A Dissertation Report on

DESIGN AND FABRICATION OF A NEW SOLAR HARNESSING SYSTEM FOR COOKING PURPOSE

SUBMITTED IN PARTIAL FULFILLMENT FOR THE AWARD OF MASTER OF TECHNOLOGY IN PRODUCTION ENGINEERING

BY

UMESH KUMAR SAHU
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UNDER THE GUIDANCE OF

Dr. HARLAL SINGH MALI
DEPARTMENT OF MECHANICAL ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

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DEPARTMENT OF MECHANICAL ENGINEERING

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CERTIFICATE

This is to certify that the dissertation entitled **"DESIGN AND FABRICATION OF A NEW SOLAR HARNESSING SYSTEM FOR COOKING PURPOSE"** is being submitted by ***Mr. Umesh Kumar Sahu,*** *M.Tech-4th Semester (*2013 PPE 5097*)* as requirement for partial fulfillment of award of the degree of ***Master of Technology, Production Engineering,*** **Mechanical Engineering Department,** Malaviya National Institute of Technology, Jaipur is found to be satisfactory and is hereby approved for submission.

Date:

Place: Jaipur

Dr. Harlal Singh Mali

Department Of Mechanical Engineering

Malaviya National Institute of Technology Jaipur,

Rajasthan

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Date: Umesh Kumar Sahu

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ABSTRACT

Solar harnessing system for house hold works can not only solve the energy problem of human kind but also can reduce the environmental degradation. This work has been done towards the new design of solar harnessing system. Requirement of new design is done considering the loss of heat energy on the path of heat transfer via media (mineral oils). The new design is based on the direct transferring of concentrated beam of solar radiation to the load /storage point by combining the principle of existing solar cookers and light pipe. The system also electronically tracks the sun making the solar rays always normal to the collection plane. The system is designed using CAD tool i.e. Autodesk Inventor and Circuit Simulation tool i.e. Proteus 7.7.

The collection plane is formed by a Fresnel lens and is used for focusing the light then another set of concave and convex lenses is used for making it into a beam. This beam can be traversed to a long distance using its reflection property. A set of hollow pipes are used with mirrors inside at 45 degree to guide the beam. This system enables user to guide concentrated solar radiation to the load point for example in cooking application. Generally a person who uses solar cooker needs to go out of the kitchen and cook food for long time into sun light or in a shelter, but this enables solar light to travel inside the kitchen and cook food easily. This radiation can also be made to fall on a heat storage device that can be used for late night or when sun is not available. The available average energy per day (Rajasthan) to store heat storage device is 204.48×10^2 kWh/m^2. A heat storage device can store energy for 4-5 days that depends on the salt used. This system works using battery power of 12 volt with solar rechargeable kit.

The identified modules of the systems are (a) Ray guiding system, (b) support frame, (c) refractors and reflectors, (d) Passage for the beam, (e) Load setup and (f) Storage system. Hence, the two modes of the system are: (a) Cook food inside kitchen and (b) Store heat into a heat storage device. With the help of this system a person can save energy in the form of electricity and fuel which is totally eco friendly and cost effective.

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1. INTRODUCTION

Todays biggest challenge is to minimize pollution by innovating newer ways to get non-conventional energy as they don't produce any pollutants. Energy requirment for Cooking is the one of the major most pollutant producing activity in india. The cooking energy demand in rural areas of developing countries is largely met with bio-fuels such as fuel wood, charcoal, agricultural residues and dung cakes, whereas Liquefied Petroleum Gas (LPG) or electricity is predominantly used in urban areas. Wood cut for cooking purpose contributes to the 16 million hectares of forest destroyed annually, which is causing indoor air pollution. Different energy sources for cooking have been evaluated and LPG stove is found to be the most preferred cooking device in India. A solar cooker is an environmental friendly and cost effective device for harnessing solar energy with less pollution.

When we think of a solar cooking device the only thing that comes into our mind is its portability, comfort of cooking and its performance (minimum loss of heat). To have comfort with cooking in solar cooking system load point should have to be inside the shelter or kitchen, so that person can protect himself from sunlight and stove's thermal radiation, so while designing the solar cooking system the designers keep this in mind and design the cooking system for minimum heat loss and maximum comfort and portability.

In all cooking system the transferring mechanism for heat, plays an important role that decides the overall efficiency of the system. Various types of cooking systems are currently available in the market that consists of one solar energy collector part, second heat transferring mechanism and third the application or load point. So following are most important point that needs to be concerned while designing new system.

1. It should be portable and easy to install.
2. Can be used inside the shelter or kitchen.
3. System that reduces heat loss.

This system design must be cost effective with compared to existing system and easily available materials.

2. LITERATURE REVIEW

2.1-BACKGROUND

The conventional box-type cooker design has been studied and modified since 1980s and various designs and their characteristics have been extensively investigated (1). Box type cooker with multiple reflectors are easy to build and use, but cooking has to be done outdoor and it is slow. Hot box ovens and concentrating solar cookers are cheap and effective; however they are limited to cooking during clear sky periods. Though parabolic cookers are used for fast cooking, cooking rate cannot be controlled and it is potentially hazardous due to focusing of sun beam (1)Solar cooking with energy storage using a pressurized water vessel (2), phase change material, pebble bed thermal energy storage (TES) (2)and box-type solar cooker with auxiliary heating have been proposed, which require the cook to work outdoors in rural areas and on roof tops in urban areas. A split-system solar cooker exists (2)which has its flat-plate collector outdoors and the cooking chamber inside the kitchen, with heat pipes transferring the energy between the two. Solar cooker with vacuum tube collector with heat pipes has been proposed where refrigerants are used for heat transfer. Multipurpose solar cooker cum water heater and single basin solar still with PCM storage have been proposed. Heat exchanger for solar hot water storage system has been proposed. For a solar cooking system to be accepted and adopted in most of the households, the following objectives have to be satisfied.

1. The cooking should be done without moving out of the kitchens.
2. A reduction in the use of conventional energy.
3. Cooking can be carried out at any time of day.
4. Time taken for cooking must be comparable with conventional cooking.

2.2 BENEFITS OF SOLAR HARNISSING SYSTEM (3):

There are plenty of excellent reasons that equate to advantages in using solar energy. Here are some advantages in using solar energy.

1. THE ABUNDANCE OF SOLAR ENERGY.

Even in the middle of winter each square meter of land still receives a fair amount of solar radiation. Sunlight is everywhere and the resource is practically inexhaustible. Even during cloudy days we still receive some sunlight and it is this that can be used as a renewable resource.

2. NOTHING TO PAY FOR SUNLIGHT.

Sunlight is totally free; there is of course some initial investment for the equipment but after the initial capital outlay you won't be receiving any bill every month for the rest of your life from the electric utility.

3. SOLAR ENERGY IS GETTING MORE COST EFFECTIVE.

The technology for solar energy is evolving at an increasing rate. At present photovoltaic technology is still relatively expensive but the technology is improving and production is increasing. The result of this is to drive costs down. Payback times for the equipment are getting shorter and in some areas where the cost of electricity is high payback may be as short as five years.

4. SOLAR ENERGY IS NON-POLLUTING.

Solar energy is an excellent alternative for fossil fuels like coal and petroleum because solar energy is practically emission free while generating electricity. With solar energy the danger of further damage to the environment is minimized. The generation of electricity through solar power produces no noise. So noise pollution is also reduced.

5. ACCESSIBILITY OF SOLAR POWER IN REMOTE LOCATIONS.

Solar power can generate electricity no matter how remote the area as long as the sun shines there. Even in areas that are inaccessible to power cables solar power can produce electricity.

6. SOLAR ENERGY SYSTEMS ARE VIRTUALLY MAINTENANCE FREE.

Once a photovoltaic array is setup it can last for decades. Once they are installed and setup there are practically zero recurring costs. If needs increase solar panels can be added with ease and with no major revamp.

2.3. SIGNIFICANT TECHNOLOGIES:

There are several methodologies for harneshing of solar energy are;

2.3.1. HYBRID SOLAR COOKING (2)

In this device in which solar collectors are used to store thermal energy. There are two levels of heat transfer with intermediate energy storage in a buffer tank. The heat is first transferred from the solar collector to the storage tank. The first pump controls the fluid flow rate to control the heat transfer from the collector to tank and the second one is for circulating fluid to the load.

2.3.2. PARABOLIC SOLAR COOKER (1)

In this solar cooker a solar parabolic concentrator is used which is constructed of steel profile and Cr-ni alloy sheet. at the centre of the concentrating reflector, a cooking pot are painted with mat black thus Cr-Ni sheet acts as a reflector to concentrate the sun's rays on the cooking pot. The reflector could be adjusted by means of two screws.

2.3.3. REFRIGERENT BASED SOLAR COOKING SYSTEM (4)

In this solar cooker a vaccum-tube collector is used with heat pipes containing dfferent refrigerants. It consists of three main components: collector, heat pipes, and oven section. collector is made up of evacuated double-wall(concentric) glass tubes mounted on parabollic concentrating chorme nickel reflectors. The heat transfer liquid used in condenser unit is Mobiltherm 605 oil which is thermally stable and Capable of a long service life without deposit formation Or viscosity increase. a simple phenomina of heat convection process is used here for getting heat.

2.3.4. STEAM BASED SOLAR COOKING SYSTEM (5)

In this cooking system a solar parabolic reflector is used to redirect solar light onto a collector where water is heated to produce steam later it is used for cooking of rice and other foods that can be prepared using steam. It consists of simple pipe arrangement to supply steam to the loads.

2.4. SOLAR COLLECTORS WITH REFLECTORS & REFRATORS:

A collector is that part of solar energy equipment which transforms solar energy into thermal energy or stored into a medium in the form of internal energy. The major component of solar system is the solar collector. For all solar energy applications various types of collectors are used and sometimes a reflector is used to redirect radiations towards the collector. Reflectors are made of different shapes, coatings and material; various coatings and materials are used for different application like infrared reflector based coating used in solar application and infrared absorber based coatings is used in Operation theater lamp. There are several of the most common collectors available in the market are (6);

1. Stationary collectors
   a. Flat-plate collectors
      i. Glazing materials
      ii. Collector absorbing plates
   b. Compound parabolic collectors
   c. Evacuated tube collectors
2. Sun tracking concentrating collectors
   a. Parabolic through collectors
   b. Linear Fresnel reflectors
   c. Parabolic dish reflector
   d. Heliostat fields collector

Among all types of solar collectors concentrating collectors are most preferred collectors because that allows to attain high temperature; large amount of solar radiation is concentrated on a relatively small collection area. This is done by introducing a reflective of refractive surface between them. Highest attainable temperature is directly based on concentration ratio.

Disadvantages of using a collectors and refractors are (6) diffused radiation, necessity of solar tracking, reflectance loss and periodic cleaning and refurbishing.

2.5. REFLECTORS AND THEIR COATINGS:

Reflectors are basically consists of a glass material with a reflector coating on its back side also protection layers can be added to give support and strength to the glass material. Aranzazu et al. In their paper of “Durability of solar reflector materials for secondary concentrators used in CSP systems” investigated about the durability of mostly used reflectors in the CSP system; these reflectors sustains heavy concentrated solar radiations as well adverse atmospheric condition. Following are few samples of reflectors that are commonly used.

Table no.2.5.1. – Commonly used reflector for solar applications (7).

SAMPLE NO	REFLECTOR MATERIAL	SAMPLE DESCRIPTION
1	Aluminum	First surface sample with special lacquer on the front surface. Back side glued to an aluminum structure for cooling system (at PSI)
2	Silver	Second surface sample with 1-mm low-iron glass front cover. Back surface white painted
3	Silver	Second surface sample with 1-mm low-iron glass front cover. Back side glued to an aluminum structure for cooling system.
4	Silver	Second surface sample with 1-mm low-iron glass front cover. Back side glued to an aluminum structure for cooling system. Edge protection type 1 (semi-gloss temperature resistant paint by Jansen)
5	Silver	Second surface sample with 1 mm thin low-iron glass front cover. Back side glued to an aluminum structure for cooling system. Edge protection type 2 (universal temperature resistant paint by Jansen)
6	Silver	Second surface sample with 3 -mm low-iron glass front cover. Black painted back surface# No protected edges.
7	Silver	Second surface sample with 2-mm low-iron glass front cover and 0.5 mm low-iron glass back cover. Edges protected with glass. Specially designed for high temperatures

2.6. REFRACTORS AND ANTI REFLECTIVE COATING:

Refractors are generally made of transparent material which causes refraction of light; here it is used for concentration of solar radiation. Fresnel lens used as refractors in most solar applications as its property of light weight & compactness. The Fresnel lens is a thin, flat optical lens which consists of a series of small narrow concentric grooves on the surface of a lightweight plastic sheet in order to reduce the thickness, weight and cost. Each groove is at a slightly different angle than the next and with the same focal length in order to focus the light toward a central focal point. Every groove can be considered as an individual small lens to bend parallel Fresnel light waves and focus the light Fresnel lens is widely used object in electric and heat generation devices. Hasan et al. Used thermoelectric module and Fresnel lens for preheating water and power generation experiment (8). Sumathy et al. Used Fresnel lens with a no of collector with different shapes to investigate thermal efficiency of their combination (9).

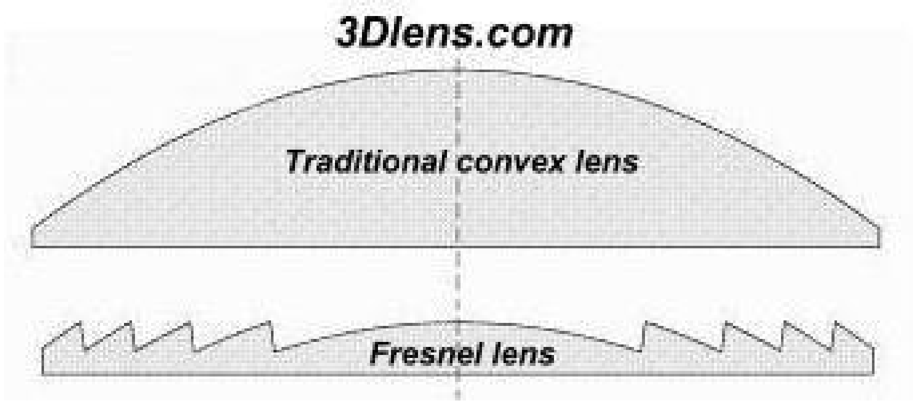


Figure:-2.6.1. Fresnel lens VS Traditional lens (10)**.**

Antireflection property of a Fresnel lens is very necessary factor that increases the transmittance of lens. This is enhanced by adding antireflective coating on the top layer of lens from which it takes incoming rays. These antireflective coatings are used in mirrors, glasses goggles, facemasks, windows for cars and for solar cell. At earlier time Mesoporous silica nanoparticles (MSNs) was used for AR coating which required high temperature treatment not suitable for Fresnel lenses having low glass transition temperature (as PMMA). Therefore later Gang et al. introduced solid silica nanoparticles which gives nearly 99.8% transmittance (11).

Tong et al. prepared a robust antifogging antireflective coating (12) on polymer substrates by hydrochloric acid vapour treatment. To obtain that film acid catalyzed silica sols were used; acid-catalyzed silica particle sol mixed with cetyltrimethyl ammonium bromide and coated on polymer substrate(PMMA) also cured by hydrochloric acid vapour in a sealed reaction kettle for a certain period. The obtained coatings on PMMA substrate showed a maximum transmittance of 100%.

2.7. MATERIALS FOR REFRACTORS (FRESNEL LENS)

In India use of Fresnel lens for solar application is not quite in trend so there is a very little availability in Indian market, mostly imported from foreign countries. However Fresnel lens available in market is made of Acrylic sheets, polycarbonates and rigid vinyl. The energy in sunlight includes several kinds of radiation; each kind has a different wavelength. Graph (see figure 2.7.1) shows the range of wavelengths found in sunlight: from ultraviolet (UV) radiation, to the visible light spectrum (the light we can see), to infrared radiation.

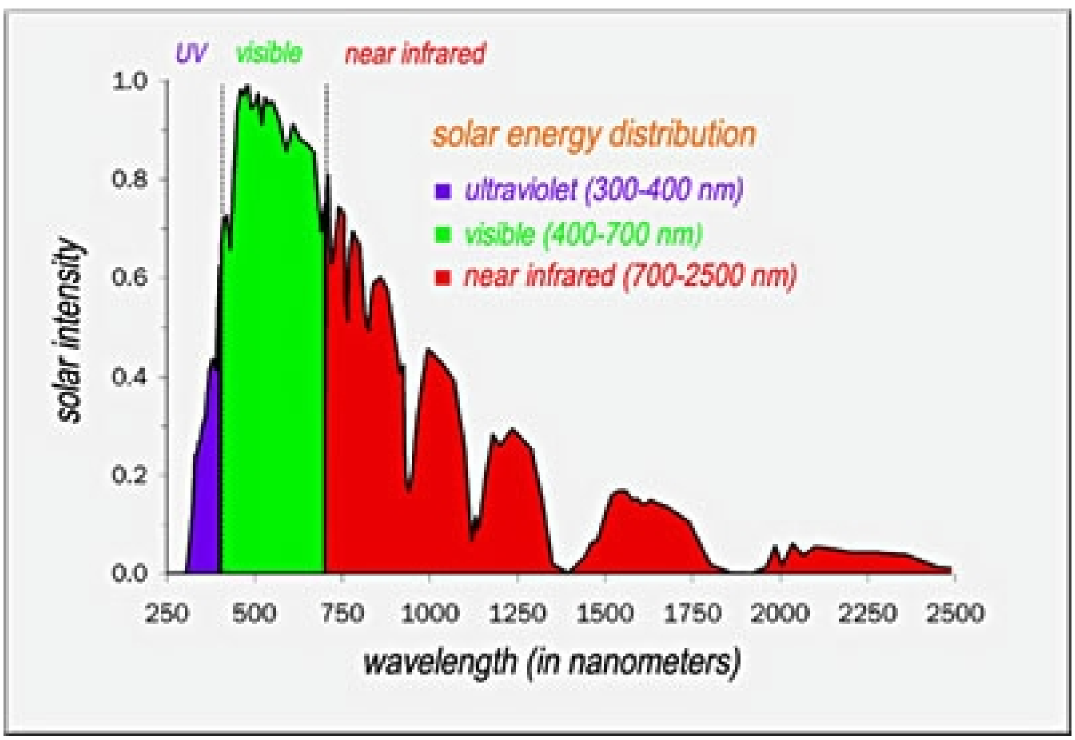


Figure:-2.7.1. Complete wavelength range of solar intensity (13).

(a) Materials for the visible light region (14)

a. *Acrylic*- Optical quality acrylic is the most widely applicable material and is a good general purpose material in the visible. Its transmittance is nearly flat and almost 92% from the ultraviolet to the near infrared.

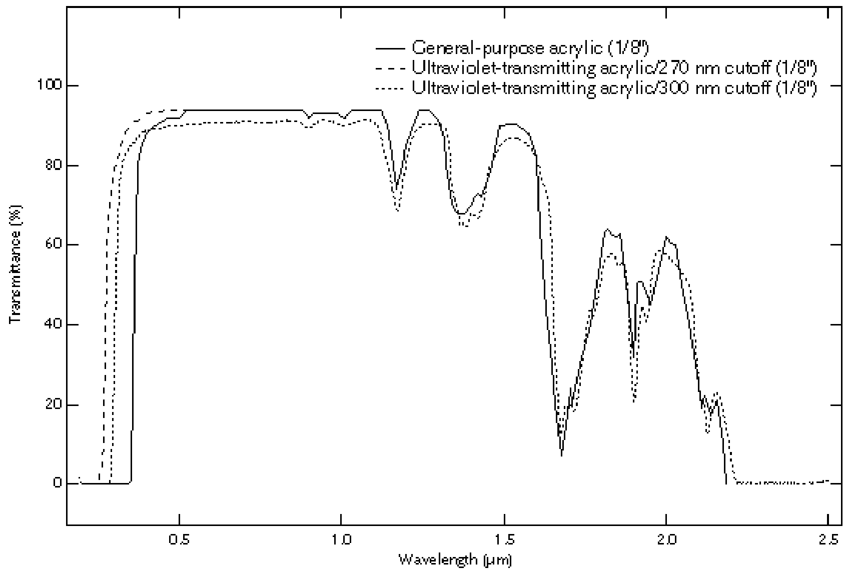


Figure:-2.7.2. Transmittance of Acrylic for solar wavelengths (14).

b. *Polycarbonate*- Polycarbonate is spectrally similar to acrylic, but is useful at higher temperatures and has a very high impact resistance. The transmittance of polycarbonate between 0.2 μm and 2.2 μm.

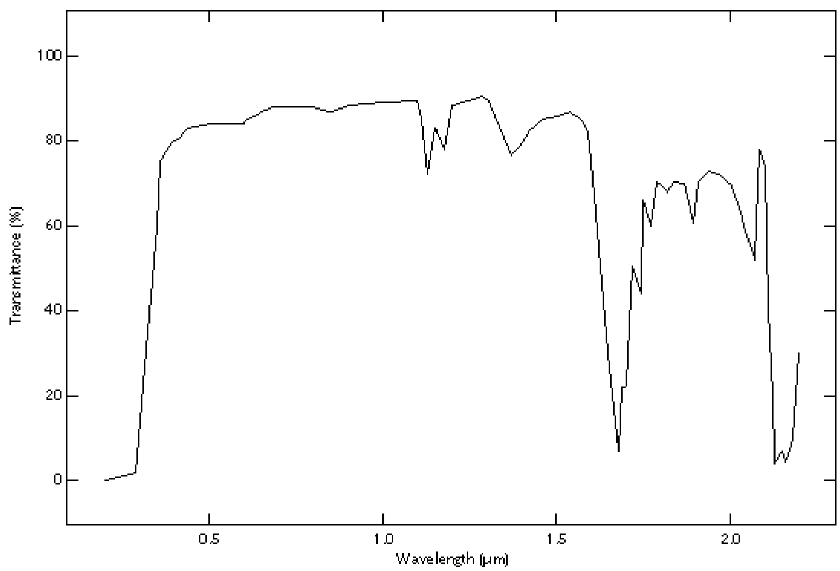


Figure:-2.7.3. Transmittance of Polycarbonate for solar wavelengths (14).

c. *Rigid vinyl*- Rigid vinyl has a number of characteristics which make it both affordable and very suitable for certain applications. It has a high index of refraction; it is reasonably inexpensive; and it can be die-cut. However, polycarbonate has very similar properties, without the problems associated with rigid vinyl, and its use is encouraged over that of rigid vinyl in new applications. Rigid vinyl has about the same temperature range as acrylic and is naturally fire-retardant. The transmittance of rigid vinyl between 0.2 µm and 2.5 µm.

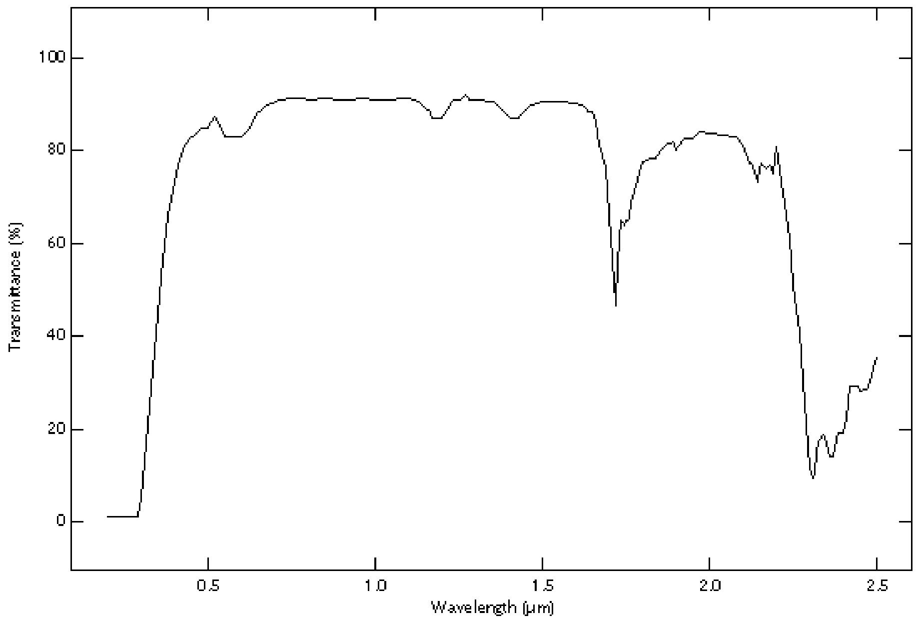


Figure:-2.7.4. Transmittance of Vinyl for solar wavelengths (14)**.**

(b) Material for infrared wavelengths (15)

a. *LODIFF® lenses* – a new lens has been developed by Fresnel technologies inc. which has greatly improved optical properties. The LODIFF® lens has several unique characteristics that minimize optical aberrations: a totally aspheric surface, an a periodic groove structure and constant depth grooves. These all combine to give the LODIFF® lens greatly improved performance over that of a conventional Fresnel lens, especially well into the infrared. Diffraction, transmittance, scattering and imaging ability have all been improved.

b. *POLY IR® Material* – Fresnel Technology, Inc. Presently produces infrared-transmitting Fresnel lenses in seven materials: POLY IR ® 1, 2, 3,4,5,6 and 7. Each has its own domain of applicability. POLY IR®1 material is an early attempt at a material for the 8 to 14 µm passive infrared range, and is no longer recommended for that use. However, it is superior to some other POLY IR® materials at shorter wavelengths, and may therefore be of some interest in applications other than passive infrared detection(and especially in multispectral applications). POLY IR®2,4 and 7 materials are recommended for use in the 8 t o14 µm passive infrared region . POLY IR®3 material offers superior transmits well through the visible region to about 4.2 µm. POLY IR®5 materials contains no hydrogen, and so is free from the strong 3.4µm absorption characteristics of hydrocarbons. POLY IR® 6 material is a visible light filtering, infrared- transmitting material with a sharp cut-off in transmittance at about 780 nm.

