every reference frame is equipped by anholonomic coordinates. Using anholonomic coordinates allows to find out relative speed of two observers and appropriate Lorentz transformation.

Synchronization of a reference frame is an anholonomic time coordinate. Simple calculations show how synchronization influences time measurement in the vicinity of the Earth. Measurement of Doppler shift from the star orbiting the black hole helps to determine mass of the black hole. According observations of Sgr A, if non orbiting observer estimates age of S2 about 10 Myr, this star is 0.297 Myr younger.

We call a manifold with torsion the metric-affine manifold. We cannot draw closed parallelogram in event space, if there exists torsion.

Learning how torsion influences on tidal force reveals similarity between tidal equation for geodesic and the Killing equation of second type. The relationship between tidal acceleration, curvature and torsion gives an opportunity to measure torsion.

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REFERENCE FRAME AND LORENTZ TRANSFORMATION

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Learning how torsion influences on tidal force reveals similarity between tidal equation for geodesic and the Killing equation of second type. The relationship between tidal acceleration, curvature and torsion gives an opportunity to measure torsion.

I. Geometric Object and Invariance Principle

A measurement of a spatial interval and a time length is one of the major tasks of general relativity. This is a physical process that allows the study of geometry in a certain area of spacetime. From a geometric point of view, the observer uses an orthonormal basis in a tangent plane as his measurement tool because an orthonormal basis leads to the simplest local geometry. When the observer moves from point to point he brings his measurement tool with him.

Notion of a geometric object is closely related with physical values measured in space time. The invariance principle allows expressing physical laws independently from the selection of a basis. On the other hand if we want to examine a relationship obtained in the test, we need to select measurement tool. In our case this is basis. Choosing the basis we can define coordinates of the geometric object corresponding to studied physical value. Hence we can define the measured value.

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Every reference frame is equipped by anholonomic coordinates. For instance, synchronization of a reference frame is an anholonomic time coordinate. Simple calculations show how synchronization influences time measurement in the vicinity of the Earth. Measurement of Doppler shift from the star orbiting the black hole helps to determine mass of the black hole.

Sections 8 and 9 show importance of calculations in orthogonal basis. Coordinates that we use in event space are just labels and calculations that we make in coordinates may appear not reliable. For instance in papers [8, 9] authors determine coordinate speed of light. This leads to not reliable answer and as consequence of this to the difference of speed of light in different directions.

Paper [10] drew my attention. To explain anomalous acceleration of Pioneer 10 and Pioneer 11 ([6]) Antonio Ranada incorporated the old Einstein's view on nature of gravitational field and considered Einstein's idea about variability of speed of light. When Einstein started to study the gravitational field he tried to keep the Minkowski geometry, therefore he assumed that scale of space and time does not change. As result he had to accept the idea that speed of light should vary in gravitational field. When Grossman introduced Riemann geometry to Einstein, Einstein realized that the initial idea was wrong and Riemann geometry solves his problem better. Einstein never returned to idea about variable speed of light.

Indeed, three values: scale of length and time and speed of light are correlated in present theory and we cannot change one without changing another. The presence of gravitational field changes this relation. We have two choices. We keep a priory given geometry (here, Minkowski geometry) and we accept that the speed of light changes from point to point. The Riemann geometry gives us another option. Geometry becomes the result of observation and the measurement tool may change from point to point. In this case we can keep the speed of light constant. Geometry becomes a background which depends on physical processes. Physical laws become background independent.

II. Torsion Tensor in General Relativity

Close relationship between the metric tensor and the connection is the basis of the Riemann geometry. At the same time, connection and metric as any geometric object are objects of measurement. When Hilbert derived Einstein equation, he introduced the lagrangian where the metric tensor and the connection are independent. Later on, Hilbert discovered that the connection is symmetric and found dependence between connection and metric tensor. One of the reasons is in the simplicity of the lagrangian.

Since an errors of measurement are inescapable, analysis of quantum field theory shows that either symmetry of connection or dependence between connection and metric may be broken. This assumption leads to metric-affine manifold which is space with torsion and nonzero covariant derivative of metric (section 12).

The effects of torsion are cumulative. They may be small but measurable. We can observe their effects not only in strong fields like black hole or Big Bang but in regular conditions as well. Studying geometry and dynamics of point particle gives us a way to test this point of view. There is mind to test this theory in condition when spin of quantum field is accumulated.

To test if the spacetime has the torsion we can test the opportunity to build a parallelogram in spacetime. We can get two particles or two photons that start their movement from the same point and using a mirror to force them to move along opposite sides of the parallelogram. We can start this test when we do not have quantum field and then repeat the test in the presence of quantum field. If particles meet in the same place or we have the same interference then we have torsion equal 0 in this thread. In particular, the torsion may influence the behaviour of virtual particles.

III. Tidal Acceleration

Observations in Solar system and outside are very important. They give us an opportunity to see where general relativity is right and to find out its limitation. It is very important to be very careful with such observations. NASA provided very interesting observation of Pioneer 10 and Pioneer 11 and managed complicated calculation of their accelerations. However, one interesting question arises: what kind of acceleration did we measure?

Pioneer 10 and Pioneer 11 performed free movement in solar system. Therefore they move along their trajectory without acceleration. However, it is well known that two bodies moving along close geodesics have relative acceleration that we call tidal acceleration. Tidal acceleration in general relativity has form

$$\frac{D^2\delta x^k}{ds^2}=R^k_{lnk}\delta x^k v^n v^l \tag{3.1}$$

where v^l is the speed of body 1 and δx^k is the deviation of geodesic of body 2 from geodesic of body 1. We see from this expression that tidal acceleration depends on movement of body 1 and how the trajectory of body 2 deviates from the trajectory of body 1. But this means that even for two bodies that are at the same distance from a central body we can measure different acceleration relative an observer.

Section 14 is dedicated to the problem what kind of changes the tidal force experiences on metric affine manifolds.

Finally the question arises. Can we use equation (14.5) to measure torsion? We get tidal acceleration from direct measurement. There is a method to measure curvature (see for instance [5]). However, even if we know the acceleration and curvature we still have differential equation to find torsion. However, this way may give direct answer to the question of whether torsion exists or not.

Deviation from tidal acceleration (3.1) predicted by general relativity may have different reason. However we can find answer by combining different type of measurement.

IV. Reference frame on Manifold

When we study manifold $\mathcal{V}$ the geometry of tangent space is one of important factors. In this section, we will make the following assumption.

- All tangent spaces have the same geometry.
- Tangent space is vector space $\mathcal{V}$ of finite dimension n.
- Symmetry group of tangent space is Lie group G.

Any homomorphism of the vector space maps one basis into another. Thus we can extend a representation of the symmetry group to the set of bases. However not every two bases can be mapped by a transformation from the symmetry group because not every nonsingular linear transformation belongs to the representation of group G. The basis that belong to selected orbit of group G is called **G - basis.**

Definition 4.1 Set $\overline{\overline{e}}=<e_{(i)},i\in I>$ of vector fields $e_{(i)}$ is called **G - reference frame,** if for any $x\in\mathcal{V}$ set $\overline{\overline{e}}(x)=<e_{(i)}(x),i\in I>$ is a G-basis in tangent space T_x.

Vector field a has expansion

$$a=a^{(i)}e_{(i)} \tag{4.1}$$

relative reference frame $\overline{\overline{e}}$.

If we do not limit definition of a reference frame by symmetry group, then at each point of the manifold we can select reference frame $\overline{\overline{\partial}}=<\partial_i>$ based on vector fields tangent to lines $x^i=const$. We call this field of bases the **coordinate reference frame**. Vector field a has expansion

$$a=a^i\partial_i \tag{4.2}$$

relative coordinate reference frame. Then standard coordinates of reference frame $\overline{\overline{e}}$ have form $e^k_{(i)}$

$$e_{(i)}=e^k_{(i)}\partial_k \tag{4.3}$$

Because vectors $e_{(i)}$ are linearly independent at each point matrix $\|e^k_{(i)}\|$ has inverse matrix $\|e^{(i)}_k\|$

$$\partial_k = e_k^{(i)} e_{(i)} \tag{4.4}$$

We use also a more extensive definition for reference frame on manifold, presented in form $\overline{\overline{e}} = (e_{(k)}, e^{(k)})$ where we use the set of vector fields $e_{(k)}$ and dual forms $e^{(k)}$ such that

$$e^{(k)}(e_{(l)}) = \delta_{(l)}^{(k)} \tag{4.5}$$

at each point. Forms $e^{(k)}$ are defined uniquely from (4.5).

In a similar way, we can introduce a coordinate reference frame (∂_i, ds^i). These reference frames are linked by the relationship

$$e_{(k)} = e_{(k)}^i \partial_i \tag{4.6}$$

$$e^{(k)} = e_i^{(k)} dx^i \tag{4.7}$$

From equations (4.6), (4.7), (4.5) it follows

$$e_i^{(k)} e_{(l)}^i = \delta_{(l)}^{(k)} \tag{4.8}$$

In particular we assume that we have $GL(n)$ - reference frame (∂, dx) raised by n differentiable vector fields ∂_i and 1-forms dx^i, that define field of bases ∂ and cobases dx dual them.

If we have function φ on V then we define **pfaffian derivative**

$$d\varphi = \partial_i \varphi dx^i$$

V. Reference Frame in Event Space

Starting from this section, we consider orthogonal reference frame $\overline{\overline{e}} = (e_{(k)}, e^{(k)})$ in Riemann space with metric g_{ij}. According to definition, at each point of Riemann space vector fields of orthogonal reference frame satisfy to equation

$$g_{ij} e_{(k)}^i e_{(l)}^j = g_{(k)(l)}$$

where $g_{(k)(l)} = 0$, if $(k) \neq (l)$, and $g_{(k)(k)} = 1$ or $g_{(k)(k)} = -1$ depending on signature of metric.

We can define the **reference frame in event space** V as $O(3,1)$- reference frame. To enumerate vectors, we use index $k = 0, ..., 3$. Index $k = 0$ corresponds to time like vector field.

Remark 5.1. We can prove the existence of a reference frame using the orthogonolization procedure at every point of space time. From the same procedure we get that coordinates of basis smoothly depend on the point.

A smooth field of time like vectors of each basis defines congruence of lines that are tangent to this field. We say that each line is a world line of an observer or a **local reference frame.** Therefore a reference frame is set of local reference
frames.

We define the **Lorentz transformation** as transformation of a reference frame

$$x'^i = f^i(x^0, x^1, x^2, x^3)$$
$$e'^i_{(k)} = a_j^i b_{(k)}^{(l)} e_{(l)}^j \tag{5.1}$$

where

$$a_j^i = \frac{\partial x'^i}{\partial x'^j}$$

$$\delta_{(i)(l)} b_{(j)}^{(i)} b_{(k)}^{(l)} = \delta_{(j)(k)}$$

We call the transformation a_j^i the holonomic part and transformation $b_{(k)}^{(l)}$ the anholonomic part.

VI. Anholonomic Coordinates

Let $E(V, G, \pi)$ be the principal bundle, where V is the differential manifold of dimension n and class not less than 2. We also assume that G is symmetry group of tangent plain.

We define connection form on principal bundle

$$\omega^L = \lambda_N^L da^N + \Gamma_i^L dx^i \quad \omega = \lambda_N da^N + \Gamma dx \tag{6.1}$$

We call functions Γ_i connection components.

If fiber is group $GL(n)$, then connection has form

$$\omega_b^a = \Gamma_{bc}^a dx^c$$
$$\Gamma_i^A = \Gamma_{bi}^a \tag{6.2}$$

A vector field a has two types of coordinates: **holonomic coordinates** a^i relative coordinate reference frame and **anholonomic coordinates** $a^{(i)}$ relative reference frame. These two forms of coordinates also hold the relation

$$a^i(x) = e_{(i)}^i(x) a^{(i)}(x) \tag{6.3}$$

at any point x.

We can study parallel transfer of vector fields using any form of coordinates. Because (5.1) is a linear transformation we expect that parallel transfer in anholonomic coordinates has the same representation as in holonomic coordinates. Hence we write

$$da^k = -\Gamma_{ij}^k a^i dx^j$$

$$da^{(k)} = -\Gamma_{(i)(j)}^{(k)} a^{(i)} dx^{(j)}$$

It is required to establish link between **holonomic coordinate of connection** Γ^k_{ij} and **anholonomic coordinates of connection** $\Gamma^{(k)}_{(i)(j)}$

$$a^i(x+dx) = a^i(x) + da^i = a^i(x) - \Gamma^i_{kp} a^k(x) dx^p \tag{6.4}$$

$$a^{(i)}(x+dx) = a^{(i)}(x) + da^{(i)} = a^{(i)}(x) - \Gamma^{(i)}_{(k)(p)} a^{(k)}(x) dx^{(p)} \tag{6.5}$$

Considering (6.4), (6.5), and (6.3) we get

$$\begin{aligned} & a^i(x) - \Gamma^i_{kp} a^k(x) dx^p \\ =& e^i_{(i)}(x+dx)\left(a^{(i)}(x) - \Gamma^{(i)}_{(k)(p)} e^{(k)}_i(x) a^i(x) e^{(p)}_p(x) dx^p\right) \end{aligned} \tag{6.6}$$

It follows from (6.6) that

$$\begin{aligned} \Gamma^{(i)}_{(k)(p)} e^{(k)}_i(x) e^{(p)}_p(x) a^i(x) dx^p &= a^{(i)}(x) - e^{(i)}_i(x+dx)\left(a^i(x) - \Gamma^i_{kp} a^k(x) dx^p\right) \\ &= a^i(x) e^{(i)}_i(x) - e^{(i)}_i(x+dx)\left(a^i(x) - \Gamma^i_{kp} a^k(x) dx^p\right) \\ &= a^i(x)\left(e^{(i)}_i(x) - e^{(i)}_i(x+dx)\right) + e^{(i)}_j(x) \Gamma^j_{ip} a^i(x) dx^p \\ &= e^{(i)}_j(x) \Gamma^j_{ip} a^i(x) dx^p - a^i(x) \frac{\partial e^{(i)}_i(x)}{\partial x^p} dx^p \\ &= \left(e^{(i)}_j(x) \Gamma^j_{ip} - \frac{\partial e^{(i)}_i(x)}{\partial x^p}\right) a^i(x) dx^p \end{aligned}$$

Because $a^i(x)$ and dx^p are arbitrary we get

$$\Gamma^{(i)}_{(k)(p)} e^{(k)}_i(x) e^{(p)}_p(x) = e^{(i)}_j(x) \Gamma^j_{ip} - \frac{\partial e^{(i)}_i(x)}{\partial x^p}$$

$$\Gamma^{(i)}_{(k)(p)} = e^i_{(k)} e^p_{(p)} e^{(i)}_j \Gamma^j_{ip} - e^i_{(k)} e^p_{(p)} \frac{\partial e^{(i)}_i}{\partial x^p} \tag{6.7}$$

We introduce symbolic operator

$$\frac{\partial}{\partial x^{(p)}} = e^p_{(p)} \frac{\partial}{\partial x^p} \tag{6.8}$$

From (4.8) it follows

$$e^i_{(l)} \frac{\partial e^{(k)}_i}{\partial x^p} + e^{(k)}_i \frac{\partial e^i_{(l)}}{\partial x^p} = 0 \tag{6.9}$$

We substitute (6.8) and (6.9) into (6.7)

$$\Gamma^{(i)}_{(k)(p)} = e^i_{(k)} e^p_{(p)} e^{(i)}_j \Gamma^j_{ip} - e^{(i)}_i \frac{\partial e^i_{(k)}}{\partial x^{(p)}} \tag{6.10}$$

Equation (6.10) shows some similarity between holonomic and anholonomic coordinates. We introduce symbol $\partial_{(k)}$ for the derivative along vector field $e_{(k)}$

$$\partial_{(k)} = e^i_{(k)} \partial_i$$

Then (6.10) takes the form

$$\Gamma^{(k)}_{(l)(p)} = e^i_{(l)} e^r_{(p)} e^{(k)}_j \Gamma^j_{ir} - e^i_{(l)} \partial_{(p)} e^{(k)}_i$$

Therefore when we move from holonomic coordinates to anholonomic, the connection transforms the way similarly to when we move from one coordinate system to another. This leads us to the model of anholonomic coordinates.

The vector field $e_{(k)}$ generates lines defined by the differential equations

$$e^j_{(l)} \frac{\partial t}{\partial x^j} = \delta^{(k)}_{(l)}$$

or the symbolic system

$$\frac{\partial t}{\partial x^{(l)}} = \delta^{(k)}_{(l)} \tag{6.11}$$

Keeping in mind the symbolic system (6.11) we denote the functional t as $x^{(k)}$ and call it the **anholonomic coordinate.** We call the regular coordinate holonomic.

From here we can find derivatives and get

$$\frac{\partial x^{(i)}}{\partial x^k} = e^{(i)}_k \tag{6.12}$$

The necessary and sufficient conditions of complete integrability of system (6.12) are

$$c^{(i)}_{(k)(l)} = 0$$

where we introduced anholonomity object

$$c^{(i)}_{(k)(l)} = e^k_{(k)} e^l_{(l)} \left(\frac{\partial e^{(i)}_k}{\partial x^l} - \frac{\partial e^{(i)}_l}{\partial x^k} \right) \tag{6.13}$$

Therefore each reference frame has n vector fields

$$\partial_{(k)} = \frac{\partial}{\partial x^{(k)}} = e^i_{(k)} \partial_i$$

which have commutator

$$[\partial_{(i)}, \partial_{(j)}] = \left(e^k_{(i)} \partial_k e^l_{(j)} - e^k_{(j)} \partial_k e^l_{(i)} \right) e^{(m)}_l \partial_{(m)} =$$
$$e^k_{(i)} e^l_{(i)} \left(-\partial_k e^{(m)}_l + \partial_l e^{(m)}_l \right) \partial_{(m)} = c^{(m)}_{(k)(l)} \partial_{(m)}$$

For the same reason we introduce forms

$$dx^{(k)} = e^{(k)} = e^{(k)}_l dx^l$$

and an exterior differential of this form is

$$\begin{aligned} d^2 x^{(k)} &= d\left(e^{(k)}_i dx^i \right) \\ &= \left(\partial_j e^{(k)}_i - \partial_i e^{(k)}_j \right) dx^i \wedge dx^j \\ &= -c^{(m)}_{(k)(l)} dx^{(k)} \wedge dx^{(l)} \end{aligned} \tag{6.14}$$

Therefore when $c^{(i)}_{(k)(l)} \neq 0$, the differential $dx^{(k)}$ is not an exact differential and the system (6.12) in general cannot be integrated. However we can create a meaningful object that models the solution. We can study how function $x^{(i)}$ changes along different lines.We call such coordinates **anholonomic coordinates on manifold.**

Remark 6.1. Function $x^{(i)}$ is a natural parameter along a flow line of vector field $\overline{e}_{(i)}$. The time coordinate along a local reference frame is the observer's proper time. Because the reference frame consists of local reference frames, we expect that their proper times are synchronized.

