SRI Y N COLLEGE (AUTONOMOUS) NARSAPUR
DEPARTMENT OF PHYSICS

STUDENT MINOR REASEARCH PROJECT

Submitted to

DEPARTMENT OF PHYSICS

Theoretical Study on the Indian Space Programme

(2018-2019)

PROJECT DONE BY

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A THEORITICAL STUDY ON THE DEVELOPMENT OF SPACE SCIENCE IN INDIA

Introduction :

The Indian Space Research Organization has completed 40 years and it occupies 5th position in the world. It was one of the first few countries to realize the potential benefits of space programmes. It has matured to a status where space has become an important element of the national infrastructure, especially in the areas of communication, broadcasting, meteorology, disaster management and resource monitoring. A major milestone in the programme of space activities is the launch of **GSLV-D1** on April 18, 2001. In 2002, Met-sat was launched for study of climatic conditions over India.

The Indian Space Programme, since its inception, has been guided by a vision which laid emphasis on the application of Space Technology for finding solutions to the problems of man and society. Self reliance in space technology has been an important target of the programme.

HISTORY :

In 1962, Indian National Committee for Space Research formed by the department of Atomic Energy and work on establishing Thumba Equitorial Rocket Launching Station **(TERLA)** started. The ISRO space programme has come a long way from a modest beginning with the Nicke Appache Rocket launch with Sodium Vapour payload on November 21,1963. The launch vehicle development programme later shifted from Thumba to the Sriharikota launching station in 1969. The ISRO's first satellite launch vehicle **(SLV-3)** was failed due to malfunctioning of first stage control system in August, 1979. Undeterred by it, the development flight of SLV-3 attempted in 1983 brought happy tidings for the ISRO as the satellite sent home more than 2,500 pictures. Till then it launched many satellites successfully. The successful launch of INSAT 3B in 2000 besides GSLV-D1, in 2001, are very significant achievements.

ISRO has signed MOU with Brunei, Canada, China, France, Germany, USA, UK etc., other than organizations like UN, ESCAP, ESA, International Astronautics Federation **(IAF)** and International Telecommunication Union. With a view to promoting Space Technology and ensure its benefits for the population in the north eastern region the North Eastern Space Applications Centre **(NE-SAC)** has been started. NE-SAC will address natural resources management and developmental communication and encourage space science research in the region.

SHARE is a programme under which India has offered to share its experience, application and training in space technology with developing countries. The specialized areas would include training in remote sensing, consultancy on designing, fabrication, maintenance, technology development, software designing etc.

Organization :

The main centres are :

The Vikram Sarabhai Space Centre **(VSSC),** at Thumba; ISRO Satellite centre **(ISAC)**; Liquid propulsion systems centre **(LPSC)**; Space Applications Centre (**SAC**); Development and Educational Communication Unit (**DECU**); ISRO Telemetry, Tracking and command Network **(ISTRAC)**; INSAT Master Control Facility (**MCF**); ISRO Inertial systems unit **(IISU)**; National Remote Sensing Agency **(NRSA);** Regional Remote Sensing Service Centres **(RRSSC)**; Physical Research Laboratory (**PRL**); National Mesosphere/ stratosphere Troposphere Radar Facility **(NMRF).**

The Satellite Technologies:

INSAT :

It was established in 1983 with the commissioning of INSAT-1B, is a joint venture of the department of space, and department of Telecommunications, Indian Meteorological Department, Doordarshan and AIR and INSAT, a multipurpose satellite system provides uninterrupted services to the country in the vital areas of tele-communication , TV broad casting, meteorology, disaster warning and distress alert.

Presently the system comprises 5 satellites –INSAT 1 series **(1982 to 1990)**, INSAT 2A in 1992, 2B in 1993, 2Cin 1995, 2D in 1997 and 3B in 2000, 3C in 2001. Another satellite, METSAT, is also being built for providing meteorological and data relay services.

GSAT :

It is intended to provide test space craft for the development flight of GSLV. It is configured around INSAT-2 structure.

IRS:

In the area of space- based remote sensing, India continues to use its IRS satellites. These provide data for applications in agriculture, forestry, surface and ground water harnessing, geology, urban planning, flood mapping etc.
The follow – on satellites in the IRS series, namely, RESOURCESAT and CARTOSAT- 1 and Technology Experiment Satellite (**TES**), which is aimed at testing and validating advanced space craft bus and payload technologies.

GRAMSAT:

As part of a countrywide GRAMSAT pilot, Swarn Jayanti Vidya Vikas Antariksh Upagraha Yojana (**Vidyavahini**) has been inaugurated in Orissa using INSAT-3B. A transponder of INSAT-3B has been provided to Andhra Pradesh for promoting distance education, tele-medicine, agri-cultural extension, e-governance and community internet centres. The GRAMSAT pilot project is planned to cover other status also in a progressive manner.

Launch Vehicle Development :

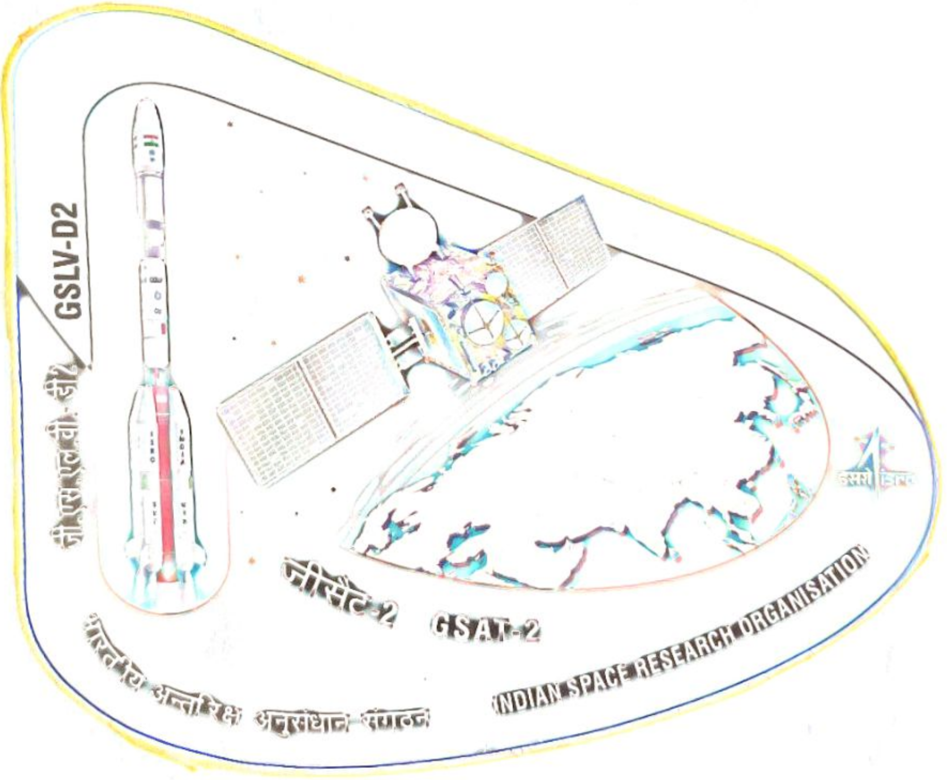
Building upon the success of SLV-3, India undertook the development of the ASLV, which had its first success on May 20, 1992, when it launched SROSS-C to near earth orbit.

PSLV:

It is technologically the most challenging endeavor of the Indian Space Programme till date. It is also the first operational launch vehicle of ISRO capable of lifting1000 to 2000 kg class satellites in Polar Sun – synchronous orbit. It is 4 stage vehicle. The launch of PSLV C3 in 2002 with 2 foreign satellites marked the beginning of the marketing of Indian Launch Vehicle Services.

GSLV:

GSLV capable of placing 2,500 kg class of communication satellites into geo-synchronous transfer orbit of about 175 km perigee and 36,000 km apogee. It is a 3- stage vehicle.



SATELLITE LAUNCHING IN SHAR CENTRE

The story of the spaceport of India dates back to 1969, May 26 when Vikram Sarabhai, former chairman of Atomic Energy Commission, carried out an aerial survey of the East Coast to identify a suitable launch range. At that time space was under the department of Atomic Energy. After extensive survey lasting for months, Sriharikota Island spreading over 170 sq.km was selected. It was the land of Yanadi tribes who have since been resettled.

Two years after the survey, on October 9,1971, the first ever Rohini Sounding Rocket was launched. In the past it has supported launches of SLV, ASLV,PSLV and GSLV.

This center also undertakes large scale production of solid rocket propellant and ground testing of solid fulled rocket stages of the Indian Launch Vehicles. In September 2002, the Sriharikota Space Centre was renamed as Prof. Satish Dhawn Space Centre.

With the Vikram Sarabhai Space Centre in Thiruvunanthapuram acting as a lead center major responsibilities for design and development of the PSLV were shared by the Liquid propulsion systems centre also at Thiruvananthapuram and the SHAR centre in Sriharikota.

A second launch pad constructed to provide support to the existing launch pad for current versions. It is capable of launching advanced launch vehicle into orbit. The facilities at that site include launch pad with jet deflector vehicle assembly building (High Bay), check-out system, propellant of gas storages and transfer facilities for earth storable and cryo propellants safety systems, instrumentation and control systems for automatic filling of propellants and gas charging operation etc.

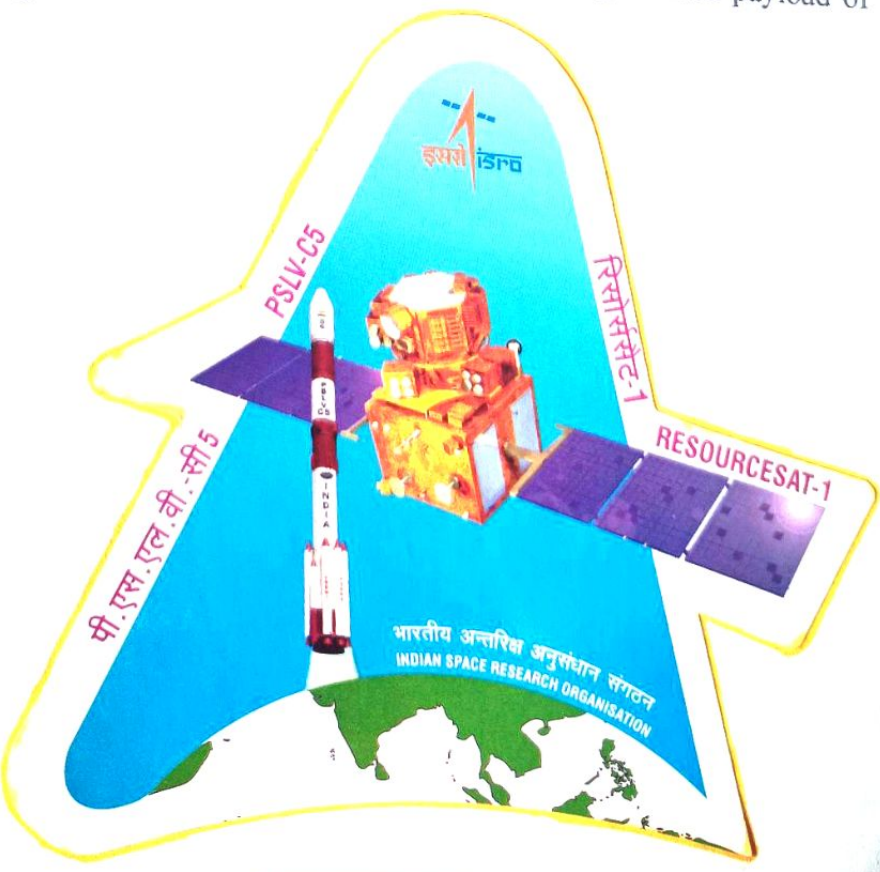
Milestones:

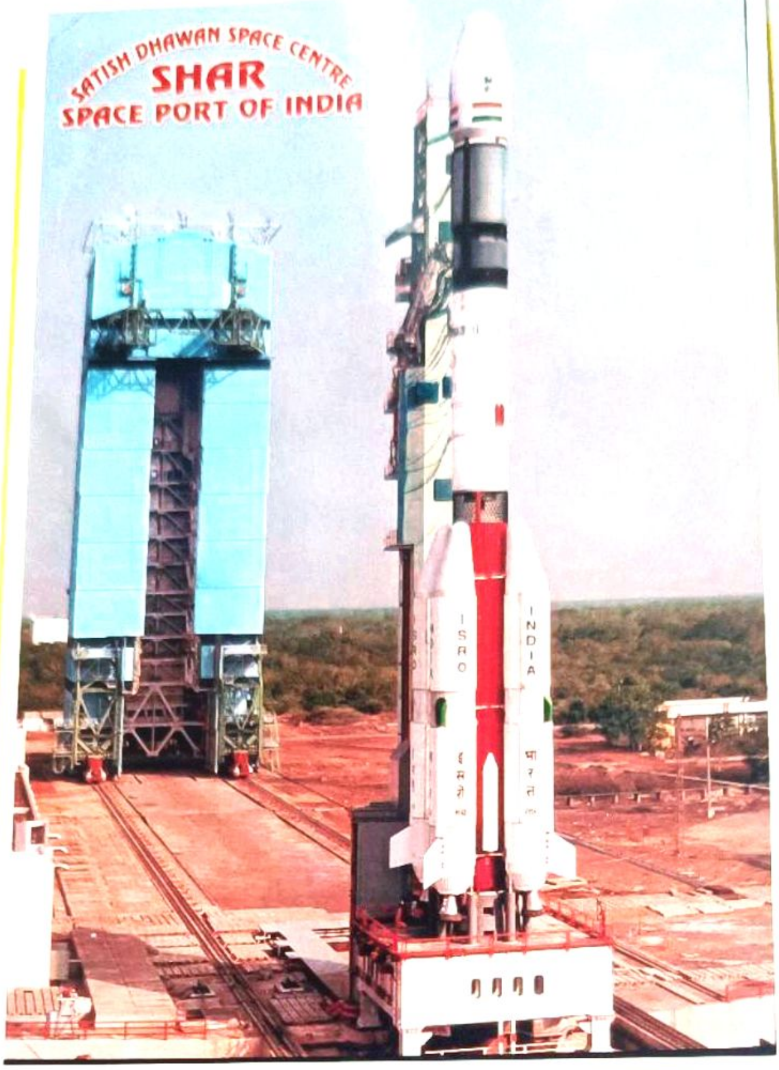
1. On September 29,1997, the 1200kg IRS-ID was successfully launched from Sriharikota Range by the PSLV-C1-countrys' first indigenous polar Satellite Launch Vehicle. It has placed India in the exclusive club of 4 Nations (USA, France, Russia and Israel) capable of launching 100kg class of satellites. It has also ended ISROs dependence on Russian and French Arian vehicles to launch IRS satellites.

2. On September 12, 2002, Indian Space Scientists successfully launched the country's first exclusive meteorological satellite (METSAT), using the versatile PSLV-C4 from Sriharikota. This was the first time the ISRO has used the PSLV to launch a meteorological satellite in the geo-synchronous transfer orbit.

3. (i). The 2nd development test flight of India's Geo-synchronous Satellite Launch Vehicle, GSLV, was successfully carried out on May 8th from SHAR. With the launch, India moved further in establishing its capability to launch geo-synchronous communication satellites.

   (ii) On May 8th, 2003, GSAT-2 was successfully launched by the indigenously developed GSLV –D2 from this centre. GSAT-2 is an experimental communications satellite with an augumented payload of 1800 kg




SATISH DHAWAN SPACE CENTRE
SHAR
SPACE PORT OF INDIA


शार केन्द्र श्रीहरिकोटा भारतीय अन्तरिक्ष अनुसंधान संगठन
GSLV-D1
Licensed for Marketing
SHAR CENTRE SRIHARIKOTA INDIAN SPACE RESEARCH ORGANISATION


शार केन्द्र श्रीहरिकोटा भारतीय
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PSLV-C3
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A THEORITICAL STUDY ON THE INDIAN SPACE PROGRAME

Introduction :

The Indian Space Research Organization has completed 40 years and it occupies 5th position in the world. It was one of the first few countries to realize the potential benefits of space programs. For a developing country like India Space Technology contributes to overall development and ensures augmentation of national income.

The Indian Space Programme, since its inception, has been guided by a vision which laid emphasis on the application of Space Technology for finding solutions to the problems of man and society. Self reliance in space technology has been an important target of the programme.

The main objectives of space program are Resource Management, Satellite Communication, Process of urbanisation, Agrometeorology, Weather observation, Technology transfer for civilian uses.

HISTORY :

The Indian Space programme started from 1962,when Dr. Vikram Sarabhai and other members of department of Atomic Energy set up the Indian national committee on Space Research(INCOSPAR). In November, 1963 the Thumba Equitorial Rocket Launching Station(TERLS), Tiruvanantapuram became operational. Later in 1972, this Thumba complex was designated as Vikram Sarabhai Space Center(VSSC).

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ISRO has signed MOU with Brunei, Canada, China, France, Germany, USA, UK etc., other than organizations like UN, ESCAP, ESA, International Astronautics Federation **(IAF)** and International Telecommunication Union. With a view to promoting Space Technology and ensure its benefits for the population in the north eastern region the North Eastern Space Applications Centre **(NE-SAC)** has been started. NE-SAC will address natural resources management and developmental communication and encourage space science research in the region.

ISRO activities are oriented predominantly towards

(i) Designing and development of the Application Satellites for communication, Remote sensing, Television broad casting & Meteorology.

(ii) Designing and development of the satellite launch vehicles to place these application satellites into the required orbits.

(iii) Establishment and operation of ground station facilities for launching and using these facilities.

DEVELOPMENTS IN SPACE RESEARCH

The Indian Space Program has come a long way from a humble beginning of testing sounding rockets to acquiring the capacity to launch gaint polar launch vehicles and putting 1200 kg class remote sensing satellites in low orbits. With the successful Geosynchronous launch vehicle(GSLV-D1), which launched gsat-1 satellite into geo-synchrounous orbit in April 2001, India joins the group of countries having capacity to launch geo-synchronous satellites.

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Satellite Launch Vehicle Development :

In Space Technology, the launch vehicle technology is the major target. These vehicles carry the satellite and place the Satellite in specified orbits.

SLV: Satellite Launch Vehicle

SLV launched Rohini class of satellites. It was a four stage vehicle containing solid propellent in all stages. It was first successful launch vehicle launched in 1980.

ASLV: Augmented Satellite Launch Vehicle

It is the improved vesion of SLV which placed the 106 kg stretched Rohini series satellite(SCROSS-C) into the orbit. It has five stages containing solid propellents.

PSLV: Polar Satellite Launch Vehicle

It is technologically the most challenging endeavor of the Indian Space Programme till date. It is also the first operational launch vehicle of

ISRO capable of lifting1000 to 2000 kg class satellites in Polar Sun – synchronous orbit. It is 4 stage vehicle having liquid fuel in one of its stages. The launch of PSLV C3 in 2002 with 2 foreign satellites marked the beginning of the marketing of Indian Launch Vehicle Services.

GSLV: Geo-Synchronous Satellite Launch Vehicle

The concept of GSLV has been conceived with a view to launching the communication satellites(INSAT) to place them in Geo-sychronous orbit.GSLV capable of placing 2,500 kg class of communication satellites into geo-synchronous transfer orbit of about 175 km perigee and 36,000 km apogee. It is a 3- stage vehicle. In first stage it has liquid Propellent motors and solid propellent motors.

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Presently the system comprises 6 satellites –INSAT 1 series (**1982 to 1990**), INSAT 2A in 1992, 2B in 1993, 2Cin 1995, 2D in 1997 and 3B in 2000, 3C in 2001,3E in 2003. Another satellite, METSAT, is also being built for providing, meteorological and data relay services.

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METSAT:

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STUDY PROJECTS

Submitted to

DEPARTMENT OF PHYSICS

SPECIAL THEORY OF RELATIVITY
(2018-2019)

PROJECT DONE BY

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SRI Y N COLLEGE, NARSAPUR

(AUTONOMOUS)

PROJECT WORK

Academic Year 2010-2011

Submitted to

DEPARTMENTOF PHYSICS

TOPIC: THEORY SPECIAL RELATIVITY

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Under the guidance of :-

Dr A R S Kumar, Head of the Department
Sri P Ramakrishna Rao, Lecturer in Physics.

THEORY

Special Relativity

Newton's laws of motion give us a complete description of the behavior moving objects at low speeds. The laws are different at speeds reached by the particles at SLAC.

Einstein's Special Theory of Relativity describes the motion of particles moving at close to the speed of light. In fact, it gives the correct laws of motion for any particle. This doesn't mean Newton was wrong, his equations are contained within the relativistic equations. Newton's "laws" provide a very good approximate form, valid when v is much less than c. For particles moving at slow speeds (very much less than the speed of light), the differences between Einstein's laws of motion and those derived by Newton are tiny. That's why relativity doesn't play a large role in everyday life. Einstein's theory supercedes Newton's, but Newton's theory provides a very good approximation for objects moving at everyday speeds.

Einstein's theory is now very well established as the correct description of motion of relativistic objects, that is those traveling at a significant fraction of the speed of light.

Because most of us have little experience with objects moving at speeds near the speed of light, Einstein's predictions may seem strange. However, many years of high energy physics experiments have thoroughly tested Einstein's theory and shown that it fits all results to date.

Theoretical Basis for Special Relativity

Einstein's theory of special relativity results from two statements -- the two basic postulates of special relativity:

1. The speed of light is the same for all observers, no matter what their relative speeds.
2. The laws of physics are the same in any inertial (that is, non-accelerated) frame of reference. This means that the laws of physics observed by a hypothetical observer traveling with a relativistic particle must be the same as those observed by an observer who is stationary in the laboratory.

Given these two statements, Einstein showed how definitions of momentum and energy must be refined and how quantities such as length and time must change from one observer to another in order to get consistent results for physical quantities such as particle half-life. To decide whether his postulates are a correct theory of nature, physicists test whether the predictions of Einstein's theory match observations. Indeed many such tests have been made -- and the answers Einstein gave are right every time!

