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This is to certify that the project work entitled *"Analysis of muon spin relaxation data for caged type superconductor $Lu_5Rh_6Sn_{18}$"* has been carried out by **Indranil Banerjee** under my supervision in the 6th semester (Session: 2016-2019).

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This is to certify that the project work entitled *"Principle of Equivalence and its consequence"* has been carried out by **Rwitabrata Chakravorty** under my supervision in the 6^{th} semester (Session: 2016-2019).

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This is to certify that the project work entitled *"Density Matrix"* has been carried out by **Samar Murmu** under my supervision in the 6th semester (Session: 2016-2019).

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This is to certify that the project work entitled *"Investigation of Iron based superconductor ThAsFeN using μSR measurements"* has been carried out by **Debasish Bhattacharyya** under my supervision in the 6^{th} semester (Session: 2016-2019).

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This is to certify that the project work entitled *"A brief review of superconductivity and thorough study of superconducting state of BiS_2 superconductor"* has been carried out by **Sayan Koley** under my supervision in the 6th semester (Session: 2016-2019).

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This is to certify that the project work entitled *"Three body problem and its solution under restricted condition"* has been carried out by **Krishnendu Maji** under my supervision in the 6th semester (Session: 2016-2019).

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ON THE EVOLUTION OF STAR AND FORMATION OF NEUTRON STAR

Sinchan Mandal Roll no: 205
Dept. of Physics
RAMAKRISHNA MISSION VIDYAMANDIRA

Introduction:

Our universe is large and the constituent elements of the universe is also large. Of which star plays the most important role. Moreover, we are said to be born from the ashes of a star. So, it will not be fruitless to examine the birth, evolution and death of a star in light of physical theories in order to better understand the universe.

Abstract:

In the above project topic, we will discuss the formation of a main sequence star, the stability of the star and the death of the star and formation of neutron star. Under the formation of stars, we will discuss the necessary condition for star formation and the virial theorem. Then how a star reaches the stable period and the equation for hydrostatic equilibrium. Then we will discuss about the death of the star and how it eventually led to the formation of neutron star.

- **The formation of a main sequence star:**

In our universe there are vast molecular clouds with masses in the range (10^5–10^6)solar masses with temperature (10-100) k and densities (10-10^4) cm^{-3}. In order to form stars from this gas clouds, the clouds must be sufficiently dense so that the attractive gravitational force predominates over the pressure which is proportional to the internal energy. The critical condition for collapse is that the gas cloud must be gravitationally bound i.e. E< 0. Now E= U+Ω. Hence the condition for collapse becomes

$$|\Omega| > U$$

Let us consider a spherical gas cloud of mass M, radius R and mean density ρ_0.The gravitational potential energy is, $\Omega = -{}^3\!/_5\, {}^{GM^2}\!/_R$, the thermal kinetic energy is, $U = {}^3\!/_2\, NK_BT$, where $N = {}^M\!/_{\mu m_H}$, μ = mean molecular weight, the mean density $\rho_0 = {}^{3M}\!/_{4\pi R^2}$.

Then from the necessary condition for collapse of the gas cloud we get,

$$M > (\frac{5k_BT}{G\mu m_H})^{3/2}(\frac{3}{4\pi\rho_0})^{1/2}$$

So, it is clear that the mass of the cloud should be greater than the certain value M_J, where the value of

QUANTUM COMPUTATION AND COMPUTER

RAMAKRISHNA MISSION VIDYAMANDIRA

NAME: PROSENJIT SARDAR

SUBJECT: PHYSICS

ROLL NO: 206 (UG-III)

Abstract:

This project shows how laws of Quantum mechanics can be used to modern computation system to handle some special problem very easily. Here the basic difference between working principle of classical and Quantum computer is given. How complex probability and superposition of sate can be used to implement Quantum bit. At the last part of this project how Quantum gate and algorithm works is presented with an example.