We introduce the **synchronization of reference frame** as the anholonomic time coordinate.

Because synchronization is the anholonomic coordinate it introduces new physical phenomena that we should keep in mind when working with strong gravitational fields or making precise measurements. I describe one of these phenomena in sections 7 - 11. To synchronize clocks of local reference frames we use classical procedure of exchange light signals.

Somebody may have impression that we cannot synchronize clock, however this conflicts with our observation. We accept that synchronization is possible until we introduce time along non closed lines. Synchronization breaks when we try synchronize clocks along closed line. Namely, a change of function along a loop is

$$\begin{aligned} \Delta x^{(i)} &= \oint dx^{(i)} \\ &= \int\int c^{(i)}_{(k)(l)} dx^{(k)} \wedge dx^{(l)} \\ &= \int\int c^{(i)}_{(k)(l)} e^{(k)}_k e^{(l)}_l dx^k \wedge dx^l \end{aligned} \tag{6.15}$$

This means ambiguity in definition of anholonomic coordinates.

From now on we will not make a difference between holonomic and anholonomic coordinates. Also, we will denote $b^{(l)}_{(k)}$ as $a^{-1}{}^{(l)}_{(k)}$ in the Lorentz transformation (5.1).

We define the curvature form for connection (6.1)

$$\Omega = d\omega + [\omega, \omega]$$
$$\Omega^D = d\omega^D + C^D_{AB} \omega^A \wedge \omega^B = R^D_{ij} dx^i \wedge dx^j$$

where we defined a curvature object

$$R^D_{ij} = \partial_i \Gamma^D_j - \partial_j \Gamma^D_i + C^D_{AB} \Gamma^A_i \Gamma^B_j + \Gamma^D_k c^k_{ij}$$

The curvature form for the connection (6.2) is

$$\Omega^{\ a}_{\ c} = d\omega^a_c + \omega^a_b \wedge \omega^b_c \tag{6.16}$$

where we defined a curvature object

$$R^D_{ij} = R^a_{bij} = \partial_i \Gamma^a_{bj} - \partial_j \Gamma^a_{bi} + \Gamma^a_{ci} \Gamma^c_{bj} - \Gamma^a_{cj} \Gamma^c_{bi} + \Gamma^a_{bk} c^k_{ij} \tag{6.17}$$

We introduce Ricci tensor

$$R_{bj} = R^a_{baj} = \partial_a \Gamma^a_{bj} - \partial_j \Gamma^a_{ba} + \Gamma^a_{ca} \Gamma^c_{bj} - \Gamma^a_{cj} \Gamma^c_{ba} + \Gamma^a_{bk} c^k_{aj}$$

VII. Anholonomic Coordinates in Central Body Gravitational Field

We will study an observer orbiting around a central body. The results are only estimation and are good when eccentricity is near 0 because we study circular orbits. However, the main goal of this estimation is to show that we have a measurable effect of anholonomity.

We use the Schwarzschild metric of a central body

$$ds^2 = \frac{r - r_g}{r} c^2 dt^2 - \frac{r}{r - r_g} dr^2 - r^2 d\phi^2 - r^2 sin^2 \phi d\theta^2$$
$$r_g = \frac{2Gm}{c^2} \tag{7.1}$$

G is the gravitational constant, m is the mass of the central body, c is the speed of light.

Connection in this metric is

$$\begin{cases} \Gamma^0_{10} = \dfrac{r_g}{2r(r-r_g)} & \\ \Gamma^1_{00} = \dfrac{r_g(r-r_g)}{2r^3} & \Gamma^1_{11} = -\dfrac{r_g}{2r(r-r_g)} \\ \Gamma^1_{22} = -(r-r_g) & \Gamma^1_{33} = -(r-r_g)\sin^2\phi \\ \Gamma^2_{12} = -\dfrac{1}{r} & \Gamma^2_{33} = -\sin\phi\cos\phi \\ \Gamma^3_{13} = -\dfrac{1}{r} & \Gamma^3_{23} = \cot\phi \end{cases} \tag{7.2}$$

I want to show one more way to calculate the Doppler shift. The Doppler shift in gravitational field is well known issue, however the method that I show is useful to better understand physics of gravitational field.

We can describe the movement of photon in gravitational field using its wave vector k^i. The length of this vector is 0; $\frac{k^i}{dx^i} = const$; a trajectory is geodesic and therefore coordinates of this vector satisfy to differential equation

$$dk^i = -\Gamma^i_{kl}k^k dx^l \tag{7.3}$$

We looking for the frequency ω of light and k^0 is proportional ω. Let us consider the radial movement of a photon. In this case wave vector has form $k = (k^0, k^1, 0, 0)$.In the central field with metric (7.1) we can choose

$$k^0 = \frac{\omega}{c}\sqrt{\frac{r}{r-r_g}}$$

$$k^1 = \omega\sqrt{\frac{r-r_g}{r}}$$

$$dt = \frac{k^0}{k^1}dr = \frac{1}{c}\frac{r}{r-r_g}dr$$

Then the equation (7.3) gets form

$$dk^0 = -\Gamma^0_{10}(k^1dt + k^0dr)$$

$$d\left(\frac{\omega}{c}\sqrt{\frac{r}{r-r_g}}\right) = -\frac{r_g\omega}{2r(r-r_g)}\left(\sqrt{\frac{r-r_g}{r}}\frac{r}{r-r_g} + \sqrt{\frac{r}{r-r_g}}\right)\frac{dr}{c}$$

$$d\omega\sqrt{\frac{r}{r-r_g}} - \omega\frac{1}{2}\sqrt{\frac{r-r_g}{r}}\frac{r_g dr}{(r-r_g)^2} = -\frac{r_g\omega dr}{r(r-r_g)}\sqrt{\frac{r}{r-r_g}}$$

$$\frac{d\omega}{\omega} = -\frac{r_g}{2r(r-r_g)}dr$$

$$\ln\omega = \frac{1}{2}\ln\frac{r}{r-r_g} + \ln C$$

If we define $\omega = \omega_0$ when $r = \infty$, we get finally

$$\omega = \omega_0\sqrt{\frac{r}{r-r_g}}$$

VIII. Time Delay in Central Body Gravitational Field

We will study orbiting around a central body. The results are only an estimation and are good when eccentricity is near 0 because we study circular orbits. However, the main goal of this estimation is to show that we have a measurable effect of anholonomity.

Let us compare the measurements of two observers. The first observer fixed his position in the gravitational field

$$t = \frac{s}{c}\sqrt{\frac{r}{r-r_g}}$$

$$r = const, \phi = const, \theta = const$$

The second observer orbits the center of the field with constant speed

$$t = s\sqrt{\frac{r}{(r-r_g)c^2 - \alpha^2 r^3}}$$

$$\phi = \alpha\, s\sqrt{\frac{r}{(r-r_g)c^2 - \alpha^2 r^3}}$$

$$r = const, \theta = const$$

We choose a natural parameter for both observers.

The second observer starts his travel when $s = 0$ and finishes it when returning to the same spatial point. Because ϕ is a cyclic coordinate the second observer finishes his travel when $\phi = 2\pi$. We have at this point

$$s_2 = \frac{2\pi}{\alpha}\sqrt{\frac{(r-r_g)c^2 - \alpha^2 r^3}{r}}$$

$$t = T = \frac{2\pi}{\alpha}$$

The value of the natural parameter for the first observer at this point is

$$s_1 = \frac{2\pi}{\alpha}c\sqrt{\frac{r-r_g}{r}}$$

The difference between their proper times is

$$\Delta s = s_1 - s_2 = \frac{2\pi}{\alpha}\left(c\sqrt{\frac{r-r_g}{r}} - \sqrt{\frac{(r-r_g)c^2 - \alpha^2 r^3}{r}}\right)$$

We have a difference in centimeters. To get this difference in seconds we should divide both sides by c.

$$\Delta t = \frac{2\pi}{\alpha}\left(\sqrt{\frac{r-r_g}{r}} - \sqrt{\frac{r-r_g}{r} - \frac{\alpha^2 r^2}{c^2}}\right)$$

Now we get specific data.

The mass of the Sun is $1.989_{10}33$ g, the Earth orbits the Sun at a distance of $1.495985_{10}13$ cm from its center during 365.257 days. In this case we get Δt = 0.1557506254450 89s. Mercury orbits the Sun at a distance of $5.791_{10}12$ cm from its center during 58.6462 days. In this case we get Δt = 0.145358734930827.s

The mass of the Earth is $5.977_{10}27$ g. The spaceship that orbits the Earth at a distance of $6.916_{10}8$ cm from its center during 95.6 mins has Δt = 1.8318_{10} - 6 s. The Moon orbits the Earth at a distance of $3.84_{10}10$ cm from its center during 27.32 days. In this case we get Δt = 1.372_{10} - 5 s.

For better presentation I put these data to tables 8.1, 8.2, and 8.3.

Because clocks of first observer show larger time at meeting, first observer estimates age of second one older then real. Hence, if we get parameters of S2 orbit from [1], we get that if first observer estimates age of S2 as 10 Myr then S2 will be .297 Myr younger.

Table 8.1 : Sun is central body, mass is $1.989_{10}33$ g

Sputnik	Earth	Mercury
distance, cm	$1.495985_{10}13$	$5.791_{10}12$
orbit period, days	365.257	58.6462
Time delay s	0.15575	0.14536

Table 8.2 : Earth is central body, mass is $5.977_{10}27$ g

Sputnik	spaceship	Moon
distance, cm	$6.916_{10}8$	$3.84_{10}10$
orbit period	95.6 mins	27.32 days
Time delay, s	$1.8318_{10} - 6$	$1.372_{10} - 5$

Table 8.3 : Sgr A is central body, S2 is sputnik

mass, $M_\odot$	$4.1_{10}6$	$3.7_{10}6$
distance sm	$1.4692_{10}16$	$1.1565_{10}16$
orbit period, years	15.2	15.2
Time delay, min	164.7295	153.8326

IX. Lorentz Transformation in Orbital Direction

The reason for the time delay that we estimated above is in Lorentz transformation between stationary and orbiting observers. This means that we have rotation in plain $(e_{(0)}, e_{(2)})$. The basis vectors for stationary observer are

$$e_{(0)} = (\frac{1}{c}\sqrt{\frac{r}{r-a}}, 0, 0, 0)$$

$$e_{(2)} = (0, 0, \frac{1}{r}, 0)$$

We assume that for orbiting observer changes of ϕ and t are proportional and

$$d\phi = \omega dt$$

Unit vector of speed in this case should be proportional to vector

$$(1, 0, \omega, 0) \tag{9.1}$$

The length of this vector is

$$L^2 = \frac{r-a}{r}c^2 - r^2\omega^2 \tag{9.2}$$

We see in this expression very familiar pattern and expect that linear speed of orbiting observer is $V = \omega r$.

However we have to remember that we make measurement in gravitational field and coordinates are just tags to label points in spacetime. This means that we need a legal method to measure speed.

If an object moves from point (t, ϕ) to point $(t + dt, \phi + d\phi)$ we need to measure spatial and time intervals between these points. We assume that in both points there are observers A and B. Observer A sends the same time light signal to B and ball that has angular speed ω. Whatever observer B receives, he sends light signal back to A.

When A receives first signal he can estimate distance to B. When A receives second signal he can estimate how long ball moved to B.

The time of travel of light in both directions is the same. Trajectory of light is determined by equation $ds^2 = 0$. In our case we have

$$\frac{r-r_g}{r}c^2dt^2 - r^2d\phi^2 = 0$$

When light returns back to observer A the change of t is

$$dt = 2\sqrt{\frac{r}{r-r_g}}c^{-1}rd\phi$$

The proper time of first observer is

$$ds^2 = \frac{r-r_g}{r}c^2 4\frac{r}{r-r_g}c^{-2}r^2 d\phi^2$$

Therefore spatial distance is

$$L = r d\phi$$

When object moving with angular speed ω gets to B change of t is $\frac{d\phi}{\omega}$. The proper time at this point is

$$ds^2 = \frac{r-r_g}{r}c^2 d\phi^2 \omega^{-2}$$

$$T = \sqrt{\frac{r-r_g}{r}}\omega^{-1}d\phi$$

Therefore the observer A measures speed

$$V = \frac{L}{T} = \sqrt{\frac{r}{r-r_g}}r\omega$$

We can use speed V as parameter of Lorentz transformation. Then length (9.2) of vector (9.1) is

$$L = \sqrt{\frac{r-r_g}{r}\left(c^2 - \frac{r}{r-r_g}r^2\omega^2\right)} = \sqrt{\frac{r-r_g}{r}}c\sqrt{\left(1-\frac{V^2}{c^2}\right)}$$

Therefore time ort of moving observer is

$$e'_{(0)} = \left(\frac{1}{L}, 0, \frac{\omega}{L}, 0\right)$$

$$e'_{(0)} = \left(\sqrt{\frac{r}{r-r_g}}c^{-1}\frac{1}{\sqrt{(1-\frac{V^2}{c^2})}}, 0, \omega\sqrt{\frac{r}{r-r_g}}c^{-1}\frac{1}{\sqrt{(1-\frac{V^2}{c^2})}}, 0\right)$$

Spatial ort $e'_{(2)} = (A, 0, B, 0)$ is orthogonal $e'_{(0)}$ and has length -1. Therefore

$$\frac{r-r_g}{r}c^2\frac{1}{L}A - r^2\frac{\omega}{L}B = 0 \tag{9.3}$$

$$\frac{r-r_g}{r}c^2A^2 - r^2B^2 = -1 \tag{9.4}$$

We can express A from (9.3)

$$A = c^{-2}\frac{r}{r-r_g}r^2\omega B$$

and substitute into (9.4)

$$c^{-2}\frac{r}{r-r_g}r^4\omega^2B^2 - r^2B^2 = -1$$

$$\frac{V^2}{c^2}r^2B^2 - r^2B^2 = -1$$

Finally spatial ort in direction of movement is

$$e'_{(2)} = \left(c^{-2}\frac{r}{r-r_g}r\omega\frac{1}{\sqrt{1-\frac{V^2}{c^2}}}, 0, \frac{1}{r}\frac{1}{\sqrt{1-\frac{V^2}{c^2}}}, 0\right)$$

$$e'_{(2)} = \left(c^{-2}\sqrt{\frac{r}{r-r_g}}\frac{V}{\sqrt{1-\frac{V^2}{c^2}}}, 0, \frac{1}{r}\frac{1}{\sqrt{1-\frac{V^2}{c^2}}}, 0\right)$$

Therefore we get transformation

$$e'_{(0)} = \frac{1}{\sqrt{1-\frac{V^2}{c^2}}}e_{(0)} + \frac{V}{c}\frac{1}{\sqrt{1-\frac{V^2}{c^2}}}e_{(2)}$$

$$e'_{(2)} = \frac{V}{c}\frac{1}{\sqrt{1-\frac{V^2}{c^2}}}e_{(0)} + \frac{1}{\sqrt{1-\frac{V^2}{c^2}}}e_{(2)} \tag{9.5}$$

If a stationary observer sends light in a radial direction, the orbiting observer observes Doppler shift

$$\omega' = \frac{\omega}{\sqrt{1-\frac{V^2}{c^2}}}$$

We need to add Doppler shift for gravitational field if the moving observer receives a radial wave that came from infinity. In this case the Doppler shift will take the form

$$\omega' = \sqrt{\frac{r}{r-r_g}}\frac{\omega}{\sqrt{1-\frac{V^2}{c^2}}}$$

We see the estimation for dynamics of star S2 that orbits Sgr A in tables 9.1 and 9.2. The tables are based on two different estimations for mass of Sgr A.

If we get mass Sgr $4.1_{10}6M_\odot$[1] then in pericentre (distance $1.868_{10}15$ cm) S2 has speed 738767495.4 cm/s and Doppler shift is $\omega'/\omega = 1.000628$. In this case we measure length 2:16474$\mu m$for emitted wave with length $2.1661\mu m$ (Br γ). In apocentre (distance $2.769_{10}16cm$) S2 has speed 49839993.28 cm/s and Doppler shift is $\omega'/\omega = 1.0000232$. We measure length $2.166049\,\mu m$ for the same wave. Difference between two measurements of wave length is 13.098 Å.

If we get mass Sgr $3.7_{10}6M_\odot$ [2] then in pericentre (distance $1.805_{10}15cm$) S2 has speed 713915922.3$cm/s$and Doppler shift is $\omega'/\omega = 1.000587$. In this case we measure length $2.16483\,\mu m$ for emitted wave with length $2.1661\mu m(\mathrm{Br}\gamma)$. In apocentre (distance $2.676_{10}16\ cm$) S2 has speed $48163414.05\ cm/s$ and Doppler shift is $\omega'/\omega = 1.00002171$. We measure length $2.1666052\mu m$ for the same wave. Difference between two measurements of wave length is $12.232\,\text{Å}$.

Difference between two measurements of wavelength in pericentre is 0.9Å. Analyzing this data we can conclude that the use of Doppler shift can help improve estimation of the mass of $\mathrm{Sgr\ A}$.

Table 9.1 : Doppler shift on the Earth of a wave emitted from S2; mass of $\mathrm{Sgr\ A}$ is $4.1_{10}6M_\odot$ [1]

	pericentre	apocentre
distance cm	$1.868_{10}15$	$2.769_{10}16$
speed cm/s	738767495.4	49839993.28
ω'/ω	1.000628	1.0000232
emitted wave $(Br\ \gamma)\ \mu m$	2.1661	2.1661
observed wave μm	2.16474	2.166049

Difference between two measurements of wavelength is $13.098\,\text{Å}$.