The Speed of Light is the same for all observers.

The first postulate -- the speed of light will be seen to be the same relative to any observer, independent of the motion of the observer -- is the crucial idea that led Einstein to formulate his theory. It means we can define a quantity *c*, the speed of light, which is a fundamental constant of nature.

Note that this is quite different from the motion of ordinary, massive objects. If I am driving down the freeway at 50 miles per hour relative to the road, a car traveling in the same direction at 55 mph has a speed of only 5 mph relative to me, while a car coming in the opposite direction at 55 mph approaches me at a rate of 105 mph. Their speed relative to me depends on my motion as well as on theirs.

Physics is the same for all inertial observers.

This second postulate is really a basic though unspoken assumption in all of science -- the idea that we can formulate rules of nature which do not depend on our particular observing situation. This does not mean that things behave in the same way on the earth and in space, e.g. an observer at the surface of the earth is affected by the earth's gravity, but it does mean that the effect of a force on an object is the same independent of what causes the force and also of where the object is or what its speed is.

Einstein developed a theory of motion that could consistently contain both the same speed of light for any observer and the familiar addition of velocities described above for slow-moving objects. This is called the *special theory of relativity*, since it deals with the *relative* motions of objects.

Note that Einstein's General Theory of Relativity is a separate theory about a very different topic -- the effects of gravity.

Relativistic Definitions

Physicists call particles with v/c comparable to 1 "relativistic" particles. Particles with v/c << 1 (very much less than one) are "non-relativistic." At SLAC, we are almost always dealing with relativistic particles. Below we catalogue some essential differences between the relativistic quantities the more familiar non-relativistic or low-speed approximate definitions and behaviors.

Gamma (γ)

The measurable effects of relativity are based on gamma. Gamma depends only on the speed of a particle and is always larger than 1. By definition:

$$\gamma = \frac{1}{\sqrt{1-(v^2/c^2)}} \geq 1$$

c is the speed of light
v is the speed of the object in question

For example, when an electronG has traveled ten feet along the acceleratorG it has a speed of 0.99c, and the value of gamma at that speed is 7.09. When the electron reaches the end of the linac, its speed is 0.99999999995c where gamma equals 100,000.

What do these gamma values tell us about the relativistic effects detected at SLAC? Notice that when the speed of the object is very much less than the speed of light ($v \ll c$), gamma is approximately equal to 1. This is a non-relativistic situation (Newtonian).

Momentum

For non-relativistic objects Newton defined momentum, given the symbol p, as the product of mass and velocity -- $p = m\,v$. When speed becomes relativistic, we have to modify this definition -- $p = gamma\ (mv)$

Notice that this equation tells you that for any particle with a non-zero mass, the momentum gets larger and larger as the speed gets closer to the speed of light. Such a particle would have infinite momentum if it could reach the speed of light. Since it would take an infinite amount of force (or a finite force acting over an infinite amount of time) to accelerate a particle to infinite momentum, we are forced to conclude that a massive particle always travels at speeds less than the speed of light.

Some text books will introduce the definition m_0 for the mass of an object at rest, calling this the "rest mass" and define the quantity ($M = gamma\ m_0$) as the mass of the moving object. This makes Newton's definition of momentum still true provided you choose the correct mass. In particle physics, when we talk about mass we always mean mass of an object at rest and we write it as m and keep the factor of gamma explicit in the equations.

Energy

Probably the most famous scientific equation of all time, first derived by Einstein is the relationship $E = mc^2$.

This tells us the energy corresponding to a mass m at rest. What this means is that when mass disappears, for example in a nuclear fission process, this amount of energy must appear in some other form. It also tells us the total energy of a particle of mass m sitting at rest.

Einstein also showed that the correct relativistic expression for the energy of a particle of mass m with momentum p is $E^2 = m^2c^4 + p^2c^2$. This is a key equation for any real particle, giving the relationship between its energy (E), momentum (p), and its rest mass (m).

If we substitute the equation for p into the equation for E above, with a little algebra, we get $E = gamma\ mc^2$, so energy is gamma times rest energy. (Notice again that if we call the quantity $M = gamma\ m$ the mass of the particle then $E = Mc^2$ applies for any particle, but remember, particle physicists don't do that.)

Let's do a calculation. The rest energy of an electron is 0.511 MeV. As we saw earlier, when an electron has gone about 10 feet along the SLAC linac, it has a speed of 0.99c and a gamma of 7.09. Therefore, using the equation *E = gamma x the rest energy*, we can see that the electron's energy after ten feet of travel is 7.09 x 0.511 MeV = 3.62 MeV. At the end of the linac, where gamma = 100,000, the energy of the electron is 100,000 x 0.511 MeV = 51.1 GeV.

The energy E is the total energy of a freely moving particle. We can define it to be the rest energy plus kinetic energy ($E = KE + mc^2$) which then defines a relativistic form for kinetic energy. Just as the equation for momentum has to be altered, so does the low-speed equation for kinetic energy ($KE = (1/2)mv^2$). Let's make a guess based on what we saw for momentum and energy and say that relativistically $KE = gamma(1/2)mv^2$. A good guess, perhaps, **but it's wrong.**

Now here is an exercise for the interested reader. Calculate the quantity $KE = E - mc^2$ for the case of v very much smaller than c, and show that it is the usual expression for kinetic energy ($1/2\ mv^2$) plus corrections that are proportional to $(v/c)^2$ and higher powers of (v/c). The complicated result of this exercise points out why it is not useful to separate the energy of a relativistic particle into a sum of two terms, so when particle physicists say "the energy of a moving particle" they mean the total energy, not the kinetic energy.

Another interesting fact about the expression that relates E and p above ($E^2 = m^2c^4 + p^2c^2$), is that it is also true for the case where a particle has no mass (m=0). In this case, the particle always travels at a speed c, the speed of light. You can regard this equation as a definition of momentum for such a mass-less particle. Photons have kinetic energy and momentum, but no mass!

In fact Einstein's relationship tells us more, it says Energy and mass are interchangeable. Or, better said, rest mass is just one form of energy. For a compound object, the mass of the composite is not just the sum of the masses of the constituents but the sum of their energies, including kinetic, potential, and mass energy. The equation $E=mc^2$ shows how to convert between energy units and mass units. Even a small mass corresponds to a significant amount of energy.

- In the case of an atomic explosion, mass energy is released as kinetic energy of the resulting material, which has slightly less mass than the original material.
- In any particle decayG process, some of the initial mass energy becomes kinetic energy of the products.

Even in chemical processes there are tiny changes in mass which correspond to the energy released or absorbed in a process. When chemists talk about conservation of mass, they mean that the sum of the masses of the atoms involved does not change. However, the masses of molecules are slightly smaller than the sum of the masses of the atoms they contain (which is why molecules do not just fall apart into atoms). If we look at the actual molecular masses, we find tiny mass changes do occur in any chemical reaction.

At SLAC, and in any particle physics facility, we also see the reverse effect -- energy producing new matter. In the presence of charged particles a photon (which only has kinetic energy) can change into a massive particle and its matching massive antiparticle. The extra charged particle has to be there to absorb a little energy and more momentum, otherwise such a process could not conserve both energy and momentum. This process is one more confirmation of Einstein's special theory of relativity. It also is the process by which antimatterG (for example the positrons accelerated at SLAC) is produced.

Units of Mass, Energy, and Momentum

Instead of using kilograms to measure mass, physicists use a unit of energy -- the electron volt. It is the energy gained by one electron when it moves through a potential difference of one volt. By definition, one electron volt (eVG) is equivalent to 1.6×10^{-19} joules.

Lets look at an example of how this energy unit works. The rest mass of an electron is 9.11×10^{-31} kg. Using $E = mc^2$ and a calculator we get:

$$E = 9.11 \times 10^{-31} \text{ kg} \times (3 \times 10^{8} \text{ m/s})^2 = 8.199 \times 10^{-14} \text{ joules}$$

This gives us the energy equivalent of one electron. So, whether we say we have 9.11×10^{-31} kg or 8.199×10^{-14} joules, we really talking about the same thing -- an electron. Physicists go one stage further and convert the joules to electron volts. This gives the mass of an electron as 0.511 MeV (about half a million eV).

So if you ask a high energy physicist what the mass of an electron is, you'll be told the answer in units of energy. You can blame Einstein for that!

Eagle-eyed readers will notice that if you solve $E=mc^2$ for m, you get $m=E/c^2$, so the unit of energy should be eV/c^2. What happened to the c^2? It's very simple, **particle physicists choose units of length so that the speed of light = 1!** How can we do that? Quite easily, as long as everyone understands the system. All we have to do is use a conversion factor to get back the "real" (i.e. everyday) units, if we want them.

Not only are mass and energy measured in eV, so is momentum. It makes life so much easier than dividing by c^2 or c all the time.

There is more information available on units in relativistic physics.

Peculiar Relativistic Effects

Length Contraction and Time Dilation

One of the strangest parts of special relativity is the conclusion that two observers who are moving relative to one another, will get different measurements of the length of a particular object or the time that passes between two eventsG.

Consider two observers, each in a space-ship laboratory containing clocks and meter sticks. The space ships are moving relative to each other at a speed close to the speed of light. Using Einstein's theory:

- Each observer will see the meter stick of the other as shorter than their own, by the same factor gamma (γ - defined above). This is called **length contraction**.
- Each observer will see the clocks in the other laboratory as ticking more slowly than the clocks in his/her own, by a factor gamma. This is called **time dilation**.

In particle acceleratorsG, particles are moving very close to the speed of light where the length and time effects are large. This has allowed us to clearly verify that length contraction and time dilation do occur.

Time Dilation for Particles

Particle processes have an intrinsic clock that determines the half-life of a decay process. However, the rate at which the clock ticks in a moving frame, as observed by a static observer, is slower than the rate of a static clock. Therefore, the half-life of a moving particles appears, to the static observer, to be increased by the factor gamma.

For example, let's look at a particle sometimes created at SLAC known as a tau. In the frame of reference where the tau particle is at rest, its lifetime is known to be approximately 3.05×10^{-13} s. To calculate how far it travels before decaying, we could try to use the familiar equation distance equals speed times time. It travels so close to the speed of light that we can use $c = 3 \times 10^8$ m/sec for the speed of the particle. (As we will see below, the speed of light in a vacuum is the highest speed attainable.) If you do the calculation you find the distance traveled should be 9.15×10^{-5} meters.

$$d = v\,t$$

$$d = (3 \times 10^{8}\ \text{m/sec})(3.05 \times 10^{-13}\ \text{s}) = 9.15 \times 10^{-5}\ \text{m}$$

Here comes the weird part - ***we measure the tau particle to travel further than this***!

Pause to think about that for a moment. This result is totally contradictory to everyday experience. If you are not puzzled by it, either you already know all about relativity or you have not been reading carefully.

What is the resolution of this apparent paradox? The answer lies in time dilation. In our laboratory, the tau particle is moving. The decay time of the tau can be seen as a moving clock. According to relativity, moving clocks tick more slowly than static clocks.