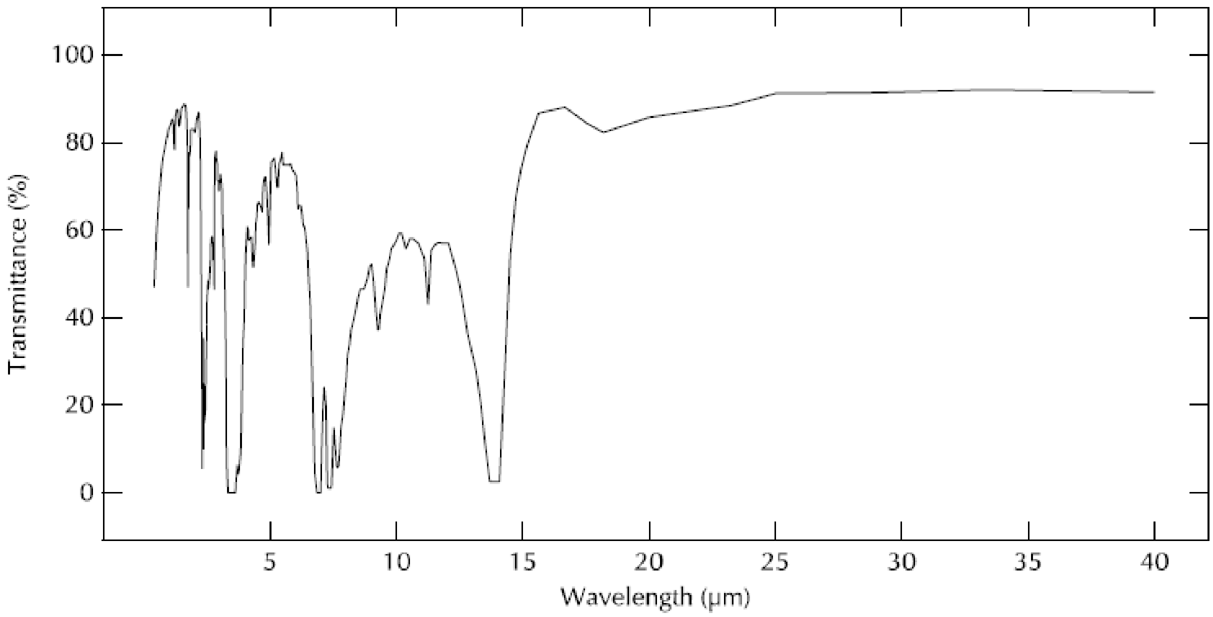


Figure:-2.7.5. Transmittance of POLY IR® for solar wavelengths (15)***.***

In our solar system a wide range of wavelength are available from which earth's surface takes only half of wavelengths and mostly gets reflected or absorbed by the earth's atmosphere. So whatever radiation comes to earth is only visible light and its nearby wavelengths. *Our sun is assumed as a black body producing radiation of 5250^{0}C* (16)*(see figure2.7.6).* Major heat of sunlight is available at top of the surface and a small amount of heat that is found closed to visible light is what we get.

Also from Wien's Displacement law for a black body higher temperature found to be at lower wavelength radiations. (See figure 2.7.7) (17)

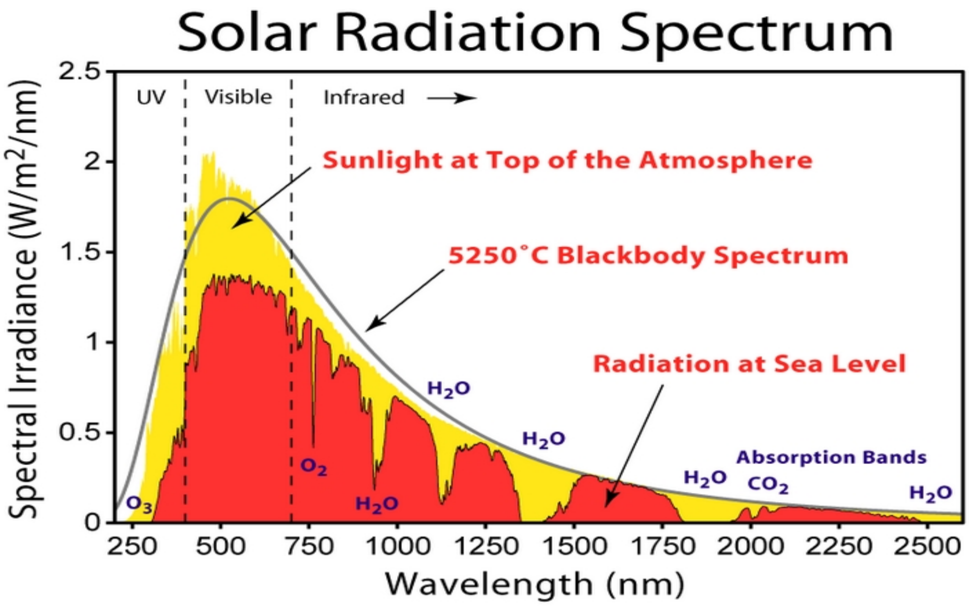


Figure:-2.7.6. Solar radiation spectrum (16)**.**

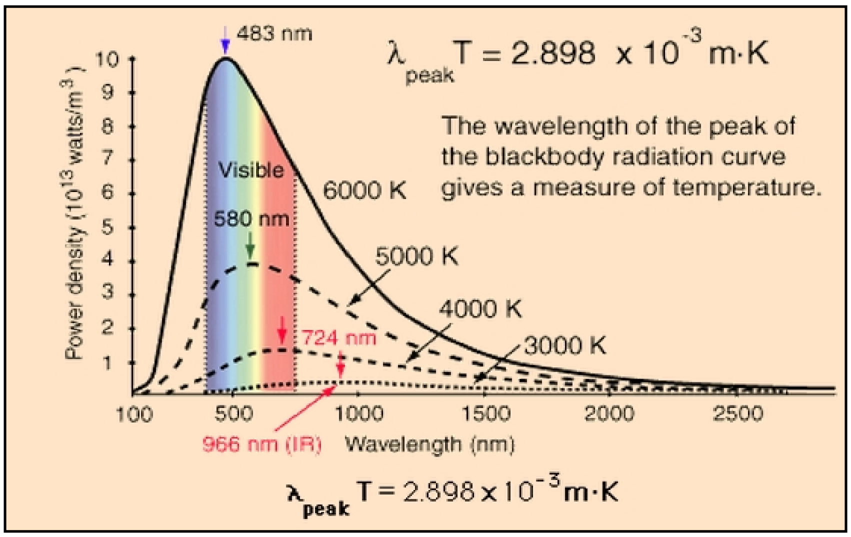


Figure:-2.7.7. Wien's displacement law (17).

The conclusion of above discussion is that we have available solar wavelengths is closed to visible light and we can utilize them using PVC/PMMC/VINYL which are quite cheap from other materials and with good mechanical properties.

2.8. RESEARCH FOR CONCEPTUAL DESIGN FROM FEW EXISTING SYSTEM.

Basically ideas for new product come from research of existing products and concepts. Here in this topic some existing system and its components have been analysed to develop conceptual design of new product.

1. LIGHT PIPES FOR THE USE OF SUNLIGHT IN ROAD TUNNELS AND DARK ROOMS OF HOUSES.

Light pipes are used as cheap and free light source where it is dark or no light; a light pipe is either made of highly polished steel material or a glass mirror pipe. Martin et al. Studied the light pipes (18) for the use of sunlight in road tunnels. In this system glass pipe is used making one end out to the roof while other end to the dark zone of tunnel, this light pipe is coated with highly reflective coating to avoid any kind of loss. These light pipe are of different lengths so that each length has to be lighted different dark zone. At point of use of light pipe a 45^0 tilted mirror is placed to get reflected light inside. (see figure 2.8.1). Idea of transferring light from outside of the room to inside is taken from this system for new product design.

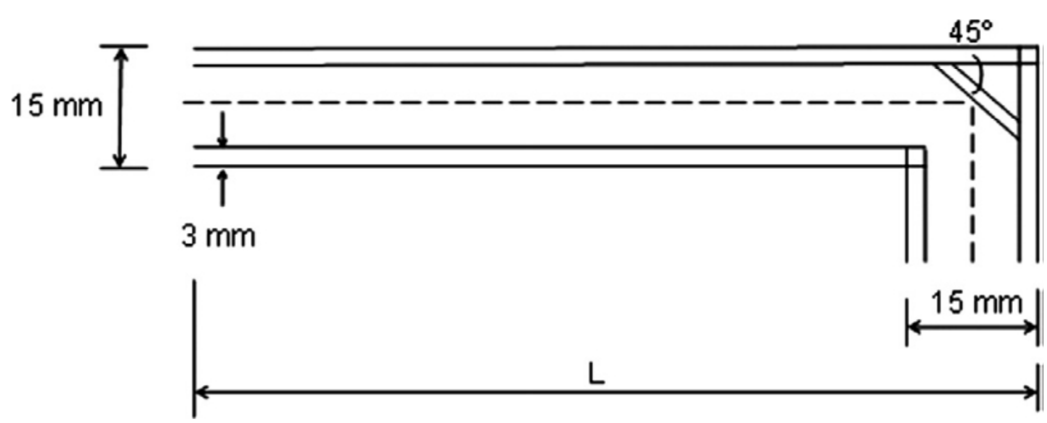


Figure:-2.8.1. Longitudinal section of one light –pipe (18)**.**

2. VENTILATION STACK INTEGRATED WITH A LIGHT PIPE

Taengchum et al. did experimental (19) study with a light pipe that is also connected with an air flow stack for night ventilation. This system is consisting of a vertical light pipe of rectangular shape of height 3 m and having cross-section of 0.0625 m^2. This pipe is surrounded by an air duct situated at a height of 3.8 m of room. At the end a diffuser plate is used to get light. Another one arrangement has been done to make forced air flow that is jacket of water, heated by solar energy. This heat exchange between air and water causes air to decrease its density and buoyancy effect make lift of air.

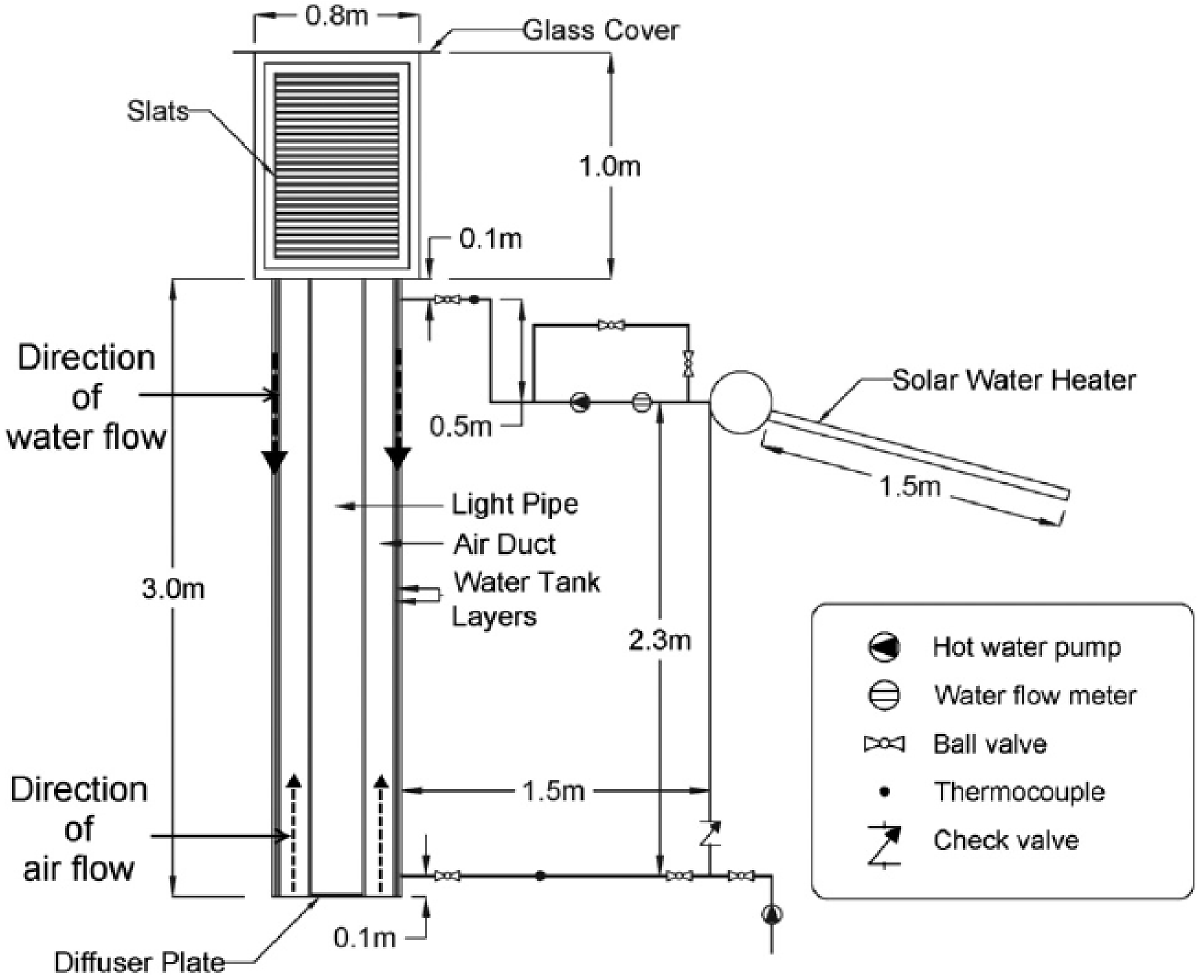


Figure:-2.8.2. (19) *The three system component.*

3. CIRCULAR LIGHT PIPE WITH ANIDOLIC CONCENTRATORS

In another paper Taengchum et al. uses anidolic (nonimaging opticals) concentrator to enhance the efficiency of light pipe (20). Anidolic concentrator is a parabolic or elliptical mirror that captures zenithal daylight and converges to a narrow opening which leads to light pipe for light application. In this system a light pipe is used at roof top and at top end of light pipe anidolic concentrator is attached.

Use of Anidolic concentrator is only to collect more and more light for a high brightness at the interior room. From this experiment an idea can be created that if large amount of solar radiation collected and transferred to other end then it can be used for heat generation applications. An experimental setup for above is shown in the figure where anidolic concentrators are fitted over light pipes (see figure 2.8.3).

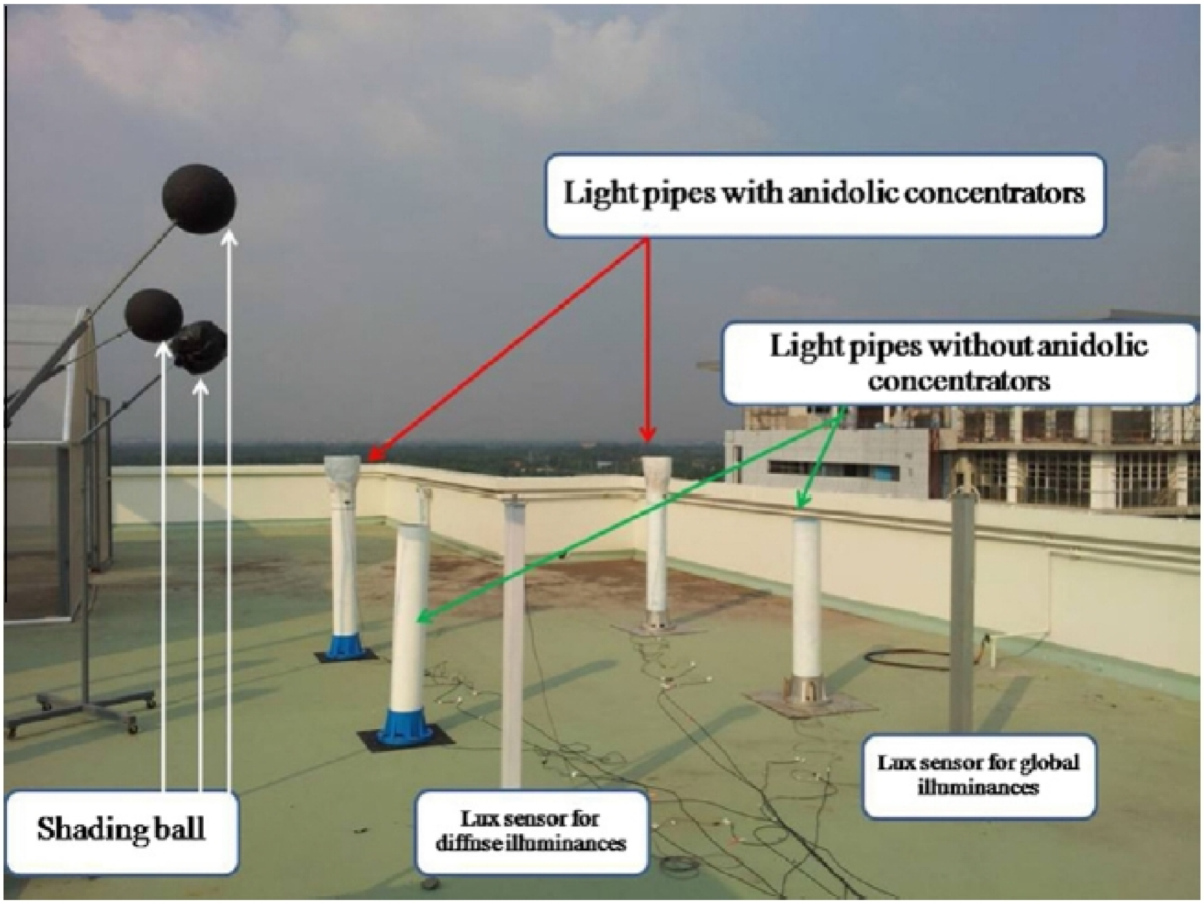


Figure:-2.8.3. Experimental setup for the experiments (20).

4. APPLICATION OF A FRESNEL LENS FOR A SOLAR STOVE AND SOLAR HEATING.

As earlier discussed Fresnel lens is used for concentrating solar radiation in solar application; here it is used for the same to focus all radiation at heat absorber plate so that it can be absorbed and transferred to load point. Valmiki et al. designed and prototyped a solar cooking stove using large Fresnel lens (21). This system consist of a large Fresnel lens, mineral oil, two stove for inside and outside the kitchen application and a photovoltaic panel consisting of solar tracking system.

Schematic view of the solar thermal loop (see figure 2.8.4) is shown in which Fresnel lens is used for concentrating radiation onto a collector plate. There are two stoves one at the outside while the other one is inside the kitchen; the mineral oil is the medium for heat transfer from one point to other. A photovoltaic panel is used to run solar tracking system as if Fresnel lens is stationary then focus of concentrated radiation will be sifted corresponding.

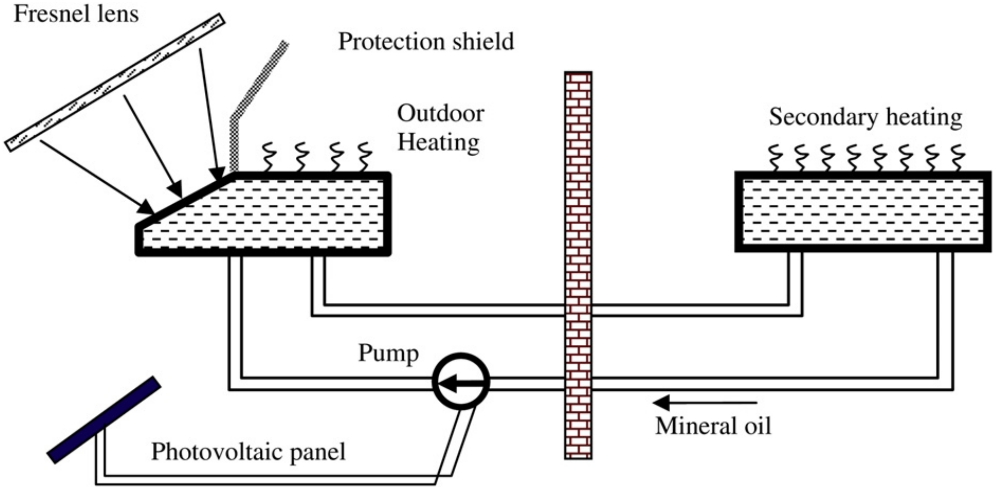


Figure:-2.8.4. Schematic view of solar thermal loop (21)***.***

From above system an idea can be created that single Fresnel lens is able to gain very high temperature and it also facilitates for a compact design for any cooking system.

5. HEAT STORAGE DEVICE.

Heat storage devices are based on concept of latent heat; oil with significant amount of nitrate salt is used in a container. Mussard et al. experimented with the absorber pipe of storage devige (22); in which difference between isolated absorber pipe and pipe without isolation has been studied. In this experiment used heat storage device is made of stainless steel with thin aluminium top plate. Inside that eight cylinders filled with nitrate salt(KNO_3-$NaNO_3$) are welded to the top plate; leaving an inlet from the absorber and same for outlet at the bottom. After assembling this container filled with oil so that salt cylinder completely submerged.(see figure 2.8.5).

Viorel Badescu modelled thermal energy storage device integrating with solar assisted heat pump system for space heating (23). Cardenas et al. used this thermal energy storage for power generation using stirling engine (24).

Figure:-2.8.5. Storage container and aluminum top with salts cylinders (22).

6. SOLAR THERMAL SYSTEM FOR HYBRID COOKING APPLICATION.

Prasanna et al. modelled and design another solar thermal system (2)for cooking application. This system is a combination of solar energy and LPG commonly used in kitchen. Thermal energy of solar radiation is firstly transferred to the kitchen by means of mineral oil using insulated pipes. This mineral oil transfers all heat to a heat storage device and energy is subsequently transferred to the cooking load.

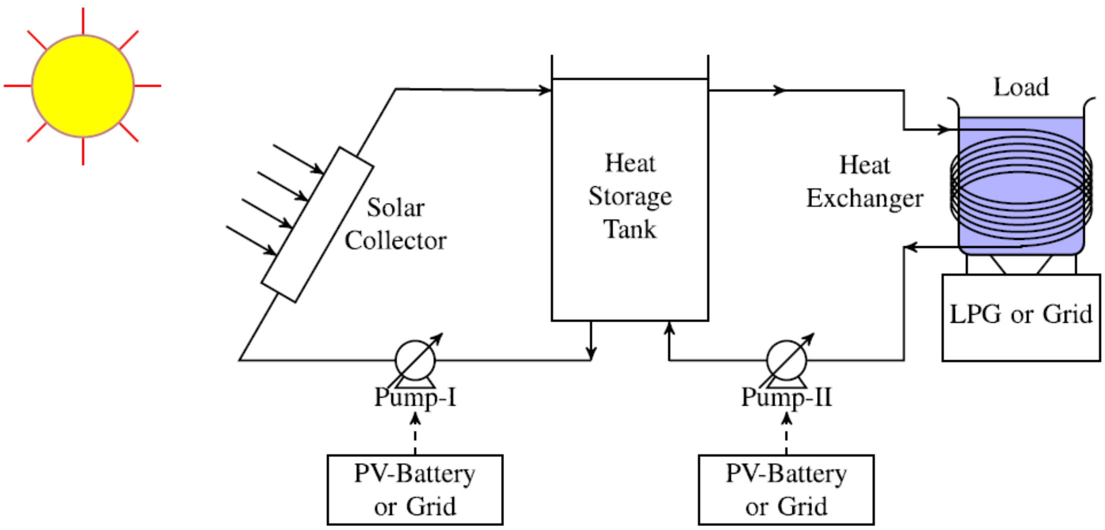


Figure:-2.8.6. Block diagram of the hybrid solar cooking system (2).

Block diagram of this hybrid system is shown (see figure 2.8.6) solar thermal absorber is placed at the roof top parabolic concentrator is also used for solar focus. With the help of absorber plate high temperature is gained and using pump transferred to heat storage tank. After that using another pump fluid is transferred to load. Size of heat storage tank decides by the capacity and use of energy at night and next day morning. More requirement of heat storage needs large size of storage tank. Few heat conducting oils are shown in table no.2.8.1.