Table 9.2 : Doppler shift on the Earth of wave emitted from S2; mass of $\mathrm{Sgr\ A}$ is $3.7_{10}6M_\odot$ [2]

	pericentre	apocentre
distance cm	$1.805_{10}15$	$2.676_{10}16$
speed cm/s	713915922.3	48163414.05
ω'/ω	1.000587	1.00002171
emitted wave $(Br\ \gamma)\ \mu m$	2.1661	2.1661
observed wave μm	2.16483	2.1666052

Difference between two measurements of wavelength is $12.232\,\text{Å}$.

X. Lorentz Transformation in Orbital Direction

We see that the Lorentz transformation in orbial direction has familiar form. It is very interesting to see what form this transformation has for radial direction. We start from procedure of measurement speed and use coordinate speed v

$$dr = vdt \tag{10.1}$$

The time of travel of light in both directions is the same. Trajectory of light is determined by equation $ds^2 = 0$.

$$\frac{r-r_g}{r}c^2dt^2 - \frac{r}{r-r_g}dr^2 = 0$$

When light returns back to observer A the change of t is

$$dt = 2\frac{r}{r-r_g}c^{-1}dr$$

The proper time of observer A is

$$ds^2 = \frac{r-r_g}{r}c^2 4\frac{r^2}{(r-r_g)^2}c^{-2}dr^2 =$$

$$= 4\frac{r}{r-r_g}dr^2$$

Therefore spatial distance is

$$L = \sqrt{\frac{r}{r-r_g}}dr$$

When object moving with speed (10.1) gets to B change of t is $\frac{dr}{v}$. The proper time of observer A at this point is

$$ds^2 = \frac{r-r_g}{r}c^2dr^2v^{-2}$$

$$T = \sqrt{\frac{r-r_g}{r}}v^{-1}dr$$

Therefore the observer A measures speed

$$V = \frac{L}{T} == \frac{\sqrt{\frac{r}{r-r_g}}dr}{\sqrt{\frac{r-r_g}{r}}v^{-1}dr} =$$

$$= \frac{r}{r-r_g}v$$

Now we are ready to find out Lorentz transformation. The basis vectors for stationary observer are

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$$e_{(0)}=\left(\frac{1}{c}\sqrt{\frac{r}{r-r_g}},0,0,0\right)$$

$$e_{(1)}=\left(0,\sqrt{\frac{r-r_g}{r}},0,0\right)$$

Unit vector of speed should be proportional to vector

$$(1,v,0,0) \quad (10.2)$$

The length of this vector is

$$L^2=\frac{r-r_g}{r}c^2-\frac{r}{r-r_g}v^2=$$

$$=\frac{r-r_g}{r}c^2\left(1-\frac{V^2}{c^2}\right) \quad (10.3)$$

Therefore time ort of moving observer is

$$e'_{(0)}=\left(\frac{1}{L},\frac{v}{L},0,0\right)=$$

$$=\left(\sqrt{\frac{r}{r-r_g}}c^{-1}\frac{1}{\sqrt{(1-\frac{V^2}{c^2})}},v\sqrt{\frac{r}{r-r_g}}c^{-1}\frac{1}{\sqrt{(1-\frac{V^2}{c^2})}},0,0\right)$$

$$=\left(\sqrt{\frac{r}{r-r_g}}c^{-1}\frac{1}{\sqrt{(1-\frac{V^2}{c^2})}},\frac{V}{c}\sqrt{\frac{r-r_g}{r}}\frac{1}{\sqrt{(1-\frac{V^2}{c^2})}},0,0\right)$$

Spatial ort $e'_{(1)}=(A,B,0,0)$ is orthogonal $e'_{(0)}$ and has length -1. Therefore

$$\frac{r-r_g}{r}c^2\frac{1}{L}A-\frac{r}{r-r_g}\frac{v}{L}B=0 \quad (10.4)$$

$$\frac{r-r_g}{r}c^2A^2-\frac{r}{r-r_g}B^2=-1 \quad (10.5)$$

We can express A from (10.4)

$$A=c^{-2}\frac{r^2}{(r-r_g)^2}vB=c^{-2}\frac{r}{r-r_g}VB$$

and substitute into (10.5)

$$\frac{r-r_g}{r}c^2c^{-4}\frac{r^2}{(r-r_g)^2}V^2B^2-\frac{r}{r-r_g}B^2=-1$$

$$\frac{r}{r-r_g}B^2\left(1-\frac{V^2}{c^2}\right)=1$$

$$B^2=\frac{r-r_g}{r}\frac{1}{1-\frac{V^2}{c^2}}$$

$$B=\sqrt{\frac{r-r_g}{r}}\frac{1}{\sqrt{1-\frac{V^2}{c^2}}}$$

$$A=c^{-2}\frac{r}{r-r_g}V\sqrt{\frac{r-r_g}{r}}\frac{1}{\sqrt{1-\frac{V^2}{c^2}}}$$

$$=c^{-2}V\sqrt{\frac{r}{r-r_g}}\frac{1}{\sqrt{1-\frac{V^2}{c^2}}}$$

Finally spatial ort in direction of movement is

$$e'_{(1)}=\left(c^{-2}V\sqrt{\frac{r}{r-r_g}}\frac{1}{\sqrt{1-\frac{V^2}{c^2}}},\sqrt{\frac{r-r_g}{r}}\frac{1}{\sqrt{1-\frac{V^2}{c^2}}},0,0\right)$$

Therefore we get transformation in in familiar form

$$e'_{(0)}=\frac{1}{\sqrt{1-\frac{V^2}{c^2}}}e_{(0)}+\frac{V}{c}\frac{1}{\sqrt{1-\frac{V^2}{c^2}}}e_{(1)}$$

$$e'_{(1)}=\frac{V}{c}\frac{1}{\sqrt{1-\frac{V^2}{c^2}}}e_{(0)}+\frac{1}{\sqrt{1-\frac{V^2}{c^2}}}e_{(1)} \quad (10.6)$$

XI. Doppler Shift in Friedman Space

We consider another example in Friedman space. Metric of the space is

$$ds^2=a^2(dt^2-d\chi^2-\sin^2\chi(d\theta^2-\sin^2\theta d\phi^2))$$

for closed model and

$$ds^2=a^2(dt^2-d\chi^2-\sinh^2\chi(d\theta^2-\sin^2\theta d\phi^2))$$

for open one. Connection in this space is (α , β get values 1, 2, 3)

$$\Gamma^0_{00}=\frac{\dot a}{a}$$

$$\Gamma^0_{\alpha\alpha}=-\frac{\dot a}{a^2}g_{\alpha\alpha}$$

$$\Gamma^\alpha_{0\beta}=\frac{\dot a}{a}\delta^\alpha_\beta$$

Because space is homogenius we do not care about direction of light. In this case

$$dk^0=-\Gamma^0_{ij}k^ik^j$$

Because k is isotropic vector tangent to its trajectory we have

$$dx^\alpha = \frac{k^\alpha}{k^0}dt$$

Because $k^0 = \frac{\omega}{a}$, then

$$d\frac{\omega}{a} = -\frac{da}{a^2}\omega + \frac{da}{\omega a}g_{\alpha\alpha}k^\alpha k^\alpha = -2\frac{da}{a^2}\omega$$

$$a d\omega + \omega da = 0$$

$$a\omega = const$$

Therefore when a grows ω becomes smaller and length of waves grows as well.

a grows during light travel through spacetime and this leads to red shift. We observe red shift because geometry changes, but not because galaxies runs away one from other.

Now we want to see how red shift changes with time if initial and final points do not move. For simplicity I will change only χ . Initial value is χ_1 and nal value is χ_2. Because $dt = d\chi$ on light trajectory we have

$$\chi = \chi_1 + t - t_1 \qquad t_2 = \chi_2 - \chi_1 + t_1$$

Therefore $a(t_1)\omega_1 = a(t_2)\omega_2$. Doppler shift is

$$K(t_1) = \frac{\omega_2}{\omega_1} = \frac{a(t_1)}{a(t_2)}$$

If initial time changes $t_1' = t_1 + dt$ then $K(t_1+dt)=a(t_1+dt)/a(t_2+dt)$

Time derivative of K is

$$\dot{K} = \frac{\dot{a}_1 a_2 - a_1\dot{a}_2}{a_2^2}$$

For closed space $a = \cosh t$. Then $\dot{a} = \sinh t$.

$$\dot{K} = \frac{\sinh t_1 \cosh t_2 - \sinh t_2 \cosh t_1}{\cosh^2 t_2} = \frac{\sinh(t_1 - t_2)}{\cosh^2 t_2}$$

K decreases when t_1 increases.

XII. Metric-Affine Manifold

For connection (6.2) we defined the **torsion form**

$$T^a = d^2x^a + \omega^a_b \wedge dx^b \tag{12.1}$$

From (6.2) it follows

$$\omega^a_b \wedge dx^b = (\Gamma^a_{bc} - \Gamma^a_{cb})dx^c \wedge dx^b \tag{12.2}$$

Putting (12.2) and (6.14) into (12.1) we get

$$T^a = T^a_{cb}dx^c \wedge dx^b = -c^a_{cb}dx^c \wedge dx^b + (\Gamma^a_{bc} - \Gamma^a_{cb})dx^c \wedge dx^b \tag{12.3}$$

where we defined **torsion tensor**

$$T^a_{cb} = \Gamma^a_{bc} - \Gamma^a_{cb} - c^a_{cb} \tag{12.4}$$

Commutator of second derivatives has form

$$u^\alpha_{;kl} - u^\alpha_{;lk} = R^\alpha_{\beta lk}u^\beta - T^p_{lk}u^\alpha_{;p} \tag{12.5}$$

From (12.5) it follows that

$$\xi^a_{;cb} - \xi^a_{;bc} = R^a_{dbc}\xi^d - T^p_{bc}\xi^a_{;p} \tag{12.6}$$

In Rieman space we have metric tensor g_{ij} and connection Γ^k_{ij}. One of the features of the Rieman space is symetricity of connection and covariant derivative of metric is 0. This creates close relation between metric and connection. However the connection is not necessarily symmetric and the covariant derivative of the metric tensor may be different from 0. In latter case we introduce the **nonmetricity**

$$Q^{ij}_k = g^{ij}_{;k} = g^{ij}_{,k} + \Gamma^i_{pk}g^{pj} + \Gamma^j_{pk}g^{ip} \tag{12.7}$$

Due to the fact that derivative of the metric tensor is not 0, we cannot raise or lower index of a tensor under derivative as we do it in regular Riemann space. Now this operation changes to next

$$a^i_{;k} = g^{ij}a_{j;k} + g^{ij}_{;k}a_j$$

This equation for the metric tensor gets the following form

$$g^{ab}_{;k} = -g^{ai}g^{bj}g_{ij;k}$$

Definition 12.1: We call a manifold with a torsion and a nonmetricity the **metric - affine manifold** [3].

Nonmetricity dramatically changes law how orthogonal basis moves in space time. However learning of parallel transport in space with nonmetricity allows us to introduce the Cartan transport and the connection compatible with the metric tensor (section [11]-10). The Cartan transport holds the basis orthonormal and this makes it valuable tool because the observer uses an orthonormal basis as his measurement tool. We will assume that nonmetricity of space time is equal 0.

XIII. Geometric Meaning of Torsion

Suppose that a and b are non collinear vectors in a point A (see gure 13.1).

We draw the geodesic L_a through the point A using the vector a as a tangent vector to L_a in the point A. Let τ be the canonical parameter on L_a and

$$\frac{dx^k}{d\tau} = a^k$$

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We transfer the vector b along the geodesic L_a from the point A into a point B that defined by any value of the parameter $\tau = \rho > 0$. We mark the result as b'.

We draw the geodesic L_b through the point A using the vector b as a tangent vector to L_b in the point A. Let φ be the canonical parameter on L_b and

$$\frac{dx^k}{d\varphi} = b^k$$

We transfer the vector a along the geodesic L_b from the point A into a point D that defined by any value of the parameter $\varphi = \rho > 0$. We mark the result as a'.

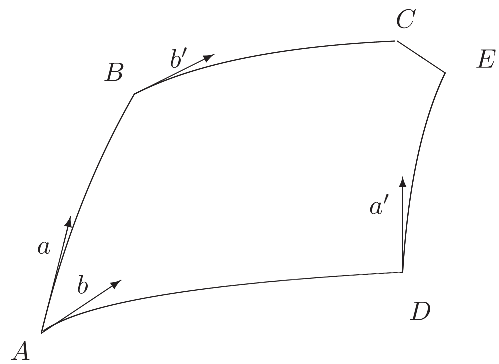

Figure 13.1 : Meaning of Torsion

We draw the geodesic $L_{b'}$ through the point B using the vector b' as a tangent vector to $L_{b'}$ in the point B. Let φ' be the canonical parameter on $L_{b'}$ and

$$\frac{dx^k}{d\varphi'} = b'^k$$

We define a point C on the geodesic $L_{b'}$ by parameter value $\varphi' = \rho$

We draw the geodesic $L_{a'}$ through the point D using the vector a' as a tangent vector to $L_{a'}$ in the point D. Let τ' be the canonical parameter on $L_{a'}$ and

$$\frac{dx^k}{d\tau'} = a'^k$$

We define a point E on the geodesic $L_{a'}$ by parameter value $\tau' = \rho$

Formally lines AB and DE as well as lines AD and BC are parallel lines. Lengths of AB and DE are the same as well as lengths of AD and BC are the same. We call this gure a **parallelogram** based on vectors a and b with the origin in the point A.

Theorem 13.1: *Suppose CBADE is a parallelogram with a origin in the point A; then the resulting figure will not be closed [4]. The value of the difference of coordinates of points C and E is equal to surface integral of the torsion over this parallelogram*[1]

$$\Delta_{CE} x^k = \iint T^k_{mn} dx^m \wedge dx^n$$

Proof : We can find an increase of coordinate x^k along any geodesic as

$$\Delta x^k = \frac{dx^k}{d\tau}\tau + \frac{1}{2}\frac{d^2x^k}{d\tau^2}\tau^2 + O(\tau^2) =$$
$$= \frac{dx^k}{d\tau}\tau - \frac{1}{2}\Gamma^k_{mn}\frac{dx^m}{d\tau}\frac{dx^n}{d\tau}\tau^2 + O(\tau^2)$$

where τ is canonical parameter and we take values of derivatives and components Γ^k_{mn} in the initial point. In particular we have

$$\Delta_{AB} x^k = a^k\rho - \frac{1}{2}\Gamma^k_{mn}(A)a^m a^n\rho^2 + O(\rho^2)$$

along the geodesic L_a and

$$\Delta_{BC} x^k = b'^k\rho - \frac{1}{2}\Gamma^k_{mn}(B)b'^m b'^n\rho^2 + O(\rho^2) \qquad (13.1)$$

along the geodesic $L_{b'}$. Here

$$b'^k = b^k - \Gamma^k_{mn}(A)b^m dx^n + O(dx) \qquad (13.2)$$

is the result of parallel transfer of b^k from A to B and

$$dx^k = \Delta_{AB} x^k = a^k\rho \qquad (13.3)$$

with precision of small value of first level. Putting (13.3) into (13.2) and (13.2) into (13.1) we will receive

$$\Delta_{BC} x^k = b^k\rho - \Gamma^k_{mn}(A)b^m a^n\rho^2 - \frac{1}{2}\Gamma^k_{mn}(B)b^m b^n\rho^2 + O(\rho^2)$$

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Common increase of coordinate x^K along the way ABC has form

$$\begin{aligned}&\Delta_{ABC}x^k=\Delta_{AB}x^k+\Delta_{BC}x^k=\\&=(a^k+b^k)\rho-\Gamma^k_{mn}(A)b^m a^n\rho^2-\\&-\frac{1}{2}\Gamma^k_{mn}(B)b^m b^n\rho^2-\frac{1}{2}\Gamma^k_{mn}(A)a^m a^n\rho^2+O(\rho^2)\end{aligned}\tag{13.4}$$

Similar way common increase of coordinate x^K along the way ADE has form

$$\begin{aligned}&\Delta_{ADE}x^k=\Delta_{AD}x^k+\Delta_{DE}x^k=\\&=(a^k+b^k)\rho-\Gamma^k_{mn}(A)a^m b^n\rho^2-\\&-\frac{1}{2}\Gamma^k_{mn}(D)a^m a^n\rho^2-\frac{1}{2}\Gamma^k_{mn}(A)b^m b^n\rho^2+O(\rho^2)\end{aligned}\tag{13.5}$$

From (13.4) and (13.5), it follows that

$$\begin{aligned}&\Delta_{ADE}x^k-\Delta_{ABC}x^k=\\&=\Gamma^k_{mn}(A)b^m a^n\rho^2+\underline{\frac{1}{2}\Gamma^k_{mn}(B)b^m b^n\rho^2}_{1}+\underline{\frac{1}{2}\Gamma^k_{mn}(A)a^m a^n\rho^2}_{2}-\\&-\Gamma^k_{mn}(A)a^m b^n\rho^2-\underline{\frac{1}{2}\Gamma^k_{mn}(D)a^m a^n\rho^2}_{2}-\underline{\frac{1}{2}\Gamma^k_{mn}(A)b^m b^n\rho^2}_{1}+O(\rho^2)\end{aligned}$$

For small enough value of ρ underlined terms annihilate each other and we get integral sum for expression

$$\Delta_{ADE}x^k-\Delta_{ABC}x^k=\iint_{\Sigma}(\Gamma^k_{nm}-\Gamma^k_{mn})dx^m\wedge dx^n$$

However it is not enough to find the difference

$$\Delta_{ADE}x^k-\Delta_{ABC}x^k$$

to find the difference of coordinates of points C and E. Coordinates may be anholonomic and we have to consider that coordinates along closed loop change (6.15)

$$\Delta x^k=\oint_{ECBADE}dx^k=-\iint_{\Sigma}c^k_{mn}dx^m\wedge dx^n$$

where c is anholonomity object.