We use this fact to multiply the time of travel in the taus moving frame by gamma, this gives the time that we will measure. Then this time times *c*, the approximate speed of the tau, will give us the distance we expect a high energy tau to travel.

What is gamma in this case? It depends on the tau's energy. A typical SLAC tau particle has a gamma = 20. Therefore, we detect the tau to decay in an average distance of 20 x (9.15×10^{-5} m) = 1.8×10^{-3} m or approximately 1.8 millimeters. This is 20 times further than we expect it to go if we use classical rather than relativistic physics. (Of course, we actually observe a spread of decay times according to the exponential decay law and a corresponding spread of distances. In fact, we use the measured distribution of distances to find the tau half-life.)

Observations particles with a variety of velocities have shown that time dilation is a real effect. In fact the only reason cosmic ray muons ever reach the surface of the earth before decaying is the time dilation effect.

Length Contraction

Instead of analyzing the motion of the tau from our frame of reference, we could ask what the tau would see in its reference frame. Its half-life in its reference frame is 3.05×10^{-13} s. This does not change. The tau goes nowhere in this frame.

How far would an observer, sitting in the tau rest frame, see an observer in our laboratory frame move while the tau lives?

We just calculated that the tau would travel 1.8 mm in our frame of reference. Surely we would expect the observer in the tau frame to see us move the same distance relative to the tau particle. Not so says the tau-frame observer -- you only moved 1.8 mm/gamma = 0.09 mm relative to me. **This is length contraction.**

How long did the tau particle live according to the observer in the tau frame? We can rearrange $d = v \times t$ to read $t = d/v$. Here we use the same speed, Because the speed of the observer in the lab relative to the tau is just equal to (but in the opposite direction) of the speed of the tau relative to the observer in the lab, so we can use the same speed. So time $= 0.09 \times 10^{-3}$ m/(3×10^{8})m/sec $= 3.0 \times 10^{-13}$ sec. **This is the half-life of the tau as seen in its rest frame, just as it should be!**

SRI Y N COLLEGE (AUTONOMOUS) NARSAPUR

DEPARTMENT OF PHYSICS

MINOR RESEARCH PROJECT

Submitted to

DEPARTMENT OF PHYSICS

A STUDY ON THE HYDRO-METEOROLOICAL PARAMETERS OVER NARSAPUR

(2018-2019)

PROJECT DONE BY

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Under the guidance of :

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A STUDY ON THE HYDRO-METEOROLOGICAL PARAMETERS OVER NARSAPUR

INTRODUTION :

In India the period June through September is considered as the southwest monsoon season. During this period prevailing weak northeasterly winds are replaced by strong south westerlies over India systematically and the country alone receives about 70% of total amount of annual rainfall.

This rainfall is of paramount thing for both Karif crop of monsoon season and Rabi crop of Post monsoon season. Thus the Indian economy is linked with the monsoon performance interms of spatial and temporal variations. The monsoon period can be divided into three phases; namely onset and advance, peak rainfall period and withdrawal of the monsoon.

Based on the principle of Subbaramayya and Bhanukumar (1978) and with added strong westerly component over southwest India, Subbaramayya et al. (1984) published a chart for mean onset dates for the year1956-83 (fig.1). When compared with these dates with the IMD mean dates (fig.2), large difference can be seen over extreme south peninsula. Subbaramayya et al. (1984) reported the pulsatory nature of the advance of southwest monsoon over India.

Bhaskara Rao (1995) reported that zonal components of winds in April and May, play an important role in formulating regression equations to forecast the dates of onset of south-west monsoon over different regions of India. The onset over north-west India will be better forecasted with May winds.

The all-India summer monsoon rainfall mainly depends upon the May temperatures. This dependency may be due to the less time gap between the monsoon season and May month.

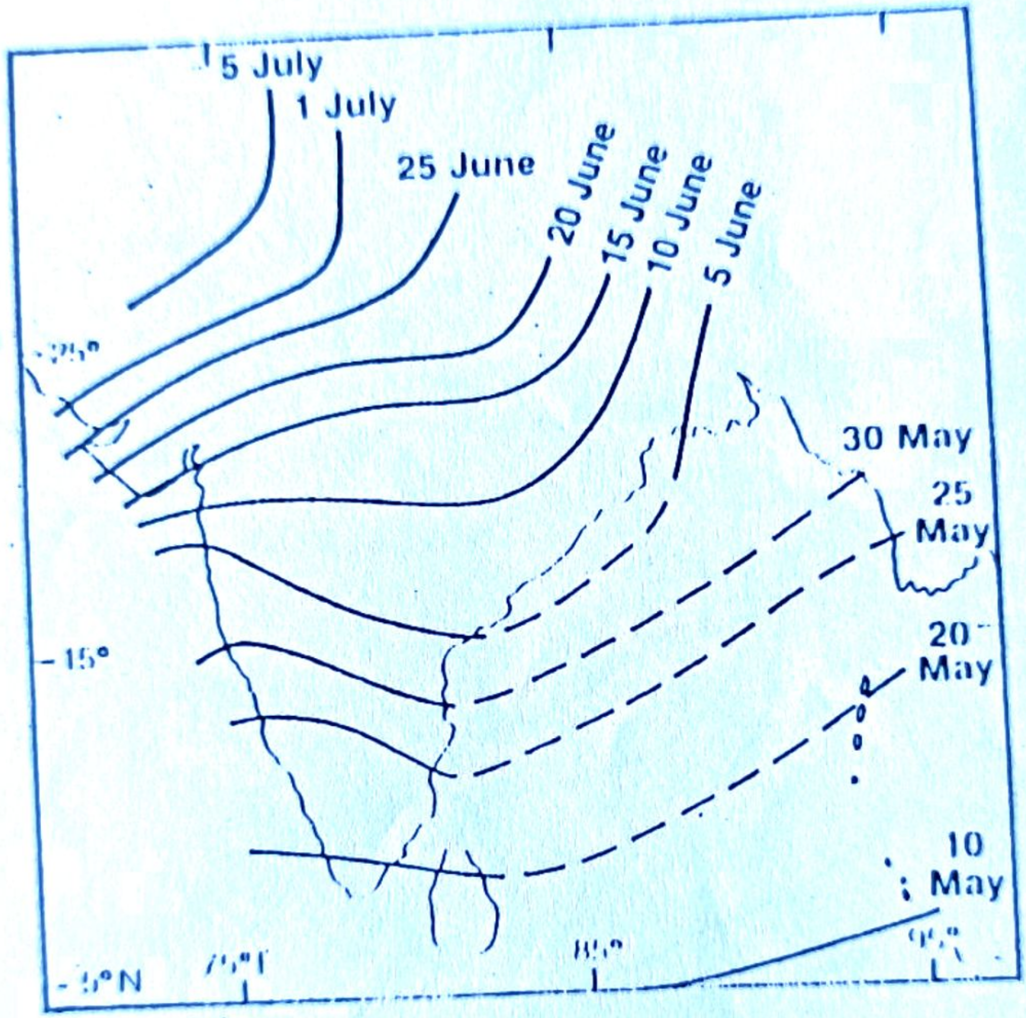

Fig.1. Mean dates of onset of southwest monsoon over India (after Subbaramayya et al. (1984))

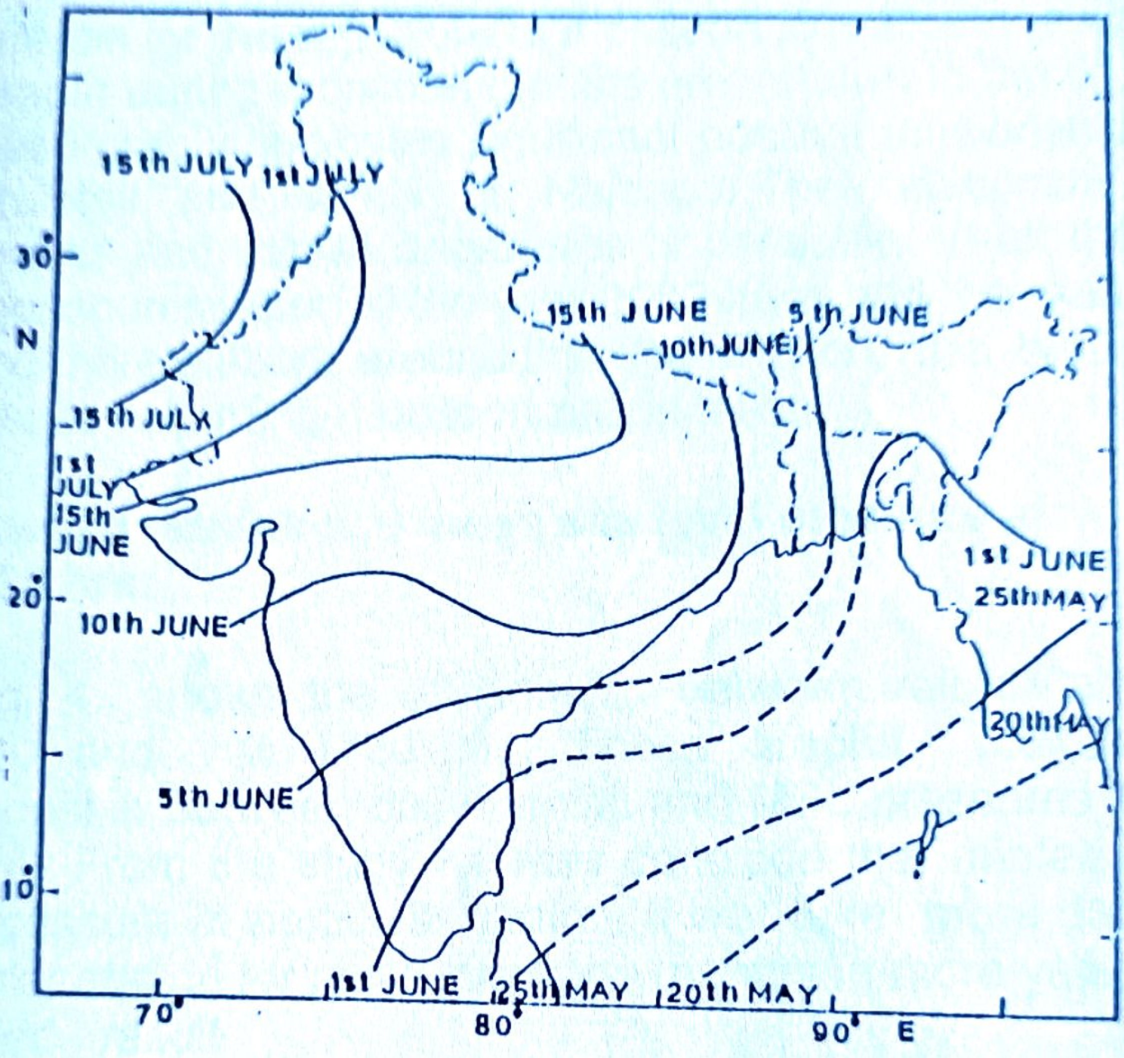

Fig. 2. Mean dates of onset of southwest monsoon (after IMD (1943)).