Introduction:

Quantum computation is one of the most fascinating field which is a combination of mathematics, physics and computer science. The main aim of this field is to apply some properties of quantum physics to solve some very important problems of modern days that are not possible by using classical computers. We will see that quantum computer can work much faster than classical computer and can be applied to solve large optimization problem.

The physics behind quantum computation:

Both in classical and quantum system a state is the package of data that gives all the information about the system. In quantum mechanics this is the wave function of the system that contain all the information of the system and by using appropriate operator we can harness different quantities. Mathematically states are represented by vector in finite or infinite dimensional space and operators are represented by matrices which operate on the ket vector and gives new state of the system. Before going to details of quantum calculation I will give basic difference between classical and quantum system.

Classical probabilistic system:

In classical world the physics is deterministic, but in quantum world the whole process is determined by probability. To have some knowledge of how probability works we will discuss classical probabilistic system in which the states are defined by the column matrix which are the superposition of basis matrices. Consider there are three boxes and a particle can be with in a box

BROWNIAN MOTION AND FLUCTUATION

NAME: ARNAB KUMAR SAHA

ROLL NO.: 207; UG-III

DEPT.: PHYSICS

RAMAKRISHANA MISSION VIDYAMANDIRA

ABSTRACT: Brownian Motion is the random motion of small particles immersed in viscous medium. It is due to the fluctuation in the motion of the medium particles on the molecular scale. This article treats the physical theory of Brownian motion. The rigorous mathematical theory, which treats the subfield of general theory of random process, is touched on but not present in any details. One dimensional random walk theory and statistical mechanics are the primary tools. It treats the history or foundation of Brownian motion , Einstein theory and Langevin's equation and its solution. Then I include the short note on "Fluctuation-Dissipation Theory" with a very interesting examples.

PHASE TRASITIONS AND THE DIFFERENCE BETWEEN 1^{ST} ORDER AND 2^{ND} ORDER

NAME-MANSURUL HOQUE.SUBJECT-PHYSICS,ROLL NO-208

What is the meaning phase?

If a system or a quantity of matter is homogeneous in physical structure and chemical composition it is called a phase.

Phase transition-A system or substance with the same chemical composition but different physical structure can exist in different phases such as solid ,liquid,or gas.And the transition from one phase to another due to external heat or energy is known as phase transition.

Condition for phase transition interms of thermodynamic parameters-when phase transition happens the temperature(T),pressure(P),and Gibbs function(g),remains constant throughout the transition.And also the increments in the specific gibbs function for two phases are equal.That is $\boxed{dg1=dg2}$

How can we define 1^{st} order and 2^{nd} order phase transition???

Phase transitions are characterized by volume (v)and entropy (s)changes and their characteristics curves and and sudden jump in the point of transition.

Now dg=-sdT+vdp.or $s=-(-\frac{\partial g}{\partial T})_p;v=(\frac{\partial g}{\partial P})_T$

For two phases separately ;we have $s_1=-(\frac{\partial g_1}{\partial T})_p;s_2=-(\frac{\partial g_2}{\partial T})_p.$

$v_1=(\frac{\partial g_1}{\partial P})_T;v_2=(\frac{\partial g_2}{\partial P})_T.$

If the first order derivatives of g change discontinuously i.e there is a sudden jump in the point of transition then the transition is known

NAME: SAHIN MOHAMMED MARUF ISLAM
ROLL: 209

SOUND AND MUSIC

INTRODUCTION: Man has curious mind. Out of this curiosity he has always wondered in different fascinating beauty of nature. He heard the thunder and watched the lightning. He tried to communicate with others, at first through symbols and then through the sound of their voices. With the gradual advancement of civilization, he learnt to speak and sing.
In this very writing I am going to point out the man's wondering about sound and music which echoes through the hearts.

What is sound?

An old riddle asked, "What comes with a carriage and goes with the carriage, is of no use to the carriage cannot move without it?" The answer is: "a noise".