Finally the difference of coordinates of points C and E is

$$\Delta_{CE}x^k=\Delta_{ADE}x^k-\Delta_{ABC}x^k+\Delta x^k=\iint_{\Sigma}(\Gamma^k_{nm}-\Gamma^k_{mn}-c^k_{mn})dx^m\wedge dx^n$$

Using (12.4) we prove the statement.

XIV. Tidal Equation

Assume that considered bodyes perform not geodesic but arbitrary movement.

We assume that both observers start their travel from the same point[2] and their speed satisfy to differential equations

$$\frac{Dv^i_I}{ds_I}=a^i_I\tag{14.1}$$

[1]Proof of this statement I found in [7]

where $I = 1, 2$ is the number of the observer and ds_I is infinitesimal arc on geodesic I. Observer I follows the geodesic of connection [11]-(10.1) when $a_I = 0$. We assume also that $ds_1 = ds_2 = ds$.

Deviation of trajectories (14.1) δx^k is vector connecting observers. The lines are infinitesimally close in the neighborhood of the start point

$$x_2^i(s_2) = x_1^i(s_1) + \delta x^i(s_1)$$
$$v_2^i(s_2) = v_1^i(s_1) + \delta v^i(s_1)$$

Derivative of vector δx^i has form

$$\frac{d\delta x^i}{ds} = \frac{d(x_2^i - x_1^i)}{ds} = v_2^i - v_1^i = \delta v^i$$

Speed of deviation δx^i is covariant derivative

$$\begin{aligned} \frac{d\delta x^i}{ds} &= \frac{d\delta x^i}{ds} + \Gamma^i_{kl}\delta x^k v_1^l \\ &= \delta v^i + \Gamma^i_{kl}\delta x^k v_1^l \end{aligned} \tag{14.2}$$

From (14.2) it follows that

$$\delta v^i = \frac{D\delta x^i}{ds} - \Gamma^i_{kl}\delta x^k v_1^l \tag{14.3}$$

Finally we are ready to estimate second covariant derivative of vector δx^i

$$\begin{aligned} \frac{D^2\delta x^i}{ds^2} &= \frac{d\frac{D\delta x^i}{ds}}{ds} + \Gamma^i_{kl}\frac{D\delta x^k}{ds}v_1^l \\ &= \frac{d(\delta v^i + \Gamma^i_{kl}\delta x^k v_1^l)}{ds} + \Gamma^i_{kl}\frac{D\delta x^k}{ds}v_1^l \\ &= \frac{d\delta v^i}{ds} + \frac{d\Gamma^i_{kl}}{ds}\delta x^k v_1^l + \Gamma^i_{kl}\frac{d\delta x^k}{ds}v_1^l + \Gamma^i_{kl}\delta x^k\frac{dv_1^l}{ds} + \Gamma^i_{kl}\frac{D\delta x^k}{ds}v_1^l \end{aligned} \tag{14.4}$$

$$\frac{D^2\delta x^i}{ds^2} = \frac{d\delta v^i}{ds} + \Gamma^i_{kl,n}v_1^n\delta x^k v_1^l + \Gamma^i_{kl}\delta v^k v_1^l + \Gamma^i_{kl}\delta x^k\frac{dv_1^l}{ds} + \Gamma^i_{kl}\frac{D\delta x^k}{ds}v_1^l$$

Theorem 14.1. Tidal acceleration has form

$$\begin{aligned} \frac{D^2\delta x^i}{ds^2} = {} & T^i_{ln}\frac{D\delta x^n}{ds}v_1^l + (R^i_{klm} + T^i_{km;l})\delta x^m v_1^k v_1^l \\ & + a_2^i - a_1^i + \Gamma^i_{ml}\delta x^m a_1^l \end{aligned} \tag{14.5}$$

Proof. The trajectory of observer 1 satisfies equation

$$\frac{Dv_1^i}{ds} = \frac{dv_1^i}{ds} + \Gamma^i_{kl}(x_1)v_1^k v_1^l = a_1^i \tag{14.6}$$

$$\frac{dv_1^i}{ds} = a_1^i - \Gamma^i_{kl}v_1^k v_1^l \tag{14.7}$$

The same time the trajectory of observer 2 satisfies equation

$$\begin{aligned} \frac{Dv_2^i}{ds} &= \frac{dv_2^i}{ds} + \Gamma^i_{kl}(x_2)v_2^k v_2^l \\ &= \frac{d(v_1^i + \delta v^i)}{ds} + \Gamma^i_{kl}(x_1 + \delta x)(v_1^k + \delta v^k)(v_1^l + \delta v^l) \\ &= \frac{dv_1^i}{ds} + \frac{d\delta v^i}{ds} + (\Gamma^i_{kl} + \Gamma^i_{kl,m}\delta x^m)(v_1^k v_1^l + \delta v^k v_1^l + v_1^k\delta v^l + \delta v^k\delta v^l) \\ &= a_2^i \end{aligned}$$

We can rewrite this equation up to order 1

$$\frac{dv_1^i}{ds} + \frac{d\delta v^i}{ds} + \Gamma^i_{kl}v_1^k v_1^l + \Gamma^i_{kl}(\delta v^k v_1^l + v_1^k\delta v^l) + \Gamma^i_{kl,m}\delta x^m v_1^k v_1^l = a_2^i$$

[2] I follow [5], page 33

Using (14.6) we get

$$
\begin{aligned}
&a_1^i + \frac{d\delta v^i}{ds} + \Gamma^i_{kl}\delta v^k v_1^l + \Gamma^i_{kl} v_1^k \delta v^l + \Gamma^i_{kl,m}\delta x^m v_1^k v_1^l = a_2^i \\
&\frac{d\delta v^i}{ds} = -\Gamma^i_{kl}\delta v^k v_1^l - \Gamma^i_{lk}\delta v^k v_1^l - \Gamma^i_{kl,m}\delta x^m v_1^k v_1^l + a_2^i - a_1^i
\end{aligned}
\tag{14.8}
$$

We substitute (14.3), (14.7), and (14.8) into (14.4)

$$
\begin{aligned}
\frac{D^2\delta x^i}{ds^2} &= -\underline{\Gamma^i_{kl}\delta v^k v_1^l}_1 - \Gamma^i_{ln}\left(\frac{D\delta x^n}{ds} - \Gamma^n_{mk}\delta x^m v_1^k\right) v_1^l - \Gamma^i_{kl,m}\delta x^m v_1^k v_1^l \\
&+ a_2^i - a_1^i \\
&+ \Gamma^i_{mk,l} v_1^k \delta x^m v_1^l + \underline{\Gamma^i_{kl}\delta v^k v_1^l}_1 \\
&+ \Gamma^i_{mn}\delta x^m (a_1^n - \Gamma^n_{kl} v_1^k v_1^l) + \Gamma^i_{nl}\frac{D\delta x^n}{ds} v_1^l \\
\frac{D^2\delta x^i}{ds^2} &= (\Gamma^i_{mk,l} - \Gamma^i_{kl,m} + \Gamma^i_{ln}\Gamma^n_{mk} - \Gamma^i_{mn}\Gamma^n_{kl})\delta x^m v_1^k v_1^l \\
&+ \Gamma^i_{nl}\frac{D\delta x^n}{ds} v_1^l - \Gamma^i_{ln}\frac{D\delta x^n}{ds} v_1^l \\
&+ a_2^i - a_1^i + \Gamma^i_{mn}\delta x^m a_1^n \\
\frac{D^2\delta x^i}{ds^2} &= (\Gamma^i_{mk,l} - \Gamma^i_{km,l} + \Gamma^i_{km,l} - \Gamma^i_{kl,m} \\
&+ \Gamma^i_{ln}\Gamma^n_{mk} - \Gamma^i_{nl}\Gamma^n_{mk} + \Gamma^i_{nl}\Gamma^n_{mk} - \Gamma^i_{nl}\Gamma^n_{km} + \Gamma^i_{nl}\Gamma^n_{km} \\
&- \Gamma^i_{mn}\Gamma^n_{kl} + \Gamma^i_{nm}\Gamma^n_{kl} - \Gamma^i_{nm}\Gamma^n_{kl})\delta x^m v_1^k v_1^l \\
&+ T^i_{ln}\frac{D\delta x^n}{ds} v_1^l + a_2^i - a_1^i + \Gamma^i_{mn}\delta x^m a_1^n \\
\frac{D^2\delta x^i}{ds^2} &= T^i_{ln}\frac{D\delta x^n}{ds} v_1^l \\
&+ (\underline{T^i_{km,l}}_2 + \underline{\Gamma^i_{km,l}}_1 - \underline{\Gamma^i_{kl,m}}_1 \\
&+ \underline{T^i_{nl}\Gamma^n_{mk}}_2 + \underline{\Gamma^i_{nl}T^n_{km}}_2 + \underline{\Gamma^i_{nl}\Gamma^n_{km}}_1 \\
&- \underline{T^i_{nm}\Gamma^n_{kl}}_2 - \underline{\Gamma^i_{nm}\Gamma^n_{kl}}_1)\delta x^m v_1^k v_1^l \\
&+ a_2^i - a_1^i + \Gamma^i_{ml}\delta x^m a_1^l
\end{aligned}
\tag{14.9}
$$

Terms underscored with symbol 1 are curvature and terms underscored with symbol 2 are covariant derivative of torsion. (14.5) follows from (14.9).

Remark 14.2 : The body 2 may be remote from body 1. In this case we can use procedure (like in [6]) based on parallel transfer. For this purpose we transport vector of speed of observer 2 to the start point of observer 1 and then estimate tidal acceleration. This procedure works in case of not strong gravitational field.

XV. Tidal Acceleration and Lie Derivative

(14.5) reminds expression of Lie derivative [11]-(7.4). To see this similarity we need to write equation (14.5) different way.

By definition

$$\frac{Da^k}{ds} = \frac{da^k}{ds} + \Gamma^k_{lp} a^l \frac{dx^p}{ds}$$

$$= a^k_{,p} v^p + \Gamma^k_{lp} a^l v^p \quad (15.1)$$

$$\frac{Da^k}{ds} = a^k_{;p} v^p$$

Because $\frac{Da^k}{ds}$ is vector, we can easy find second derivative

$$\frac{D^2 a^k}{ds^2} = \frac{D\frac{Da^k}{ds}}{ds} = \frac{D(a^k_{;p} v^p)}{ds} \quad (15.2)$$
$$= a^k_{;pr} v^p v^r + a^k_{;p} v^p_{;r} v^r$$

On the last step we used (15.1) when $a^k = v^k$. When v^p is tangent vector of trajectory of observer 1 from (14.1) it follows that

$$\frac{Dv^i}{ds} = v^i_{;r} v^r = a^i_1 \quad (15.3)$$

From (15.2) and (15.3) it follows that

$$\frac{D^2 a^k}{ds^2} = a^k_{;pr} v^p v^r + a^k_{;p} a^p_1 \quad (15.4)$$

Theorem 15.1 : *Speed of deviation of two trajectories* (14.1) *satisfies equation*

$$\mathcal{L}_{\frac{D\delta x^n}{ds}} \Gamma^i_{kl} v^k v^l = a^i_2 - a^i_1 + \Gamma^i_{ml} \delta x^m a^l_1 \quad (15.5)$$

Proof. We substitute (15.1) and (15.4) into (14.5).

$$\delta x^i_{;kl} v^k v^l + \delta x^k_{;p} a^p_1 = T^i_{ln} \delta x^n_{;k} v^k v^l_1 + (R^i_{klm} + T^i_{km;l}) \delta x^m v^k_1 v^l_1$$
$$+ a^i_2 - a^i_1 + \Gamma^i_{ml} \delta x^m a^l_1$$
$$0 = (T^i_{ln} \delta x^n_{;k} - \delta x^i_{;kl} + R^i_{klm} \delta x^m + T^i_{km;l} \delta x^m) v^k_1 v^l_1$$
$$+ a^i_2 - a^i_1 - \delta x^k_{,p} a^p_1 \quad (15.6)$$

(15.5) follows from (15.6) and [11]-(7.4).

At a first glance one can tell that the speed of deviation of geodesics is the Killing vector of second type. This is an option, however equation

$$\mathcal{L}_{\frac{D\delta x^n}{ds}} \Gamma^i_{kl} = 0$$

does not follow from equation

$$\mathcal{L}_{\frac{D\delta x^n}{ds}} \Gamma^i_{kl} v^k v^l = 0 \quad (15.7)$$

However equation (15.7) shows a close relationship between deep symmetry of spacetime and gravitational field.

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Special Symbols and Notations

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Unified Concepts in Cosmic, Atomic and Nuclear Physics

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Abstract - In this paper an attempt is made to understand the basic unified concepts of gravity, electromagnetism, nuclear charge radius, cosmic geometry; cosmic mass density, cosmic thermal energy density and cosmic red shift. The four key assumptions are : 1) Planck's constant increases with cosmic time. 2) Being a primordial evolving black hole and angular velocity being H_t universe is always rotating with light, speed. 3) Atomic gravitational constant is squared Avogadro number times the classical gravitational constant and 4) Avogadro number is discrete and hence the atomic gravitational constant is discrete. This may be the root cause of discrete nature of revolving electron's potential energy. Finally it can be suggested that current cosmological changes may be reflected in any existing atom.

Keywords : planck's constant; hubble length; hubble mass; hubble volume; hubble density; cosmic red shift; CMBR temperature; avogadro number; atomic gravitational constant.

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UNIFIED CONCEPTS IN COSMIC, ATOMIC AND NUCLEAR PHYSICS

Strictly as per the compliance and regulations of :

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U. V. S. Seshavatharam [α], S. Lakshminarayana [σ] & B.V.S.T. Sai [ρ]

Abstract - In this paper an attempt is made to understand the basic unified concepts of gravity, electromagnetism, nuclear charge radius, cosmic geometry; cosmic mass density, cosmic thermal energy density and cosmic red shift. The four key assumptions are : 1) Planck's constant increases with cosmic time. 2) Being a primordial evolving black hole and angular velocity being H_t, universe is always rotating with light speed. 3) Atomic gravitational constant is squared Avogadro number times the classical gravitational constant and 4) Avogadro number is discrete and hence the atomic gravitational constant is discrete. This may be the root cause of discrete nature of revolving electron's potential energy. Finally it can be suggested that current cosmological changes may be reflected in any existing atom.

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I. Introduction

For a cosmologist, there are only few parameters needed to describe the universe. All models are based on Einstein's theory of general relativity. The world models are characterized by two parameters: the current rate and the deceleration of the expansion. The first parameter is called the Hubble constant after Edwin Hubble [1]. The other parameter describes the change of the expansion and depends on the energy density and the curvature of the universe. The contributions to the density are expressed as fractions of the critical density. The expansion itself is typically measured by the redshift and is the ratio of the scale factor at two different times of the expansion. In 1947, Hubble suggested that [2]:

"The red shifts are more easily interpreted as evidence of motion in the line of sight away from the earth – as evidence that the nebulae in all directions are rushing away from us and that the farther away they are, the faster they are receding. This interpretation lends itself directly to theories of expanding universe. The interpretation is not universally accepted, but even the most cautious of us admit that red shifts are evidence of either an expanding universe or of some hitherto unknown principle of nature".

"Attempts have been made to attain the necessary precision with the 100 inch, and the results appear to be significant. If they are valid, it seems likely that the red-shifts may not be due to an expanding universe, and much of the current speculation on the structure of the universe may require re-examination. The significant data, however, were necessarily obtained at the very limit of a single instrument, and there were no possible means of checking the results by independent evidence. Therefore the results must be accepted for the present as suggestive rather than definitive".

"We may predict with confidence that the 200 inch will tell us whether the red shifts must be accepted as evidence of a rapidly expanding universe, or attributed to some new principle in nature. Whatever may be the answer, the result may be welcomed as another major contribution to the exploration of the universe."

In physics history, for any new idea or observation or new model - at the very beginning – their existence was very doubtful. The best examples were : 1) Existence of atom 2) Existence of quantum of energy 3) Existence of integral nature of angular momentum 4) Existence of wave mechanics 5) Six quarks having fractional charge 6) Confusion in confirming the existence of muon/pion 7) Existence of Black holes 8) Black hole radiation 9) Einstein's cosmological Lambda term 10) Cosmic red shift 11) Discovery of CMBR and 12) Accelerating universe [3-11] and so on.

"Hubble volume" can be considered as a key tool in cosmology and unification. Some cosmologists use the term 'Hubble volume' to refer to the volume of the observable universe. With reference to the Mach's principle [12] and the Hubble volume, at any cosmic time, if "Hubble mass" is the product of cosmic critical density and the Hubble volume, then it can be suggested that, "within the Hubble volume, each and every point in free space is influenced by the Hubble mass". In this paper an attempt is made to understand the basic unified concepts of the four fundamental cosmological interactions. With this approach unification of gravity and electromagnetism, nuclear charge radius, cosmic red shift and cosmic expansion etc. can be studied in a unified manner.

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Note that, Einstein, more than any other physicist, untroubled by either quantum uncertainty or classical complexity, believed in the possibility of a complete, perhaps final, theory of everything. [13]. He also believed that the fundamental laws and principles that would embody such a theory would be simple, powerful and beautiful. Physicists are an ambitious lot, but Einstein was the most ambitious of all. His demands of a fundamental theory were extremely strong. If a theory contained any arbitrary features or undetermined parameters then it was deficient, and the deficiency pointed the way to a deeper and more profound and more predictive theory. There should be no free parameters – no arbitrariness. According to his philosophy, electromagnetism must be unified with general relativity, so that one could not simply imagine that it did not exist. Furthermore, the existence of matter, the mass and the charge of the electron and the proton (the only elementary particles recognized back in the 1920s), were arbitrary features. One of the main goals of a unified theory should be to explain the existence and calculate the properties of matter. . In this paper authors made an attempt to understand the basic concepts of unification via particle cosmology [14,15].

a) The cosmic 'critical density' and its dimensional analysis

Physicists and astronomers have long believed that the universe has mirror symmetry, like a basketball. But recent findings from the University of Michigan suggest that the shape of the Big Bang might be more complicated than previously thought, and that the early universe spun on an axis. A left-handed and right-handed imprint on the sky as reportedly revealed by galaxy rotation would imply the universe was rotating from the very beginning and retained an overwhelmingly strong angular momentum. This recent news can be seen at following two web sites. http://phys.org/news/2011-07-universe-born-symmetry-cosmos.html and http://news.discovery.com/space/do-we-live-in-a-spinning-universe-110708.html.