Table no.2.8.1. – Liquid used for sensible heat in heat storage devices (22).

Medium	**Temp range**	**Heat capacity**	**Thermal conductivity**
Water	0 to 100	4190	0.63
Caloria HT	-10 to 315	2300	-
Dowtherms	12 to 260	2200	0.112
Therminol55	-18 to 315	2400	-
Therminol 66	-9 to 343	2100	0.106
Ethylene glycol	-	2382	0.249
Hitec	141 to 540	1560	0.61
Engine oil	Up to 160	1880	0.145
Draw salt	220 t 540	1550	0.57
Sodium	100 to 760	1300	67.5
Lithium	180 to 1300	4190	38.1

2.9. RESEARCH GAPS

1. The main disadvantage with a phase change material of heat storage device is that they are expensive and their ability of changing phase diminishes after a no of cycles.
2. Another problem with heat storage device is design of heat exchanger; these designs fail with low temperature difference which leads to inefficiencies.
3. Water based heat storage devices has problem of freezing and boiling. It also causes corrosion to the container body.
4. There are several limitations with sensible heating liquid; water has high heat capacity and thermal conductivity but low working temp range while therminol 66 oil has a good working temp range but low heat capacity and thermal conductivity. Also hitec has working range of 540^0 but very low heat capacity.
5. Anti reflective coating needs to be more robust, antifogging, and efficient to increase transmittance of lens. Few researches have been done in this area, to improve transmittance about 99.99%.
6. Mirrors which are subjected to high concentrated solar radiation needs to be more robust and anti corrosive, also can sustain high reflectivity for a long time.
7. In the solar cooker that uses Schefller dish and provides shelter has one stove that absorbs heat firstly then radiates to the cooking pot which takes long time and also looses too much heat using radiation.

2.10. OBJECTIVES

1) Generate new ideas for a new system from literature reviews and gaps.
2) Design the system components for a prototype development using CAD/CAE tools.
3) To carry out trials for modelling and fabrication till the best results / design is achieved (Design Validate).
4) Using rapid prototyping preparing a model.
5) Identify proper material and equipments for fabrication.
6) To make a working Prototype of a new solar tracking system.
7) Testing of prototype system.

3. DESIGN OF A DIRECT SOLAR HARNESSING SYSTEM

TRIAL 1:

3.1 – PRINCIPLE OF TRANSPORTING SOLAR RAYS

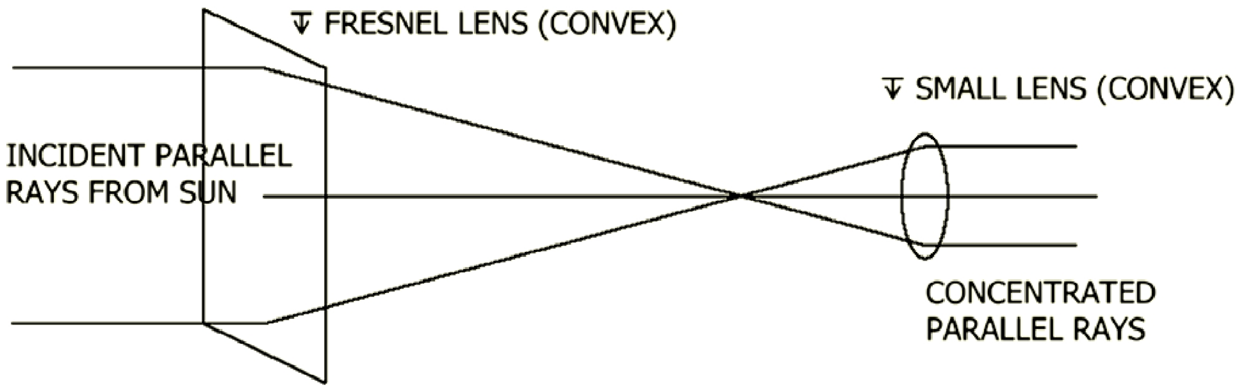


Figure:-3.1.1.Combination of lenses to get concentrated solar radiation.

When a parallel light passes through a convex lens it converges firstly to a focal point then expands, in other way if a diverge light passes through lens that too coming from a focal point makes itself parallel (see figure 3.1.1). This phenomena is used for this system where a large Fresnel lens is used to collect large solar intensity and to focus it on a point, this focus point should be focal length of smaller lens so that it become parallel again which is concentrated.

The main parameters for this combination are Focal length and Diameter of lens, where focal length affects the compactness of system while size of lens affects the availability of area to collect solar radiation. Smaller lens size decides the concentrated beams diameter for example if we want a 50 mm diameter of concentrated radiation then we must use a 50 or more than 50 diameter lens while the focal length can disturb the diameter of concentrated radiation diameter, for that calculation has been done in next topic.

The same system can be made using two different parabolic or concave mirrors, as larger mirror will concentrate parallel rays to a focus point and another smaller mirror will again make parallel and concentrated beam of solar radiation. For this setup a hole will be needed inside the larger mirror to let pass through beam from it.

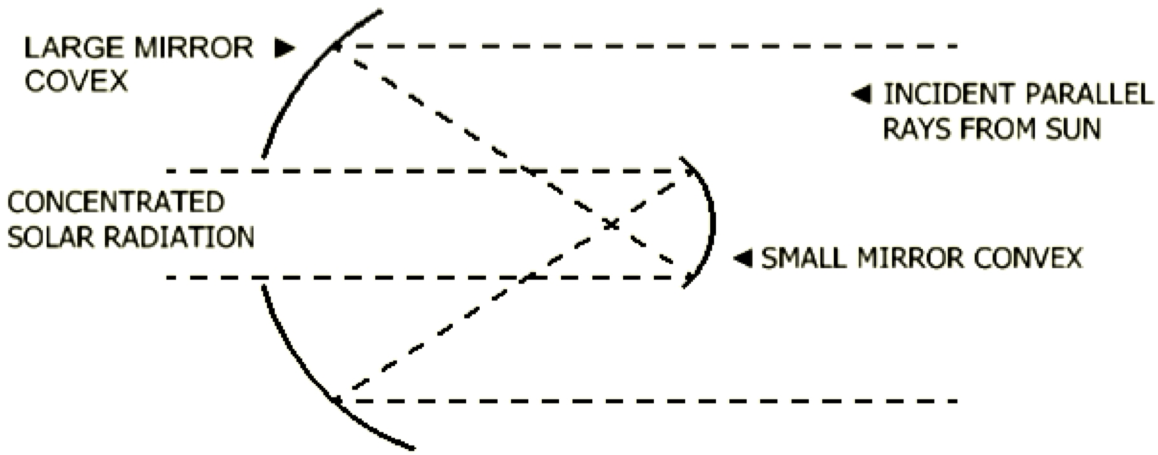


Figure:-3.1.2.Combination of mirrors to get concentrated solar radiation.

3.2 - PROPOSED DESIGN FOR SOLAR HARNESSING SYSTEM

In this system (see figure 3.2.1) a parabolic concentrator is used to focus all incident solar rays. Another mirror is used to receive solar rays and converts it into a parallel rays which can be easily transfer to very long distance without losing its energy. In old systems a lots of energy loses in between due to convection or conduction but here it is direct supply of heat. One heat storage setup is added to store heat for all the time whenever system in not in use, which can be used later at night for cooking.

Identified modules are as follows,

a) Solar tracking system
b) Lens/ mirror setup
c) Load setup
d) Passage
e) Heat Storage system

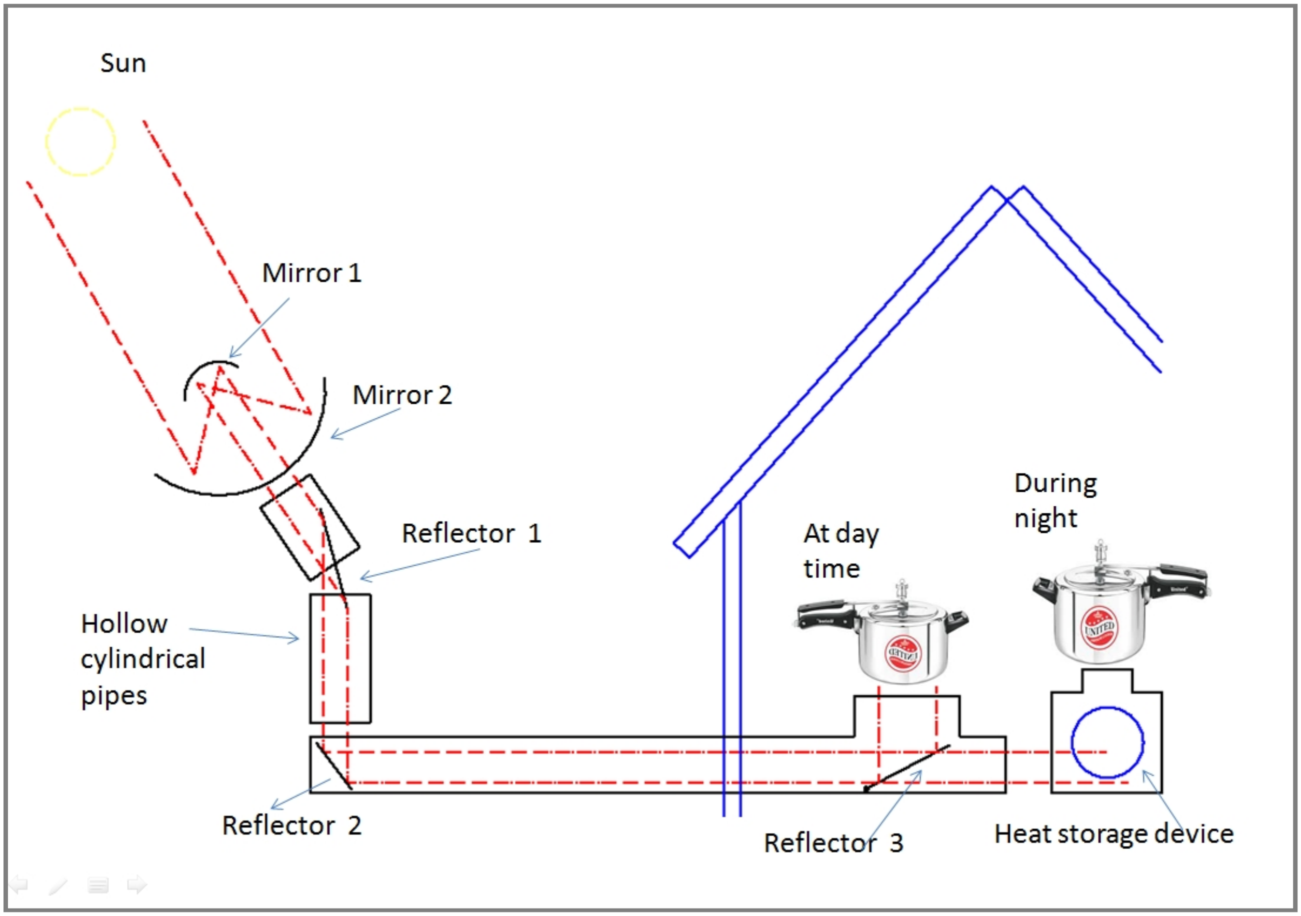


Figure:-3.2.1.Proposal of design for new solar harnessing system.

3.3 - CALCULATIONS

1. CALCULATION FOR AVAILABILITY OF HEAT

All calculations has done w.r.t. solar irradiation in Jaipur, Rajshtan, India (25). Considering lenses of 100 % efficiency and 25^{0}C average temperature and water with density of 1000 Kg/m^3. From figure 3.1.1. Annual average solar radiation is 5.68 kWh/m^2/day or 204.48 x 10^2 kj/m^2/day.

Suppose this energy is used to boil water using 1m^2 Fresnel lens then, Using relation, $Q = mc\, dT \ldots\ldots\ldots\ldots (1)$

$$204.48 \times 10^2\, kj = M \times 4.186 \times (100 - 25)\, kj$$

$$M = 65.13\, Kg$$

Or $M = 65.13\, Litres/\, day \ldots\ldots\ldots\ldots (2)$

Solar Radiation

Annual Average: **5.68** (kWh/m^2/day)

Monthly Average

Jan	**4.22**
Feb	**5.23**
Mar	**6.26**
Apr	**7.02**
May	**7.43**
Jun	**6.61**
Jul	**5.91**
Aug	**5.37**
Sep	**5.96**
Oct	**5.55**
Nov	**4.60**
Dec	**3.98**

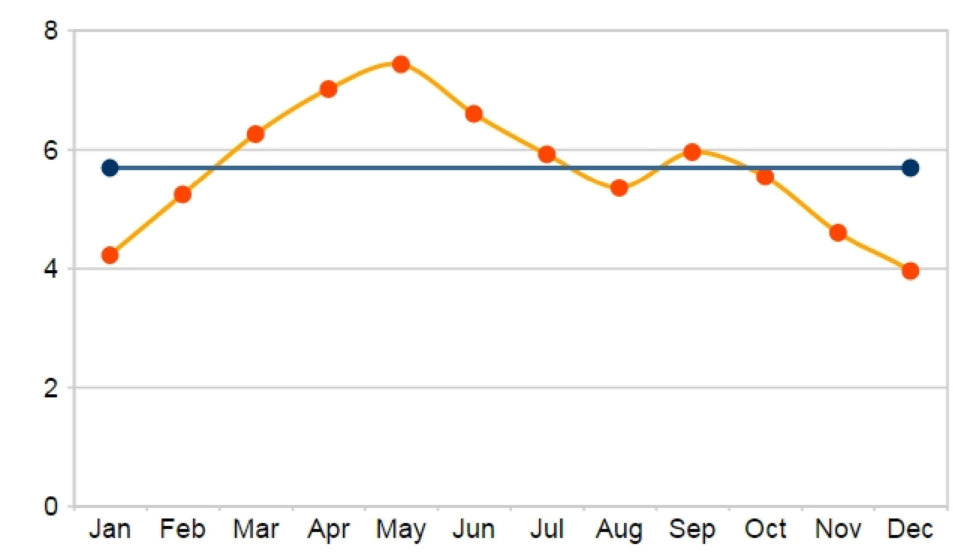


Figure:-3.3.1 Solar irradiation in Jaipur, Rajsthan, India. (25).

For a $300 \times 300\, mm^2$ or $0.09 m^2$ fresnel lens,

$$m = M \times 0.9\ litres\ /day$$

$$m = 65.13 \times 0.9\ litres\ /day$$

$$m = 5.86\ litre/day \ldots\ldots\ldots\ldots (3)$$

From above calculation we can conclude that a prototype of this new system would be able to boil 5.86 liter in a day for 100 percent efficiency of all lenses.

2. CALCULATION FOR LENSES AND THEIR POSITIONS

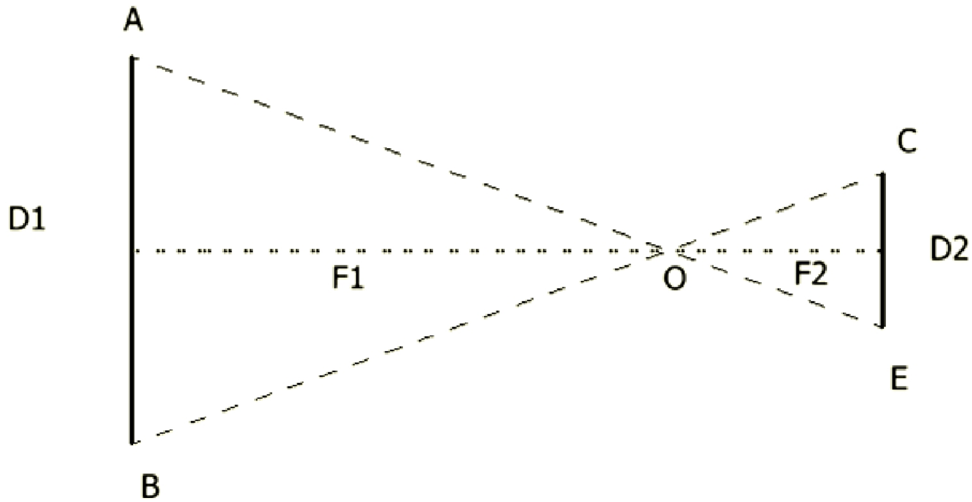


Figure:-3.3.2. Relation for lens's focal length and their position for this system.

D1 = Diagonal of larger lens

D2 = Diagonal of smaller lens

F1 = focal length of larger lens

F2 = focal length of smaller lens

As parallel rays focuses to focal point incoming rays will concentrate to point O and also act as source point for small lens, and small lens will make it again parallel. Following relation will help to design this arrangement,

$$\frac{D1}{F1} = \frac{D2}{F2} \ldots\ldots\ldots\ldots\ldots (4)$$

Now consider we have a Fresnel lens having diagonal of 1.41m (1 m^2) and focal length of 1.8 m, and requirement is to get 0.1m diameter concentrated radiation using 0.1m diameter lens, then

$$\frac{1.41}{1.8} = \frac{0.1}{F2}$$

$$F2 = 0.128\, m \ldots\ldots\ldots\ldots\ldots (5)$$

So for 0.1m diameter we need small lens of 0.128m focal length or less then 0.128m focal length.

3. CALCULATION FOR LENS'S POSITIONS

Indian market has been surveyed for availability of Fresnel lens and convex lenses; there are very less flexibility for getting desired focal length and size of lens. Following are sizes and focal lengths of lens found in online market which are suitable for trials or prototyping.

Table no.3.3.1. – Lens availability in Indian market.(By dated 10/4/2015)

Sr no.	Size (mm)	Material	EFL
1	180X260	PVC Sheet	300
2	250X165	PMMA Glass	140
3	275X210	PVC Sheet	300
4	300X300	Acrylic Glass	280
5	56 dia (Concave)	Silica Glass	80
6	50 dia (convex)	Silica Glass	64.5

From above table it is clear is that larger the size larger the collecting area will be so the preference will be given to 300×300 mm^2. So calculation is purely depends on focal length of larger length that may affect the requirement of small convex lens.

Fresnel lens is of 300 length and 300 width so the diagonal will be of 424.26 as longest length that has to be consider because rays coming from this edge will be passing through lens diameter. Let the convex lens's diameter be unknown then From Equation ... (4) we have,

D1=424.26 mm

F1=280 mm

F2=64.5 mm

Now,

$$\frac{D1}{F1} = \frac{D2}{F2}$$

$$\frac{424.26}{280} = \frac{D2}{64.5}$$

$$D2 = 97.73mm \ldots\ldots\ldots\ldots\ldots (5)$$

This is greater than available lens's diameter so there will be some loss in radiation which is illustrated in below diagram (see figure 3.3.3). In diagram incident rays are get focused onto a point O. Hatched area is loss of energy as it is not passing through smaller lens and not parallel to the concentrated rays. In this case two correction can be made first one is if focal length of smaller lens decreased so that area of unaffected rays gets reduced or vanishes in other word rays would not pass over the lens (see figure 3.3.4). And secondary focal length of larger lens increased that will also decrease area of unaffected rays (see figure 3.3.5).

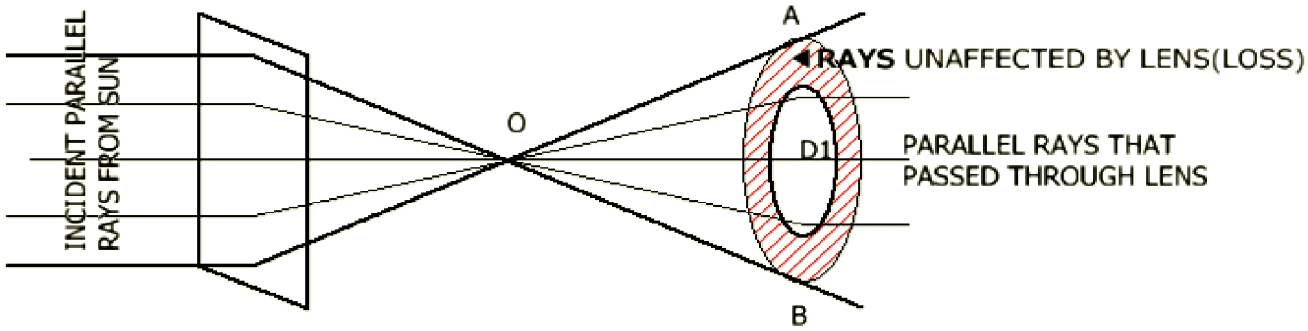


Figure:-3.3.3. Loss in rays due to smaller diameter of convex lens.

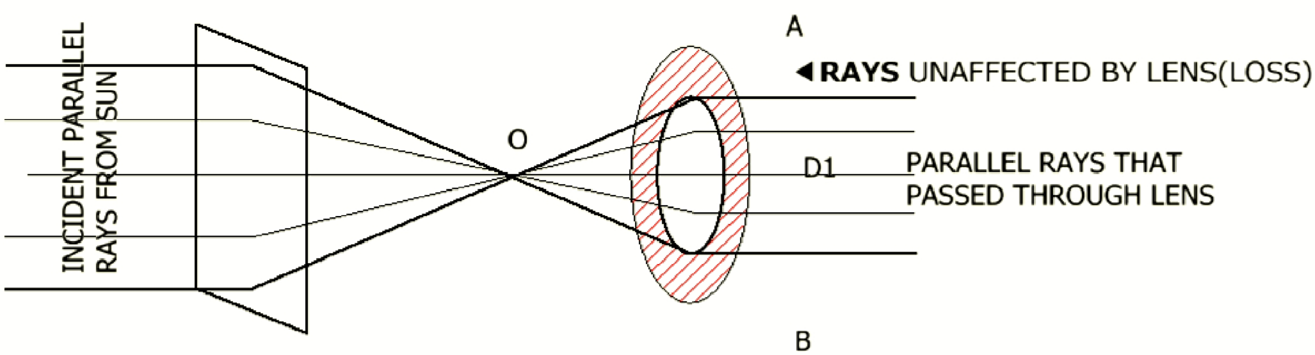


Figure:-3.3.4. Rays does not passing over the lens.

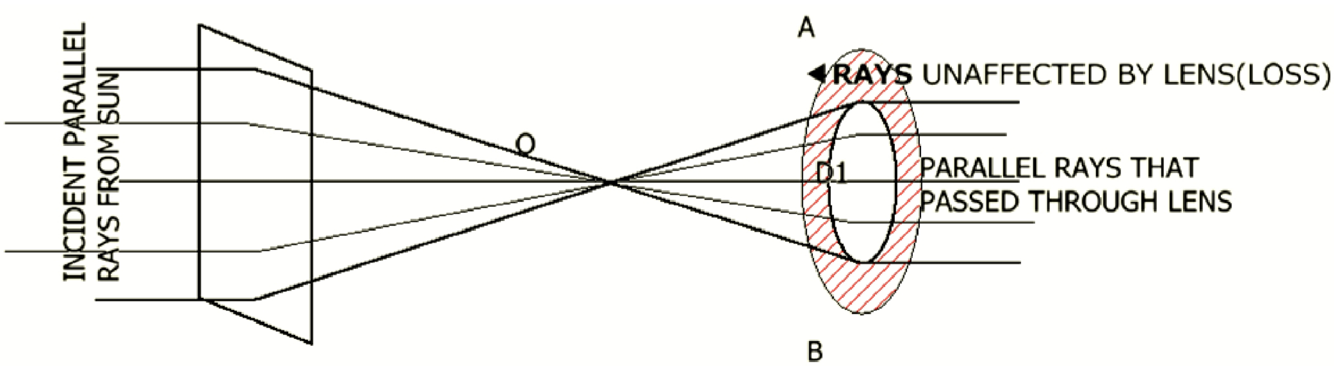


Figure:-3.3.5. Rays does not passing over the lens.

In the case of unavailability of proper focal length lens a concave lens can be used to remove the area of unaffected area. Concave lens will help in increasing the focal length of large lens as combined lens. Or a convex lens can be added to smaller lens in order to decrease its focal length. Use of concave lens is shown in diagram (see figure 3.3.6).

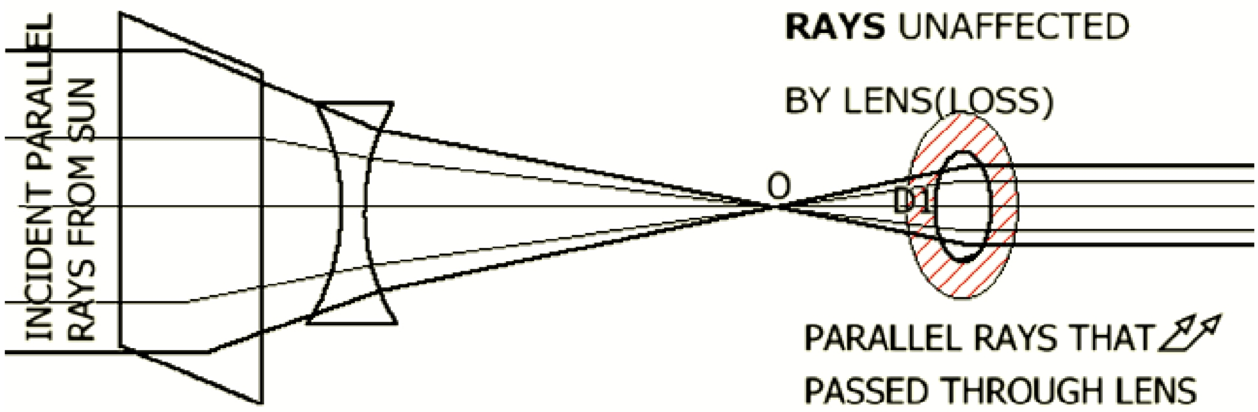


Figure:-3.3.6. Addition of a concave lens to avoid passing of rays over the lens.