And we can understand the advancement of the carriage by hearing the noise. We understand that it is not a car but a carriage only hearing it's noise, a form of "sound".

Now the question arises about the definition of sound. There were great debates in the early years between physicists and philosophers on what was sound. Is it the vibrations produced or the sensation produced only to mind of the listener? It confuses a cause (a physical vibration of some material thing) with an effect (a physiological sensation in an animal brain). So the ambiguity on the definition of sound --- vibration or perception or both; still puzzles.

Beauty and facts of sound

Jean Baptiste Fourier has discovered in 1801, that any series of waves can be described as a series of simple sine waves. This assumption corresponds to the age old Pythagorean assumption that sound waves of music bear simple numerical relationship.

Example: If the length of the plucked string is doubled then if it was originally sounding the note C, then the new note will also sound C but one octave lower.

Octave:	A	B	C	D	E	F	G
	Sa	Re	Ga	Ma	Pa	Dha	Ni

Why music sounds so pleasing or musical?

Harmonics make music sound musical. The more harmonics that can be heard, the richer and fuller is the sound. Harmonics are the integral multiple of the fundamental frequency.

When a string of a violin is bowed it emits the fundamental frequency along with its overtones. This makes the sound emitted so musical.

So this is the time to answer an interesting question.
When same note is played by an instrument live i.e. in front of the listener and recorded

<u>Title</u>

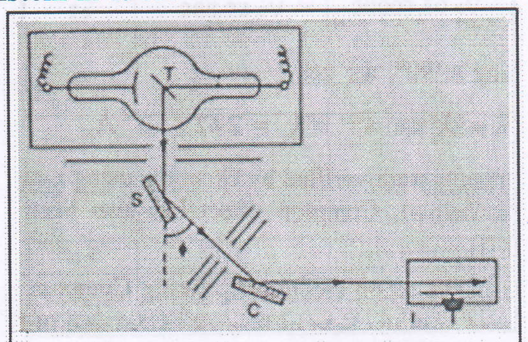
<u>Compton Effect</u>

NAME- KINGSHUK PANJA

YEAR -3RD SUBJECT- PHYSICS

ROLL -254

The corpuscular nature of radiation is directly proved by the experiment of **Compton** in 1923 after the explanation of **Photoelectric effect** by **Einstein** in 1905.

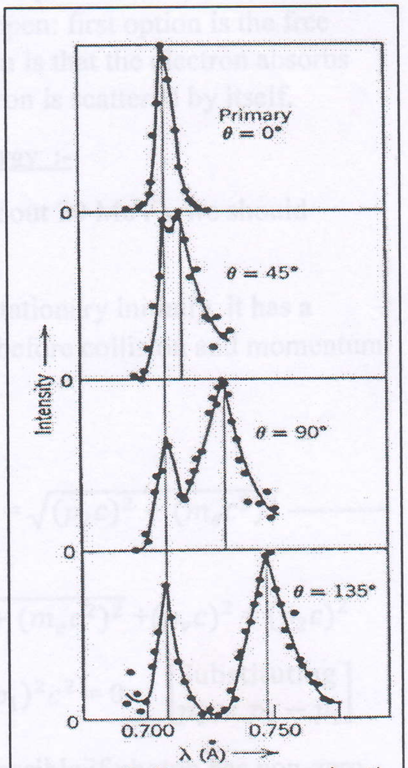


<u>Fig.</u>:- Compton's experiment apparatus

<u>Experiment:</u> T is a molybdenum target in x-ray tube. The monochromatic K-α x-radiation scatters from carbon scatterer S and collides a crystal C passing through a no. of slits in **Bragg's spectrometer.** The diffracted rays from C enter a ionized chamber which measures the intensity of the diffracted beam.

It is possible to measure the wavelength of scattered ray by measuring the angle of diffraction at which the intensity is maximum.