With a simple derivation it is possible to show that, Hubble's constant (H_t) represents cosmological angular velocity [16-18]. Assume that, a planet of mass (M) and size (R) rotates with angular velocity (ω_e) and linear velocity (v_e) in such a way that, free or loosely bound particle of mass (m) lying on its equator gains a kinetic energy equal to potential energy as,

$$\frac{1}{2}mv_e^2 = \frac{GMm}{R} \tag{1}$$

$$R\omega_e = v_e = \sqrt{\frac{2GM}{R}} \quad \text{and} \quad \omega_e = \frac{v_e}{R} = \sqrt{\frac{2GM}{R^3}} \tag{2}$$

i.e Linear velocity of planet's rotation is equal to free particle's escape velocity. Without any external power or energy, test particle gains escape velocity by virtue of planet's rotation. Using this idea, 'Black hole radiation' and 'origin of cosmic rays' can be understood. Note that if Earth completes one rotation in one hour then free particles lying on the equator will get escape velocity. Now writing, $M = \frac{4\pi}{3}R^3\rho_e$,

$$\omega_e = \frac{v_e}{R} = \sqrt{\frac{8\pi G\rho_e}{3}} \quad \text{Or} \quad \omega_e^2 = \frac{8\pi G\rho_e}{3} \tag{3}$$

$$\text{Density, } \rho_e = \frac{3\omega_e^2}{8\pi G} \tag{4}$$

In real time, this obtained density may or may not be equal to the actual density. But the ratio may have some physical meaning. The most important point to be noted here, is that, as far as dimensions and units are considered, from equation (4), it is very clear that, proportionality constant being,

$$\text{density} \propto (\text{angular velocity})^2 \tag{5}$$

Equation (4) is similar to "flat model concept" of cosmic "critical density"

$$\rho_c = \frac{3H_t^2}{8\pi G} \tag{6}$$

Comparing equations (4) and (6) dimensionally and conceptually, i.e.

$$\rho_e = \frac{3\omega_e^2}{8\pi G} \quad \text{with} \quad \rho_c = \frac{3H_t^2}{8\pi G} \tag{7}$$

$$H_t^2 \to \omega_e^2 \quad \text{and} \quad H_t \to \omega_e \tag{8}$$

It is very clear that, dimensions of 'Hubble's constant' must be 'radian/second'. In any physical system under study, for any one 'simple physical parameter' there will not be two different units and there will not be two different physical meanings. This is a simple clue and brings "cosmic rotation" into picture. This is possible in a closed universe only. Cosmic models that depends on this "critical density" may consider 'angular velocity of the universe' in the place of 'Hubble's constant'. In the sense, 'cosmic rotation' can be included in the existing models of cosmology. Then the term 'critical density' simply appears as the 'spherical volume density' of the closed and expanding universe. Galaxies spin, stars spin, and planets spin. So, why not the whole universe? The consequences of a spinning universe would be profound.

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II. Possible Assumptions in Unified Cosmic Physics

The possible assumptions in unified cosmic physics can be expressed in the following way [19-21], [22-35]:

1. Planck's constant increases with cosmic time.
2. Being a primordial evolving black hole [16-18] and angular velocity being H_t, universe is always rotating with light speed.
3. Atomic gravitational constant is squared Avogadro number [23, 24] times the classical gravitational constant. Thus,

$$G_A \cong N^2 G \tag{9}$$

where (G_A) is the Atomic gravitational constant, (N) is the Avogadro number and (G) is the classical gravitational constant.

4. Avogadro number is discrete and hence the atomic gravitational constant is discrete. Thus

$$(n.N)^2 G \cong n^2 \left(N^2 G\right) \cong n^2 G_A \tag{10}$$

Where $n = 1, 2, 3, ..$ This may be the root cause of discrete nature of revolving electron's potential energy.

Thus at any given cosmic time t,

5. Hubble length (c/H_t) can be considered as the gravitational or electromagnetic interaction range.
6. Planck's constant inccrases with increasing cosmic time and $\frac{d(h)}{dt}$ is a measure of cosmic rate of expansion. It is possible to show that, potential energy of electron in hydrogen atom is directly proportional to $\hbar^2$. Bohr's second postulate which suggests that potential energy of electron in hydrogen atom is inversely proportional to $\hbar^2$ seems to be a coincidence [36, 37].
7. Past light quanta emitted from aged galaxy will have less Planck's constant and show a red shift with reference to the receiving galaxy. During journey light quanta will not lose energy and there will be no change in light wavelength.
8. The basic definition of redshift (z) seems to be $z \cong \frac{\lambda_G - \lambda_0}{\lambda_G}$ but not $z \cong \frac{\lambda_G - \lambda_0}{\lambda_0}$. Here λ_G is the wave length of light received from observed galaxy and λ_0 is the wave length of light in laboratory. Note that, based on the increasing value of the Planck's constant, red shift (z) will be directly proportional to the age difference of our galaxy and the old galaxy (Δt). Thus $z \propto \Delta t$ and $z \cong H_t \Delta t$. Here H_t is the proportionality constant. In this way H_0 can be incorporated directly. Our galaxy and observed galaxy age difference is, $\Delta t \cong \frac{z}{H_t}$. If $c\Delta t$ is a measure of galaxy distance, then $c\Delta t \cong z \cdot \frac{c}{H_t}$.

   In this way, the basic and original definition of 'galaxy receding' and 'accelerating universe' concepts can be eliminated and a 'decelerating or expanded universe' concept can be continued without any difficulty.
9. Like a primordial black hole, universe is evolving and rotating. Being a black hole and angular velocity being H_t, universe is always rotating with light speed.
10. The Schwarzschild radius [16-18] of universe is

$$\frac{2GM_t}{c^2} \cong \frac{c}{H_t} \tag{11}$$

Where M_t is the cosmic mass at that time. Thus the cosmic mass can be expressed as

$$M_t \cong \frac{c^3}{2GH_t}. \tag{12}$$

It can be called as the Hubble mass. Thus the cosmic volume density takes the following well known 'critical density' form,

$$(\rho_v)_t \cong \frac{c^3}{2GH_t} \div \frac{4\pi}{3}\left(\frac{c}{H_t}\right)^3 \cong \frac{3H_t^2}{8\pi G}. \tag{13}$$

It can be caled as the cosmic Hubble density.

III. Applicastions of the Proposed Assumptions

a) Cosmic matter density

Approximate ratio of cosmic volume density $(\rho_v)_t$ and matter density $(\rho_m)_t$ can be expressed as

$$\left(\frac{\rho_v}{\rho_m}\right)_t \cong 1 + \ln\sqrt{\frac{4\pi\varepsilon_0 GM_t^2}{e^2}} \tag{14}$$

Note that, at present obtained matter density ρ_m can be compared with the elliptical and spiral galaxy matter density. Based on the average mass-to-light ratio for any galaxy [38]

$$(\rho_m)_0 \cong 1.5 \times 10^{-32} \eta h_0 \text{ gram/cm}^3 \tag{15}$$

where for any galaxy, $\langle M/L \rangle_{Galaxy} = \eta \langle M/L \rangle_{\text{Sun}}$ and the number: $h_0 \cong \frac{H_0}{100 \text{ Km/sec/Mpc}} \cong \frac{70.75}{100} \cong 0.7075.$ Note that elliptical galaxies probably comprise about 60% of the galaxies in the universe and spiral galaxies are thought to make up about 20% of the galaxies in the universe. Almost 80% of the galaxies are in the form of elliptical and spiral galaxies. For spiral galaxies, $\eta h_0^{-1} \cong 9 \pm 1$ and for elliptical galaxies, $\eta h_0^{-1} \cong 10 \pm 2$. For our galaxy inner part, $\eta h_0^{-1} \cong 6 \pm 2$. Thus the average ηh_0^{-1} is very close to 8 to 9 and its corresponding matter density is (6.0 to 6.67) $\times 10^{-32}$ gram/cm^3.

b) Wavelength of the CMB radiation

Authors noticed two approximate methods for estimating the CMB radiation. Geometric mean of the 2 methods is fitting with the observational data accurately [39].

Method-1 : Pair particles creation and annihilation in 'free space'- is an interesting idea. In the expanding universe, by considering the proposed charged M_C and its pair annihilation as characteristic cosmic phenomena, origin of the isotropic CMB radiation can be addressed. With reference to the Wein's displacement law and if $(M_e)^{\pm} \cong \sqrt{\frac{e^2}{4\pi\varepsilon_0 G}}$ represents a characteristic fundamental unified charged mass unit, wave length of the most strongly emitted CMB radiation can be expressed as

$$(\lambda_m)_t \cong \left(\frac{\rho_v}{\rho_m}\right)_t \frac{G\sqrt{M_t M_e}}{c^2} \cong \left[1+\ln\left(\frac{M_t}{M_e}\right)\right]\frac{G\sqrt{M_t M_e}}{c^2} \tag{16}$$

Note that this expression is free from the 'radiation constants'. If H_0 is close to 70 km/sec/Mpc, obtained (most strongly emitted) wavelength of the CMB radiation is 1.37 mm.

Method-2 : This method is based on the pair annihilation of $(M_e)^{\pm}$. Thermal energy can be expressed as

$$k_B T_t \cong \sqrt{\frac{M_e}{M_t}}\cdot\left[(M_e)^{+}+(M_e)^{-}\right]c^2 \cong \sqrt{\frac{M_e}{M_t}}\cdot 2M_e c^2 \tag{17}$$

Based on Wein's displacement law,

$$(\lambda_m)_t \cong \frac{b}{T_t} \cong \sqrt{\frac{M_t}{M_e}}\cdot\frac{bk_B}{2M_e c^2} \tag{18}$$

If H_0 is close to 70 km/sec/Mpc, obtained (most strongly emitted) wavelength of the CMB radiation is 0.822 mm.

Method-3 : Considering the geometric mean wave length of wave length obtained from methods-1 and 2, wave length of the most strongly emitted CMB radiation can be expressed as

$$(\lambda_m^2)_t \cong \left[1+\ln\left(\frac{M_t}{M_e}\right)\right]\cdot\left(\frac{M_t}{2M_e}\right)\cdot\left(\frac{bk_B G}{c^4}\right) \tag{19}$$

$$(\lambda_m)_t \cong \sqrt{\left[1+\ln\left(\frac{M_t}{M_e}\right)\right]\cdot\left(\frac{M_t}{2M_e}\right)\cdot\left(\frac{bk_B G}{c^4}\right)} \tag{20}$$

If H_0 is close to 70 km/sec/Mpc, obtained (most strongly emitted) wavelength of the CMB radiation is 1.064 mm. In this way, in a semi empirical approach, the observed CMB radiation temperature can be understood. Clearly speaking,

$$(\lambda_m)_t \propto \sqrt{1+\ln\left(\frac{M_t}{M_e}\right)} \propto \sqrt{\left(\frac{\rho_v}{\rho_m}\right)_t} \tag{21}$$

$$(\lambda_m)_t \propto \sqrt{\frac{M_t}{2M_e}} \tag{22}$$

and $\sqrt{\frac{bk_B G}{c^4}} \cong 1.818\times10^{-35}$ m seems to be a constant and can be considered as the characteristic thermal wave length.

The most important point is that, as the black hole universe is expanding, its expansion rate can be checked with $\frac{d}{dt}(\lambda_m)_t$. Present observations indicates that, CMB radiation is smooth and uniform. Thus it can be suggested that, at present there is no detectable cosmic expansion or cosmic acceleration.

c) Characteristic Nuclear Charge Radius

At any given cosmic time, in a semi empirical way, the characteristic nuclear charge radius [39,40] can be expressed as

$$R_{ct} \cong \left(\frac{Gm_p^2}{G_A m_e^2}\right)\frac{c}{H_t} \tag{23}$$

Here m_p is the proton rest mass. At present If H_0 is close to 70 km/sec/Mpc,

$$R_{c0} \cong \left(\frac{Gm_p^2}{G_A m_e^2}\right)\frac{c}{H_0} \cong 1.23 \text{ fm} \tag{24}$$

Thus it can be suggested that, $R_{ct} \propto \frac{c}{H_t}$. This is a very strange and peculiar result and is beyond the current physics concepts and interpretations. Interpretation seems to be a big puzzle.

d) Scattering Distance Between Electron And The Nucleus

If $1.21 \text{ to } 1.23 \text{ fm}$ is the characteristic scattering distance between electron and the nucleus [40, 41], semi empirically it is noticed that,

$$\left(\frac{\hbar c}{\sqrt{GG_A}m_e^2}\right)^2 \frac{2Gm_e}{c^2} \cong 1.21565 \text{ fm} \tag{25}$$

Here it is very interesting to consider the role of the Schwarzschild radius of the 'electron mass'. This is a very strange and peculiar result and is beyond the current physics concepts and interpretations.

e) Characteristic Reduced Planck's Constant

From above semi empirical relations it is noticed that,

$$\hbar \cong \sqrt{\frac{M_0}{m_e}} \cdot \frac{Gm_p m_e}{c} \tag{26}$$

This is also a very strange and peculiar result and is beyond the current physics concepts and interpretations. Based on the this coincidence, magnitude of the present Hubble's constant [42,43] can be expressed as

$$H_0 \cong \frac{Gm_p^2 m_e c}{2\hbar^2} \cong 70.75 \text{ Km/sec/Mpc} \tag{27}$$

At any given cosmic time, the characteristic reduced Planck's constant can be expressed as

$$\hbar_t \cong \sqrt{\frac{M_t}{m_e}} \cdot \frac{Gm_p m_e}{c} \tag{28}$$

where M_t is the cosmic mass at time t. As cosmic time passes, magnitude of $\hbar_t$ increases.

f) Electron's Characteristic Potential Energy

At any given cosmic time, in hydrogen atom, electron's characteristic potential energy [35,36] can be expressed as

$$E_{pt} \cong -\left(\frac{\hbar_t c}{G_A m_e^2}\right)^2 \cdot \frac{\sqrt{m_p m_e} \cdot c^2}{2} \tag{29}$$

Thus it can be suggested that, $E_{pt} \propto \hbar_t^2$.

$$E_{pt} \cong -\left(\frac{Gm_p^2}{G_A m_e^2} \cdot \frac{c}{H_t} \cdot \frac{c^2}{2\left(n^2.G_A\right)m_e}\right)\frac{\sqrt{m_p m_e} \cdot c^2}{2} \tag{30}$$

$$E_{pt} \cong -\left(\frac{R_{ct}c^2}{2\left(n^2.G_A\right)m_e}\right)\frac{\sqrt{m_p m_e} \cdot c^2}{2} \tag{31}$$

Here G_A is the proposed atomic gravitational constant and R_{ct} is the characteristic nuclear charge radius and $\left(2G_A m_e / c^2\right)$ is the characteristic black hole radius of electron where G_A is the operating atomic gravitational constant. Thus at present,

$$E_{p0} \cong -\left(\frac{R_{c0}c^2}{2\left(n^2.G_A\right)m_e}\right)\frac{\sqrt{m_p m_e} \cdot c^2}{2} \cong -27.12 \text{ eV} \tag{32}$$

This is a note worthy observation. Thus it can be suggested that, $E_{pt} \propto \frac{c}{H_t}$. Note that in Bohr's theory of Hydrogen atom, the role of nuclear charge radius and role of proton rest mass is not clear.

g) Bohr Radius of Hydrogen Atom

From above relations, at present Bohr radius of hydrogen atom can be expressed as

$$a_0 \cong \frac{4G_A m_e}{c^2 R_{c0}} \cdot \frac{e^2}{4\pi\varepsilon_0 \sqrt{m_p m_e} c^2} \tag{33}$$

Note that, 4 characteristic length units are appearing in this expression. This is a very simple relation and from General theory of relativity, the most note worthy observation is the role of $\left(\frac{4G_A m_e}{c^2 R_{c0}}\right)$. Its interpretation seems to be connected with 'bending of electron path' due to nuclear charge radius. Other discrete Bohr radii can be obtained as

$$a_n \cong \frac{4\left(n^2.G_A\right)m_e}{c^2 R_{c0}} \cdot \frac{e^2}{4\pi\varepsilon_0 \sqrt{m_p m_e} c^2} \tag{34}$$

h) About The Fine Structure Ratio

In physics, the fine-structure ratio (α) is a fundamental physical constant, namely the coupling constant characterizing the strength of the electromagnetic interaction. Being a dimensionless quantity, it has constant numerical value in all systems of units. The most precise value of α obtained experimentally (as of 2012) is based on a measurement of 'Linde g factor' using a 'one-electron' so-called 'quantum cyclotron' apparatus, together with a calculation via the theory of QED. Independent of the Planck's constant, inverse of the fine structure ratio can be expressed as

$$\left(\frac{1}{\alpha}\right)_t \cong \ln\left(\frac{x}{1+\ln x}\right) \tag{35}$$

Where $x \cong \frac{M_t}{M_e} \cong \sqrt{\frac{4\pi\varepsilon_0 G M_t^2}{e^2}}.$ When $x^2 \cong \frac{4\pi\varepsilon_0 G M_t^2}{e^2} \cong \frac{M_t^2}{M_e^2} \cong 1, \ \frac{1}{\alpha} \to 0.$ In this way, in a unified manner, the present fine structure ratio can be fitted. From this relation it is possible to say that, cosmological rate of change in fine structure ratio, $(d\alpha/dt)$ may be considered as an index of the future cosmic acceleration. Many physicists think its possible variation [44] and experiments are in progress.