A concave lens is purchased according to the availability in the store and position of lens is calculated considering the same lenses used above in equation 4. A calculation is done to calculate position of lenses when a concave lens is used also it is shown that how one can calculate the positions if there is no proper lens available. Again from table 3.3.1 and reference to the figure (see figure 3.3.7)

Using lens formula (26)

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \ldots\ldots\ldots\ldots\ldots (6)$$

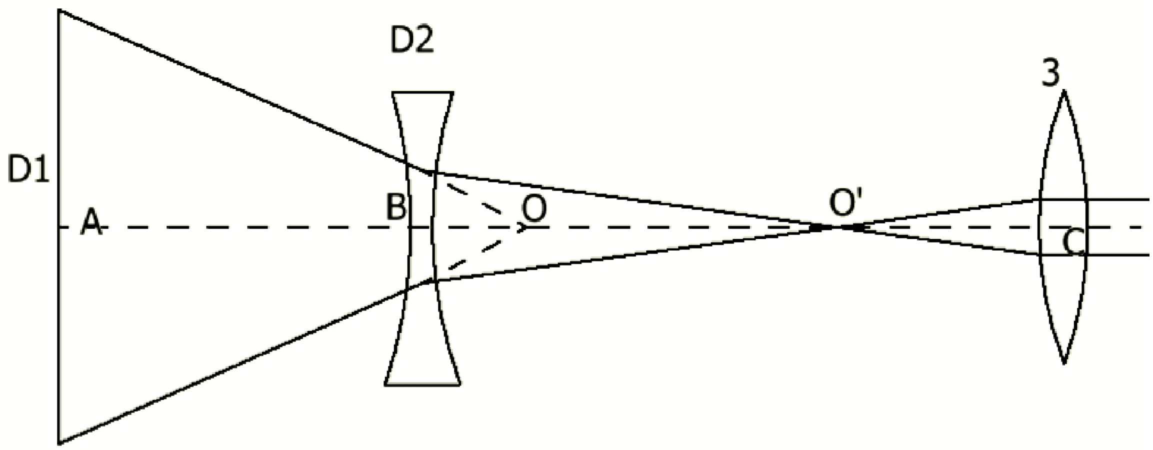


Figure:-3.3.7.Ray diagram for lens arrangement.

Where v is image formation point, u is source point of rays and f is focal length of lens, now putting values u= ∞ as coming rays are from infinite, and f= 280,

$$\frac{1}{v} - \frac{1}{1/0} = \frac{1}{280}$$

$$v = 280\,mm \ldots\ldots\ldots\ldots\ldots (7)$$

Now adding a lens 2(concave) between focal point O and lens 1, new image point will be shifted to right side. Calculating the value of OB,

$$\frac{OB}{D2} = \frac{AO}{D1}$$

$$\frac{OB}{56} = \frac{280}{424.26}$$

$$OB = 36.96\,mm \ldots\ldots\ldots\ldots\ldots (8)$$

Again using lens formula to find the new image point after introducing concave lens. Where point O is virtual source of rays for concave; using lens formula again,

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{v} - \frac{1}{36.96} = \frac{1}{-80}$$

$$v = 68.96\,mm \ldots\ldots\ldots\ldots\ldots (9)$$

Now calculating the diameter for lens required to harness all rays with 64.28 mm EFL lens. From below diagram (see figure 3.3.8) D_2=56, AO=68.96, OB=64.28,

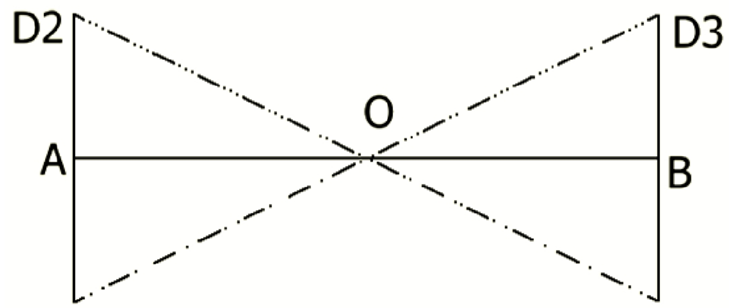


Figure:-3.3.8. Calculation for the third lens's diameter.

Now,

$$\frac{D3}{64.28} = \frac{56}{68.96}$$

$$D3 = 52.2\,mm \ldots\ldots\ldots\ldots\ldots (10)$$

Where $D3 = 52.2\,mm$ is the diameter of convex lens if focal length used is 64.28, but the available lens is of diameter 50mm (refer table 3.3.1). So there will be some loss in this arrangement too.

4. CALCULATIONS FOR FIRST TRIAL OF CONCENTRATED SOLAR BEAM GUIDING SYSTEM

In this design two hollow pipes are used to guide solar rays inside it and a mirror is used inside joint of these two to get a concentric solar ray guiding with respect to its pipe(see figure).

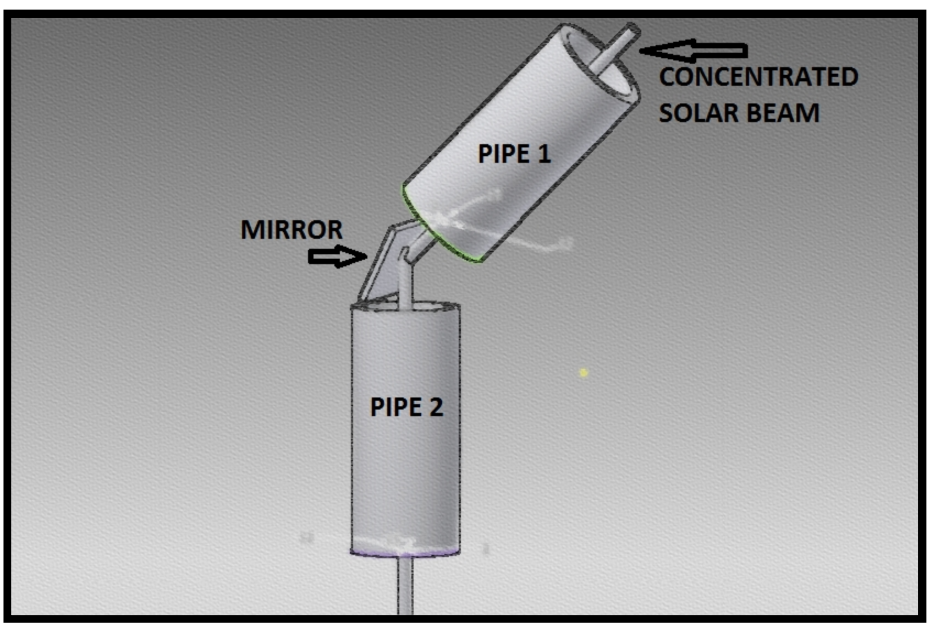


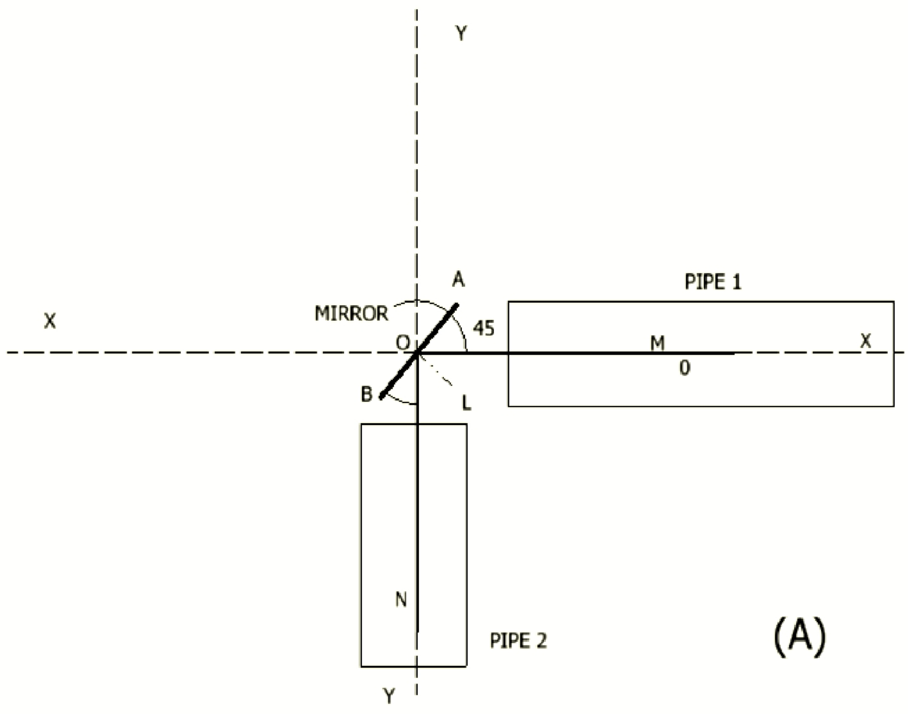
Figure:-3.3.9. Concentrated solar beam guiding system.

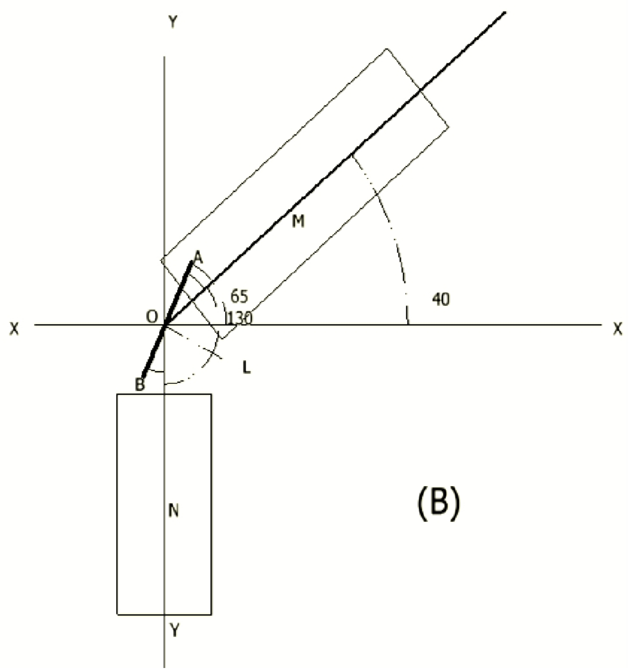
Major parts in this system are:-

1. Concentrated solar beam
2. Hollow pipes
3. A mirror

In a day this system needs to be turning 90^0 to track sun rays. The challenge is to design a mechanism for these system so that whatever angle is made by upper pipe the concentric nature between pipe and concentrated solar rays does not get affected.

Following are the few conditions (see figure 3.4.2) for the system that has to be followed.





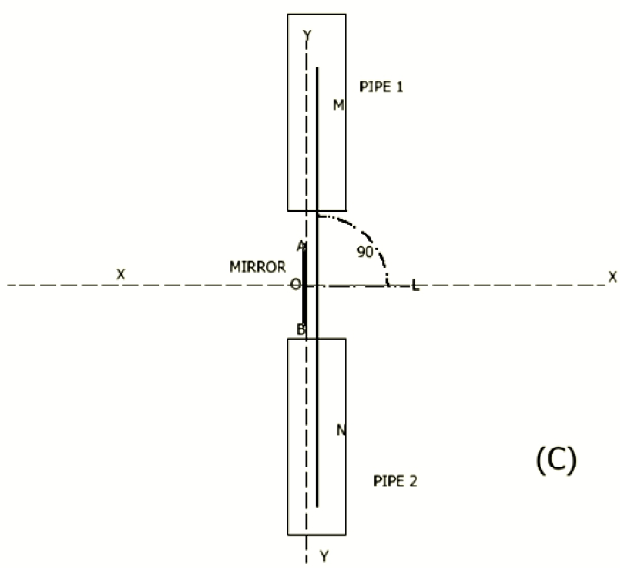


Figure:-3.3.10. Various orientations for pipe and inside mirror, (A) Pipe angle at 0^0, (B) Pipe angle at 40^0, (C) Pipe at 90^0.

- From figure 3.4.2 .(a) initially **pipe is at 0^0** then various angles are

  Angle MOX = 0^0

As we know that a mirror reflects rays always making equal angle to its normal

As, Angle MON = 90^0

Now due to reflection, Angle AOM =Angle BON = K

We know,

180 = Angle AOM + Angle MON + Angle BON

180 = K + 90 + K

180 – 90 = 2K

K= 45, or Angle AOM =Angle BON = 45^0

Therefore, **Angle AOX (mirror) = Angle AOM = 45^0**............. (11)

- From figure 3.4.2.(b), **pipe rotates by 40^0** then various angles are

Angle MOX = 40^0

Angle MON = $40^0 + 90^0 = 130^0$

Now due to reflection, Angle AOM =Angle BON = K

We know,

180 = Angle AOM + Angle MON + Angle BON

180 = K + 130 + K

180 – 130 = 2K

K= 25, or Angle AOM =Angle BON = 25^0

Therefore **,** **Angle AOX(mirror) = 25^0+40^0 =65^0** .... (12)

- From figure 3.4.2.(c), **pipe rotates to 90^0** then various angles are,

Angle MOX = 90^0

Angle MON = $90^0 + 90^0 = 180^0$

Now due to reflection, Angle AOM =Angle BON = K

We know,

180 = Angle AOM + Angle MON + Angle BON

180 = K + 180 + K

180 – 180 = 2K

K= 0, or Angle AOM =Angle BON = 0^0

Therefore, **Angle AOX(mirror) = $0^0+90^0=90^0$** .... (13)

So from above equations,

Table no.3.3.2. – Change in angle for pipes and mirror.

Sr. no.	**Pipe angle(w.r.t. x axis)**	**Mirror angle(w.r.t. x axis)**	**Change in pipe angle**	**Change in mirror angle**
1	0	45	0	0
2	40	65	40	20
3	90	90	90	180

From above table we can conclude that rotation of pipe and mirror are depends on in the ratio of 2:1,

$$Wpipe/Wmirror = 2/1 \quad .... (14)$$

To get above results in this mechanism a gear train is used. It has following specifications,

Table no.3.3.3. – Gear dimension used in prototyping.

Sr no.	**Dimensions**	**Gear 1**	**Gear 2**	**Gear 3**
1	Pitch circle	11.250	22.500	22.500
2	Base dia.	10.729	21.459	21.459
3	Addendum dia.	13.683	25.179	25.179
4	Dedendum dia.	8.684	20.180	20.180
5	module	1.125	1.125	1.125
6	Gear ratio	1:2	2:1	2:1
7	No of teeth	10	20	20

Let for GEAR 1, no of teeth = T_1

Angular velocity= W_1

Let for GEAR 2, no of teeth = T_2

Angular velocity= W_2

Let for GEAR 3, no of teeth = T_3

Angular velocity= W_3

Then gear train equation is,

$$\frac{W1}{W2} \times \frac{W2}{W3} = \frac{T2}{T1} \times \frac{T3}{T2}$$

$$\frac{W1}{W3} = \frac{T3}{T1}$$

Now from above table putting value for gear,

$$\frac{W1}{W3} = \frac{20}{10} = \frac{2}{1} \ldots\ldots\ldots\ldots\ldots (14)$$

This is the required ratio for pipe rotation and mirror rotation.

3.4 – COMPONENT DESIGNS AND ASSEMBLY OF COMPONENTS IN CAD MODEL (IN MM) FOR FIRST TRIAL

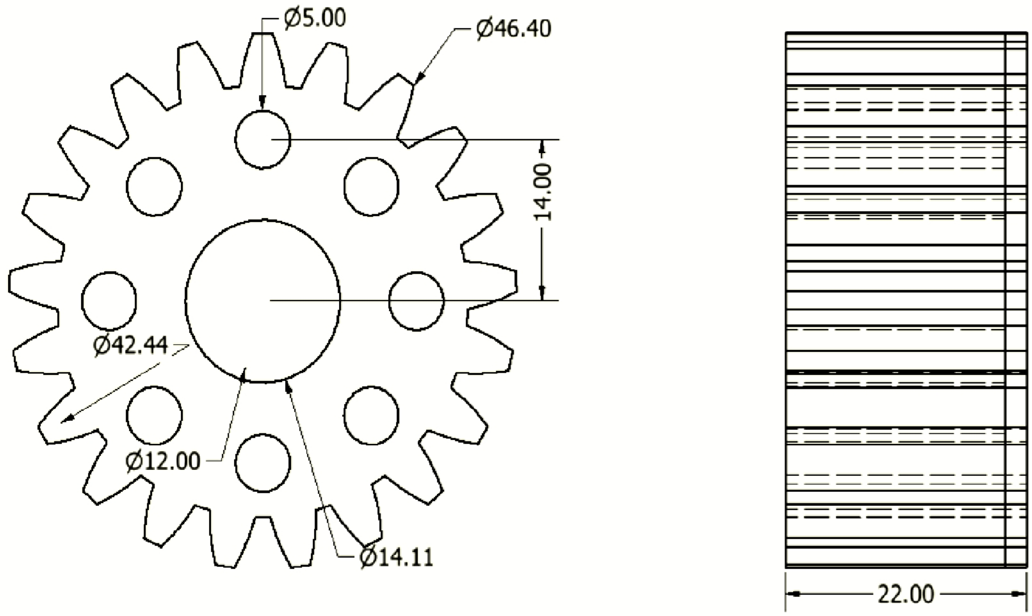
As this system is new so no standard components were available in the market. At start three things were kept in mind while designing first was the lens holder’s arrangement, second rays guiding system and third were the sun trackabl1e which needs some rotation.

1. At first the two gear were designed which was required to rotate a mirror inside the hollow pipe to guide the concentrated solar radiation inside the hollow pipe again. So the requirement of the gear was to follow the gear ratio of 2:1 as discussed earlier in the topic(see table 3.3.3). The gear and the base just designed randomly so that further designs can be start. After completion it can be scaled according to need.
2. After making gears the components for the lens holder were made. So the requirement was that lens should rotate and move for all 12 degree of freedom. As these parts had to bear the load of lens so it was rigid and also light weight as it has to contribute some load to the frame body.(see below figure B,D,G,J,K & M)
3. There are two support parts which were designed on the basis of holding all the loads with the help of three legs. Both parts are the concentric cylinder and sleeve to provide rotational motion (see figure E&F).
4. There are two bearing attachment (H &I) parts which were designed in order to get angular motion between the lens arrangement and the hollow pipes as discussed in the fourth point of topic calculations.

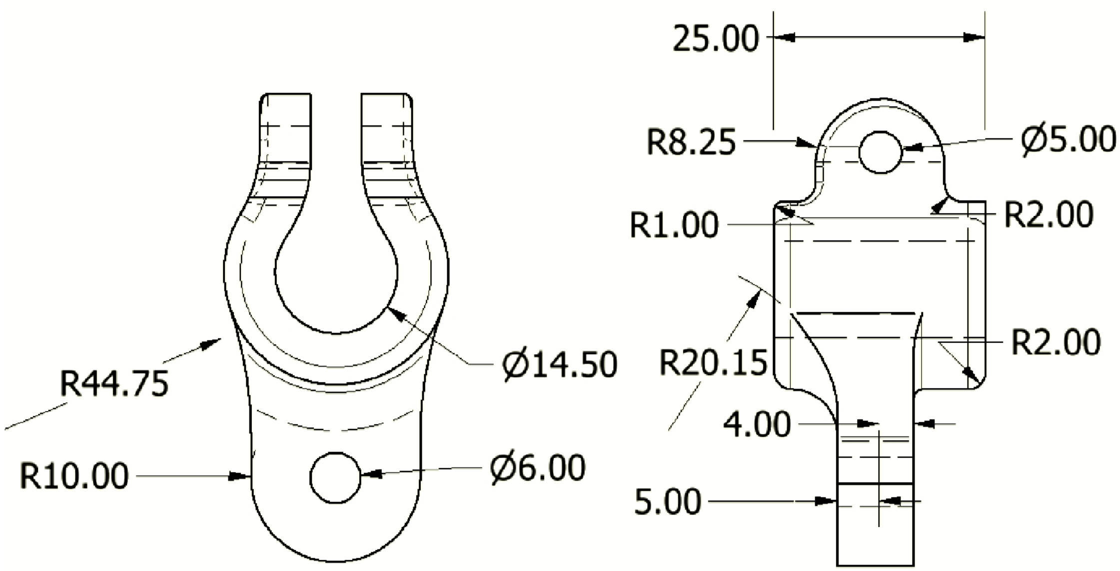
All the components were created and continuously assembled in the assembly environment of CAD tool so that a proper dimension ratio could be maintained. After getting all parts printed in RAPID PROTOTYPING MACHINE assembled (see figure 3.4.1). The gear parts were removed from the assembly as it got failed to rotate accurately for which it was designed. The support parts were also got failed as the designed rotating parts were vertical and a large tolerance of 4-5 mm. The pipe used in this assembly was same for all the supports to get minimum variations in the design.

1. COMPONENTS DETAIL.

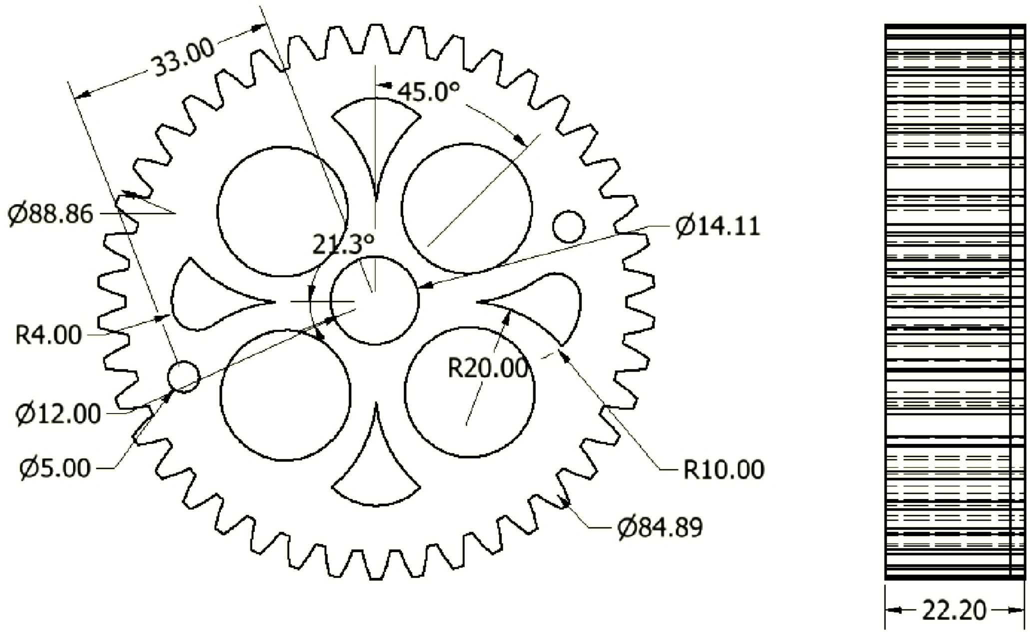
(A) Small size gear.(see table 3.3.3)



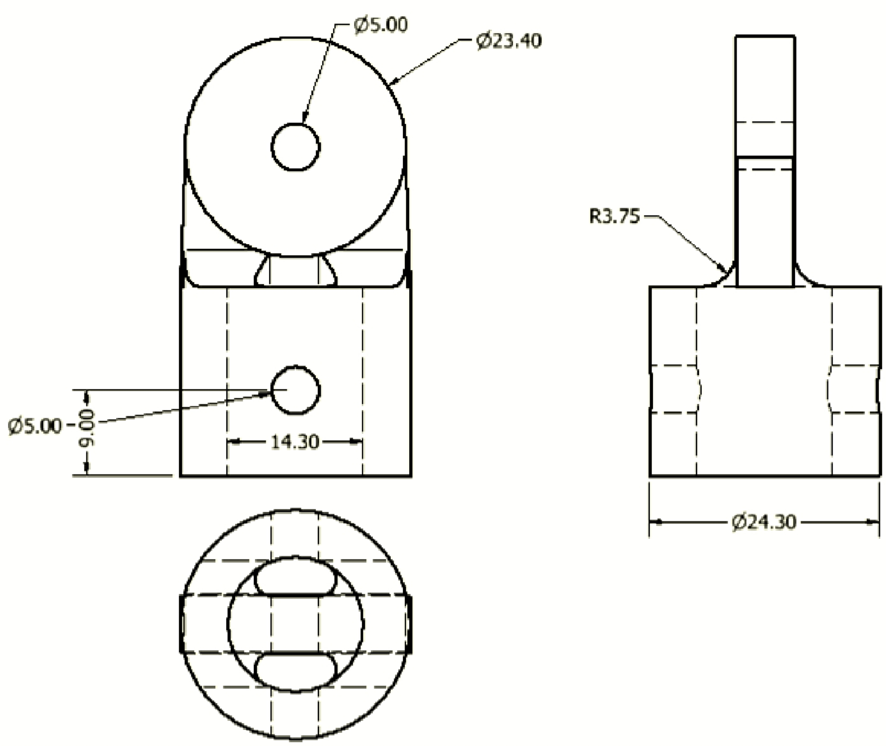
(B) Pipe attachment part 1.