At 90° scattering angle, plotting graph of intensity(I) <u>vs</u> wavelength (λ), he found that one peak's wavelength is same to the incident wavelength but other peak's wavelength is different from it (greater than incident wave).



<u>Fig</u> :- Graph of Intensity vs wave-length in Compton scattering experiment

<u>Explanation through classical theory of wave scattering</u>(Thomson scattering) :-

According through this classical theory, when wave of frequency ν is incident on free electron, its varying electric field sets the electron oscillating. During oscillation, when the free electron accelerates, it emits EM waves of same frequency when it is stationary relative to the observer. But as it is moving, due to doppler shift, the wavelength of emitted EM wave is increased. But the frequency of emitted EM wave should decrease continuously and attains a final value as electron reaches its final velocity which contrary to experimental results.

So, Classical theory of wave scattering fails to explain this.

Analysis Of Muon Spin Relaxation Data For Caged Type Superconductor $Lu_5Rh_6Sn_{18}$

Indranil Banerjee (268)

Ramakrishna Mission Vidyamandira, Belur Math, Howrah

The caged type compound $Lu_5Rh_6Sn_{18}$, in it's superconducting state has been analysed on the basis of data acquired from magnetization and muon-spin relaxation or rotation (μSR) measurements. The zero field, transverse field and longitudinal field data has been analysed. The zero-field μSR (ZF-μSR) measurements(data) show the appearance of a spontaneous internal magnetic field below the transition temperature. This shows that the transition into superconducting state in this material is marked by the breaking of the time-reversal symmetry (TRS). The dependence of the magnetic penetration depth on temperature was measured using the transverse field μSR (TF-μSR).

Superconductors generally are explained by the BCS theory using the concept of Cooper pairs of electrons as the carriers in the superconducting phase. Often this theory fails in case of strongly electron correlated systems. These are the non-BCS type materials. Broken symmetries lead to some fascinating properties one of which is the superconducting state. Time reversal symmetry (TRS) requires a system to be at the same states at times t ant –t as well. Broken TRS results in the appearance of spontaneous weak magnetic fields as detected by ZF-μSR. As of the probing of the internal properties of the material μSR is a robust an unparalleled technique. The non zero moments of the cooper pairs locally align to set up extremely feeble magnetic fields which can be sensitively probed by this technique. The muons used are the surface muons which are almost 100% spin polarised with their spin antiparallel to their momenta.

The caged type superconducting structures present rather interesting properties and thus naturally have been drawing a pool of researcher over the past few years since their advent.

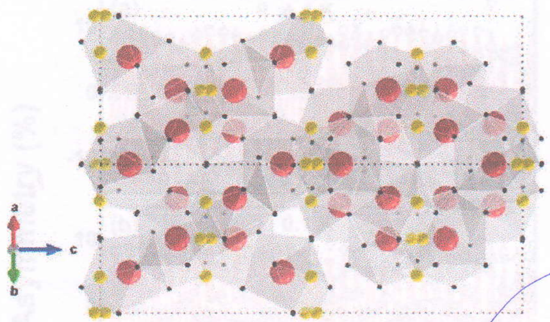


Fig. A caged type compound structure

Their structures comprises of large cage type atomic frameworks containing small atoms ("rattlers") which can vibrate with an considerable amplitude. The weak structural coupling along with strong electron-phonon coupling renders them with their characteristic anharmonic vibrations. $Lu_5Rh_6Sn_{18}$ (T_c = 4K) can be classified as a caged type compound. Similar materials like $Sc_5Rh_6Sn_{18}$ (T_c = 5K) and $Y_5Rh_6Sn_{18}$ (T_c = 3K) are also

Principle of Equivalence and Its Consequence

Rwitabrata Chakravorti
Roll No: 269
Department of Physics, Ramakrishna Mission Vidyamandira
(Dated: March 27,2019)

Abstract: Gravity is one of the hardest puzzles to human mind for a long time. Newton gave us a mechanical theory of gravitation that treat gravity as a force between masses. It was very successful but fail when the gravitation is too strong. It also does not respect Special theory of relativity. Einstein was the first one to reveal the true nature of gravity as a curvature in space-time. The theory he formulated is called General theory of Relativity. The entire field of general relativity begin with a simple observation. This observation is called principle of equivalence. In this project I tried to show how the true geometric nature of gravity is revealed by using this principle. And how a mathematically consisted theory of gravity can be started using this foundational principle.