DATA AND ANALYSIS :

Now the present study is around Narsapur , West Godavari in Andhra Pradesh. The study station is located behind the Vasista Godavari. For this study the rainfall wind speeds, mean sea level pressures and temperarure data sets are obtained from the Meteorological Observatory at Narsapur. These data sets are taken for the present study as day wise around this station.

Relationship between the rainfall and wind speed over Narsapur:

The time series graphs for the departure of monsoon rainfall and wind speeds over Narsapur during monsoon months are shown in the fig. 3 (a,b and c). These graphs indicates significant positive relationship between daily rainfall and winds at Narsapur.The relationship between wind speeds and rainfall departures is persistent in all the months during monsoon season in the year 2003.If we add the data for more years and more stations around this sub-division, this study may give good results regarding monsoon precipitation.

Relationship between rainfall and mean sea level pressure at 0830 hrs and 1730 hrs:

The graphs in fig. 4, shows the relationship between rainfall and pressure at 0830 and at 1730 hrs. These graphs indicate insignificant relationship between daily rainfall and MSL pressures at two times per day. From the study we may conclude that rainfall is independent on pressure at particular station. If we take more data sets at the particular station for more monsoon months in more years. we can get detailed result.

Relationship between Monthly Rainfall over Narsapur and its Normal values:

The graph in fig. 5, shows the Relationship between rainfall and its normal values at Narsapur for all the months of the year 2003. The graph indicates significant relationship for all the months. In this minor study only one station has been considered but this study is expanded for more stations, it may give prominent result.

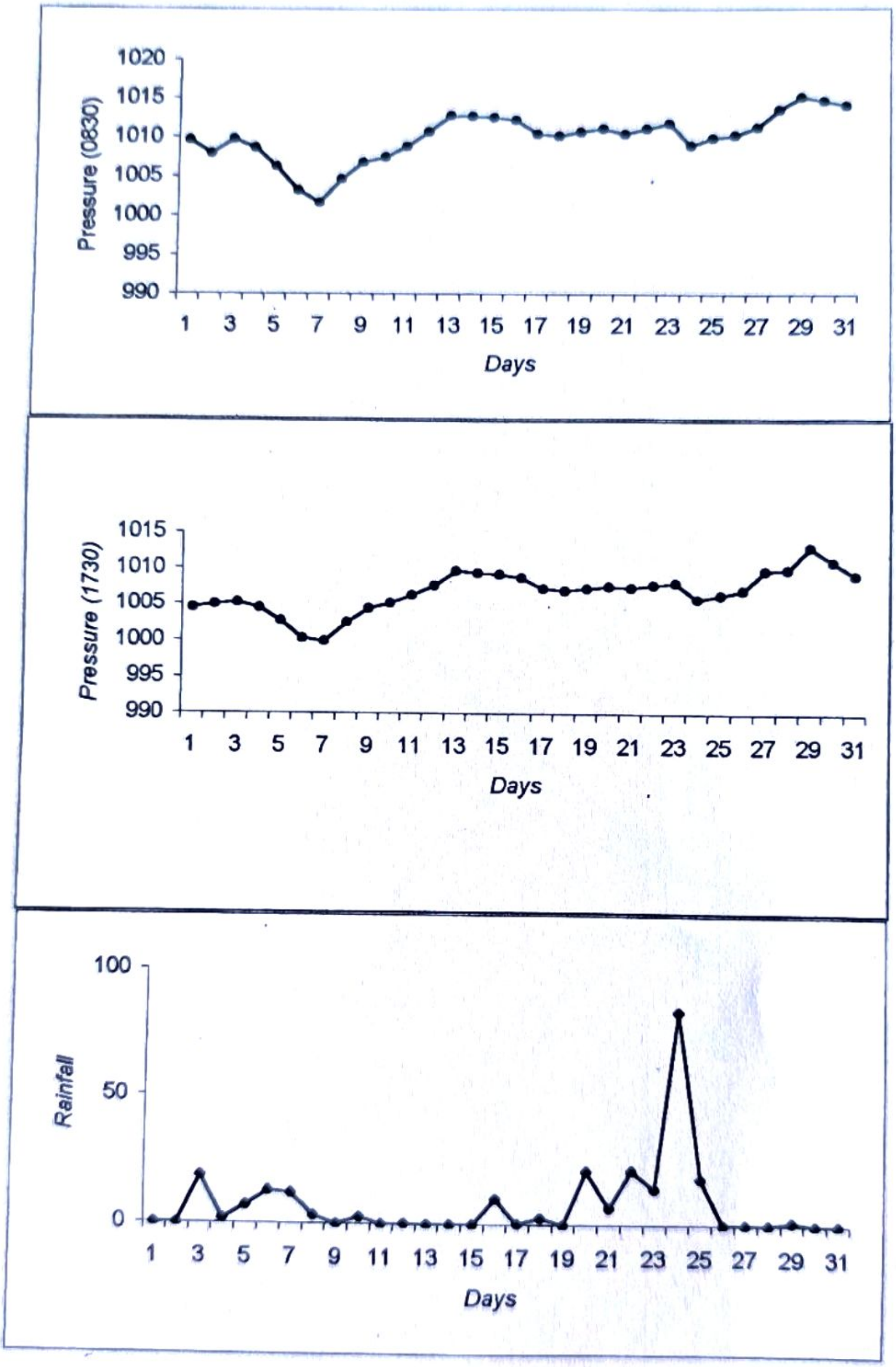
1020
1015
1010
1005
1000
995
990
Pressure (0830)
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Days
1015
1010
1005
1000
995
990
Pressure (1730)
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Days
100
50
0
Rainfall
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Days

Fig. 4.

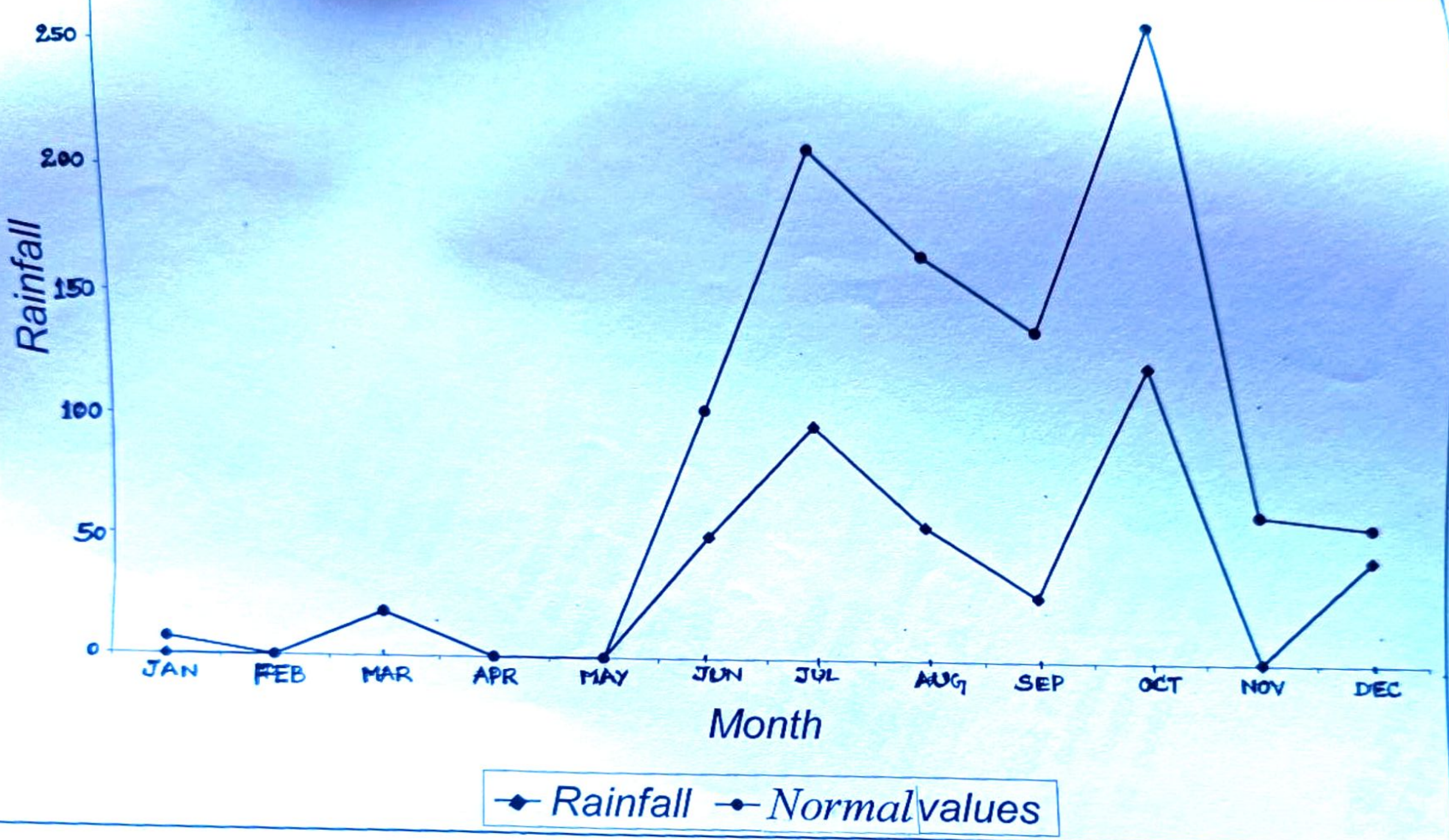
250
200
150
100
50
0
Rainfall
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
Month
Rainfall
Normal values

Fig. 5

SRI Y N COLLEGE (AUTONOMOUS) NARSAPUR

DEPARTMENT OF PHYSICS

STUDY PROJECT

Submitted to

DEPARTMENT OF PHYSICS

TSUNAMIS
(2018-2019)

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Would you like to learn more about tsunamis?

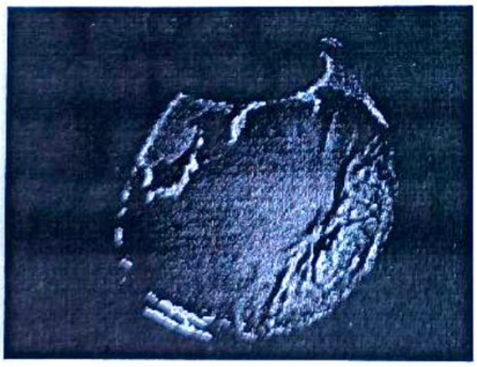
What does "tsunami" mean?

Tsunami is a Japanese word with the English translation, "harbor wave." Represented by two characters, the top character, "tsu," means harbor, while the bottom character, "nami," means "wave." In the past, tsunamis were sometimes referred to as "tidal waves" by the general public, and as "seismic sea waves" by the scientific community. The term "tidal wave" is a misnomer; although a tsunami's impact upon a coastline is dependent upon the tidal level at the time a tsunami strikes, tsunamis are unrelated to the tides. Tides result from the imbalanced, extraterrestrial, gravitational influences of the moon, sun, and planets. The term "seismic sea wave" is also misleading. "Seismic" implies an earthquake-related generation mechanism, but a tsunami can also be caused by a nonseismic event, such as a landslide or meteorite impact.