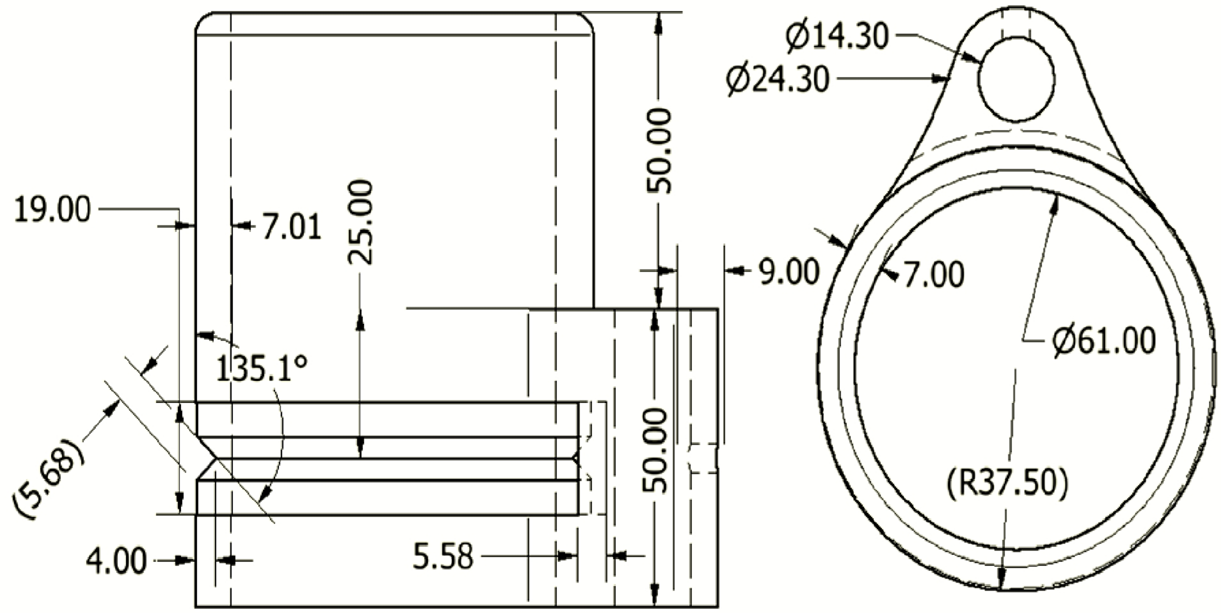
(C) large gear. (see table 3.3.3)



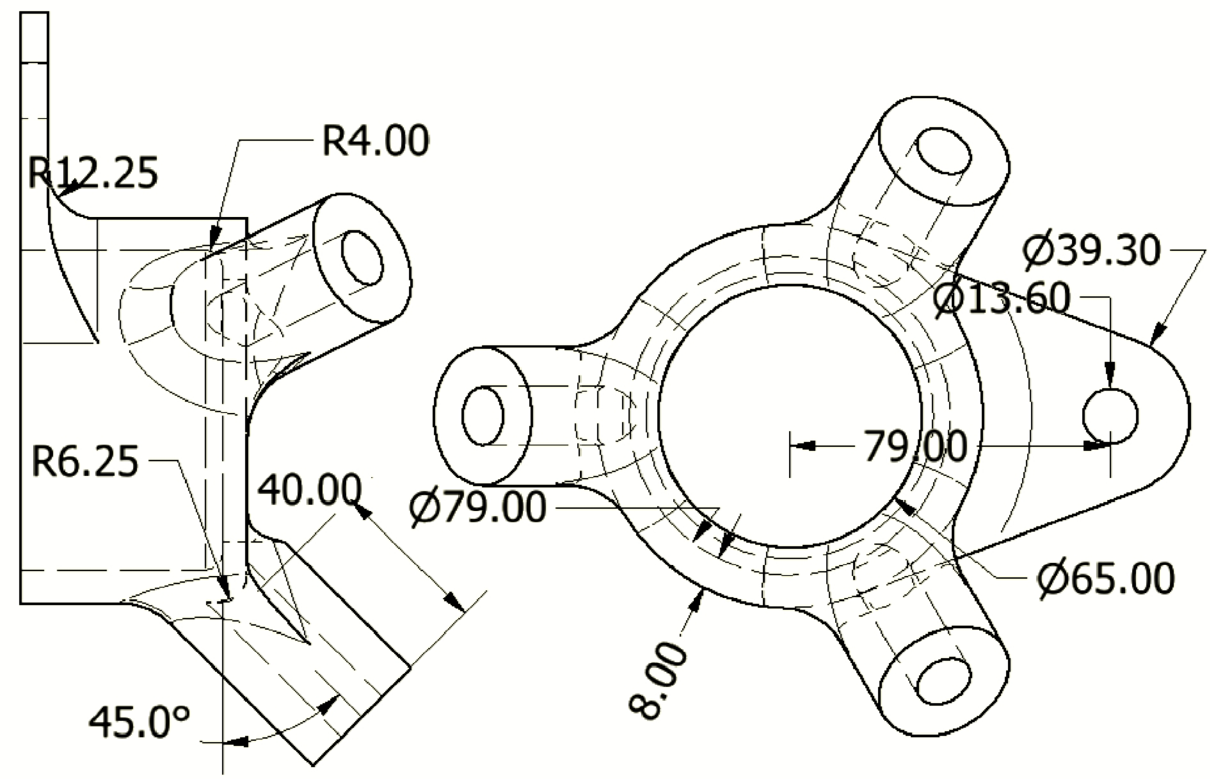
(D) lens support part1.



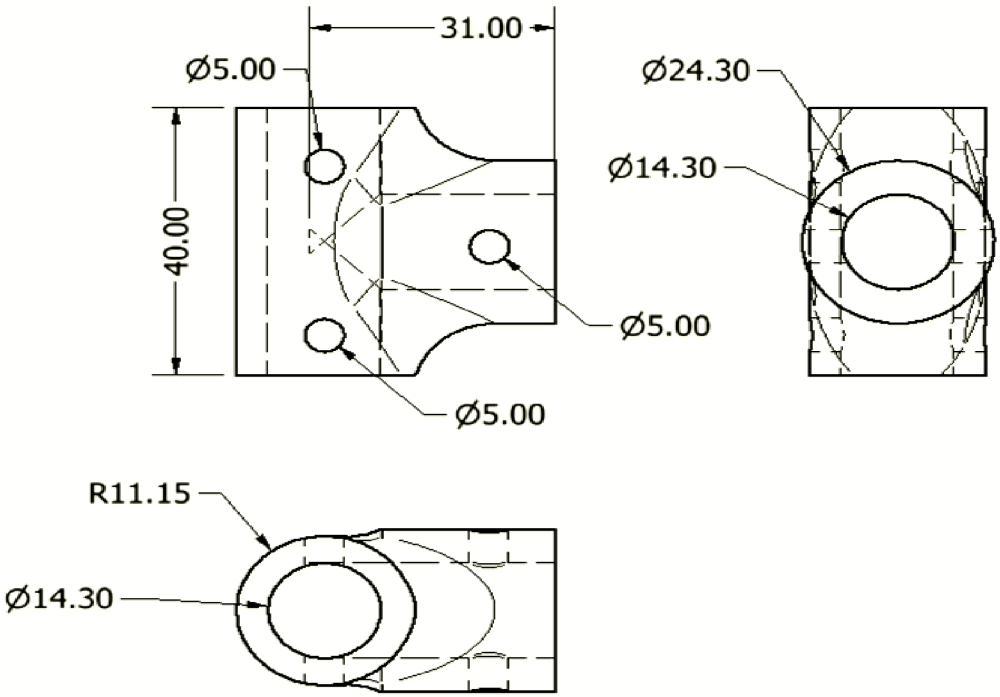
(E) Support part 1.



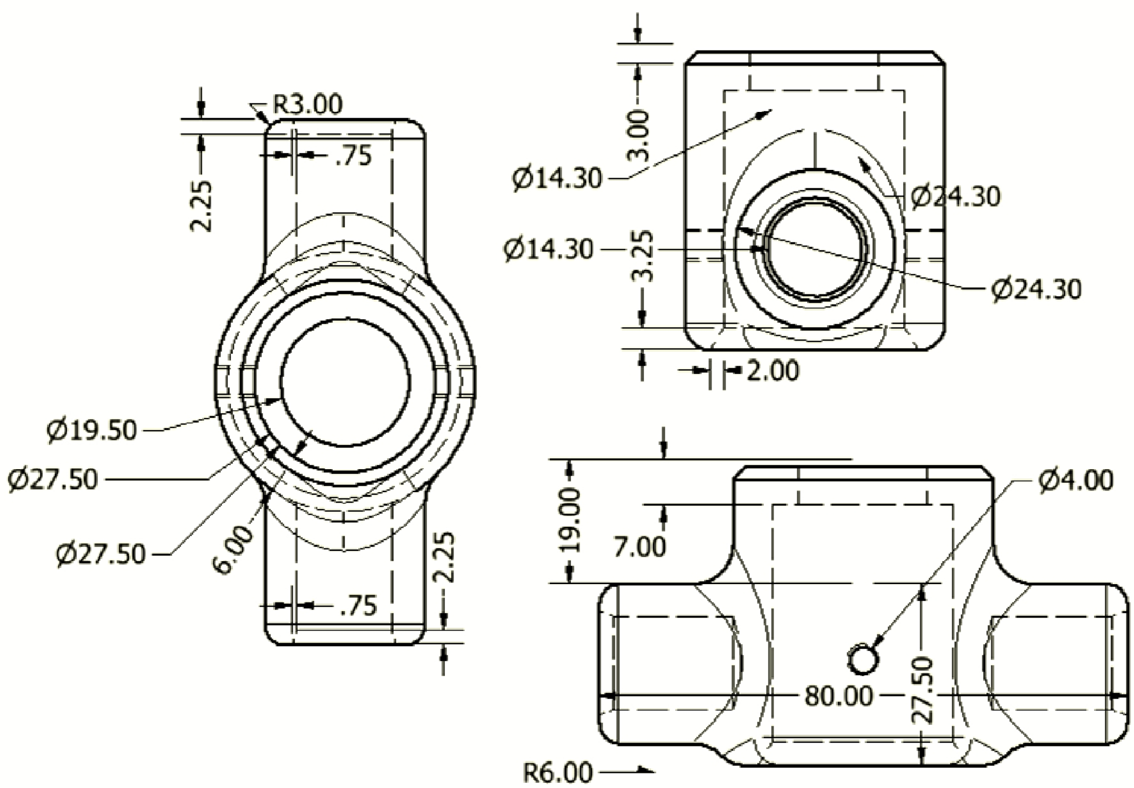
(F) Support part 2.



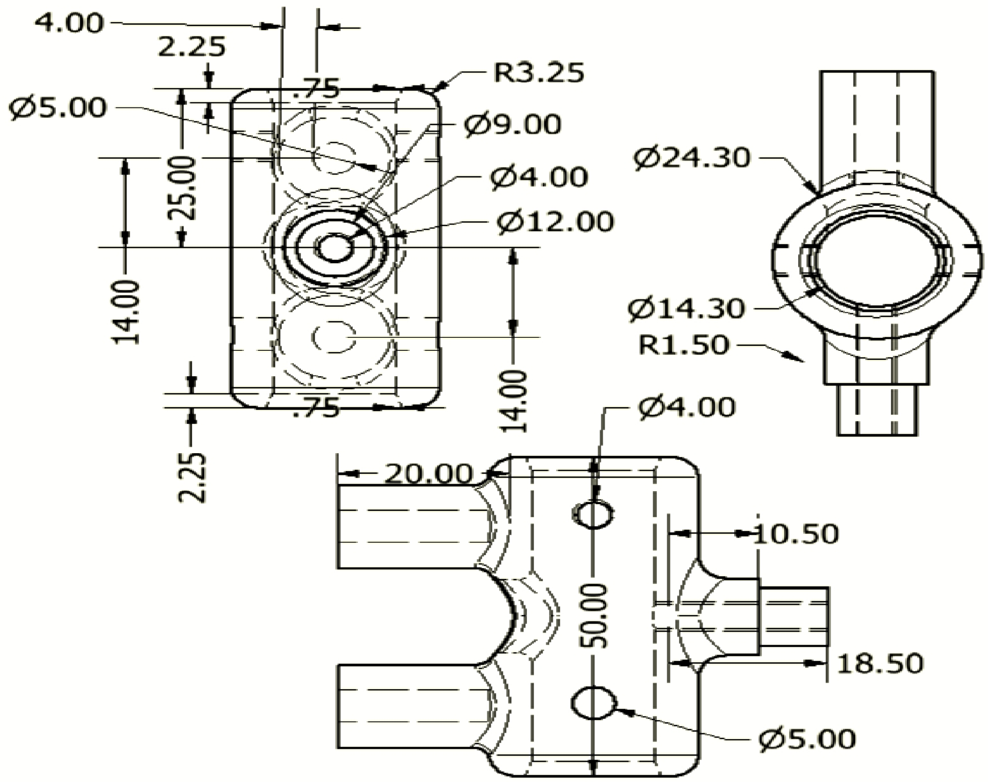
(G) Pipe attachment part 3.



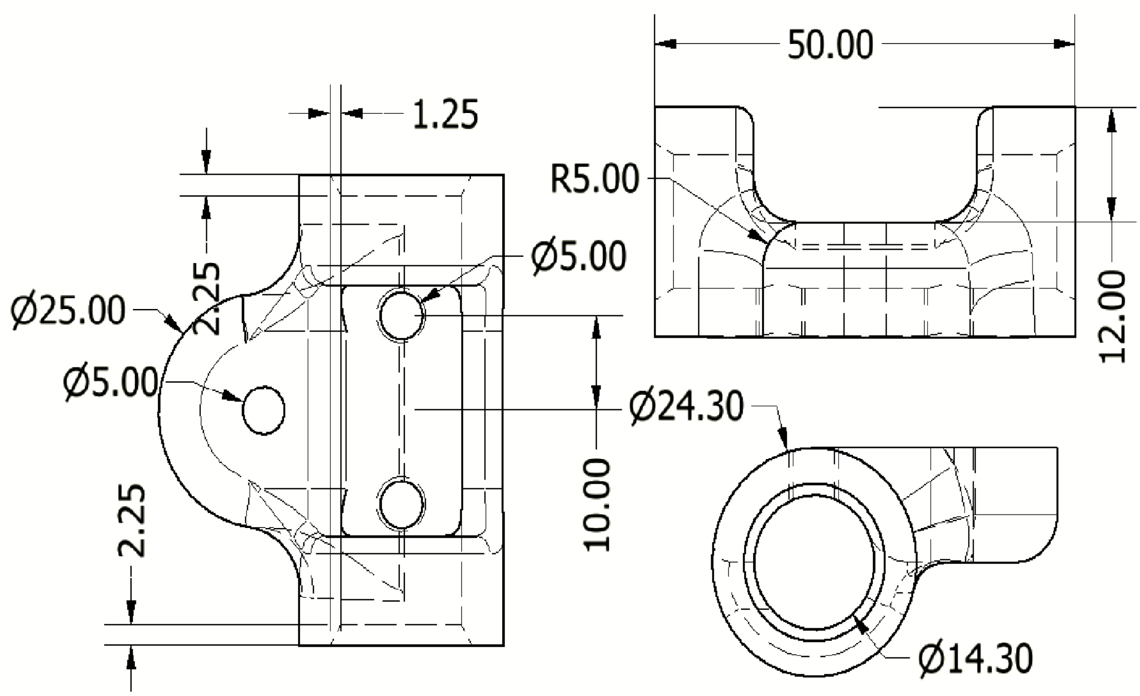
(H) Bearing attachment part 1.



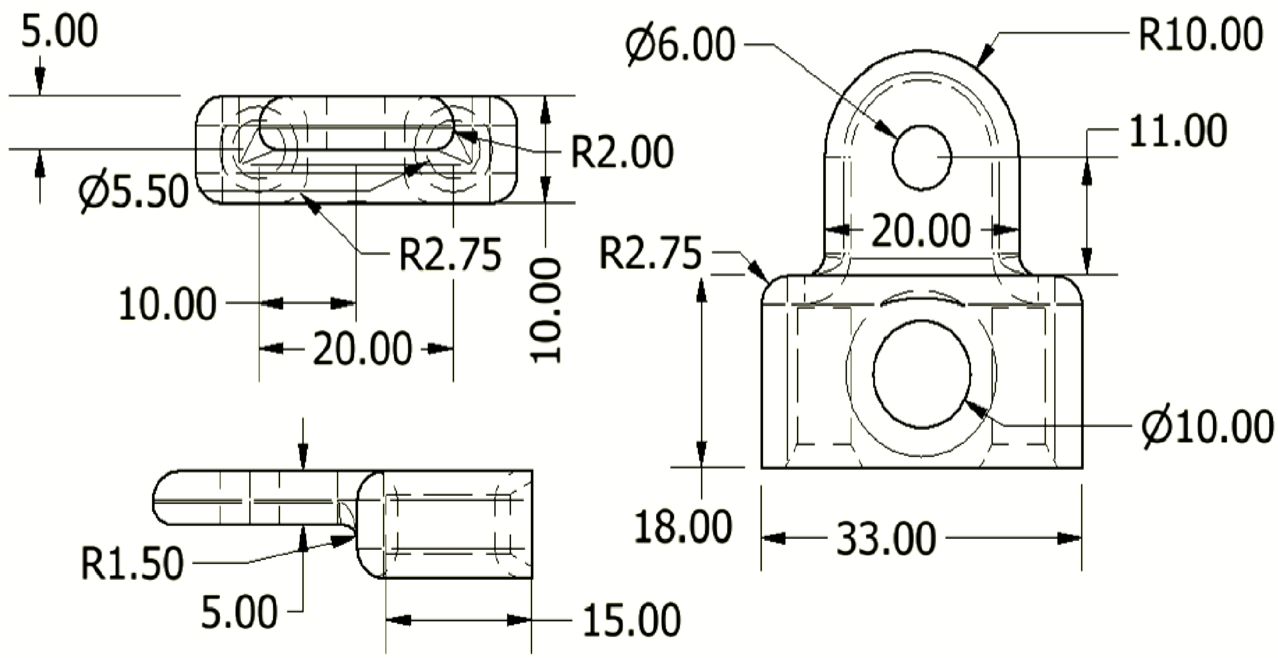
(I) Bearing attachment part 2.



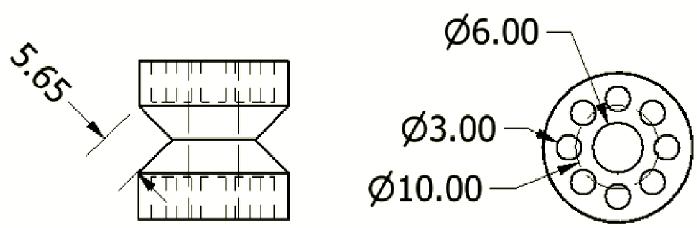
(J) Pipe attechment part 4.



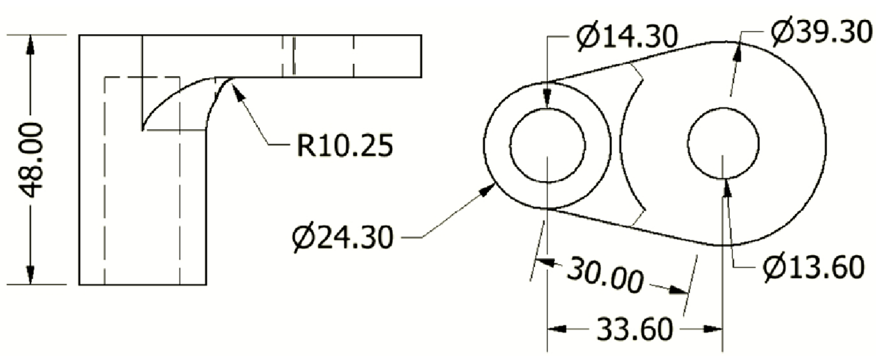
(K) lens support part2.



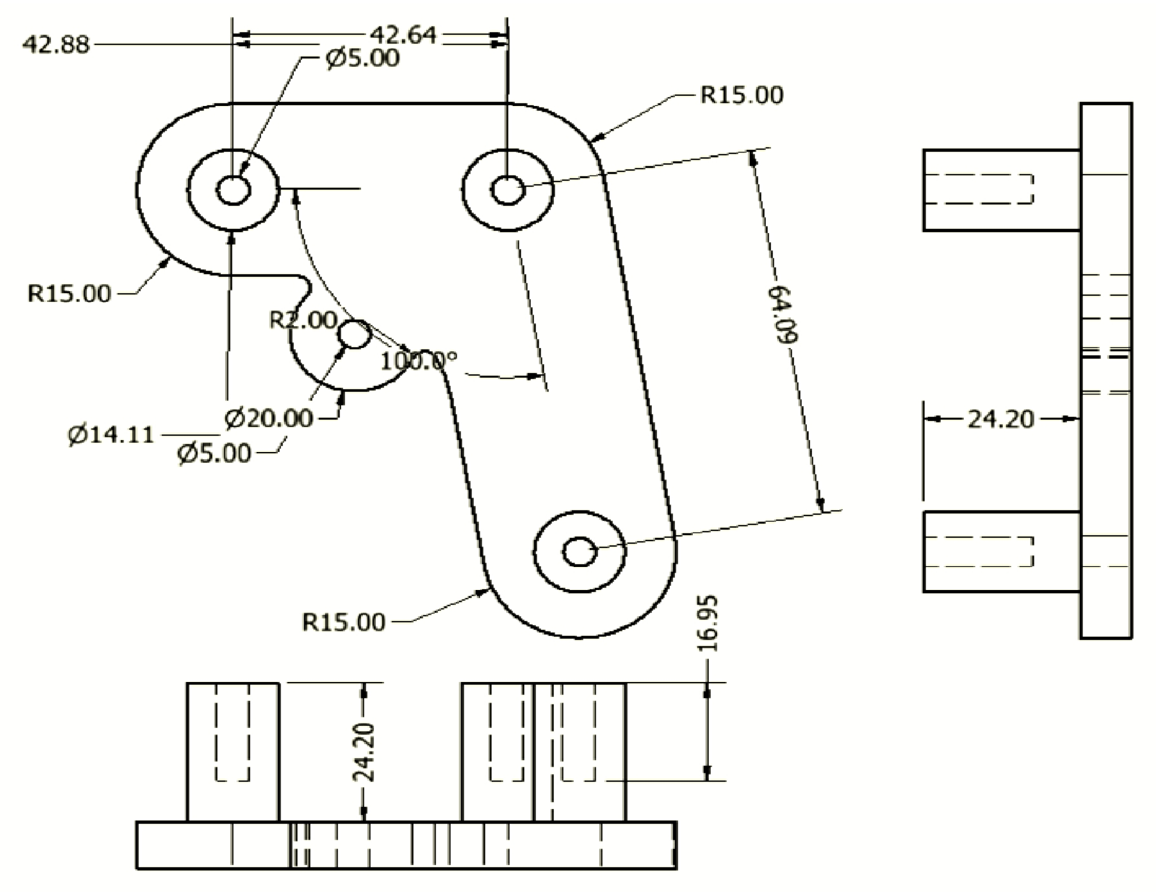
(L) Motor shaft hub.



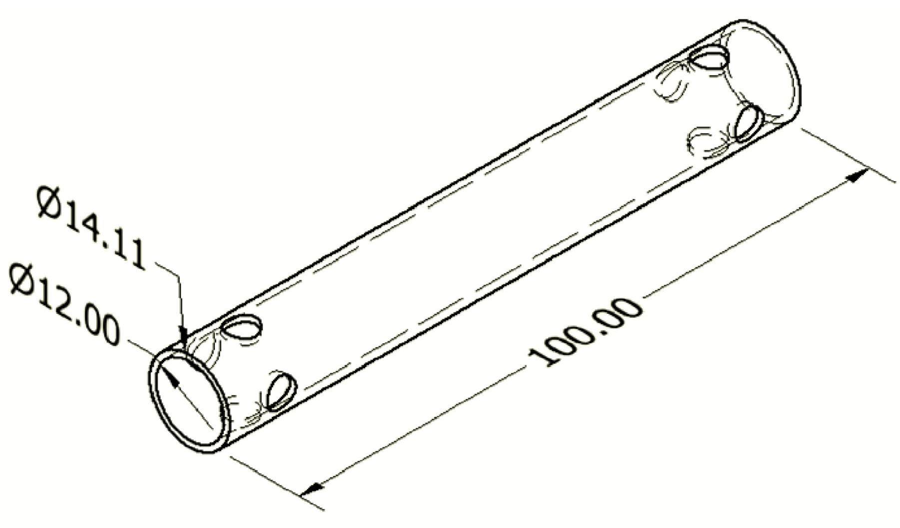
(M) Motor holder.