1. INTRODUCTION

The Special theory of relativity was formulated on two fundamental postulates, the laws of physics are same in all **inertial reference** frame and the **Invariance** of the speed of light. It neither account for gravity nor accelerated frame of reference.

First think about Newtonian gravity and S.T.R. Newtonian gravity was formulated on action-at-a-distance principle. It says gravity effects its surrounding instantaneously. But from STR we know nothing causally connected can travel faster than the speed of light (in free space). The challenge is how to modify or reformulate the law of gravity so that it obeys S.T.R (or vice versa).

Secondly, we do not know how the equation that describe the laws of physics behave under non-inertial reference frame transformation. How forces on a non-inertial frame effect the nature of space-time? For example, two observers on the centre and the edge of a relativistic disk will measure the ratio of circumference and diameter, different. The observer on the edge is moving in a circle with velocity v. He is accelerating toward the centre. So, he is a non-inertial observer. For him the length of the circumference will be greater than $2\pi r$ due to length contraction of his scale. And the length of the diameter will be same as observed by the observer at the centre because length of the scale perpendicular to velocity does not change. So, the ratio of circumference and diameter will be greater than π. Whereas the ratio is still π for the observer at centre because he is an inertial observer. This is a clear-cut hint that for non-inertial observer the space-time is not homogeneous or isotropic. We do not know how the laws of physics changes under this asymmetric space-time transformation. The space-time is not flat "Minkowski space-time" anymore. So, either we have to generalised the principle of relativity by invoking some fundamental postulate so that law physics behave same under non-inertial transformation or we have to abandoned the principle of relativity for these cases.

2. Mass, Gravity and Acceleration

Think of a stationary object in an arbitrary gravitational field. Gravitational force on the body is ,

$F = \frac{GMm_g}{r^2}$ where M is the mass of the source body m_s is the mass of the test body r is the distance between them. $\frac{GM}{r^2}$ is constant $(= g)$ for a particular point r. So, the gravitational force is $F = m_g g$. Equating it with Newtonian force law we have acceleration of the body, $a = \frac{m_g}{m_i} g$. m_i is the Newtonian inertial mass. From experience and experiment we

DENSITY MATRIX

NAME: SAMAR MURMU ROLL: 270

▲**Abstract**: -

We described here the quantum mechanical tool the "Density Matrix". First we go through why the idea of density matrix come, how it is represented and then it properties.Its evolution with time and finally its application.

▲**Introduction**: -

The density operators or matrices was introduced by John Von Neumann in 1927 and develop by Lev landau and Felix Bloch in 1927 and 1946 respectively.Here we develop a powerful formalism of quantum mechanics this formalism gives us a structure which we can address such cases

We assume that subspace of hilbert space for the universe in which we are performing to work.

●Pure state: In quantum mechanics a system is represented by state vector and the system is considered as statistical ensemble of states. If we can represent the system with the single state vector (ket vector) and it does not interact with the surroundingthen it is called the pure state.

●Mixed state: But generally we can't find such state in reality we find mixture of pure state, so it is called mixed state. Mixed state is also called super position of pure states. Formalism of density matrix arises because of these mixed states. Mixed state is mixture of pure state so we don't have complete information about the system so we need to perform statistical average in order to describe quantum observable. So we characterize the mixed state with density matrix in which all the properties of our system is encoded and we can find all observable of the system from the density matrix..

Density Matrix nothing but a representation. It is defined as

$\rho=|\psi\rangle\langle\psi|$.............................. the outer product of the wave vector of the system

Where ψ is the wave function of the system which we are considered.