IV. To Fit the Rms Radius of Proton

Let R_p be the rms radius of proton. Define two radii R_1 and R_2 as follows.

$$R_1 \cong \left(\frac{\hbar c}{\sqrt{G_A G m_p^2}}\right)^2 \frac{2Gm_p}{c^2} \cong 1.9637\times10^{-25} \text{ m} \quad (36)$$

$$R_2 \cong \left(\frac{\hbar c}{\sqrt{G_A G m_p^2}}\right)^3 \frac{2Gm_p}{c^2} \cong 5.521\times10^{-11} \text{ m} \quad (37)$$

It is noticed that,

$$R_p \cong \left(R_1 R_2^2\right)^{\frac{1}{3}} \cong 8.4278\times10^{-16} \text{ m} \quad (38)$$

$$\text{Thus, } R_p \cong \left(\frac{\hbar c}{\sqrt{G_A G m_p^2}}\right)^{8/3} \frac{2Gm_p}{c^2} \quad (39)$$

This can be compared with the 2010 CODATA recommended rms radius of proton fm [45]. Recent work on the spectrum of muonic hydrogen (an exotic atom consisting of a proton and a negative muon) indicates a significantly lower value for the proton charge radius, $R_p \cong 0.84184(67)$ fm and the reason for this discrepancy is not clear. This is 10 times more precise than all the previous determinations [46]. Here the most interesting thing is that, R_2 is very close to the Bohr radius of Hydrogen atom. It is very surprising to note that, with R_2 ionic radii of atoms can be fitted very easily as

$$(R)_A \cong A^{1/3}\cdot\left(\frac{R_2}{\sqrt{2}}\right) \cong A^{1/3}\cdot 3.904\times10^{-11} \text{ m} \quad (40)$$

where $(R)_A$ is the ionic radius of mass number A. If $A=7, (R)_A \cong 0.0747$ nm, if $A=23, (R)_A \cong 0.111$ nm and if $A=39, (R)_A \cong 0.132$ nm. Their corresponding recommended radii are 0.076 nm, 0.102 nm and 0.138 nm respectively [47].

a) To fit the gram mole

From relations (26) and (39), proton rms radius can be expressed as

$$R_p \cong \left(\frac{\sqrt{M_0 m_e}}{N m_p}\right)^{8/3} \frac{2Gm_p}{c^2} \quad (41)$$

On rearranging,

$$N m_p \cong \left(\frac{2Gm_p}{c^2 R_p}\right)^{3/8} \sqrt{M_0 m_e} \cong M_g \quad (42)$$

where M_g is the mass of 'gram mole' [48] expressed in kg or gram. Please note that, (Nm_p) is very close to the magnitude of gram mole. These relations are speculative and puzzling but at the same time they are peculiar. Interpretation seems to be complicated. Authors are working in this new direction.

b) To fit the nuclear binding energy

Inverse of the strong coupling constant [49,50] can be expressed as

$$\left(\frac{1}{\alpha_s}\right)_t \cong \ln\left(\frac{4\pi\varepsilon_0 G_A m_e^2}{e^2}\right) - \ln\sqrt{1+\left(\frac{1}{\alpha}\right)_t} \quad (43)$$

Thus at present,

$$\left(\frac{1}{\alpha_s}\right)_0 \cong \ln\left(\frac{4\pi\varepsilon_0 G_A m_e^2}{e^2}\right) - \ln\sqrt{1+\left(\frac{1}{\alpha}\right)_0} \quad (44)$$

$$\cong 8.9106 \cong 1/0.1122258$$

At present in the semi empirical mass formula [51-54], coulombic energy constant can be expressed as

$$a_c \cong \alpha\cdot\alpha_s\cdot m_p c^2 \cong 0.7684 \text{ MeV.} \quad (45)$$

Surface energy constant can be expressed as

$$a_s \cong \left(\frac{2G_A m_e}{R_c c^2}\right)^{1/4}\cdot a_c \cong 19.37 \text{ MeV.} \quad (46)$$

Volume energy constant can be expressed as

$$a_v \cong \left(\frac{G_A m_e}{R_c c^2}\right)^{1/4}\cdot a_c \cong 16.29 \text{ MeV.} \quad (47)$$

Asymmetric energy constant can be expressed as

$$a_a \cong \frac{2}{3}(a_v + a_s) \cong 23.77 \text{ MeV.} \quad (48)$$

Similarly pairing energy constant can be expressed as

$$a_p \cong \frac{1}{3}(a_v + a_s) \cong 11.88 \text{ MeV.} \quad (49)$$

$$\text{Thus, } (a_v + a_s) \cong (a_p + a_a) \cong 3a_p \quad (50)$$

V. Discussion & Conclusions

After sometime in the late 1920s Einstein became more and more isolated from the mainstream of fundamental physics. To a large extent this was due to his attitude towards quantum mechanics, the field to which he had made so many revolutionary contributions. Einstein, who understood better than most the implications of the emerging interpretations of quantum mechanics, could never accept it as a final theory of physics. He had no doubt that it worked, that it was a successful interim theory of physics, but he was convinced that it would be eventually replaced by a deeper, deterministic theory [13].

Every day quantum mechanics is strongly connected with the constancy of Planck's constant. String theory, quantum cosmology, quantum chromodynamics (QCD) etc. are strongly based on the constancy of Planck's constant. With reference to the present concepts of cosmic acceleration and with laboratory experiments one may not decide whether universe is accelerating or decelerating. Many experiments are under progress to detect and confirm the existence of dark matter and dark energy. Along with these experiments if one is willing to think in this new direction, from atomic and nuclear inputs it may be possible to verify the future cosmic acceleration.

With the proposed concepts and with the advancing science and technology, from the ground based laboratory experiments, from time to time the concept $d(h_0)/dt$ can be put for experimental tests. There is no need to design a new experiment. Well established experiments are already available by which Planck's constant can be estimated. Moreover, conducting an experiment in this direction is also very simple. Only thing is that the same experiment has to be repeated for several times or continuously. This is also very simple. Thus in the near future one can expect the real picture.

Alternatively in a theoretical way, the proposed applications or semi empirical relations can be given a chance and the subject of elementary particle physics and cosmology can be studied in a unified manner [55-57]. It is true that the proposed relations are speculative and peculiar also. By using the proposed relations and applying them in fundamental physics, in due course their role or existence can be verified. With these relations, Hubble constant can be estimated from atomic and nuclear physical constants. If one is able to derive them with a suitable mathematical model, independent of the cosmic redshift and CMBR observations, the future cosmic acceleration can be verified from atomic and nuclear physical constants.

In understanding the basic concepts of unification or TOE, role of dark energy and dark matter is insignificant. Even though string theory was introduced for understanding the basics of strong interaction, its success seems to be a dilemma because of its higher dimensions and the non-coupling of the nuclear and Planck scale [13]. Based on the proposed relations and applications, Hubble volume or Hubble mass, can be considered as a key tool in unification as well as cosmology. Considering the proposed relations and concepts it is possible to say that there exists a strong relation between cosmic Hubble mass, Avogadro number and unification. Now the new set of proposed relations are open to the science community. Whether to consider them or discard them depends on the physical interpretations, logics, experiments and observations. In most of the critical cases, 'time' only will decide the issue. The mystery can be resolved only with further research, analysis, discussions and encouragement.

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Harmonic and Wave Maps Coupled with Einstein's Gravitation

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HARMONIC AND WAVE MAPSCOUPLED WITH EINSTEINS GRAVITATION

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Harmonic and Wave Maps Coupled with Einstein's Gravitation

Rainer Schimming [α] & Ragab M. Gad [σ]

Abstract - In this paper we discuss the coupled dynamics, following from a suitable Lagrangian, of a harmonic or wave map ø and Einstein's gravitation described by a metric *g*. The main results concern energy conditions for wave maps, harmonic maps from warped product manifolds, and wave maps from wave-like Lorentzian manifolds.

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I. Introduction

Scalar fields on a space or space-time manifold (X, g), which satisfy a linear or nonlinear field equation, attract enduring attention; cf, e.g., [1, 2, 3]. The *Dirichlet Lagrangian* or *energy density*

$$e = \frac{1}{2}|d\phi|^2 = \frac{1}{2}g^{ab}(\partial_a\phi)(\partial_b\phi), \tag{1.1}$$

of a one-component scalar field $\phi = \phi(x)$ leads to a linear field equation of Laplace or D'Alembert type. Here we denote

$$g = g_{ab}dx^a dx^b, \quad (g^{ab}) := (g_{ab})^{-1}, \quad \partial_a := \frac{\partial}{\partial x^a}.$$

The Dirichlet Lagrangian e admits a natural generalization to a multi-component scalar field $\phi = \phi(x)$ if the range of ϕ is suitably geometrized, namely if $im\,\phi$ lies in a Riemannian manifold (Y, h). That means, ϕ becomes a map $X \to Y$, $x \mapsto y$ between a source manifold (X, g) and a target manifold (Y, h). The choice of the Lagrangian

$$e = e[\phi] = e[\phi, g] = \frac{1}{2}|d\phi|^2, \tag{1.2}$$

where now

$$|d\phi|^2 := tr(\phi^* h) \equiv g^{ab}(\partial_a\phi^i)(\partial_b\phi^j)h_{ij}(\phi^k),$$

leads to the generally semi-linear field equation with Laplace-like or D'Alembert-like principal part

$$tr(\nabla d\phi)^i \equiv g^{ab}\nabla_a\partial_b\phi^i = 0. \tag{1.3}$$

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Here we denote $h = h_{ij}dy^i dy^j$ and the special covariant derivative ∇ is built from g, h, ϕ as will be explained in section 2.

A map $\phi : X \longrightarrow Y$ between properly Riemannian manifolds (X, g), (Y, h) which satisfies (1.3) is called a *harmonic map* [4, 5]. A map $\phi : X \longrightarrow Y$ from a Lorentzian manifold (X, g) to a properly Riemannian manifold (Y, h) which satisfies (1.3) is called a *wave map* [6, 7, 8, 9, 3].

In this paper, we take (Y, h) as a fixed background and consider g and ϕ as dynamical objects. The dynamics shall follow from the Lagrangian

$$L = \kappa R - e, \tag{1.4}$$

where R denotes the scalar curvature of g and $\kappa \neq 0$ is a coupling constant. Variation with respect to g yields, for $dimX \geq 3$, the *Einstein equation* in the form

$$\kappa Ric = \phi^* h, \tag{1.5}$$

in components

$$\kappa R_{ab} = (\partial_a \phi^i)(\partial_b \phi^j)h_{ij}. \tag{1.6}$$

Variation with respect to ϕ yields (1.3).

A Lorentzian metric g can be interpreted as *gravitation*. According to the Kaluza-Klein principle, the space-time manifold (X, g) may have a higher dimension.

A positive definite metric g on X can be given a physical interpretation through a Lorentzian metric constructed from it as follows. Consider the product manifold $\tilde{X} := \Re \times X$ with points (t, x) and equip it with the Lorentzian metric $\tilde{g} := dt^2 - g$. Extend $\phi : X \longrightarrow Y$ to $\tilde{\phi} : \tilde{X} \longrightarrow Y$ by setting $\tilde{\phi}(t, x) := \phi(x)$, that means $\tilde{\phi} := \phi \circ pr_2$, where pr_2 is the projection $\tilde{X} \longrightarrow X$ to the second factor. The field equations (1.5), (1.3) for $(\tilde{X}, \tilde{g})$, $\tilde{\phi}$ reduce to (1.5), (1.3) for (X, g), ϕ.

Let us sketch our main results.

• The energy-momentum tensor T of a wave map obeys several energy conditions. In particular, if v is a causal (i.e. non-spacelike) vector field then the momentum one-form $I := T(\cdot, v)$ is causal again.

• The Einstein equation (1.5) implies that the conditions $Ric(v, v) = 0$, $Ric(\cdot, v) = 0$, $\phi_* v = 0$ for a vector field v are equivalent to each other. Moreover, then v is a Ricci collineation, i.e. $\pounds_v Ric = 0$. Some conclusions are drawn from this latter fact.

• A submersive map $\phi : X \to Y$ between a pure manifold X and a Riemannian manifold (Y, h) can locally be made to a harmonic or wave map by a suitable choice of a metric g on X.

• We study the case of warped product $X = {'X} \times {''X}$, $g = {'g} \oplus w^2\, {''g}$. Several propositions are proved by means of the argument that the integral of a Laplace expression over a closed manifold ${'X}$ vanishes.

• We study radiation conditions for a Lorentzian manifold (X, g). The Einstein equation (1.5) leads from one condition to a stronger condition.

II. Preliminaries

We consider dimensions

$$m := dimX \geq 3, \quad n := dimY \geq 1$$

and adopt the following index convention: indices $a, b, c, ...$ label the components of geometric objects on X; indices $i, j, k, ...$ label the components of geometric objects on Y.
Tensor fields on Y become multi-component scalar fields on X by insertion of $y = \phi(x)$, where $x \in X$, $y \in Y$. For covariant tensor fields on Y there is also the conventional pull-back map ϕ^*. For instance, the metric $h = h_{ij}dy^i dy^j$ yields $h \circ \phi$ with components $h_{ij}(\phi^k) = h_{ij}(\phi^k(x^a)$ on X and also the pull-back $\phi^* h$ on X with components $(\partial_a \phi^i)(\partial_b \phi^j)(h_{ij}(\phi^k)$. The object $\phi^* h$ is called *first fundamental form* of $\phi : X \to Y$.
We will occasionally write

$$\phi^* h = h(d\phi, d\phi)$$

and also use the bilinear symmetric form $h(\cdot, \cdot)$ with tensorial entries.
Some natural covariant derivative ∇ with components ∇_a is built from g, h, ϕ according to the following rules.

1- ∇ applied to tensor fields on X equals the Levi-Civita derivative ${}^g\nabla$ to g. For instance,

$$\nabla_a v^c := \partial_a v^c + {}^g\Gamma^c_{ab} v^b,$$

where $v = v^a \partial_a$ is a vector field on X and ${}^g\Gamma^c_{ab}$ are the Christoffel symbols to (g_{ab}).

2- ∇ applied to tensor fields on Y equals some pull-back of the Levi-Civita derivative ${}^h\nabla$ to h. For instance,

$$\nabla_a w^k := (\partial_a \phi^i)(\partial_i w^k + {}^h\Gamma^k_{ij} w^j),$$

where $w = w^i \partial_i$ is a vector field on Y and ${}^h\Gamma^k_{ij}$ are the Christoffel symbols to (h_{ij}). Here $\nabla_a w^k$ is understood to depend on $y^l = \phi^l(x^c)$.
3- There are natural product rules for mixed quantities, the components of which carry both indices $a, b, ...$ and $i, j, ...$ For instance, the *differential* $d\phi$ of $\phi : X \longrightarrow Y$ with components $\partial_a \phi^i$ is a mixed tensor field. The covariant derivative $\nabla d\phi$ of $d\phi$ is called *second fundamental form* of ϕ. It has the components

$$\nabla_a \partial_b \phi^k = \partial_a \partial_b \phi^k - {}^g\Gamma^c_{ab} \partial_c \phi^k + {}^h\Gamma^h_{ij} (\partial_a \phi^i)(\partial_b \phi^j)$$

and the symmetry property

$$\nabla_a \partial_b \phi^k = \nabla_b \partial_a \phi^k.$$

More on calculus for maps between (pseudo-) Riemannian manifolds can be found in the literature, e.g. [4, 5].

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III. The Field Equations

The field theory for g and ϕ considered here is based on the Lagrangian

$$L = \kappa R - e, \tag{3.1}$$

which is the sum of the *gravitational Lagrangian* κR and the *matter Lagrangian* e. Here $R = R[g]$ denotes the scalar curvature of g, $\kappa \neq 0$ is a coupling constant and $e = e[\phi] = e[g, \phi]$ is given by (1.2).
The idea to couple a harmonic map, formerly also called *sigma model*, with Einstein's gravitation appeared in [10, 11, 12] and other early papers.
The following is well-known [10, 11, 12, 13, 14, 15, 16, 17, 18, 7, 8, 9]. We abbreviate $detg := det(g_{ab})$.

Proposition 3.1 *Variation of $L|detg|^{\frac{1}{2}}$ with respect to g yields the Einstein equation in the form*

$$\kappa(Ric - \frac{1}{2}Rg) = \phi^*h - eg. \tag{3.2}$$

If $m = dimX \geq 3$ then this is equivalent to

$$\kappa Ric = \phi^*h. \tag{3.3}$$

Variation of $L|detg|^{\frac{1}{2}}$ with respect to ϕ yields

$$tr(\nabla d\phi) = 0, \tag{3.4}$$

where $\nabla d\phi$ is the second fundamental form of ϕ and the trace tr refers to the metric g.

The right-hand side of (3.2)

$$T := \phi^*h - eg \tag{3.5}$$

is called *energy-momentum tensor of ϕ*. There holds $e = \frac{1}{2}tr(\phi^*h)$ and (3.5) is equivalent to

$$T - (m-2)^{-1}(trT) = \phi^*h.$$

Proposition 3.2 *From the field equation (3.4) for ϕ there follows that T is divergence-free:*

$$\nabla^b T_{ab} = 0.$$

The *proof* follows from the identity

$$\nabla^b T_{ab} = h_{ij}(\partial_a \phi^i)(tr\nabla d\phi)^j.$$

IV. Energy Conditions for a Wave Map

Let now the metric g have Lorentzian signature $(+ - ... -)$.

Definition 4.1 Let a symmetric two-form $T = T_{ab}dx^a dx^b$ on X be interpreted as an energy-momentum tensor field and let $v = v^a\partial_a$ be a unit timelike vector field on X, i.e., $v_a v^a \equiv g_{ab}v^a v^b = 1$. Then $T(v, v) \equiv$

$T_{ab}v^a v^b$ is called *energy density*, $I := T(\cdot, v)$ with components $I_a := T_{ab}v^b$ is called *momentum one-form*, and $J := I - T(v,v)v$ with components $J_a := I_a - T(v,v)v_a$ is called *proper momentum one-form*.

Physically, v is interpreted as the unit tangent vector to the world line of an observer. This observer measures the quantities $T(v,v)$, I, J.

Every unit timelike vector field $v = v^a\partial_a$ on X gives rise to a positive definite metric $g^+ = g^+_{ab}dx^a dx^b$ on X with components $g^+_{ab} = 2v_a v_b - g_{ab}$. The inverse $(g^{ab}_+) := (g^+_{ab})^{-1}$ has the representation $g^{ab}_+ = 2v^a v^b - g^{ab}$.