(N) Gear support base body.



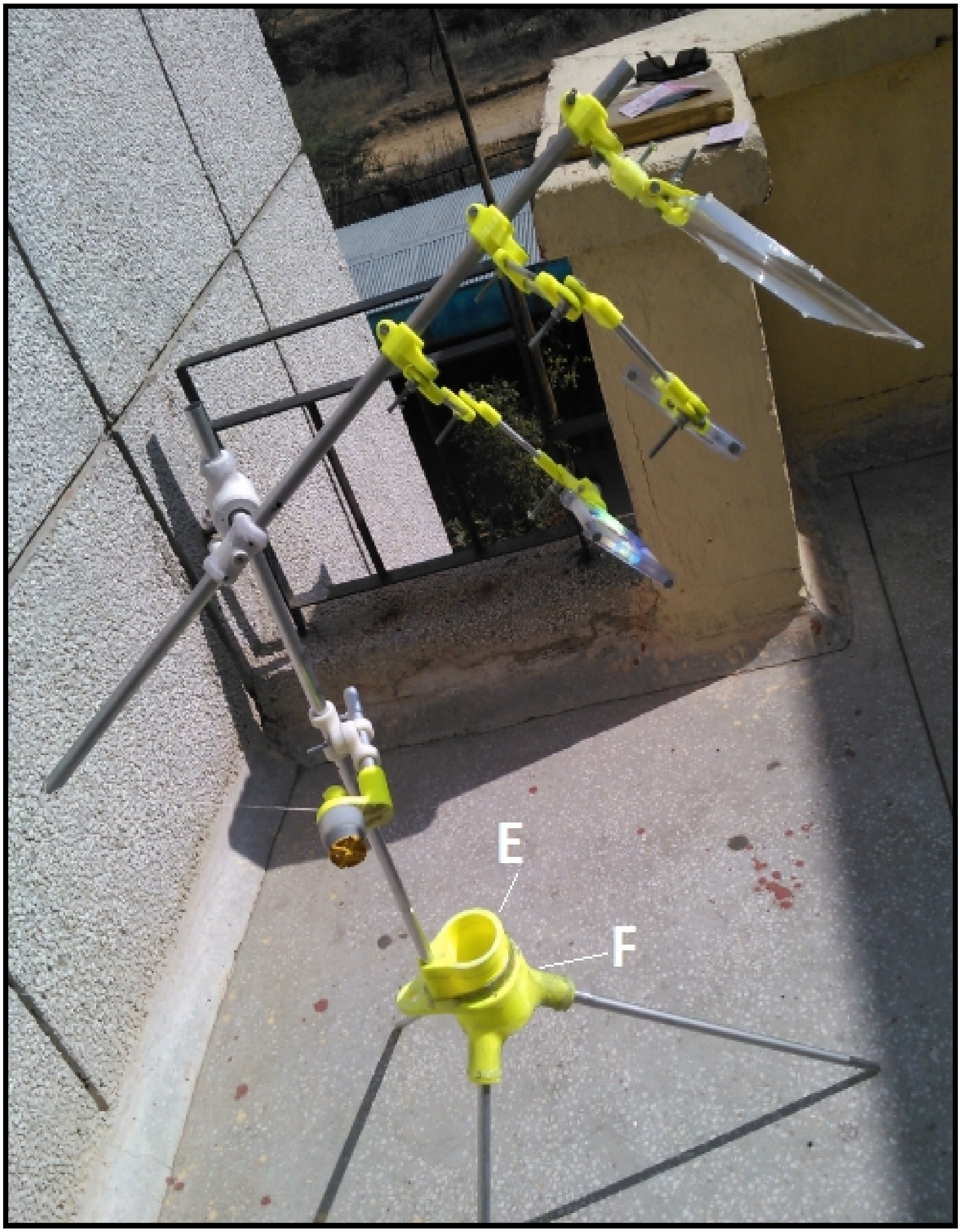
(O) Pipe.



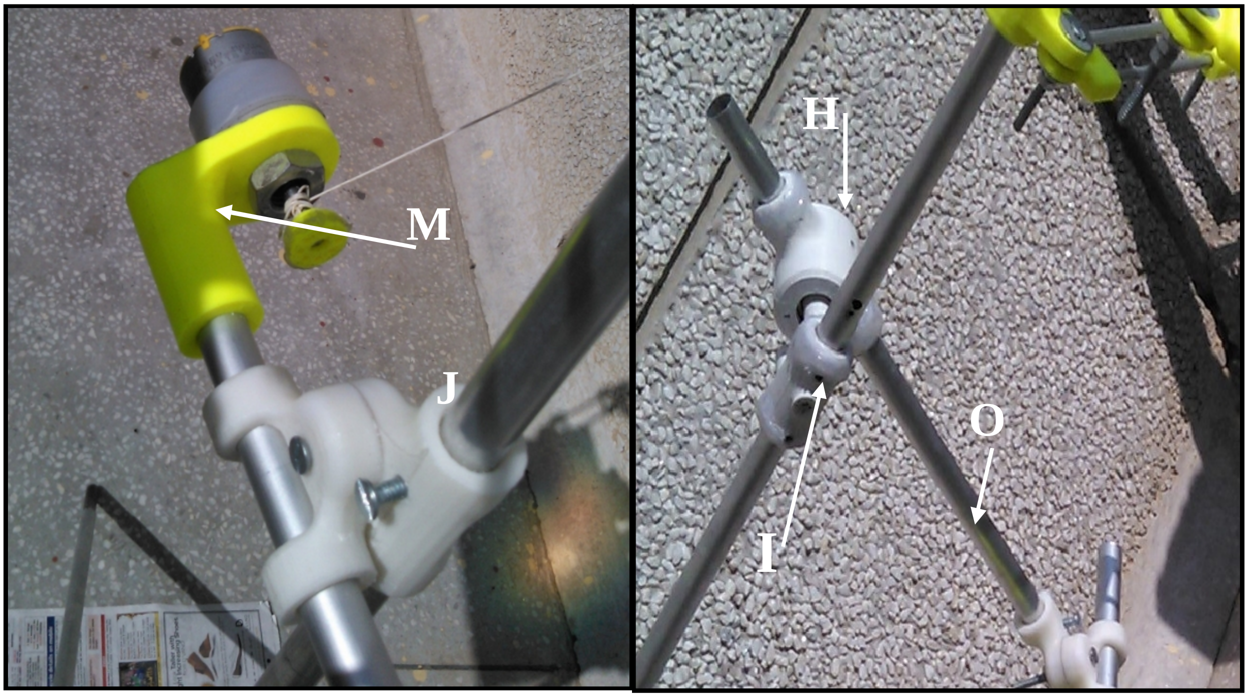
All models got printed in 3D printer for assembly purpose.

2. ASSEMBLY PICTURES.

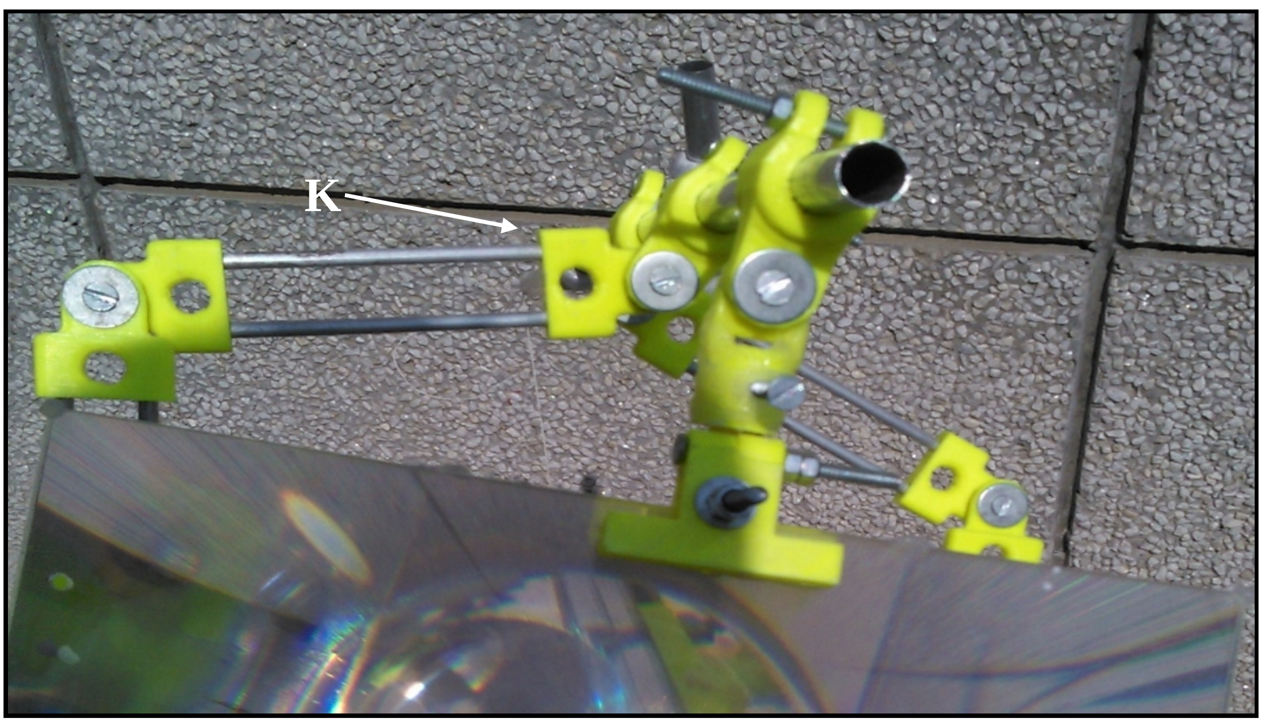
1



2



3



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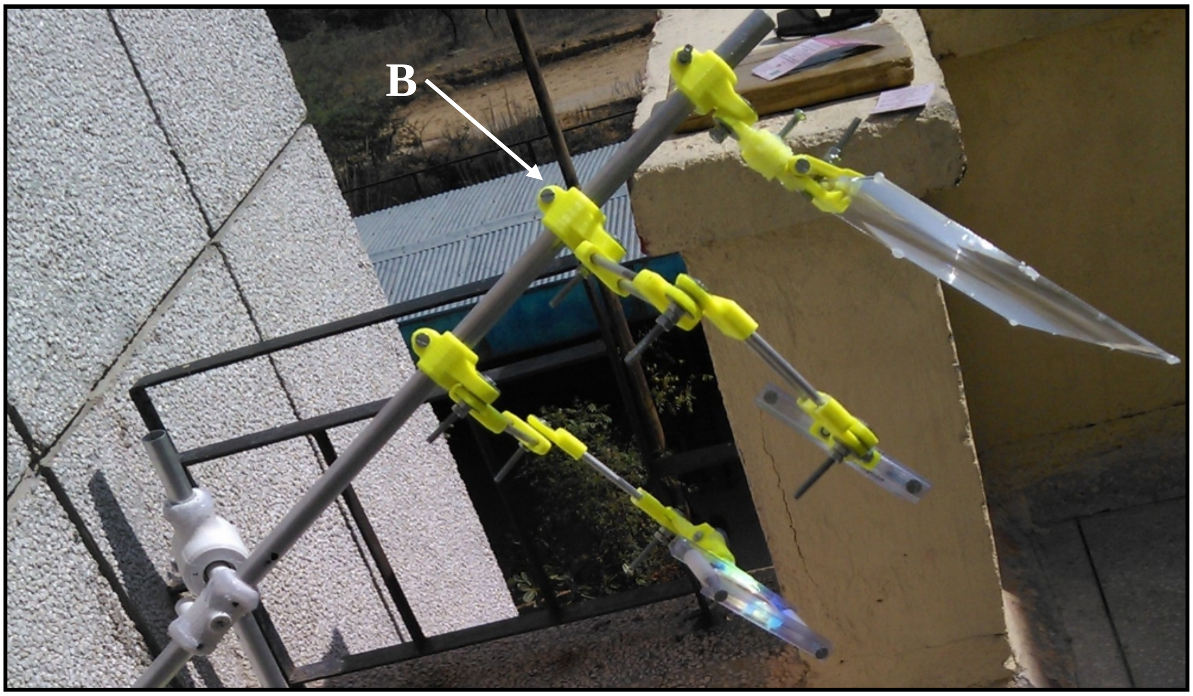


5

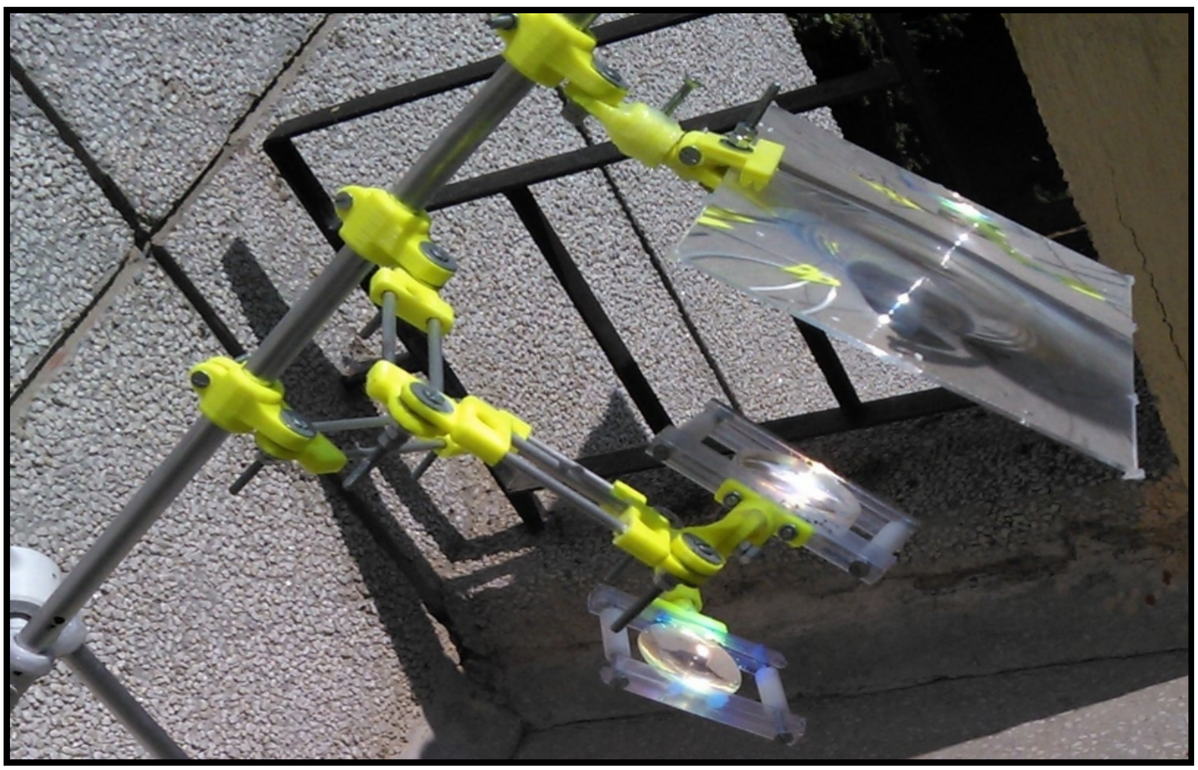


Figure:-3.4.1. First trial based Assembly of components (1, 2, 3, 4&5).

TRIAL 2:

3.5 – DEISGN MODIFICATIONS BASED ON TRIAL 1

Previously components were designed to identify components and important modules for the system. So based on those components some changes have been done; like gear has been removed because of lack of accuracy. Again need of sensors have been identified and included in new design. Following are the new changes that have been done.

This design (see figure 3.4.2 & 3.4.3) uses a Fresnel lens (1) to collect solar radiation from a large area and transfers to a convex lens (2) that concentrates the solar radiation into smaller diameter. A plane solar mirror (3) is used to reflect and guide the concentrated solar radiation; this mirror also used for further reflection with an angle of 45^{0} (4). This consequent reflection redirect concentrated solar radiation to load point or heat storage point. This system is consist of solar tracker; uses a microcontroller that connects with various actuators. A piston (5) is used to track vertical motion, while a geared motor (6) is used to control horizontal motion of the lens system. Inside the cabinet there is a rotating mirror attachment (7) that redirects solar radiation inside the hollow pipe. Another geared motor (8) used to control its (7) motion. The geared motors are attached with belts (9) to rotate parts. Bearing (10) is used to give rotating motion between upper body part and bottom part. Light dependent registers (11) are used for solar tacking; 4 LDR's are at top, controls piston (5) and geared motor (6) for horizontal and vertical motion. Two LDR's inside the pipe controls another geared motor (8).

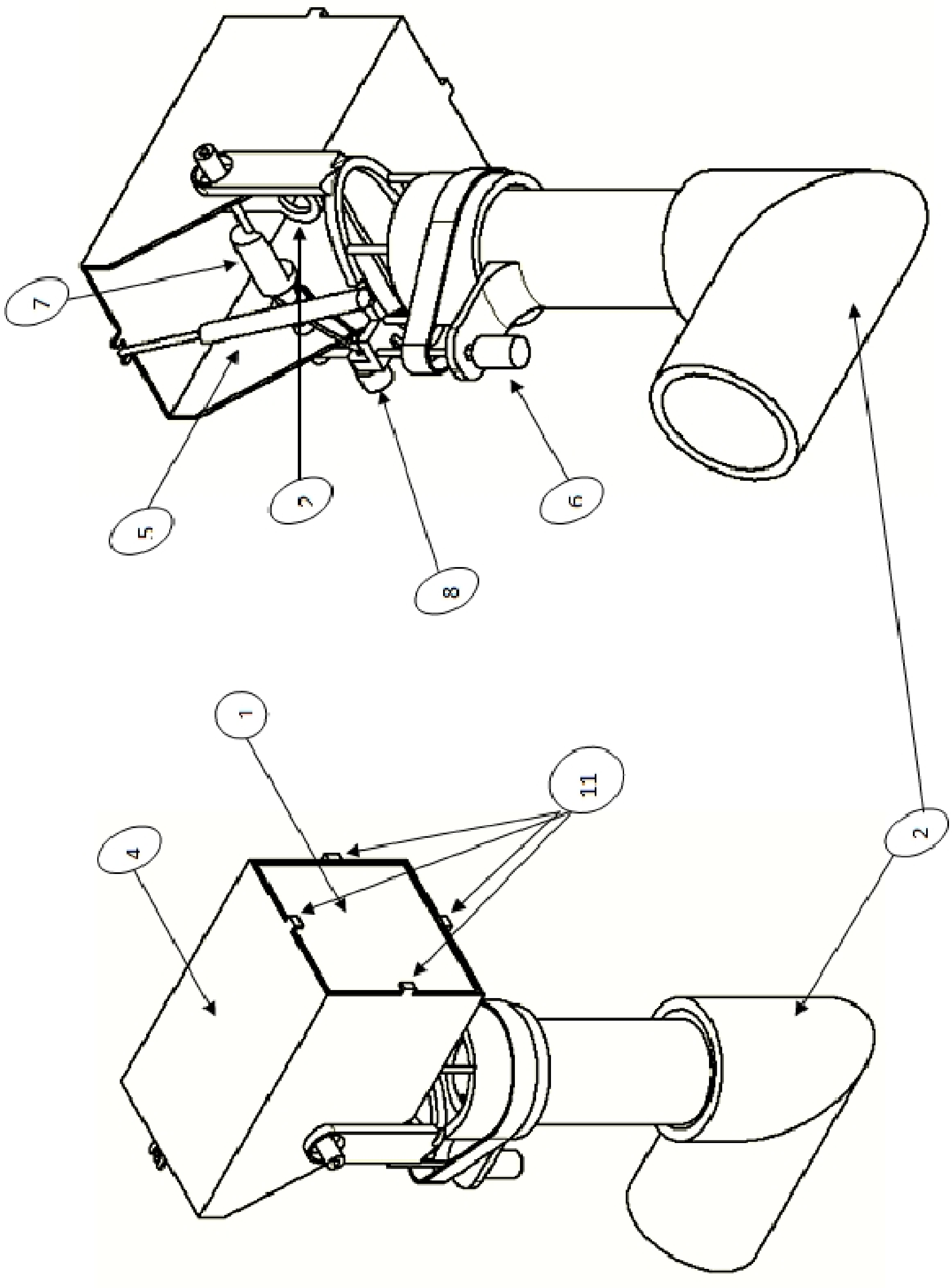


Figure:-3.5.2. New proposal of design.

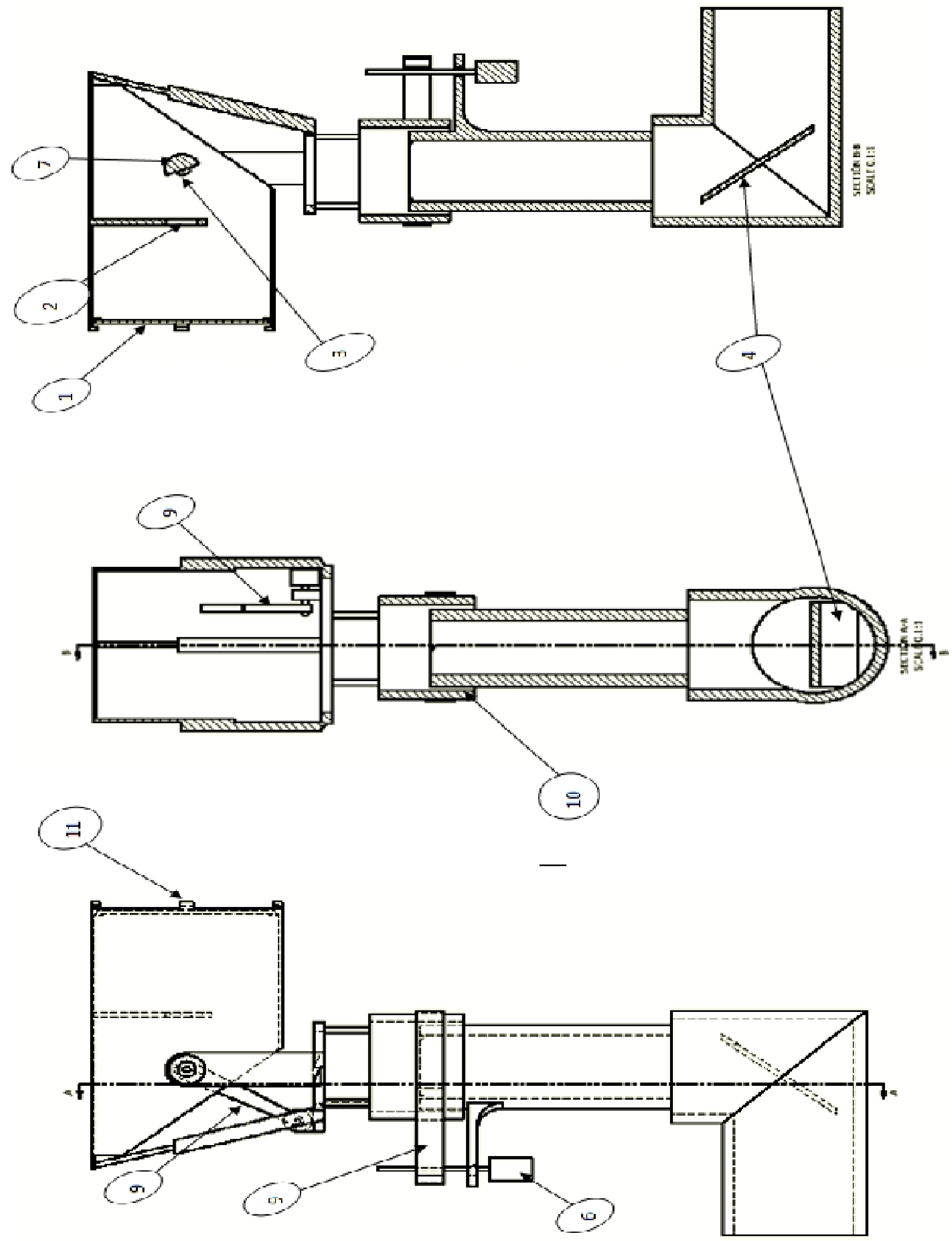
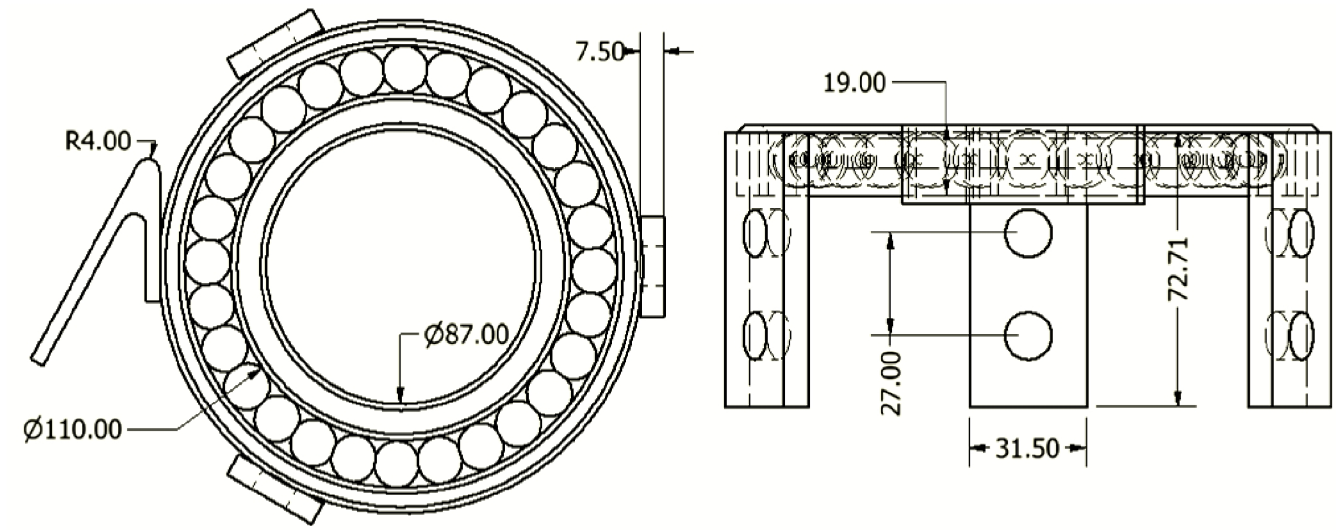


Figure:-3.5.3. Side view and cross section view of new proposed design.