In quantum mechanics we can write the wave function as a linear combination of basis state

$$|\psi\rangle=\Sigma c_n|n\rangle$$

Where c_n is the probability amplitude and $|n\rangle$ is the basis vector

Similarly,

$$\langle\psi|=\Sigma c_m^*\langle m|$$

Where $c_m$is the probability amplitude and $|m\rangle$ is the basis vector

Now,

FORMATION OF A WHITE DWARF

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ABSTRACT : This is very difficult to explain the evolution of white dwarf in actual scientific term .As the density of gas cloud is very low at the first stage of evolution of star ,We use the kinetic theory of gas to explain the evolution of first stage of star. When the star becomes very small we use quantum-mechanical degeneracy pressure to explain the stability of a white dwarf. Jeans criteria suggests to participate a gas cloud in formation of star and we reach up to white dwarf by Chandrasekhar's limit. But when electron degeneracy pressure fails, we cannot get a white dwarf star. In this project I describe the evolution of a white dwarf star.

RAMAN AMPLIFICATION AND ITS APPLICATION

DEPARTMENT OF PHYSICS

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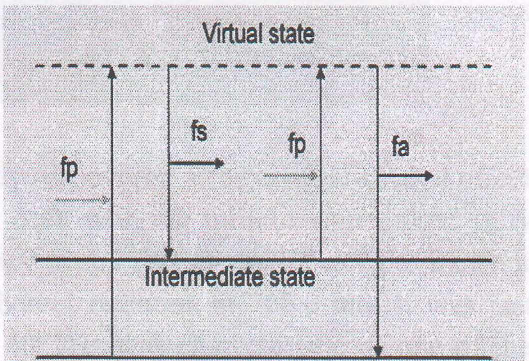
ABSTRACT : It was not so surprising that little sustained interest was aroused by the practical aspects of Raman effect at the early twenty century. But After the invention of laser technology or strong intense source, the situation was changed dramatically. So, in this project we are investigating the use of FRAs from an application perspective. First of all, we discuss the stimulated Raman scattering from the very basic idea of Raman effect and find out the form of intensities and powers. Then we want to find some applications in Raman laser, and drawbacks in terms of cross-talk in WDM system and try to find out it's remedy.

RAMAN EFFFECT : In **1928,** sir **C. V. Raman** along with **K. S. Krishnan** observe the spectrum of the light scattered when illuminating the liquid carbon tetrachloride with monochromatic radiation from mercury (λ=4358.3 Å) and show a strong band at γ_0=22938 cm^{-1} and weaker band at $\gamma_0 \pm 218$, $\gamma_0 \pm 314$, $\gamma_0 \pm 459, \gamma_0 - 762\ and\ \gamma_0 - 790 cm^{-1}$. Independently around the same time, the effect was also observed (in quartz) by two Russian physicists **G. Landsberg** and **L. Mandelstam**. This shift of the wavelength from the parent wavelength after scattering is named **Raman scattering**. Quantum mechanically the Raman effect is briefly discussed below;

In stokes generation process, the incoming photon of frequency f_p excites (inelastic collision) a molecule from the ground state to the virtual state. The molecule returns to the intermediate state releasing a stokes photon of frequency f_s. Since the energy difference between the ground state and the virtual states is greater than the energy difference between the intermediate state and the virtual state, the frequency is lower than the incident photon ($f_p > f_s$).