Theorem 4.1 *Consider the energy-momentum tensor*

$$T = \phi^* h - eg \tag{4.1}$$

of a map $\phi : X \longrightarrow Y$ between (X,g) and (Y,h). The energy density equals

$$T(v,v) = e_+ := e[\phi, g_+] \equiv \frac{1}{2} g^{ab}_+ (\partial_a \phi^i)(\partial_b \phi^j) h_{ij}. \tag{4.2}$$

It is a positive definite quadratic form in $d\phi$. The momentum one-form I obeys the estimate

$$e^2 \leq |I|^2 \leq e_+^2, \tag{4.3}$$

where

$$|I|^2 := I_a I^a \equiv g^{ab} I_a I_b. \tag{4.4}$$

Proof:
Let us abbreviate $f := \phi^* h$ with components $f_{ab} := (\phi^* h)_{ab} = (\partial_a \phi^i)(\partial_b \phi^j)h_{ij}$. We calculate

$$\begin{aligned} T(v,v) &= T_{av} v^a v^b = (f_{ab} - e g_{ab}) v^a v^b \\ &= f_{ab} v^a v^b - e = \tfrac{1}{2}(2v^a v^b - g^{ab}) f_{ab} = \tfrac{1}{2} g^{ab}_+ f_{ab} = e_+. \end{aligned}$$

The proper momentum one-form J is orthogonal to v, that means $J_a v^a = 0$. Considering that, we find that

$$\begin{aligned} 0 &\leq g^{ab}_+ J_a J_b = -g^{ab} J_a J_b \\ &= -g^{ab} J_a (I_b - e_+ v_b) = -g^{ab} J_a I_b \\ &= -g^{ab}(I_a - e_+ v_a) I_b = -I_a I^a + e_+^2. \end{aligned}$$

Thus, the right-hand side inequality of (4.3) is proved. In order to prove the left-hand side of (4.3), we start with the remark that the matrix (f_{ab}) is positive semi-definite. Let us consider a fixed point $x_0 \in X$ and use coordinates x^a such that

$$v^a = \delta^a_0, \quad g^{ab}_+ = \delta^{ab} \tag{4.5}$$

in that very point x_0. Actually, such coordinates exist. The following 2×2 subdeterminants of (f_{ab}) are non-negative:

$$f_{00} f_{11} - f_{10} f_{10} \geq 0,$$

$$f_{00} f_{22} - f_{20} f_{20} \geq 0,$$

...

$$f_{00}f_{mm} - f_{m0}f_{m0} \geq 0.$$

Let us sum up:

$$f_{00}f_{aa} - f_{a0}f_{a0} \geq 0. \tag{4.6}$$

Here a summation convention applies to the index a and the coordinate conditions (4.5) are assumed. The inequality (4.6) can be brought into a coordinate-invariant form

$$g_+^{ab}(f_{ab}v^c v^d f_{cd} - v^c f_{ac} v^d f_{bd}) \geq 0.$$

Here we insert

$$g_+^{ab} f_{ab} = 2e_+, \quad v^c v^d f_{cd} = e + e_+,$$

$$v^c f_{ac} = v^c(T_{ac} + eg_{ac}) = I_a + ev_a,$$

$$g_+^{ab}(I_a + ev_a)(I_b + ev_b) = 2e_+(e + e_+) + e^2 - |I|^2.$$

Taking all this together, the left-hand side inequality of (4.3) follows.
The conditions

$$T(v,v) \geq 0, \quad |I|^2 \geq 0$$

together form the *dominant energy condition*, which expresses that the energy density is non-negative and that the momentum I is causal. The latter condition physically means that the momentum I propagates with a velocity which is not greater than the velocity of light.
The so-called *strongy energy condition* also holds in the present situation, namely in the form

$$(m-2)T(v,v) \geq trT.$$

Theorem 4.2 *Consider the energy-momentum tensor* $T = T_{ab}dx^a dx^b$ *to* ϕ *as above and lightlike vector fields* $l = l^a\partial_a$, $n = n^a\partial_a$ *such that* $l^a n^a \equiv g_{ab}l^a n^b = 1$. *Then*

$$T(l,l) \equiv T_{ab}l^a l^b = h(\phi_* l, \phi_* l) \geq 0, \tag{4.7}$$

and the one-form $I := T(\cdot, l)$ *with components* $I_a := T_{ab}l^b$ *obeys*

$$0 \leq |I|^2 \leq 2T(l,l)T(l,n). \tag{4.8}$$

Proof:
Assertion (4.7) follows from

$$T(l,l) = (f_{ab} - eg_{ab})l^a l^b = f_{ab}l^a l^b = h_{ij}(l^a\partial_a\phi^i)(l^b\partial_b\phi^j).$$

The projection tensor p with components

$$p_{ab} := l_a n_b + n_a l_b - g_{ab}$$

is a useful tool. It is orthogonal to l and n, i.e.

$$p_{ab}l^b = p_{ab}n^b = 0,$$

and it is positive semi-definite. Hence

$$0 \le p^{ab} I_a I_b = (2l^a n^b - g^{ab}) I_a I_b = 2T(l,l)T(l,n) - |I|^2,$$

which proves the right-hand side inequality of (4.8)
Below we will also use

$$p^{ab} T_{ab} = (2l^a n^b - g^{ab}) T_{ab} = 2T(l,n) - trT = 2T(l,n) + (m-2)e.$$

Let us, in order to complete the proof, consider a fixed point $x_0 \in X$ and use coordinates x^a such that

$$l^a = l_0^a, \quad n^a = \delta_1^a, \quad (p_{ab}) = diag(0,0,1,...,1)$$

in that very point x_0, where $diag$ indicates a diagonal matrix. Formally the same 2×2 subdeterminants of (f_{ab}) as in the preceding proof are non-negative. Their sum is now in another way transformed into a coordinate-invariant form

$$p^{ab}[f_{ab}(l^c l^d f_{cd}) - (l^c f_{ac})(l^d f_{bd})] \ge 0.$$

Here we insert

$$p^{ab} f_{ab} = p^{ab}(T_{ab} + e g_{ab}) = p^{ab} T_{ab} - (m-2)e = 2T(l,n),$$

$$l^c l^d f_{cd} = T(l,l), \quad p^{ab}(l^c f_{ac})(l^d f_{bd}) = p^{ab} I_a I_b = 2T(l,l)T(l,n) - |I|^2.$$

The result $|I|^2 = g^{ab} I_a I_b \ge 0$ follows.
Physically, theorem (4.2) can be interpreted in terms of a fictional observer which moves faster and faster. In the limit, he reaches the velocity of light and v turns to l. The energy density $T(l,l)$ then remains non-negative and the momentum I remains causal.

Corollary 4.3 *There holds* $T(l,n) \ge 0$. *Especially,* $T(l,n) = 0$ *iff* $I_a = T(l,l)n_a$.

Proof:
The formulas (4.7), (4.8) imply $T(l,n) \ge 0$. If $T(l,n) = 0$ then $|I|^2 = 0$ and

$$0 = p^{ab}(l^c f_{bc}) = p^{ab} I_b = (l^a n^b + n^a l^b - g^{ab}) I_b = T(l,l)n^a - I^a$$

V. Implications of the Einstein Equation

Let us study

$$\kappa Ric = \phi^* h, \tag{5.1}$$

for given background (Y,h) as a relation between g and ϕ. Contraction with g^{-1} yields

$$\kappa R = 2e. \tag{5.2}$$

Double Contraction with a vector field $v = v^a \partial_a$ on X yields

$$\kappa Ric(v,v) = h(\phi_* v, \phi_* v), \tag{5.3}$$

with the interpretation that $y = \phi(x)$ is to be inserted into the right-hand side of (5.3); $\phi_* v$ denotes the push-forward of v with respect to ϕ. As a conclusion, $\kappa Ric(v, v)$ is positive definite in $\phi_* v$ and is positive semi-definite in v.

Proposition 5.1 *From (5.1) there follows that Ric and $d\phi$, interpreted as linear map, have the same rank:*

$$r := rank(Ric) = rank(d\phi). \tag{5.4}$$

In particular:
$r = 0$ iff ϕ is constant.
$r = m \equiv dimX$ iff ϕ is an immersion.
$r = n \equiv dimY$ iff ϕ is a submersion.
$r = m = n$ iff ϕ is a local diffeomorphism.

The *proof* of (5.4) is an exercise in linear algebra.
Note that $r = 0$ means that (X, g) is Ricci flat, i.e., $Ric = 0$.

Proposition 5.2 *If (5.1) holds then the conditions*

$$Ric(v, v) = 0, \tag{5.5}$$

$$Ric(\cdot, v) = 0, \tag{5.6}$$

$$\phi_* v = 0 \tag{5.7}$$

for a vector field $v = v^a \partial_a$ on X are equivalent to each other. Moreover, they imply

$$\pounds_v Ric = 0, \tag{5.8}$$

where $\pounds_v$ denotes the Lie derivative with respect to v.

Proof:
Equation (5.3) in components reads

$$\kappa R_{ab} v^a v^b = h_{ij} (\phi_* v)^i (\phi_* v)^j,$$

where $(\phi_* v)^i = v^a \partial_a \phi^i$. Moreover, (5.1) implies

$$\kappa R_{ab} v^b = h_{ij} (\partial_a \phi^i)(\phi_* v)^j.$$

These formulas and the definiteness of h give the first assertion. Next, we use comoving coordinates x^a, which are adapted to v, that means $v^a = \delta^a_0$, and we get

$$(\phi^* v)^i = v^a \partial_a \phi^i = \partial_0 \phi^i,$$

$$\kappa \pounds_v R_{ab} = \kappa \partial_0 R_{ab} = \partial_0 (\partial_a \phi^i \partial_b \phi^j h_{ij}(\phi^k)).$$

If $\partial_0 \phi^i = 0$ then also $\partial_0 R_{ab} = 0$. This fact can be translated into the second assertion.

Proposition 5.3 *If the Ricci tensor vanishes on the vectors of some integrable distribution in the tangent bundle TX and (5.1) holds then ϕ is constant on each leaf of the foliation to the distribution.*

Proof:
A distribution of rank s in TX is integrable iff it admits adapted coordinates x^a, which means that the distribution is locally spanned by the coordinate vector fields $\partial_1, \partial_2, ..., \partial_s$. The assumption becomes

$$Ric(\partial_a, \partial_b) = 0 \quad for\ a, b = 1, 2, ..., s.$$

Proposition (5.2) then implies

$$\partial_1 \phi^i = 0,\ \partial_2 \phi^i = 0,\ ...,\ \partial_s \phi^i = 0.$$

Hence ϕ^i does not depend on $x^1, x^2, ..., x^s$ and is constant if the point x varies in a leaf of the foliation, i.e., if $x^{s+1} = const.,\ ...,\ x^m = const.$

Proposition 5.4 *The Einstein equation (5.1) implies*

$$\kappa(\nabla_a R_{bc} + \nabla_b R_{ca} - \nabla_c R_{ab}) = 2h_{ij}(\nabla_a \partial_b \phi^i)(\partial_c \phi^j). \tag{5.9}$$

Proof:
Covariant differentiation of (5.1) gives

$$\kappa \nabla_c R_{ab} = h_{ij}[(\nabla_c \partial_a \phi^i)(\partial_b \phi^j) + (\partial_a \phi^i)(\nabla_c \partial_b \phi^j)].$$

Some rearrangement yields (5.9).

Proposition 5.5 *The Einstein equation (5.1) implies*

$$h(tr(\nabla d\phi), d\phi) = 0. \tag{5.10}$$

This equation for a submersion ϕ implies the harmonic or wave map equation (3.4).

Proof:
The Einstein tensor $Ric - \frac{1}{2}Rg$ is divergence-free. This fact and (5.9) imply

$$2h(tr(\nabla d\phi), d\phi)_c \equiv 2h_{ij} tr(\nabla d\phi)^i (\partial_c \phi^j) = \kappa g^{ab}(\nabla_a R_{bc} + \nabla_b R_{ca} - \nabla_c R_{ab}) = 0.$$

If ϕ is a submersion, then the matrix with elements $h(\cdot, d\phi)_{ic} = h_{ij}\partial_c \phi^j$ has maximal rank and therefore (5.10) implies (3.4).

Proposition 5.6 *If the Ricci tensor is covariantly constant, i.e., $\nabla Ric = 0$, and the Einstein equation (5.1) holds for a submersion ϕ, then ϕ is totally geodesic, that means*

$$\nabla d\phi = 0. \tag{5.11}$$

Proof:
If $\nabla Ric = 0$ then (5.9) reduces to $h_{ij}(\nabla_a \partial_b \phi^i)(\partial_c \phi^j) = 0$. If, additionally, ϕ is a submersion, then (5.11) follows by means of the rank argument already used in the preceding proof.

The next proposition needs some preparation. A diffeomorphism $f : X \longrightarrow X$ is called a *Ricci symmetry* iff

$$f^{*}Ric = Ric. \tag{5.12}$$

A vector field $v = v^a \partial_a$ on X is called an *infinitesimal Ricci symmetry* or a *Ricci collineation* iff

$$\pounds_v Ric = 0. \tag{5.13}$$

It is well known that the flow f_t for $t \in I$ of a Ricci collineation v is a one-parameter family of Ricci symmetries, i.e. $f_t^{*}Ric = Ric$. Here $x = f_t(x_0)$ by definition represents the solution of the initial-value problem

$$\frac{dx}{dt} = v(x), \quad x|_{t=0} = x_0$$

and I denotes an open interval which contains 0.

Proposition 5.7 *Let $v = v^a \partial_a$ be a Ricci collineation of (X, g). Then the Einstein equation (5.1) implies that $\phi : X \longrightarrow Y$ is invariant under the flow f_t for $t \in I$ of v, that means*

$$\phi \circ f_t = \phi. \tag{5.14}$$

Proof:
Let us again use comoving coordinates such that $v^a = \delta^a_0$. In these co-ordinates, f_t is expressed by a translation $x^0 \mapsto x^0 + t$, $x^1 \mapsto x^1$, ..., $x^{m-1} \mapsto x^{m-1}$. We know already from the proof of proposition (5.2) $\partial_0 \phi^i = 0$, i.e. each ϕ^i is independent of x^0. Hence $\phi^i = \phi^i(x^a)$ does not change under $x^0 \mapsto x^0 + t$, which is just expressed by (5.14).

The following definition is useful.
Definition 5.1 A property of subsets of a manifold X holds *globally* if it is valid for X. It holds *locally* if every point $x_0 \in X$ has a neighborhood U such that the property is valid for U.

Theorem 5.8 *Let $\phi : X \longrightarrow Y$ be a submersion between smooth manifolds X, Y and let Y be equipped with a positive definite metric h.*
1- Locally there is a positive definite metric g on X such that ϕ becomes a harmonic map (X, g) and (Y, h).
2- Locally there is a Lorentzian metric g on X such that ϕ becomes a wave map.

Proof:
We consider (5.1) and use the fact that the *problem of prescribed Ricci curvature* is locally solvable in the two cases [19, 20]. More precisely: cf., eg.

1- Einstein's equation (5.1) locally has a positive definite solution g. It can be constructed, e.g., through some boundary value problem [19]. By assumption, ϕ is a submersion; proposition 5.5 implies $tr(\nabla d\phi) = 0$.
2- Einstein's equation (5.1) locally has a Lorentzian solution g. It can be constructed, e.g., through some Cauchy initial value problem cf., e.g. [20]. An argument like in item 1 completes the proof.

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VI. Product and Warped Product Source Manifolds

Definition 6.1: The *product* (X, g) of two (pseudo-) Riemannian manifolds $('X, 'g)$, $(''X, ''g)$ is given by $X = 'X \times ''X$ as a product of manifolds and by

$$g(u, v) = 'g('u, 'v) \; + \; ''g(''u, ''v)$$

where u, v are vector fields on X, $'u, 'v$ are the push-forwards of u, v with respect to the projection $X \longrightarrow 'X$, and $''u$, $''v$ are the push-forwards of u, v with respect to the projection $X \longrightarrow ''X$.
We write then

$$g = 'g \oplus ''g,$$

$$dim'X = 'm, \quad dim''X = ''m, \quad m = 'm + ''m.$$

We apply the index convention

$$'a, \, 'b, \, 'c, \, ... = 1, 2, ..., 'm; \quad ''a, \, ''b, \, ''c, \, ... = 'm + 1, \, 'm + 2 \, , ..., m.$$

Definition 6.2: The *warped product* (X, g) is given by $X = 'X \times ''X$ like above and by

$$g(u, v) = 'g('u, 'v) \; + \; w^2 \, ''g(''u, ''v),$$

where the *warping function* w is a map $'X \longrightarrow \Re$ with positive values $w > 0$.
We write then

$$g = 'g \oplus w^2 \, ''g,$$

The following is known.

Proposition 6.1 *If (X, g) is the product of $('X, 'g)$, $(''X, ''g)$ then the Einstein equation $\kappa Ric = \phi^* h \equiv h(d\phi, d\phi)$ decomposes into the two Einstein equations*

$$\kappa 'Ric = h('d\phi, 'd\phi), \quad \kappa'' Ric = h(''d\phi, ''d\phi) \tag{6.1}$$

and the orthogonality condition with respect to h:

$$h('d\phi, ''d\phi) = 0, \tag{6.2}$$

in components

$$\kappa \, 'R_{'a \, 'b} = h_{ij}(\partial_{'a} \phi^i)(\partial_{'b} \phi^j), \quad \kappa \, ''R_{''a \, ''b} = h_{ij}(\partial_{''a} \phi^i)(\partial_{''b} \phi^j), \tag{6.3}$$

$$h_{ij}(\partial_{'a} \phi^i)(\partial_{''b} \phi^j) = 0 \tag{6.4}$$

Proposition 6.2 *If (X, g) is the warped product of $('X, 'g)$, $(''X, ''g)$ with warping function w then the Einstein equation $\kappa Ric = \phi^* h \equiv h(d\phi, d\phi)$ decomposes into*

$$\kappa('Ric - ''m w^{-1} \, '\nabla' dw) = h('d\phi, 'd\phi), \tag{6.5}$$

$$\kappa(''Ric - \frac{1}{''m} w^{2-''m} \, ''\Delta w^{''m} \, ''g) = h('d\phi, ''d\phi), \tag{6.6}$$

$$h('d\phi, ''d\phi) = 0. \tag{6.7}$$

The trace parts of (6.5), (6.6) read

$$\kappa('R - ''mw^{-1}\,'\Delta w) = 2\,'e, \tag{6.8}$$

$$\kappa(''R - w^{2-''m}\,'\Delta w^{''m}) = 2\,''e. \tag{6.9}$$

The proof is an exercise in higher differential geometry

We say that $\phi : 'X \times ''X \longrightarrow Y$ does not depend on $'x$ iff the restriction $\phi(\cdot, ''x) : 'X \longrightarrow Y$ is a constant map for every $''x \in ''X$. We say that ϕ does not depend on $''x \in ''X$ in the analogous situation.