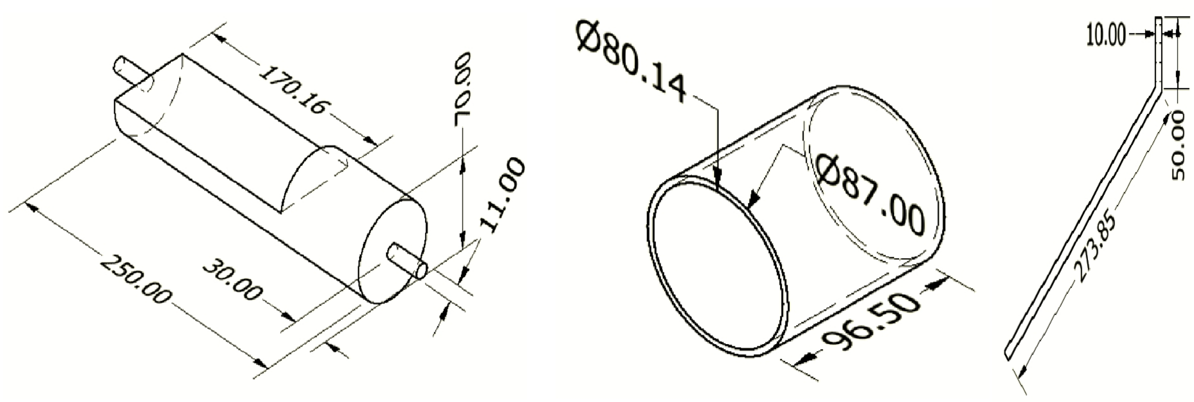
3.6 COMPONENT DESIGNS AND ASSEMBLY OF COMPONENTS IN CAD MODEL (IN MM) FOR SECOND TRIAL

Following designs have been modeled in CAD software; start of designing process was based on the cheapest and availability of greatest diameter of bearing. The available diameter of bearing was

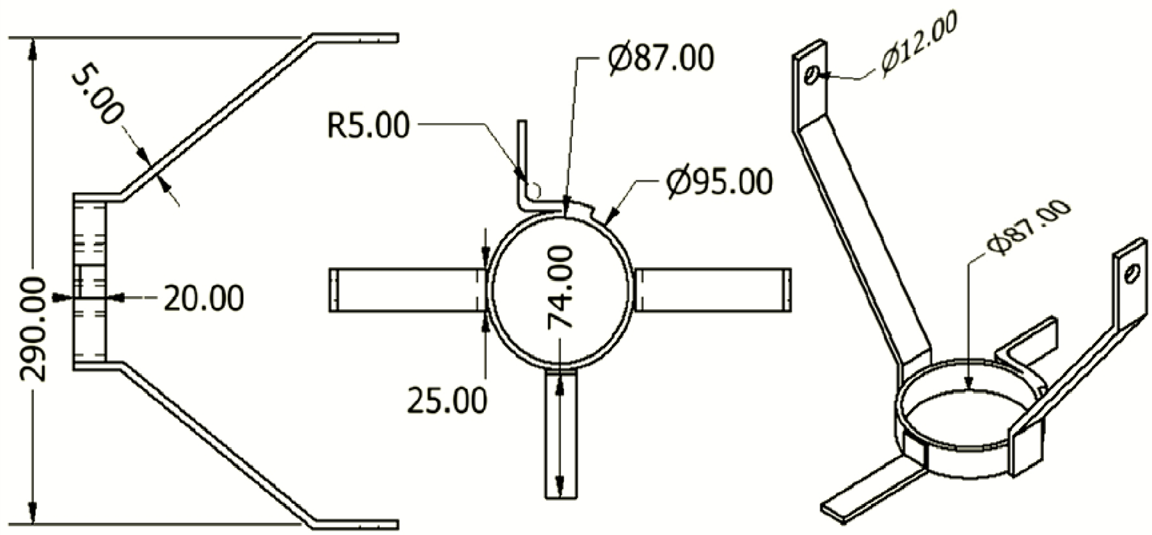
(A) Bearing part.



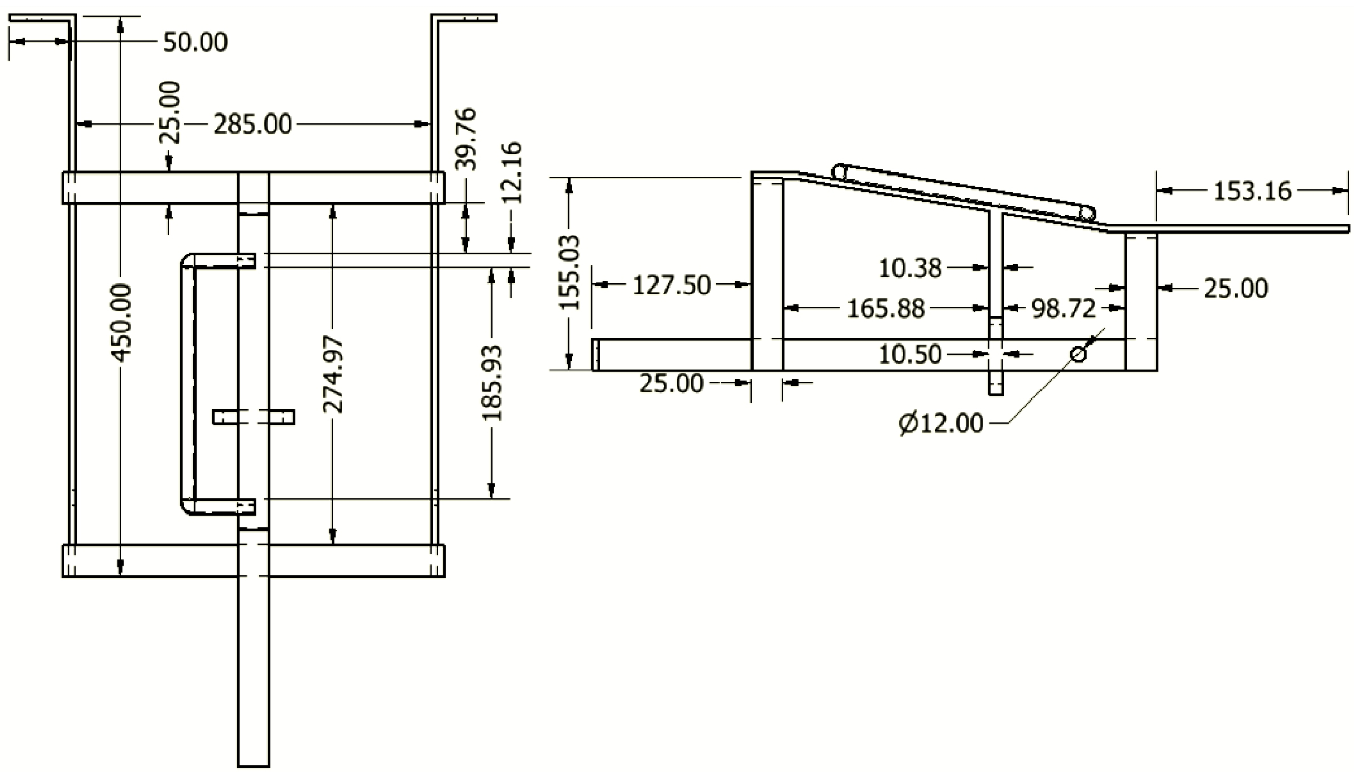
(B) Mirror attachment, Base Pipe & leg.



(C) Frame support.



(D) Frame body.



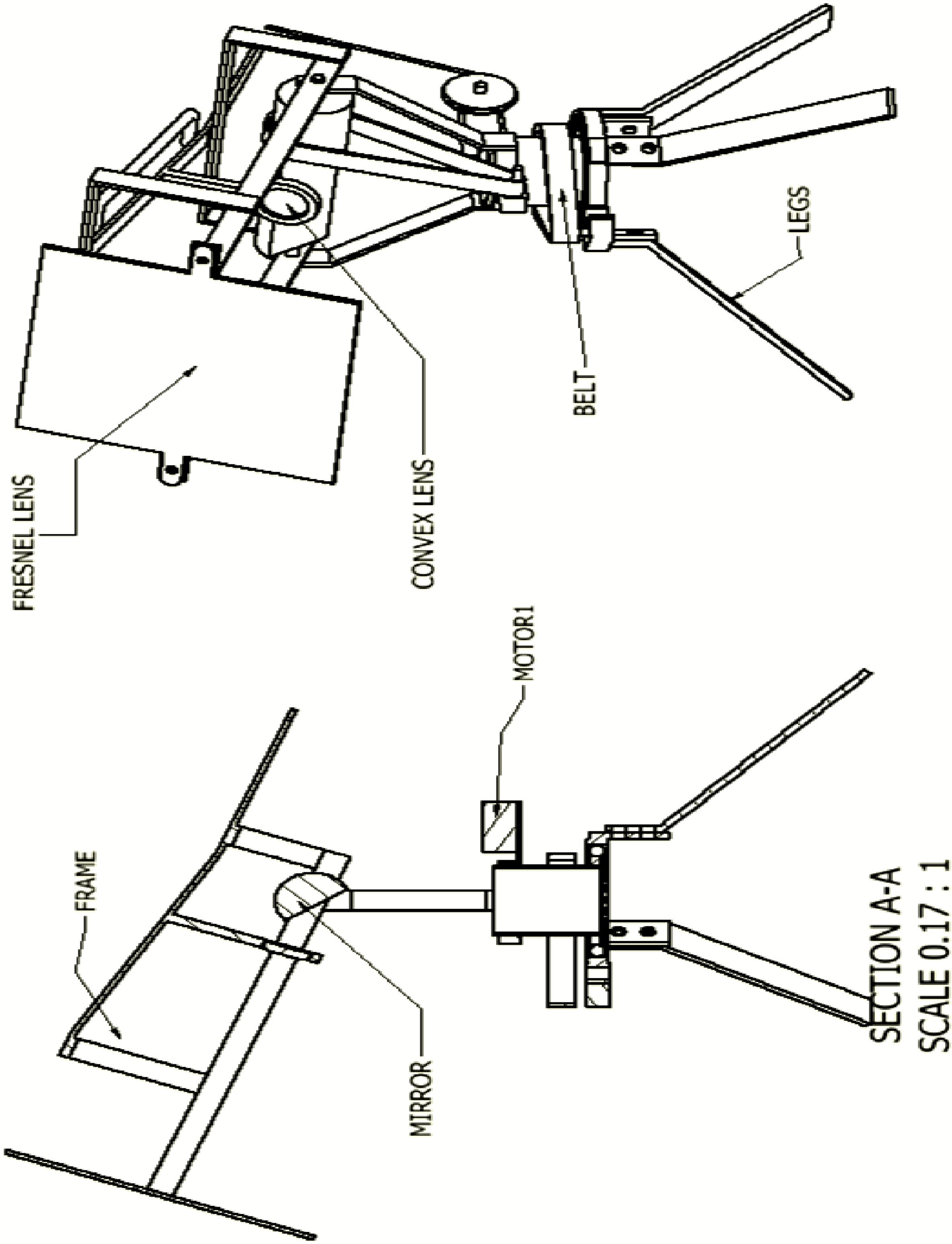


Figure:-3.6.1. Assembled diagram for system.

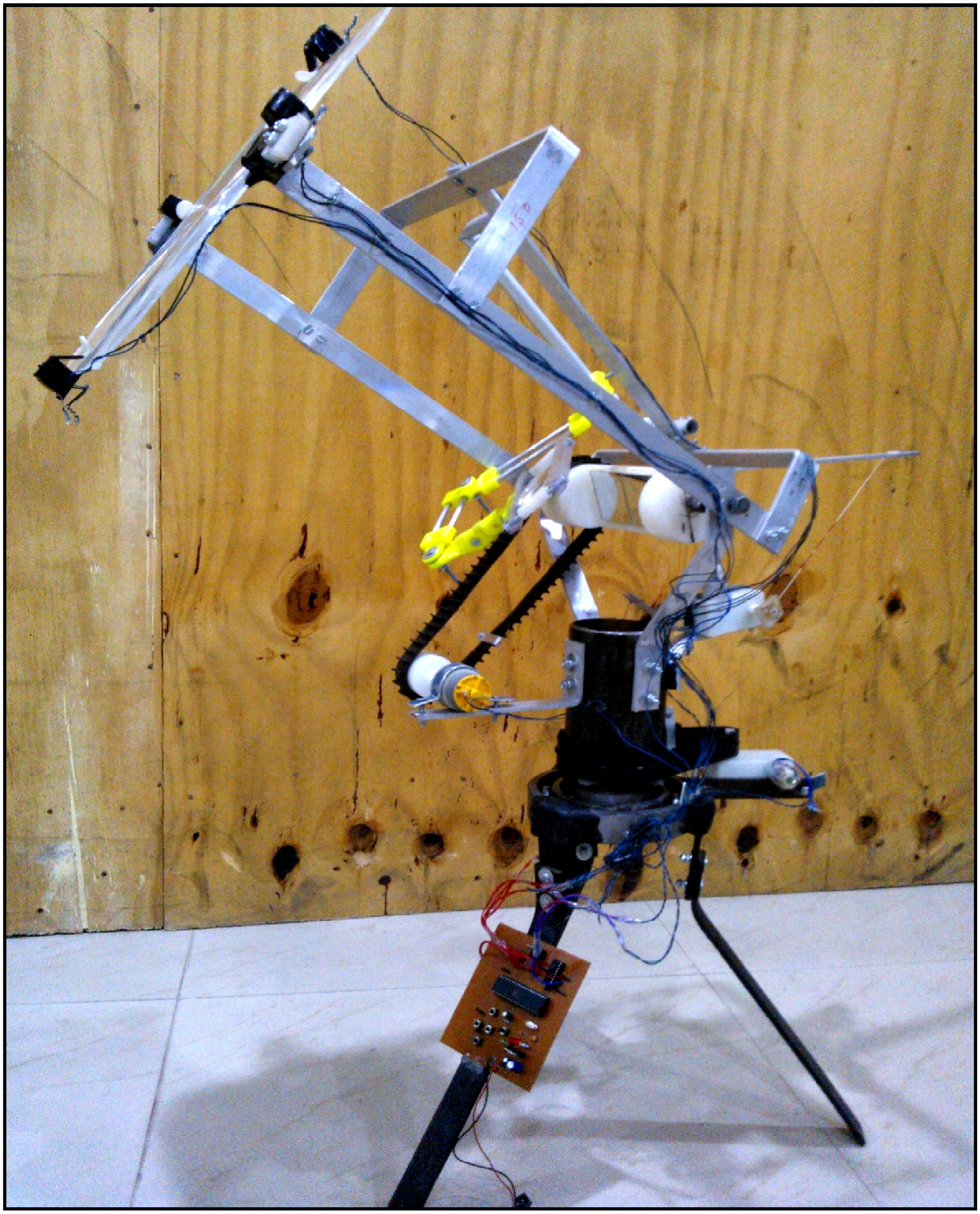


Figure:-3.6.2. The completely assembled model of system.

3.7 SOLAR TRACKING SYSTEM DESIGN AND SIMULATION

Solar tracking system is the system that makes solar radiations availability for all the time to the system. There are two types solar tracking used, first one is mechanical clock based tracking system that requires data of all position of sun for whole year and secondary requires an electrical power source and sensors. The work explained here is based on the sensor dependent solar tracking system.

This system needs three actuators to operate all motions, first actuator used for upward and downward tracking, second actuator used to track horizontal tracking. And the third one is used for mirror rotation that is inside the cabinet to redirect solar radiation into the hollow pipe. To control these actuators a microcontroller (89C51) is used with 5 volt supply that is supplied by solar cell. All actuator are controlled using 12 volt supply that is also supplied by solar cell using a chargeable battery.

For actuating purpose three geared motor have been used in simulation. These geared motor are able to supply 20-25 Kg.cm torque using 12 volt supply. These geared motor contains multiple gear trains to reduce rpm and generate high torque. There are two types of steeper motor made of plastic gears and metal gears; here metal cannot be used because it rotates additionally because of inertial effect of metal.

Similarly LDRs (light dependent resistor) have been used to track sun radiation. It loses its resistivity after getting light so this phenomenon is used. Sensor is such modified to attach into the system that it doesn’t get any radiation until the radiations are not normal to Fresnel lens. So these LDRs are used as data input unit; four LDRs are mounted on top of the Fresnel lens so two of them work for upward and downward tracking, other two are used for horizontal tracking.

Below a program hierarchy is shown to generate program. All coding is done in the software “Keil micro vision” in C language. And a Hex file generated to burn into microcontroller.

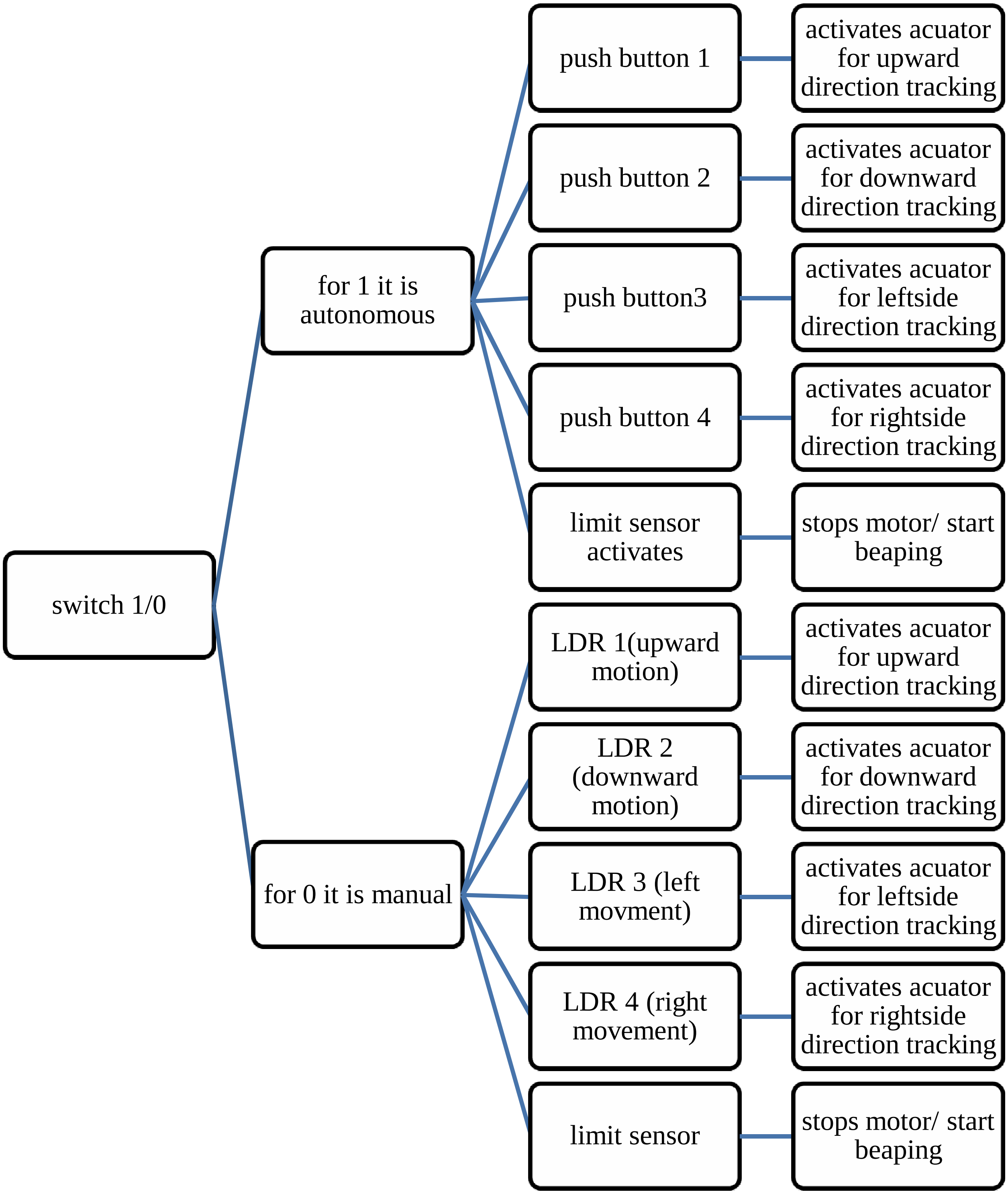


Figure:-3.7.1. The flow chart used in Keil software with C Programming.

Following is the C code for above discussed programming.

USING 8051 MICROCONTROLLER

```
#include<reg51.h>
sbit a=P3^0;
sbit b=P3^1;        // ASSIGNING OF PORT 3 FOR VARIOUS INPUTS
sbit c=P3^2;
sbit d=P3^3;
sbit e=P3^4;
sbit f=P3^5;
        sbit g=P1^0;
        sbit h=P1^1;        // ASSIGNING OF PORT 3 FOR VARIOUS INPUTS
        sbit i=P1^2;
        sbit j=P1^3;
void main()
{
while(1)
{
        if(e==1)            //AUTONOMUS LOOP START
        {
                if(a==1 && f==0)
                {
                P2=0x01;
                }
                else if(b==1 && f==0)
                {
                P2=0x02;
                 }
                 else if(c==1 && f==0)
                {
                P2=0x04;
                }
                else if(d==1 && f==0)
                {
                P2=0x08;
                 }
                 else if(a==1 && f==1)
                {
                P2=0x00;
                 }
                  else if(b==1 && f==1)
                {
                P2=0x00;
                 }
                  else if(c==1 && f==1)
                {
                P2=0x00;
                 }
                  else if(d==1 && f==1)
                {
                P2=0x00;
                        }
```

```
                        else
                {
                        P2=0x00;
                }                               //WITH IN AUTONOMOUS LOOP
        }
         else                                            // MANUAL LOOP START
        {
                 if(g==1)
                {
                P2=0x01;
                }
                else if(h==1)
                {
                P2=0x02;
                 }
                 else if(i==1)
                {
                P2=0x04;
                }
                else if(j==1)
                {
                P2=0x08;
                 }
                 else
                {
                 P2=0x00;
                 }
        }
}
}
```

To simulate above code for an 8051 microcontroller PROTEUS 7.0 design suit is used and simulated. Also a circuit diagram prepared using the same version of ARES PROFESSINAL design suit to make a PCB panel. Below a simulation capture is shown where 89c51 is used and L293D is used for motor driver and four inputs are given as LDR's input and two inputs for limit sensors and single input for autonomous and manual mode.