In the anti-stokes generation process, the incoming photon of frequency f_p excites a molecule from the intermediate state to the virtual state. The molecule returns to the ground state releasing a anti-stokes photon of frequency f_p. Since the energy difference between the virtual and intermediate levels is smaller than the energy difference between the ground state and the virtual states, the frequency of the anti-stokes photon is higher than the incident photon

Title

Investigation of iron-based superconductor ThAsFeN using μSR measurements

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Abstract

Here, I have reviewed the superconducting ground state of the recently discovered iron-based superconductor ThFeAsN by doing transverse field (TF) muon-spin rotation (μSR) data analysis. This compound crystallizes in the tetragonal layered structure. Magnetization and resistivity data exhibit superconductivity at 30 K. Nonlinear magnetic field dependence of the specific heat coefficient ϒ has been found in the low-temperature limit, which shows that there is a nodal energy gap. My investigation of the TF-μSR result shows that the temperature depends on the superfluid density is better characterized by a two-gap model either isotropic s+s wave or s+d wave than a single gap s-wave model for the superconducting gap, matching with other iron-based superconductors. The combination of ϒ(H) and TF–μSR results suggest that the (s+d)-wave is the most consistent for the gap structure of ThFeAsN. The observation of two gaps in ThFeAsN suggests a multiband nature of superconductivity possibly arising from the d bands of Fe ions.

Introduction

Onnes(1911) measured the electrical conductivity of various metals and discovered the sudden disappearance of the resistance of a solid mercury wire in liquid helium. Gradually a wide range of superconductors have been found with high transition temperatures (Tc), and it is hoped that in a room-temperature superconductor can be realized. Following the discovery of superconductivity it took a huge time for a theoretical understanding to be obtained on a microscopic level .At least **BCS** (Bardeen-Cooper-Schrieffer,1957) theory describes superconductivity as a microscopic effect caused by condensation of Cooper pairs into a boson-like state .Nevertheless, BCS theory often fails to represent the superconductivity observed in strongly correlated materials. Numerous powerful correlated superconducting materials, having magnetic f or d electrons elements. Gauge symmetry is broken in the case of conventional superconductor and other symmetries of the Hamiltonian might be broken for the non bcs superconductors.

For Non -BCS superconductors various theoretical model built upon on magnetic interactions and spin fluctuations have been proposed to understand the superconducting pairing mechanism. BCS superconductors can show gap anisotropy, although they remain nodeless and gap sign became same over the Fermi surface, whereas non-BCS superconductors may have nodes in the gap function along a particular direction and the location of the nodes is closely associated with the pairing symmetry. Therefore analysis of the superconducting gap structure of strongly correlated f and d electron superconductors is very important for understanding the physics of unconventional pairing mechanisms in these types of materials.

Unconventional superconductivity has been observed in high-temperature cuprates, iron pnictides and heavy fermion materials which have strong electron correlations and quasi-two dimensionality. This materials type of superconductor that display superconductivity which not conform to either the conventional BCS theory .

A BRIEF REVIEW OF SUPERCONDUCTIVITY AND A THOROUGH STUDY OF SUPERCONDUCTING STATE OF BiS_2 BASED SUPERCONDUCTOR

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RAMAKRISHNA MISSION VIDYAMANDIRA

ABSTRACT : Here in this project I expressed a short review of superconductivity and described a detailed explanation of BiS_2 superconductor. The influence of electron doping on semimetallic SrFBiS2 has been investigated by means of resistivity, zero and transverse – field (ZF/TF) muon spin relaxation/rotation (μSR) experiments. I have made analysis of datas about BiS_2 superconductor given by my project guide Dr. Amitava Bhattacharya I also highlighted the basics of superconductivity.

KEYWORDS: Superconductors, BiS_2 based superconductor, muon spin spectroscopy, Meissner effect, London penetration depth.

THREE-BODY PROBLEM AND ITS SOLUTION UNDER RESTRICTED CONDITION

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ABSTRACT :

Three-body problem is a vast area to research and its solution is extensively used in astrophysics. The exact solution of the three body problem can body problem can be achieved by numerical method.Though analytical solution of the three body problem is possible in some restricted cases.In my project work I have studied why the exact solution of three body problem is not possible.I have formulated the equation of motion of the three body problem and solved it for a restricted case,where the mass of the 3rd body is negligible compared to the other two bodies.