How do tsunamis differ from other water waves?

Tsunamis are unlike wind-generated waves, which many of us may have observed on a local lake or at a coastal beach, in that they are characterized as shallow-water waves, with long periods and wave lengths. The wind-generated swell one sees at a California beach, for example, spawned by a storm out in the Pacific and rhythmically rolling in, one wave after another, might have a period of about 10 seconds and a wave length of 150 m. A tsunami, on the other hand, can have a wavelength in excess of 100 km and period on the order of one hour.

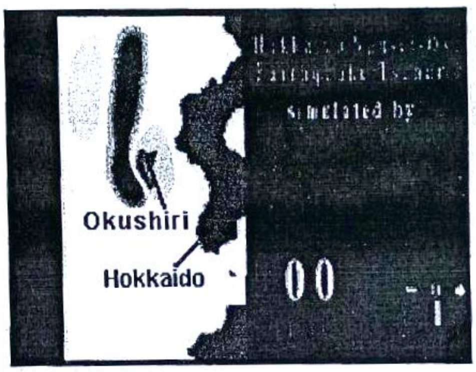
As a result of their long wave lengths, tsunamis behave as shallow-water waves. A wave becomes a shallow-water wave when the ratio between the water depth and its wave length gets very small. Shallow-water waves move at a speed that is equal to the square root of the product of the acceleration of gravity (9.8 m/s/s) and the water depth - let's see what this implies: In the Pacific Ocean, where the typical water depth is about 4000 m, a tsunami travels at about 200 m/s, or over 700 km/hr. Because the rate at which a wave loses its energy is inversely related to its wave length, tsunamis not only propagate at high speeds, they can also travel great, transoceanic distances with limited energy losses.



Note the vastness of the area across which the tsunami travels - Japan, which is over 17,000 km away from the tsunami's source off the coast of Chile, lost 200 lives to this tsunami. Also note how the wave crests bend as the tsunami travels - this is called refraction. Wave refraction is caused by segments of the wave moving at different speeds as the water depth along the crest varies. Please note that the vertical scale has been exagaerated in this animation - tsunamis are only about a meter high at the most in the open ocean.

How do earthquakes generate tsunamis?

Tsunamis can be generated when the sea floor abruptly deforms and vertically displaces the overlying water. Tectonic earthquakes are a particular kind of earthquake that are associated with the earth's crustal deformation;



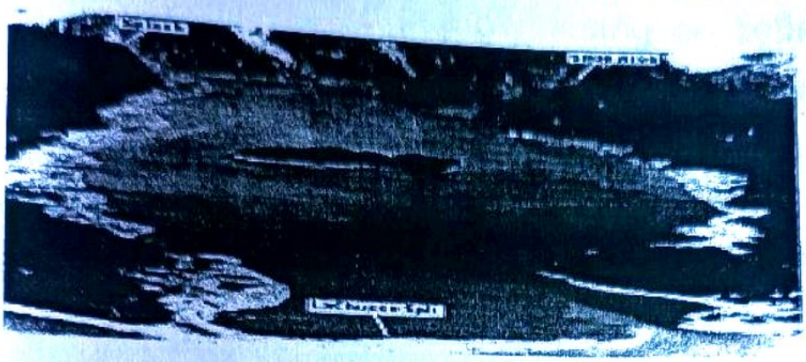
when these earthquakes occur beneath the sea, the water above the deformed area is displaced from its equilibrium position. Waves are formed as the displaced water mass, which acts under the influence of gravity, attempts to regain its equilibrium. When large areas of the sea floor elevate or subside, a tsunami can be created.

Large vertical movements of the earth's crust can occur at plate boundaries. Plates interact along these boundaries called faults. Around the margins of the Pacific Ocean, for example, denser oceanic plates slip under continental plates in a process known as subduction. Subduction earthquakes are particularly effective in generating tsunamis.

Areas in blue represent a water surface that is lower than the mean water level, while areas in red represent an elevated water surface. The initial water-surface profile, as shown in this image, reflects a large, long uplifted area of the sea floor lying to the west (left) of Okushiri Island, with a much smaller subsided area immediately adjacent to the southwest corner of Okushiri

How do landslides, volcanic eruptions, and cosmic collisions generate tsunamis?

A tsunami can be generated by any disturbance that displaces a large water mass from its equilibrium position. In the case of earthquake-generated tsunamis, the water column is disturbed by the uplift or subsidence of the sea floor. Submarine landslides, which often accompany large earthquakes, as well as collapses of volcanic edifices, can also disturb the overlying water column as sediment and rock slump downslope and are redistributed across the sea floor. Similarly, a violent submarine volcanic eruption can create an impulsive force that uplifts the water column and generates a tsunami. Conversely, supermarine landslides and cosmic-body impacts disturb the water from above, as momentum from falling debris is transferred to the water into which the debris falls. Generally speaking, tsunamis generated from these mechanisms, unlike the Pacific-wide tsunamis caused by some earthquakes, dissipate quickly and rarely affect coastlines distant from the source area.



This image shows Lituya Bay, Alaska, after a huge, landslide-generated tsunami occurred on July 9, 1958. The earthquake-induced rockslide, shown in upper right-hand corner of this image, generated a 525 m splash-up immediately across the bay, and razed trees along the bay and across LaChausse Spit before leaving the bay and dissipating in the open waters of the Gulf of Alaska.

What happens to a tsunami as it approaches land?

As a tsunami leaves the deep water of the open ocean and travels into the shallower water near the coast, it transforms. If you read the "How do tsunamis differ from other water waves?" section, you discovered that a tsunami travels at a speed that is related to the water depth - hence, as the water depth decreases, the tsunami slows. The tsunami's energy flux, which is dependent on both its wave speed and wave height, remains nearly constant. Consequently, as the tsunami's speed diminishes as it travels into shallower water, its height grows. Because of this shoaling effect, a tsunami, imperceptible at sea, may grow to be several meters or more in height near the coast. When it finally reaches the coast, a tsunami may appear as a rapidly rising or falling tide, a series of breaking waves, or even a bore.

What happens when a tsunami encounters land?

Just like other water waves, tsunamis begin to lose energy as they rush onshore - part of the wave energy is reflected offshore, while the shoreward-propagating wave energy is dissipated through bottom friction and turbulence. Despite these losses, tsunamis still reach the coast with tremendous amounts of energy. Tsunamis have great erosional potential, stripping beaches of sand that may have taken years to accumulate and undermining trees and other coastal vegetation. Capable of inundating, or flooding, hundreds of meters inland past the typical high-water level, the fast-moving water associated with the inundating tsunami can crush homes and other coastal structures. Tsunamis may reach a maximum vertical height onshore above sea level, often called a runup height, of 10, 20, and even 30 meters.

SRI Y N COLLEGE (AUTONOMOUS) NARSAPUR

DEPARTMENT OF PHYSICS

STUDY PROJECTS

Submitted to

DEPARTMENT OF PHYSICS

JOULE – THOMSON EFFECT
(2018-2019)

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Joule–Thomson effect:

From Wikipedia, the free encyclopedia

(Redirected from Joule-Thomson effect)
Jump to: navigation, search

In thermodynamics, the **Joule–Thomson effect** or **Joule–Kelvin effect** or **Kelvin–Joule effect** describes the temperature change of a gas or liquid when it is forced through a valve or porous plug while kept insulated so that no heat is exchanged with the environment.[1][2][3] This procedure is called a *throttling process* or *Joule–Thomson process*.[4] At room temperature, all gases except hydrogen, helium and neon cool upon expansion by the Joule–Thomson process.[5][6]

The effect is named for James Prescott Joule and William Thomson, 1st Baron Kelvin who discovered it in 1852 following earlier work by Joule on *Joule expansion,* in which a gas undergoes free expansion in a vacuum.

Description

The *adiabatic* (no heat exchanged) expansion of a gas may be carried out in a number of ways. The change in temperature experienced by the gas during expansion depends not only on the initial and final pressure, but also on the manner in which the expansion is carried out.

- If the expansion process is reversible, meaning that the gas is in thermodynamic equilibrium at all times, it is called an *isentropic* expansion. In this scenario, the gas does positive work during the expansion, and its temperature decreases.

- In a free expansion, on the other hand, the gas does no work and absorbs no heat, so the internal energy is conserved. Expanded in this manner, the temperature of an ideal gas would remain constant, but the temperature of a real gas may either increase or decrease, depending on the initial temperature and pressure.
- The method of expansion discussed in this article, in which a gas or liquid at pressure P_1 flows into a region of lower pressure P_2 via a valve or porous plug under steady state conditions and without change in kinetic energy, is called the Joule–Thomson process. During this process, enthalpy remains unchanged (see Appendix).

Temperature change of either sign can occur during the Joule–Thomson process. Each real gas has a Joule–Thomson (Kelvin) inversion temperature[2] above which expansion at constant enthalpy causes the temperature to rise, and below which such expansion causes cooling. This inversion temperature depends on pressure; for most gases at atmospheric pressure, the inversion temperature is above room temperature, so most gases can be cooled from room temperature by isenthalpic expansion.

Physical mechanism

As a gas expands, the average distance between molecules grows. Because of intermolecular attractive forces (see *Van der Waals force*), expansion causes an increase in the potential energy of the gas. If no external work is extracted in the process and no heat is transferred, the total energy of the gas remains the same because of the conservation of energy. The increase in potential energy thus implies a decrease in kinetic energy and therefore in temperature.

A second mechanism has the opposite effect. During gas molecule collisions, kinetic energy is temporarily converted into potential energy. As the average intermolecular distance increases, there is a drop in the number of collisions per time unit, which causes a decrease in average potential energy. Again, total energy is conserved, so this leads to an increase in kinetic energy (temperature). Below the Joule–Thomson inversion temperature, the former effect (work done internally against intermolecular attractive forces) dominates, and free expansion causes a decrease in temperature. Above the inversion temperature, gas molecules move faster and so collide more often, and the latter effect (reduced collisions causing a decrease in the average potential energy) dominates: Joule–Thomson expansion causes a temperature increase.

The Joule–Thomson (Kelvin) coefficient

The rate of change of temperature T with respect to pressure P in a Joule–Thomson process (that is, at constant enthalpy H) is the *Joule–Thomson (Kelvin) coefficient* μ_{JT}. This coefficient can be expressed in terms of the gas's volume V, its heat capacity at constant pressure C_p, and its coefficient of thermal expansion α as:[1][3][7]

See the Appendix for the proof of this relation. The value of μ_{JT} is typically expressed in °C/bar (SI units: K/Pa) and depends on the type of gas and on the temperature and pressure of the gas before expansion.

All real gases have an *inversion point* at which the value of μ_{JT} changes sign. The temperature of this point, the *Joule–Thomson inversion temperature*, depends on the pressure of the gas before expansion.