Theorem 6.3 *Let in the situation of proposition 6.2 the restriction $\phi('x, \cdot) : ''X \longrightarrow X$ be a submersion for every $'x \in 'X$. Then ϕ does not depend on $'x$.*

Proof:

If every $\phi('x, \cdot)$ is a submersion then the quantities $h_{ij}\partial_{''b}\phi^j$ in (6.4) form a matrix of maximal rank, and (6.4) implies $\partial_{'a}\phi^i = 0$, which gives the assertion.

Theorem 6.4 *Let in the situation of proposition 6.2 the first factor $('X, 'g)$ be properly Riemannian and closed. Then the following holds.*

(i) The symmetric two-form $\kappa''Ric$ is positive semi-definite.
(ii) If $\kappa''Ric$ is not everywhere positive then $w = const.$
(iii) $\kappa \int_{'X} w\,'Rd'vol \geq 0$.
(iv) If $\int_{'X} w\,'Rd'vol = 0$ then $w = const.$ and ϕ does not depend on $'x$.

Proof:

(i) Multiply (6.6) by $w^{''m-2}$ and evaluate the two-forms at a vector field $''v \neq 0$ on $''X$:

$$\kappa[w^{''m-2}\,''Ric(''v, ''v) - \frac{1}{''m}('\Delta w^{''m})|''v|^2] = w^{''m-2}h(''d\phi(''v), ''d\phi(''v)). \tag{6.10}$$

Integrate this equation over $'X$; the Laplacian term does not contribute, hence

$$\kappa''Ric(''v, ''v)\int_{'X} w^{''m-2}d'vol = \int_{'X} w^{''m-2}h(''d\phi(''v), ''d\phi(''v))d'vol.$$

Both the integrals are non-negative, hence $\kappa''Ric(''v, ''v) \geq 0$ for every $''v$.
(ii) If $''Ric(''v, ''v)(''x_0) = 0$ for some point $''x_0 \in ''X$ then

$$\int_{'X} w^{''m-2}h(''d\phi(''v(''x_0)),\ ''d\phi(''v('x_0))d'vol = 0,$$

which implies $''d\phi(''v(''x_0)) = 0$. Evaluation of (6.10) at the point $''x_0$ reduces (6.10) to

$$('\Delta w^{''m})|''v(''x_0)|^2 = 0.$$

We can assume $|''v(''x_0)|^2 \neq 0$; hence $w^{''m}$ is a harmonic function. A harmonic function on a closed manifold is constant.
(iii) Multiply (6.8) by w and integrate then over $'X$. The Laplacian term does not contribute; hence

$$\kappa\int_{'X} w\,'Rd'vol = \int_{'X} v\,'ed'vol \geq 0.$$

(iv) The last integral vanishes only if $'e = 0$, which implies $'d\phi = 0$, hence $\phi(\cdot, ''x) = const$ for fixed $''x \in ''X$. But then $''e(\cdot, ''x) = const$ and the standard separation argument can be applied to

$$\kappa w^{2-'m} \, '\Delta w^{''m} = \kappa'' R - 2''e. \tag{6.11}$$

Thus both sides of (6.11) equal a constant c. Integration of

$$\kappa' \Delta w^{''m} = cw^{''m-2}$$

yields $c = 0$. Hence $w^{''m}$ is a harmonic function on the closed manifold $'X$. We find $w^{''m} = const$, $w = const$.

Proposition 6.5 *Let in the situation of the preceding theorem the second factor $(''X, ''g)$ be properly Riemannian with vanishing scalar curvature: $''R = 0$. Then $w = const$ and ϕ does not depend on $''x \in ''X$.*

Proof:
Now equation (6.9) reduces to

$$-\kappa' \Delta w^{''m} = 2w^{''m-2} \; ''e$$

and we have $''e \geq 0$. Integration over the closed manifold $'X$ yields

$$0 = \int_{'X} w^{''m-2} \; ''ed'vol,$$

which implies

$$''e \equiv ''tr \, h(''d\phi, ''d\phi) = 0.$$

Hence $''d\phi = 0$, i.e. ϕ does not depend on $''x$, and $w^{''m}$ becomes a harmonic function. We arrive at $w^{''m} = const$, $w = const$.

Example 6.1. Let in the situation of proposition 6.2 the first factor $('X, 'g)$ be the unit circle S^1. It is a flat properly Riemannian closed manifold. Theorem 6.4 implies that $w = const$ and ϕ does not depend on $'x$.

Example 6.2. A static metric $g = w^2 dt^2 - 'g$ can be interpreted as a warped product metric on $X = 'X \times ''X$ where there the second factor $''X$ is one-dimensional. The proof of proposition 6.5 works, with a slight modification, for this case. Hence Einstein's equation $\kappa Ric = \phi^* h$ implies that $w = const$ and ϕ does not depend on $t \in ''X$.

VII. Source Manifolds with Radiation Conditions

Lichnerowicz [21] proposed *conditions of pure radiation* for a Lorentzian manifold (X, g):

$$R_{abcd} l^d = 0, \quad R_{ab[cd} l_{e]} = 0,$$

where R_{abcd} are the components of the Riemann curvature tensor and $l = l^a \partial_a$ is a lightlike vector field. Bel [22] proposed weaker conditions:

$$R_{abcd} l^b l^d = 0, \quad l^b R_{ab[cd} l_{e]} = 0, \quad l_{[f} R_{ab][cd} l_{e]} = 0.$$

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There are also radiation conditions for the Ricci tensor Ric or for the *Einstein tensor* $G := Ric - \frac{1}{2}Rg$ with components

$$G_{ab} := R_{ab} - \frac{1}{2}Rg_{ab},$$

namely

$$R_{ab}l^b = 0, \quad R_{a[b}l_{c]} = 0,$$

$$G_{ab}l^b = 0, \quad G_{a[b}l_{c]} = 0.$$

One of the present authors studied radiation conditions in [23, 24].

Theorem 7.1 *If the Einstein equation $\kappa Ric = \phi^* h$ holds then the conditions*

$$G_{ab}l^b = 0, \tag{7.1}$$

$$R_{a[b}l_{c]} = 0 \tag{7.2}$$

for a lightlike vector field $l = l^a\partial_a$ are equivalent to each other.

Proof:
There is another lightlike vector field $n = n^a\partial_a$ such that $l^a n_a = 1$. Then the sum $v := l + n$ is timelike with $v^a v_a = 2$ and $g^+_{ab} = v_a v_b - g_{ab}$ are the components of a positive definite metric g_+.

Let us consider

$$\psi^{\,i}_{\,a} := 2v^b l_{[a}\partial_{b]}\phi^i \equiv l_a(\phi_* v)^i - \partial_a\phi^i$$

and calculate

$$g^{ab}_+ h_{ij}\psi^{\,i}_{\,a}\,\psi^{\,j}_{\,b} = -g^{ab}h_{ij}\psi^{\,i}_{\,a}\,\psi^{\,j}_{\,b} = h_{ij}(\phi_* v)^i(\phi_* l)^j - e = \kappa G_{ab}v^a l^b.$$

Here we made use of

$$g^{ab}_+ = v^a v^b - g^{ab}, \quad v^a\psi^{\,i}_{\,a} = 0$$

and of $\kappa Ric = \phi_* h$. If $G_{ab}l^b = 0$ then the above positive definite expression vanishes and we get

$$\psi^{\,i}_{\,a} = 0, \quad \partial_a\phi^i = l_a(\phi_* v)^i,$$

$$\kappa R_{ab} = h_{ij}(\partial_a\phi^i)(\partial_b\phi^j) = l_a l_b h(\phi_* v, \phi_* v).$$

Conversely, from $R_{ab} = rl_a l_b$ with some scalar r there follow $R = 0$ and (7.1).

We here dwell again on the fact that to every smooth vector field $v = v^a\partial_a$ on X there are comoving coordinates $x^a = x^0, x^1, ..., x^{m-1}$, which means $v^a = \delta^a_0$. The adaptedness of coordinates is preserved by coordinate transformations of the form

$$\bar{x}^0 = x^0 + f(x^i), \quad \bar{x}^i = \bar{x}^i(x^j). \tag{7.3}$$

We apply in this section the index convention

$$a, b, c, ... = 0, 1, 2, ..., m-1;$$

$$i, j, k, ... = 1, 2, ..., m-1;$$

$$I, J, K, ... = 2, 3, ..., m-1.$$

Proposition 7.2 *A Lorentzian manifold (X, g) admits a lightlike*
... hypersurface-orthogonal Killing vector field $l = l^a\partial_a$, that means

$$l_{[c}\nabla_a l_{b]} = 0, \quad \nabla_{(a}l_{b)} = 0,$$

iff in coordinates adapted to l the metric assumes the form

$$g = 2g_{01}dx^0dx^1 + g_{ij}dx^idx^j, \tag{7.4}$$

where g_{01}, g_{ij} do not depend on x^0. The component $g_{01} = g_{01}(x^k)$ is invariant under gauge transformations (7.3) and the part $g_{IJ}dx^Idx^J$ of (7.4) shows tensorial behavior under the part $\bar{x}^i = \bar{x}^i(x^j)$ of (7.3). Moreover, the matrix $(g_{IJ}) = (g_{IJ}(x^k))$ is negative definite.
... covariantly constant vector field $l = l^a\partial_a$, that means $\nabla_a l_b = 0$, iff in coordinates adapted to l the metric assumes the form

$$g = 2dx^0dx^1 + g_{ij}dx^idx^j, \tag{7.5}$$

where the components g_{ij} do not depend on x^0.
... covariantly constant vector field $l = l^a\partial_a$ such that the Bel condition

$$l_{[e}R_{ab][cd}l_{f]} = 0 \tag{7.6}$$

holds iff there are coordinates adapted to l such that

$$g = 2g_{01}dx^0dx^1 + g_{11}(dx^1)^2 + 2g_{1I}dx^1dx^I - dx^Idx^I, \tag{7.7}$$

where g_{11}, g_{1I} do not depend on x^0 and summation over I is applied.
... covariantly constant vector field $l = l^a\partial_a$ such that the Lichnerowicz condition

$$l_{[e}R_{ab]cd} = 0 \tag{7.8}$$

holds iff there are coordinates adapted to l such that

$$g = 2g_{01}dx^0dx^1 + g_{11}(dx^1)^2 - dx^Idx^I, \tag{7.9}$$

where g_{11} does not depend on x^0 and summation over I is applied.

All these facts together with *proof* and additional information are given in the papers [24, 23].

A Lorentzian manifold (X, g) which admits a covariantly constant lightlike vector $l = l^a\partial_a$ is called a *plane-fronted gravitational wave with parallel rays*, abbreviated *pp-wave*. Note that from $\nabla_a l_b = 0$ and the Ricci identity there follows the Lichnerowicz condition

$$R_{abcd}l^d = 0.$$

Theorem 7.3 *A metric (7.4) satisfies an Einstein equation $\kappa Ric = \phi^*h$ iff $g_{01} = g_{01}(x^1, x^K)$ is a harmonic function of $x^K = x^2, x^3, ..., x^{m-1}$ with respect to the positive definite metric (which depends on x^1 as a parameter) $-g_{IJ}dx^Idx^J$.*

Proof:
Some calculation gives the components

$$R_{00} = 0, \quad R_{01} = \frac{1}{2}\Delta g_{01}$$

of the Ricci tensor $Ric = R_{ab}dx^a dx^b$, where Δ denotes the Laplace operator with respect to $-g_{IJ}dx^I dx^J$. By proposition 5.2, from $R_{00} \equiv R_{ab}l^a l^b = 0$ and $\kappa Ric = \phi^* h$ there follows $R_{01} \equiv R_{1b}l^b = 0$. The assertion follows.

Theorem 7.4 *Let $m = dimX = 4$. A metric of the form (7.7) satisfies an Einstein equation $\kappa Ric = \phi^* h$ iff it satisfies (7.8), that means iff it can be brought into the form (7.9).*

Proof:
Calculation of Ricci components gives $R_{IJ} = 0$; in particular $R_{II} = 0$ (without summation). By Proposition 5.2, from this and $\kappa Ric = \phi^* h$ there follows $R_{1I} = 0$. For $m = 4$, there are only two independent curvature components of type R_{iJKL}, namely

$$R_{1223} = -R_{13}, \quad R_{1323} = R_{12}.$$

Thus we get $R_{iJK2} = 0$ which is expressed by (7.9) in a coordinate invariant way.

VIII. Discussion

The literature on harmonic or wave maps is very extensive. There are good surveys on harmonic maps [4, 5]. Work on such maps in the role of matter fields coupled with gravitation began about 1980 [10, 11]. One of the authors of this paper worked, with coauthors, already on this subject; we refer to the paper [17] and the unpublished preprint [25].

The Einstein equation $\kappa Ric = \phi^* h$ or $\kappa G = T$, where $G = Ric - \frac{1}{2}Rg$ denotes the Einstein tensor and $T = \phi^* h - eg$ the energy-momentum tensor of ϕ, exhibits some remarkable properties:

- The rank of Ric, taken as a linear map, equals the rank of the differential $d\phi$ (Proposition 5.1).

- The symmetries of the Ricci tensor Ric and of the map ϕ are closely related to each other (Propositions 5.2, 5.3, 5.7).

- If ϕ is submersive then the Einstein equation implies the harmonic or wave map equation (Proposition 5.5; cf. also Proposition 5.6).

- In the Lorentzian case there are identities and estimates for the energy-momentum tensor T which indicate a physically good behavior of T (Proposition 3.2, Theorems 4.1, 4.2).

- In the Lorentzian case there is a tendency to enhance radiation conditions. That means, the Einstein equation leads from one condition to a stronger condition (Section 7).

There is also a situation where the Einstein equation serves as an auxiliary construction: for a given submersion ϕ there locally exists a metric g on X which makes ϕ to a harmonic or wave map (Theorem 5.8).

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One paper cannot touch all aspects of a subject. We did not discuss here:

- Bochner-Weitzenböck technique [5, 13, 14, 15],
- consequences of second variation formulas,
- factorizations of the map ϕ [18],
- exact solutions [10, 7, 8, 9, 12, 13, 14, 15, 16, 11],
- coupling of ϕ to a gravitational theory other than Einstein's theory.

These topics are by far not exhausted and could be subjects of further research.

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- Author Name in Font Size of 11 with one column as of Title.
- Abstract Font size of 9 Bold, "Abstract" word in Italic Bold.
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- Two Column with Equal Column with of 3.38 and Gaping of .2
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- Paragraph before Spacing of 1 pt and After of 0 pt.
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- Large Images must be in One Column
- Numbering of First Main Headings (Heading 1) must be in Roman Letters, Capital Letter, and Font Size of 10.
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You can use your own standard format also.
Author Guidelines:

1. General,

2. Ethical Guidelines,

3. Submission of Manuscripts,

4. Manuscript's Category,

5. Structure and Format of Manuscript,

6. After Acceptance.

1. GENERAL

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Complete support for both authors and co-author is provided.

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Original research paper: Such papers are reports of high-level significant original research work.

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Research articles: These are handled with small investigation and applications

Research letters: The letters are small and concise comments on previously published matters.

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The recommended size of original research paper is less than seven thousand words, review papers fewer than seven thousands words also.Preparation of research paper or how to write research paper, are major hurdle, while writing manuscript. The research articles and research letters should be fewer than three thousand words, the structure original research paper; sometime review paper should be as follows:

Papers: These are reports of significant research (typically less than 7000 words equivalent, including tables, figures, references), and comprise:

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(c) Up to ten keywords, that precisely identifies the paper's subject, purpose, and focus.

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(e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition; sources of information must be given and numerical methods must be specified by reference, unless non-standard.

(f) Results should be presented concisely, by well-designed tables and/or figures; the same data may not be used in both; suitable statistical data should be given. All data must be obtained with attention to numerical detail in the planning stage. As reproduced design has been recognized to be important to experiments for a considerable time, the Editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned un-refereed;

(g) Discussion should cover the implications and consequences, not just recapitulating the results; conclusions should be summarizing.

(h) Brief Acknowledgements.

(i) References in the proper form.

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Search engines for most searches, use Boolean searching, which is somewhat different from Internet searches. The Boolean search uses "operators," words (and, or, not, and near) that enable you to expand or narrow your affords. Tips for research paper while preparing research paper are very helpful guideline of research paper.

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References

References follow the Harvard scheme of referencing. References in the text should cite the authors' names followed by the time of their publication, unless there are three or more authors when simply the first author's name is quoted followed by et al. unpublished work has to only be cited where necessary, and only in the text. Copies of references in press in other journals have to be supplied with submitted typescripts. It is necessary that all citations and references be carefully checked before submission, as mistakes or omissions will cause delays.

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TECHNIQUES FOR WRITING A GOOD QUALITY RESEARCH PAPER:

1. Choosing the topic: In most cases, the topic is searched by the interest of author but it can be also suggested by the guides. You can have several topics and then you can judge that in which topic or subject you are finding yourself most comfortable. This can be done by asking several questions to yourself, like Will I be able to carry our search in this area? Will I find all necessary recourses to accomplish the search? Will I be able to find all information in this field area? If the answer of these types of questions will be "Yes" then you can choose that topic. In most of the cases, you may have to conduct the surveys and have to visit several places because this field is related to Computer Science and Information Technology. Also, you may have to do a lot of work to find all rise and falls regarding the various data of that subject. Sometimes, detailed information plays a vital role, instead of short information.

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7. Use right software: Always use good quality software packages. If you are not capable to judge good software then you can lose quality of your paper unknowingly. There are various software programs available to help you, which you can get through Internet.

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22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. **Think technically:** Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

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33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

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To make a paper clear

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Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
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In every sections of your document

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· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

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· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

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The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

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- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

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- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
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Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

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Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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