In a gas expansion the pressure decreases, so the sign of is always negative. With that in mind, the following table explains when the Joule–Thomson effect cools or warms a real gas:

If the gas temperature is	then μ_{JT} is	since is	thus must be	so the gas
below the inversion temperature	positive	always negative	negative	cools
above the inversion temperature	negative	always negative	positive	warms

Helium and hydrogen are two gases whose Joule–Thomson inversion temperatures at a pressure of one atmosphere are very low (e.g., about 51 K (−222 °C) for helium). Thus, helium and hydrogen warm up when expanded at constant enthalpy at typical room temperatures. On the other hand nitrogen and oxygen, the two most abundant gases in air, have inversion temperatures of 621 K (348 °C) and 764 K (491 °C) respectively: these gases can be cooled from room temperature by the Joule–Thomson effect.[1]

For an ideal gas, μ_{JT} is always equal to zero: ideal gases neither warm nor cool upon being expanded at constant enthalpy.

Applications

In practice, the Joule–Thomson effect is achieved by allowing the gas to expand through a throttling device (usually a valve) which must be very well insulated to prevent any heat transfer to or from the gas. No external work is extracted from the gas during the expansion (the gas must not be expanded through a turbine, for example).

The effect is applied in the Linde technique as a standard process in the petrochemical industry, where the cooling effect is used to liquefy gases, and also in many cryogenic applications (e.g. for the production of liquid oxygen, nitrogen, and argon). Only when the Joule–Thomson coefficient for the given gas at the given temperature is greater than zero can the gas be liquefied at that temperature by the Linde cycle. In other words, a gas must be below its inversion temperature to be liquefied by the Linde cycle. For this reason, simple Linde cycle liquefiers cannot normally be used to liquefy helium, hydrogen, or neon.

JOULE THOMSON EFFECT

What is the Joule-Thomson effect? When a non-ideal gas suddenly expands from a high pressure to a low pressure there is often a temperature change. Officially, the ratio of $\Delta T/\Delta P$ is known as the Joule-Thomson coefficient. Note that this is far from a reversible effect! It is however an adiabatic effect, and in many applications adibaticity (yes, that is a real word!) results from the simple fact that the pressure change occurs too quickly for significant heat transfer to occur. For many gases at room temperature, the $\Delta T/\Delta P$ ratio is positive. Thus, a pressure drop is accompanied by a temperature drop. For example, if a tank of CO_2 is opened to the atmosphere, one can see a spray of fine dry ice particles emerging at about $-78\ ^{o}$C. Expansion of air from a very high pressure to atmospheric pressure can be used to cool the air to the point of liquification. Low-temperature distillation of the liquid thus produced is then used to make liquid nitrogen (nbp at 77 K), liquid oxygen (nbp = ?? K) and even liquid Ar (nbp = ??K).. The latter, you may recall, constitutes about 1% of natural air. For a few gases, He and H_2 in particular, the JT coefficient is negative at room temperature. However, the sign switches to a positive value at lower temperatures, and so it is still possible to liquify these gases by JT expansion if they are first cooled, say by liquid nitrogen.

The even more official definition of the Joule-Thomson coefficient is given by the following equation, which is discussed fully in the Derivations manual discussion of this effect:

→

Read the Shoemaker, et al. source for a more general background. The thermocouples are both copper-constantan, and you already have a calibration equation from lab 1 which can be used to convert voltage differences between the two junctions to temperature differences. The microvoltmeter is very sensitive to stray sources of voltage. Recommended gases are carbon dioxide and nitrogen. Hook up the carbon dioxide first (it shows the largest effect and is therefore easiest to work with at the star.) Make about 10 measurements between 50 and 200 kPa. For each pressure, set the pressure changes slowly, make sure that the magnetic stirrer is off, then step back and wait for the voltage to stabilize.

Analyzing the data: The Joule-Thomson coefficient is nearly constant over the limited range of the experiment. The μVvalues are proportional to ΔT, and therefore a plot of μV vs. kPa should be fairly linear. Before switching gases, make an Excel plot to see if the data is in fact reasonably linear. There may be a problem if there is significant curvature, and this should be ascertained before changing the gas.

For the final plots, use the "xyLsquare" Excel sheet on the lab computers. This is an interesting case where the "x" and "y" values are readings which both hxave significant uncertainties which you can estimate. The recommended spreadsheet allows both x and y uncertainties to be incorporated into a "weighted" linear fit which leads to much more realistic uncertainty estimates for the slope. The slope will, of course, be in units of uV per kPa.

Take the slope (and its uncertainty) and convert it to K per atm units which may be compared to literature values (see "Big Atkins" on reserve in the library for the accepted values for common gases.)

The report should include:

1. A derivation with discussion of the significant equations used in the Joule-Thomson
analysis. There is information on this in the Derivations manual, and in Shoemaker et al.
2. Show how to get the result for the JT coefficient predicted by the Van der Waals equation – the derivation is outlined in the Shoemaker et al. resource.
3. Graphs and least-squares analysis of voltage changes versus pressure changes. Show how the results lead to your experimental JT values and their uncertainties.

4. Compare the experimental results with the accepted literature values and with values predicted by the Van der Waals-based theory (item 2 above).
5. References to literature sources, in accepted journal style.
The reports should be written individually.

SRI Y N COLLEGE (A), NARSAPUR

ACADEMIC YEAR 2018-2019

PROJECT WORK

SUBMITTED TO

DEPARTMENT OF PHYSICS

TOPIC: Carnot's cycle

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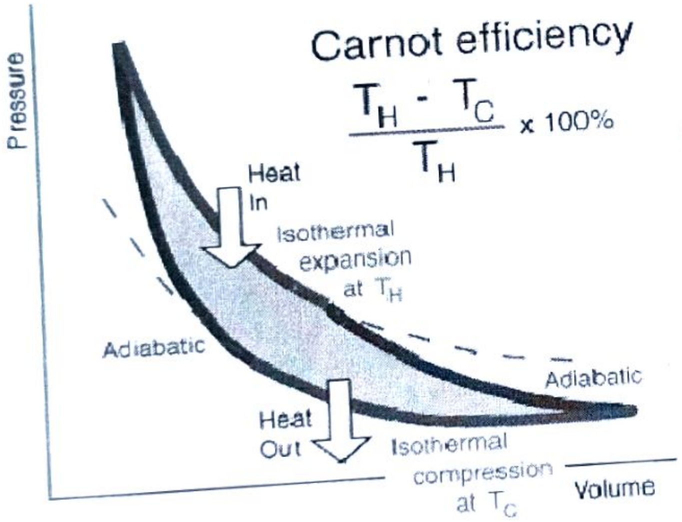
CARNOT CYCLE.

The most efficient heat engine cycle is the Carnot cycle, consisting of two isothermal processes and two adiabatic processes. The Carnot cycle can be thought of as the most efficient heat engine cycle allowed by physical laws. When the second law of thermodynamics states that not all the supplied heat in a heat engine can be used to do work, the Carnot efficiency sets the limiting value on the fraction of the heat which can be so used.

In order to approach the Carnot efficiency, the processes involved in the heat engine cycle must be reversible and involve no change in entropy. This means that the Carnot cycle is an idealization, since no real engine processes are reversible and all real physical processes involve some increase in entropy.



For

T_H = ⌐ K

T_C = ⌐ K

the Carnot efficiency is

⌐ %

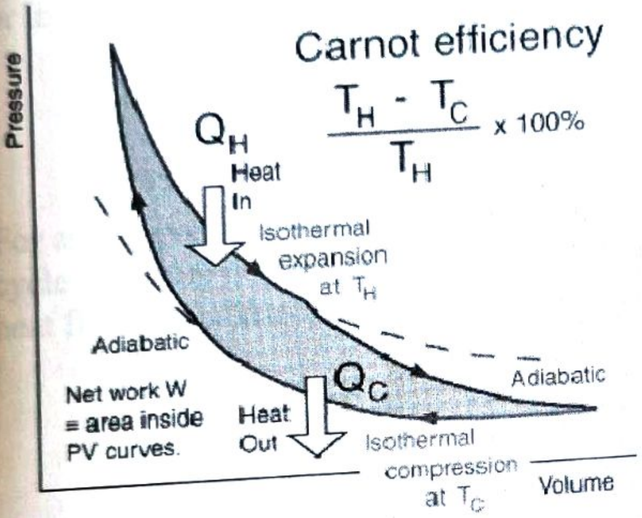
The temperatures in the Carnot efficiency expression must be expressed in Kelvins. For the other temperature scales, the following conversions apply:

T_H = ⌐ K = ⌐ °C = ⌐ °F

T_C = ⌐ K = ⌐ °C = ⌐ °F

The conceptual value of the Carnot cycle is that it establishes the maximum possible efficiency for an engine cycle operating between T_H and T_C. It is not a practical engine cycle because the heat transfer into the engine in the isothermal process is too slow to be of practical value. As Schroeder puts it "So don't bother installing a Carnot engine in your car; while it would increase your gas mileage, you would be passed on the highway by pedestrians."

Entropy and the Carnot Cycle



The efficiency of a heat engine cycle is given by

$$\eta = \frac{W}{Q_H} = \frac{Q_H - Q_C}{Q_H}$$

For the ideal case of the Carnot cycle, this efficiency can be written

$$\eta = \frac{T_H - T_C}{T_H}$$

Using these two expressions together

$$1 - \frac{Q_C}{Q_H} = 1 - \frac{T_C}{T_H}$$

$$\frac{Q_C}{T_C} = \frac{Q_H}{T_H} \quad or \quad \frac{Q_H}{T_H} - \frac{Q_C}{T_C} = 0$$

If we take Q to represent heat added to the system, then heat taken from the system will have a negative value. For the Carnot cycle

$$\sum_i \frac{Q_i}{T_i} = 0$$

which can be generalized as an integral around a reversible cycle

$$\oint \frac{dQ}{T} = 0 \text{ Clausius Theorem}$$

For any part of the heat engine cycle, this can be used to define a change in entropy S for the system

$$S(B) - S(A) = \int_A^B \frac{dQ}{T}$$

or in differential form at any point in the cycle

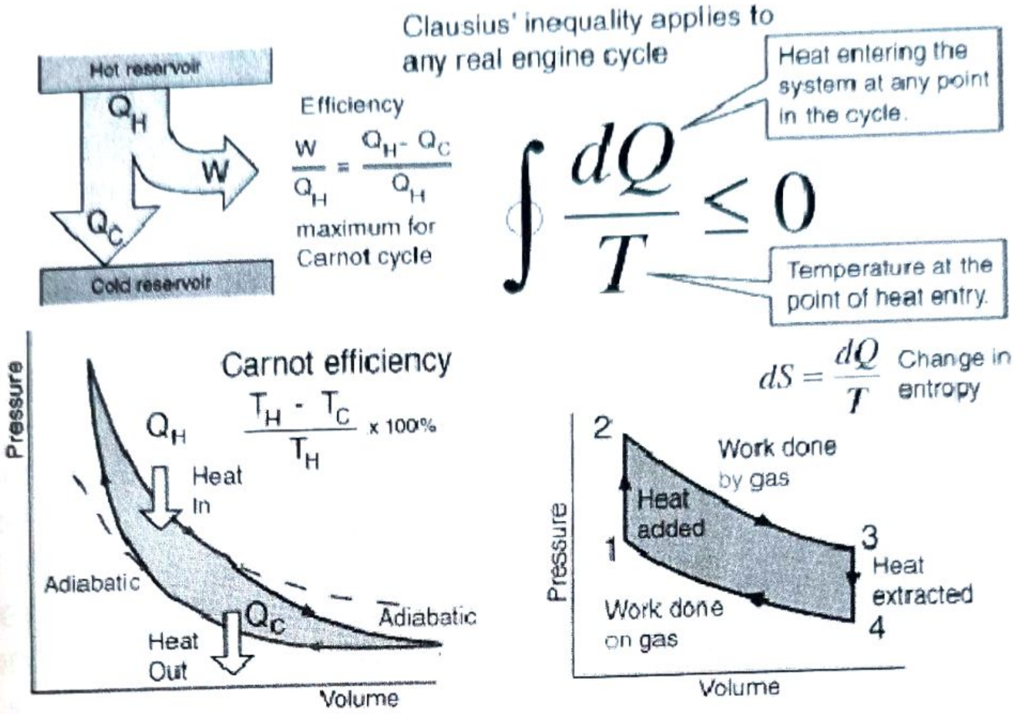
$$dS = \frac{dQ}{T}$$

For any irreversible process, the efficiency is less than that of the Carnot cycle. This can be associated with less heat flow to the system and/or more heat flow out of the system. The inevitable result is

$$\oint \frac{dQ}{T} \leq 0 \text{ Clausius Inequality}$$

Any real engine cycle will result in more entropy given to the environment than was taken from it, leading to an overall net increase in entropy.

The Clausius Theorem and Inequality



The equality above represents the Clausius Theorem and applies only the the ideal or Carnot cycle. Since the integral represents the net change in entropy in one complete cycle, it attributes a zero entropy change to the most efficient engine cycle.

The Clausius Inequality applies to any real engine cycle and implies a negative change in entropy on the cycle. That is, the entropy given to the environment during the cycle is larger than the entropy transferred to the engine by heat from the hot reservoir. In the simplified heat engine where the heat Q_H is all added at temperature T_H, then an amount of entropy $\Delta S = Q_H/T_H$ is added to the system and must be removed to the environment to complete the cycle. In general, the engine temperature will be less than T_H for at least part of the time when heat is being added, and any temperature difference implies an irreversible process. Excess entropy is created in any irreversible process, and therefore more heat must be dumped to the cold reservoir to get rid of this entropy. This leaves less energy to do work.

CARNOT'S CYCLE OF HEAT ENGINE:

Thermodynamics is a branch of physics which deals with the energy and work of a system. Thermodynamics deals with the large scale response of a system which we can observe and measure in experiments. As aerodynamicists, we are most interested in the thermodynamics of propulsion systems and high speed flows. To understand how a propulsion system works, we must study the basic thermodynamics of gases.

Gases have various properties that we can observe with our senses, including the gas pressure p, temperature T, mass, and volume V that contains the gas. Careful, scientific observation has determined that these variables are related to one another, and the values of these properties determine the state of the gas. A thermodynamic process, such as heating or compressing the gas, changes the values of the state variables in a manner which is described by the laws of thermodynamics. The work done by a gas and the heat transferred to a gas depend on the beginning and ending states of the gas and on the process used to change the state.

It is possible to perform a series of processes, in which the state is changed during each process, but the gas eventually returns to its original state. Such a series of processes is called a cycle and forms the basis for understanding engines. The Carnot Cycle is one of the fundamental thermodynamic cycles and is described on this web page. We will use a p-V diagram to plot the various processes in the Carnot Cycle. The cycle begins with a gas, colored yellow on the figure, which is confined in a cylinder, colored blue. The volume of the cylinder is changed by a moving red piston, and the pressure is changed by placing weights on the piston. We have two heat sources; the red one is at a nominal 300 degrees, and the purple one is at 200 degrees. Initially, the gas is in State 1 at high temperature, high pressure, and low volume.

* The first process performed on the gas is an isothermal expansion. The 300 degree heat source is brought into contact with the cylinder, and weight is removed, which lowers the pressure in the gas. The temperature remains constant, but the volume increases. During the process from State 1 to State 2 heat is transferred from the source to the gas to maintain the temperature. We will note the heat transfer by Q1 into the gas.
* The second process performed on the gas is an adiabatic expansion. During an adiabatic process no heat is transferred to the gas. Weight is removed, which lowers the pressure in the gas. The temperature decreases and the volume increases as the gas expands to fill the volume. During the process from State 2 to State 3 no heat is transferred.
* The third process performed on the gas is an isothermal compression. The 200 degree heat source is brought into contact with the cylinder, and weight is added, which raises the pressure in the gas. The temperature remains constant, but the volume decreases. During the process from State 3 to State 4 heat is transferred from the gas to heat source to maintain the temperature. We will note the heat transfer by Q2 away from the gas.
* The fourth process performed on the gas is an adiabatic compression. Weight is added, which raises the pressure in the gas. The temperature increases and the volume decreases as the gas is compressed. During the process from State 4 to State 1 no heat is transferred.

At the end of the fourth process, the state of the gas has returned to its original state and the cycle can be repeated as often as you wish. During the cycle, work W has been produced by the gas, and the amount of work is equal to the area enclosed by the process curves. From the first law of thermodynamics, the amount of work produced is equal to the net heat transferred during the process:

W = Q1 - Q2

The Carnot Cycle has performed as an engine, converting the heat transferred to the gas during the processes into useful work. A similar Brayton Cycle explains how a gas turbine engine works, and an Otto Cycle explains how an internal combustion engine works.

SRI Y N COLLEGE (AUTONOMOUS) NARSAPUR
DEPARTMENT OF PHYSICS

STUDY PROJECT

Submitted to

DEPARTMENT OF PHYSICS

FIRE ALARM
(2018-2019)

PROJECT DONE BY

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FIRE ALARM

INTRODUCTION:

Fire Alarm circuit built around 555 timer IC. A reverse biased Germenium Diode is used here as a heat sensor. At room Temperature the reverse resistance of the diode being very high (over 10 K Ohm), it produces no effect on Transistor T_1 which conducts and keeps the reset pin 4 of IC1 at ground level, and so the alarm does not sound.

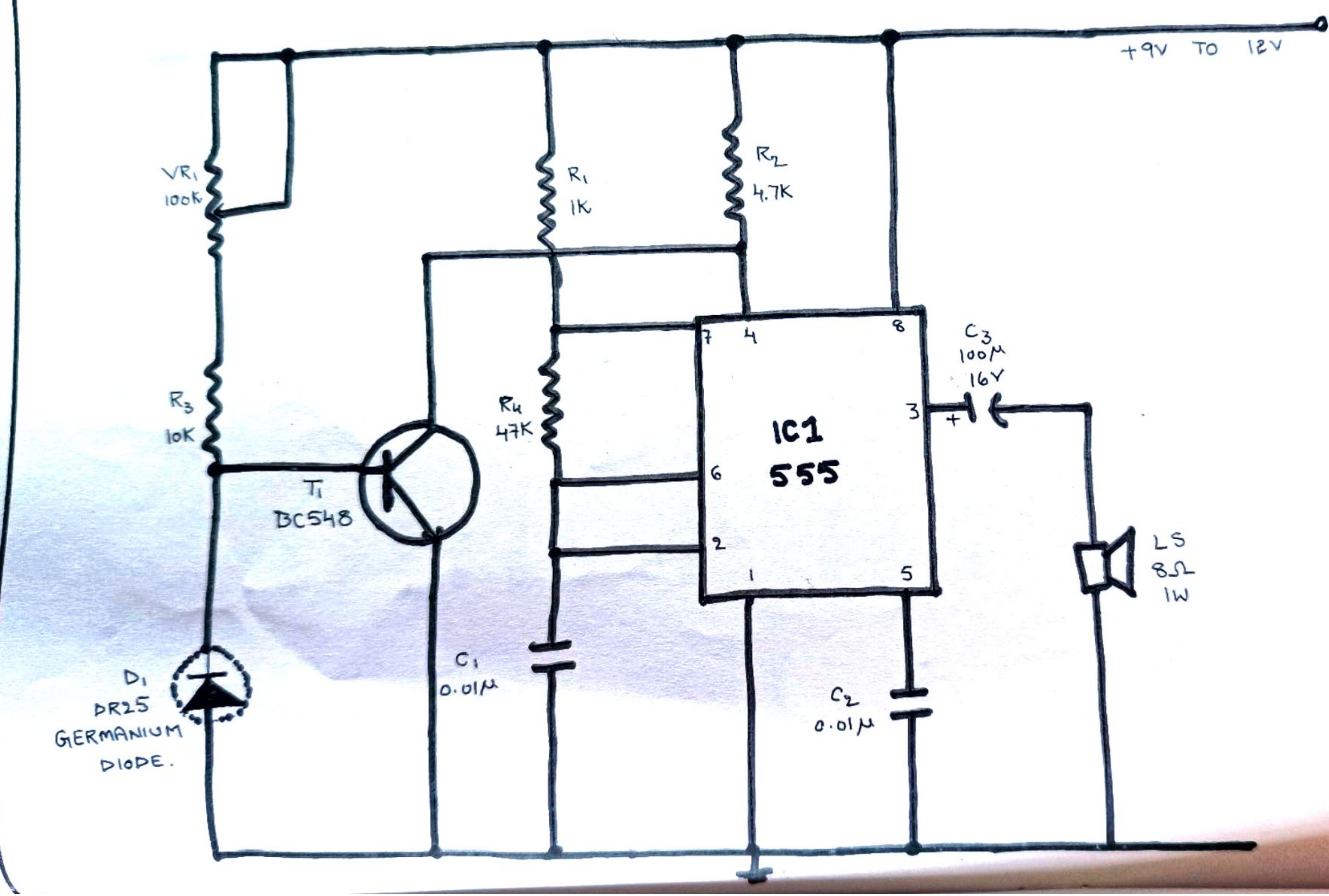
WORKING:

When temperature in the vicinity of diode D_1 (the sensor) increases in case of fire, the reverse resistance of D_1 drops. At about 70^0 C its resistance drops to a value below 1 K Ohm. This stops T_1's conduction and the IC's reset pin 4 becomes 'positive' through resistor R_2 which sounds the alarm.

For installation of the alarm, two or three reverse biased Germanium diodes connected in parallel can be kept at different locations. In case of a fire, any of the diodes can sense the heat and raise the alarm.

DR_{25} diode is recommended for use as a senser.

FIRE ALARM



+9V TO 12V
VR1
100K
R1
1K
R2
4.7K
R3
10K
R4
47K
T1
BC548
IC1
555
7
4
8
6
2
1
5
3
C3
100µ
16V
+
LS
8Ω
1W
C1
0.01µ
C2
0.01µ
D1
DR25
GERMANIUM
DIODE.

LIST OF PARTS:

Resistors:

VR1	100 KΩ
R1	1 KΩ
R2	4.7 KΩ
R3	10 KΩ
R4	47 KΩ

Loud Speaker: LS 8 Ω/1W

Power Supply: 9V to 12V

IC's: IC 555

Diodes:

D1	DR 25(Germanium)

Transistor:

T1	BC 548

Capacitors:

C1	0.01 µF
C2	0.01 µF
C3	100 µF/16V