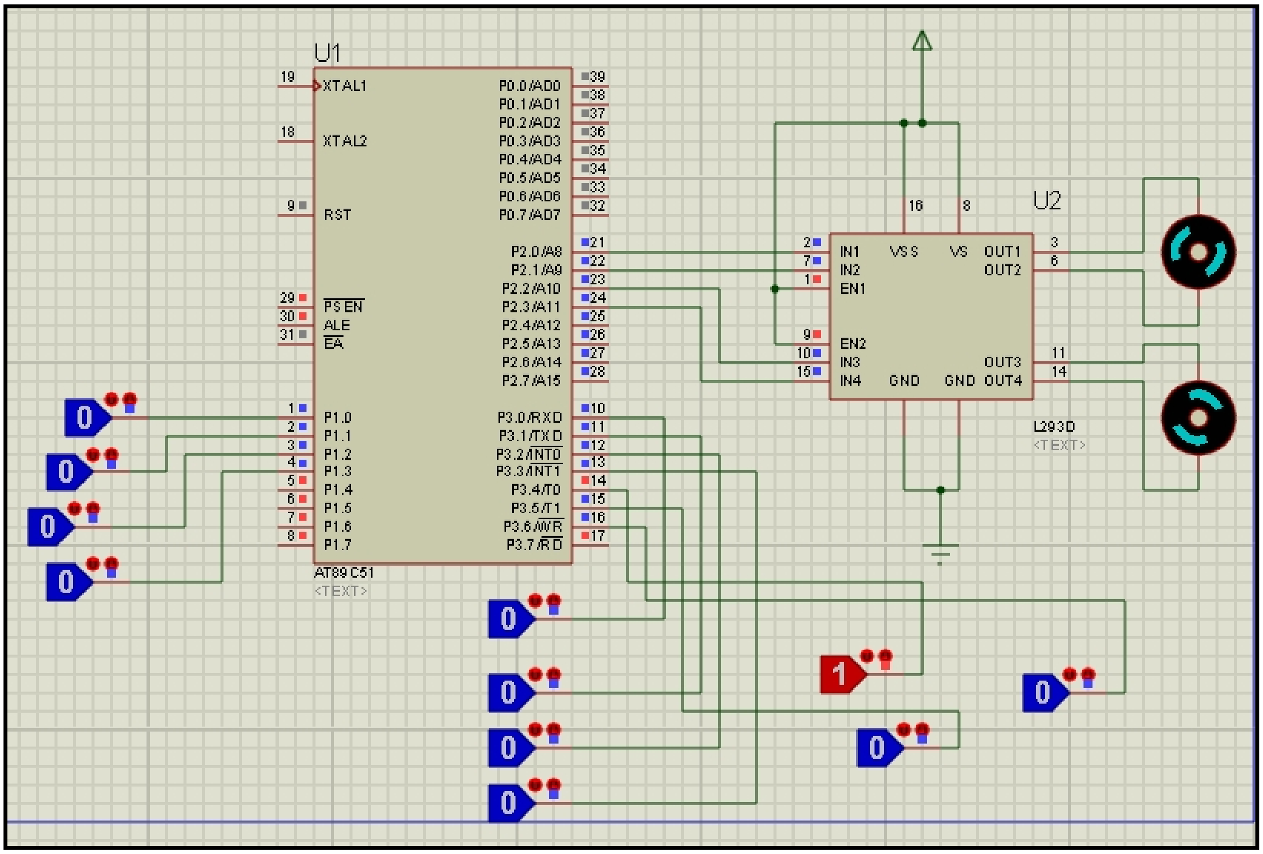


Figure:-3.7.2. Simulation done in PROTEUS 7.0 for solar tracking system.

3.8 MODELLING OF MODIFIED SENSOR

During modification of LDR sensor first condition is that no radiation will interact with LDR until Fresnel lens is normal to the solar rays. So in modeling four walls have been added in order to cover the LDR from sidewise so that no light can enter from other then opening from top. It is designed in such a way that light can entre from top only. Also the whole component is painted black so that no reflected radiation can disturb the operation.

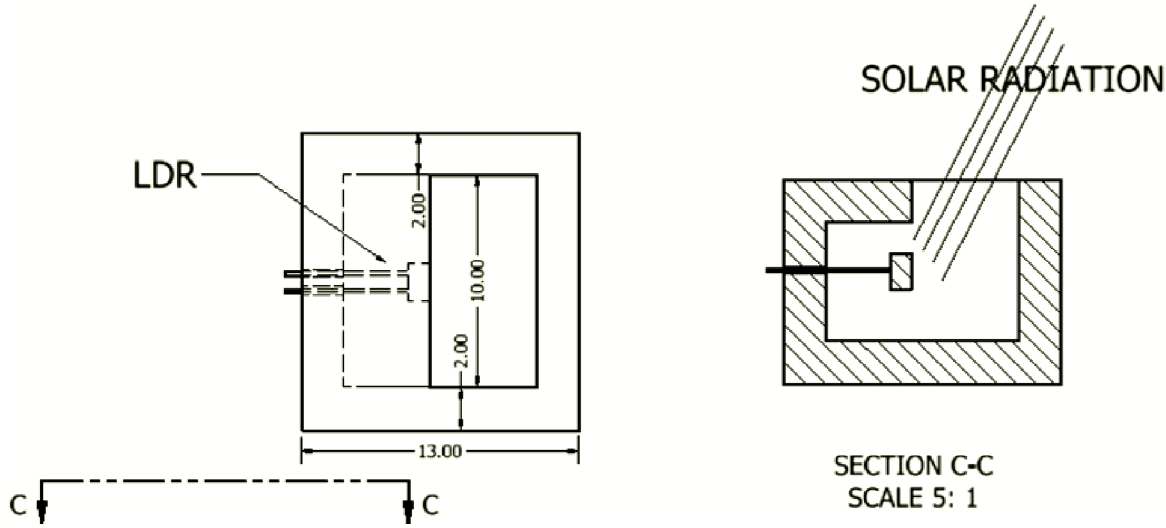


Figure:-3.7.3. Sensor modification modeling.

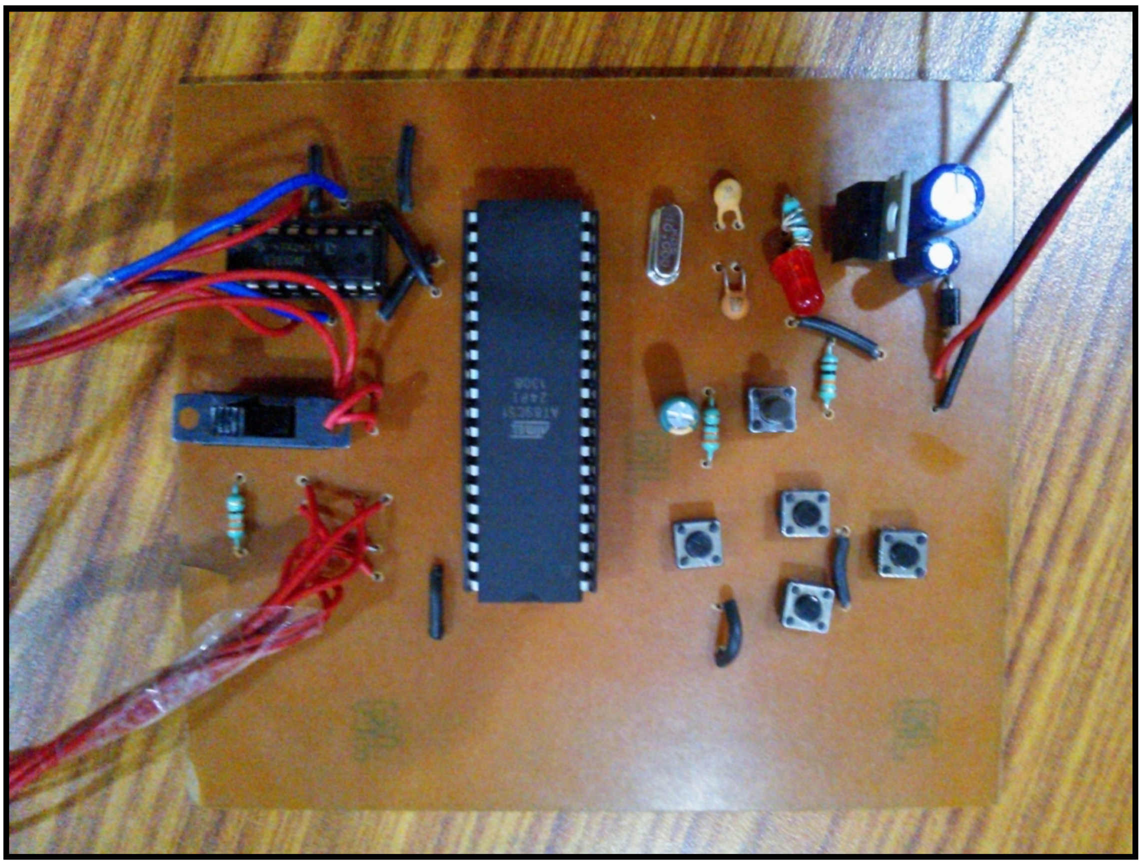


Figure:-3.8.1. Built circuit board for solar tracking.

4. TESTING OF SYSTEMS FOR DIFFERENT TRIAL

TRIAL 1:

In this first trial all parts have been assembled and tried to make functioning. All printed parts using rapid prototyping, checked for tolerances and fitting allowances so that they can be assembled easily. The produced parts have their exact dimensions as they modeled.

4.1. TESTING FOR LENS ARRANGEMENTS

In this trial three lenses have been arranged as discussed in chapter 3 (topic3.3). The combination of these three lenses needs too much accuracy. In the figure (see figure 4.1.1.) rays incidents to Fresnel lens are not normal so the shape made by these rays will not be perfect rectangle. On the other hand these rays are producing some orange colour shades that shows also poor refraction of lens .The first need that comes to mind is to have a perfect sun tracker which will provide exact normal rays to the Fresnel lens; this will help to get perfect rectangle shape. If the primary rays are not parallel then consequent rays will get more deflected and at the end rays will have great distance.

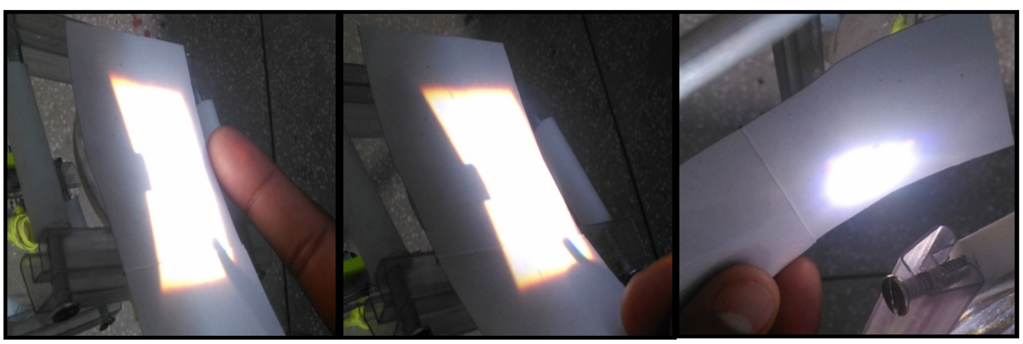


Figure:-4.1.1. Refracted rays shape after Fresnel lens (left and middle) and after the combination of lens(right) .

Using three lenses makes it more and more disturbed parallel rays. If the first lens fails to take normal rays to its surface then the whole combination will fail to provide a good concentrated radiation. So it is very necessary to make lenses all the time parallel so that they can provide parallel non-disturbed rays. This combination is able to provide a good concentrated solar beam (see figure 4.1.1 right).

4.2. TESTING OF SELECTED MECHANISM

In this section selected mechanisms have been evaluated by making it functioning. The selected mechanisms are like the frame body, ray guiding mechanism (gears) etc..

1. Frame body design in first trial is designed to identify the different modules. The identified modules are ray guiding mechanism, lens supporting frame and base body that allows rotation to solar tracking system. This frame body is not robust to bear all environmental factors like wind pressure.
2. Gear mechanism is supposed to guide rays into the hollow pipe but in this trial it is failed because the gear made by rapid prototyping is not accurate with dimension. This requirement can be fulfilled by making high précised gear. Here an automatic guiding system is proposed in order to fulfill the accurate guiding.
3. From the title no 3.4- support parts are made to provide rotating facility to the system for solar tracking. It was designed as two concentric sleeves with lubricant (grease), in order to provide rotational motion but because of having vertical alignment between these two it got failed. Based on this failure design has to be changed in next trial.

Figure:-4.1.2. Support parts that provide rotational motion.

4. The geared motor used in first trial is made of metallic gear. It is to provide very high torque to the system to control motion. The main drawback of using this gear motor is

excessive rotational motion which disturbs motion accuracy. Replacing this motor is another requirement.

TRIAL 2:

In this second trial design of the whole body has been changed in such a way so that it can easily guide solar beam inside the hollow pipe. The shape of the system has been developed by keeping in mind that the required robustness must get fulfilled in order to give strength to install it outside of the room. In this trial aluminum has been chosen as the frame body for easy bending and fabrication. It also provides light weight as well as good strength to the system.

4.3. TESTING OF MECHANISM FEASIBILITY FOR SOLAR TRACKING AND RAY GUIDING

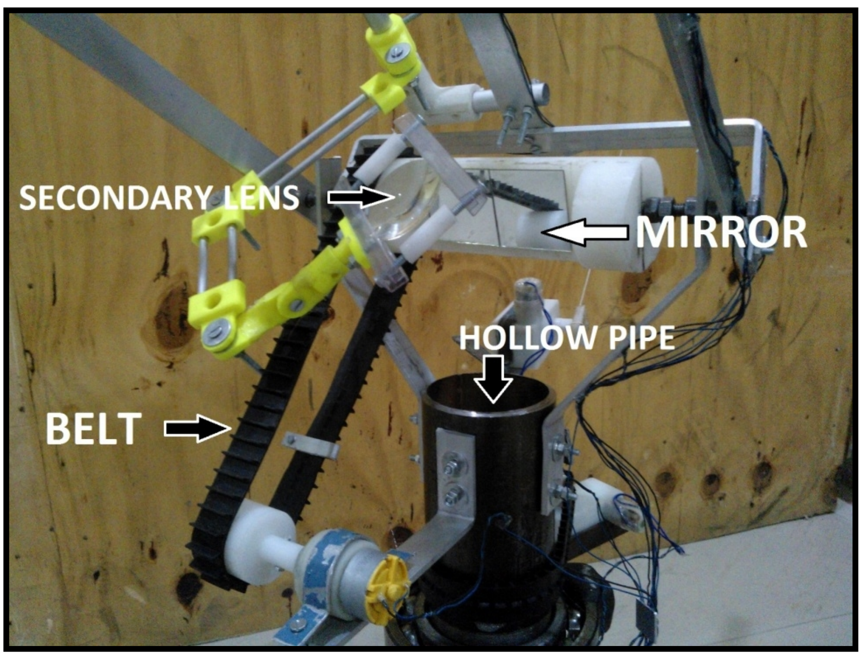


Figure:-4.1.3. The Mechanism to guide solar beam inside the hollow pipe.

The mechanism shown above (see figure 4.1.3) is designed to pass solar beam through the hollow pipe from which the whole beam can be guided to further distance. In this mechanism after passing through secondary lens the solar beam will strike to the mirror and get redirected to inside the hollow pipe. The belt and motor is provided to control that mirror as the main lens moves up or down the angle of mirror needs to be changed.

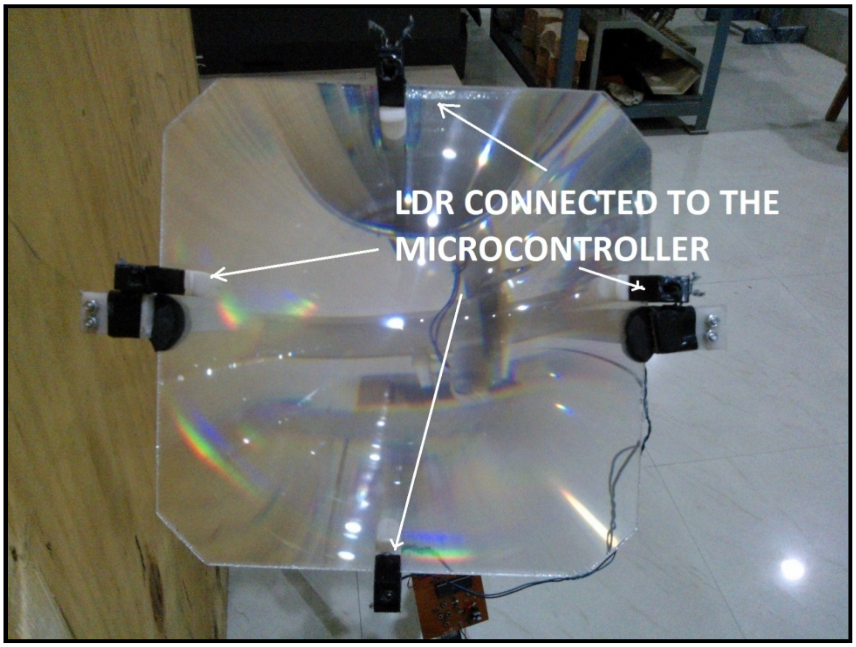


Figure:-4.1.4.Attachment of four LDR sensors for the solar tracking.

The above figure shows the position of four light dependent resistors which helps in the solar tracking. The function for these LDR sensors is to make Fresnel lens all the time normal to the incident solar rays. The design of the modified LDR sensor has been discussed in the topic 3.7.

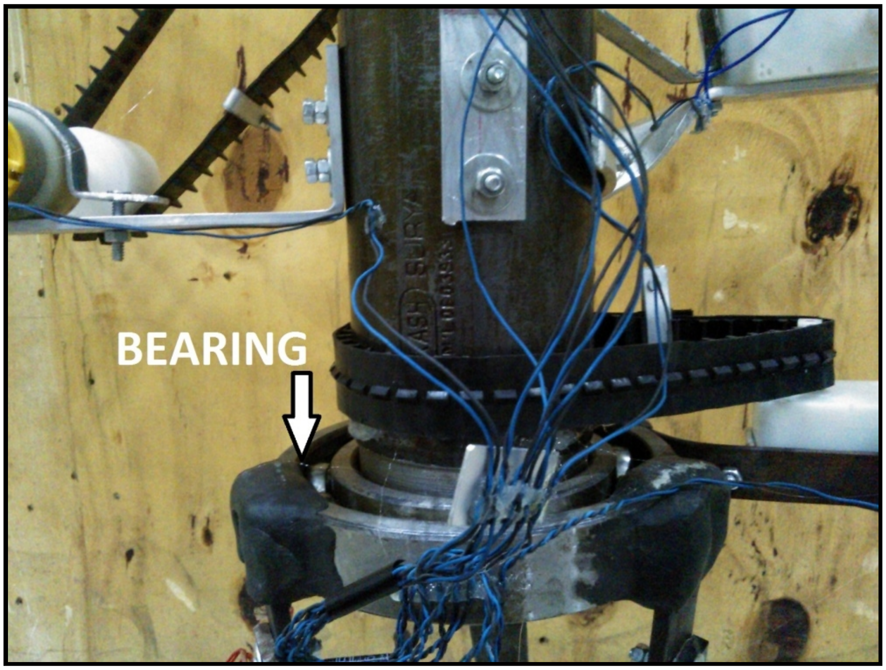


Figure:-4.1.5.Bearing attached to provide rotational motion.

The bearing is added (see figure 4.1.5) in between the base part and the upper part that provides rotation between them which is the requirement of solar tracking. This mechanism is controlled using a motor and microcontroller.

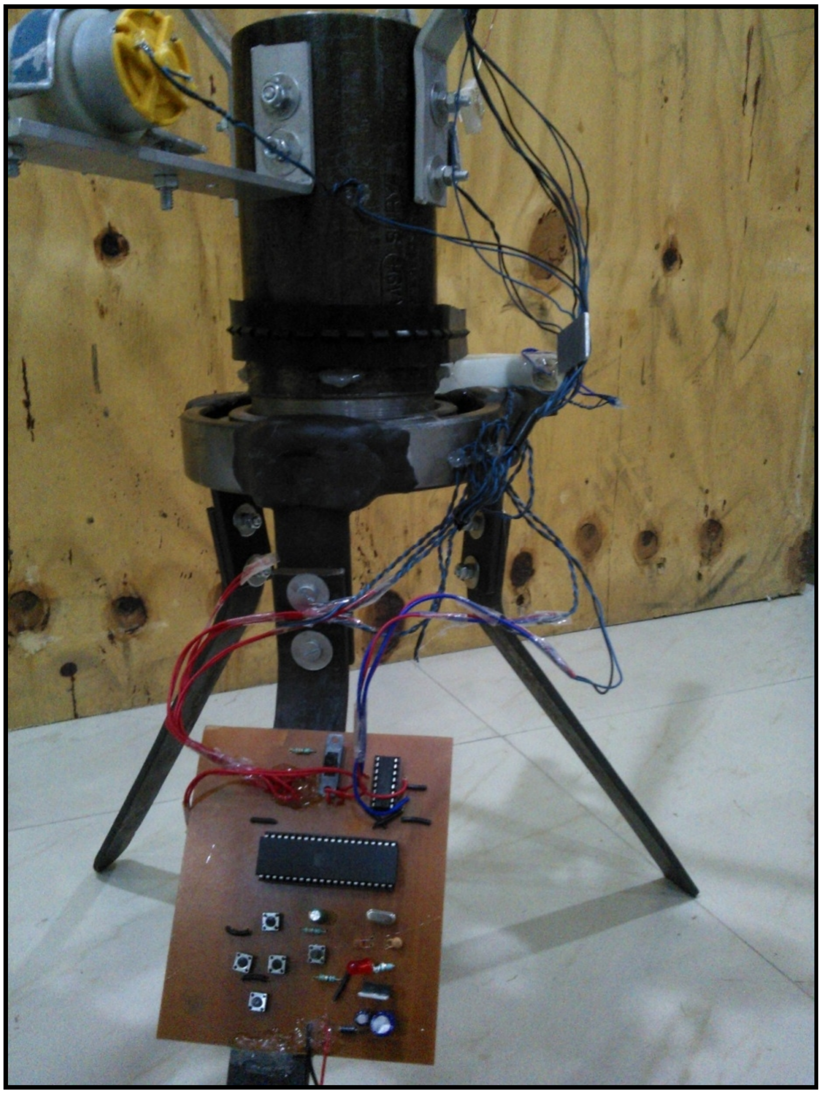


Figure:-4.1.6.Conected microcontroller to all actuators.

The wired controller is placed in such way that it would not restrict the any of the motion required for solar tracking.

5. RESULTS AND DISCUSSION

Using three lenses in first trial results more and more disturbed parallel rays. If the first lens is failed to concentrate all rays into a single point then rays will get more and more disturbed in next consequent refraction. So it is very necessary to make lenses all the time parallel so that they can provide uniform non-disturbed rays. There are few samples of concentrated beam as the result shown below (see figure 4.1.2). In figure A & D are the result of wrong positioning of lenses, B & C are of due to tilted lens and E&F are of same continues beam and is able to travel few meters.

The lenses combination has not been changed for the next trial as there is no other lens combination available in the market. To get perfect circle of beam without making any loss the lens required should must follow the rule discussed in the topic 2(calculations 3.3).

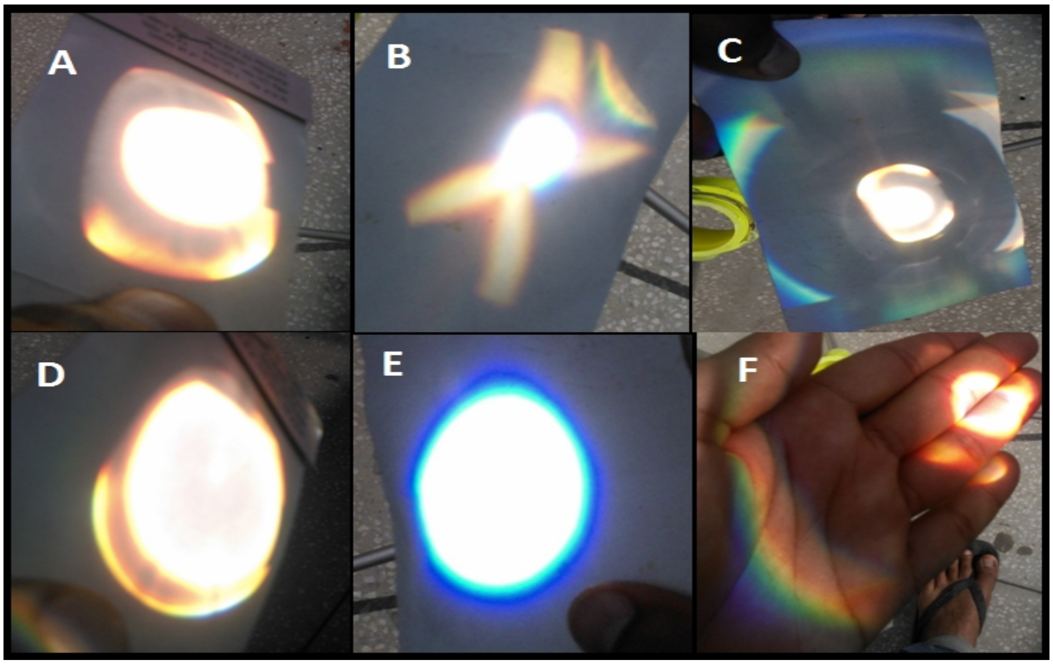


Figure:-5.1.1. Refracted rays after passing through three refractive lenses.

The whole assembly of the second trial has been tested for its mechanism which was successful. The bearing provided in between the upper and bottom support portion, gives the good rotational motion for solar tracking. The whole body is made of aluminum which is light and having good machine ability.

In the solar tracking light dependent resistors is used as input for the microcontroller which controls the gear motors to track sun. The simulation is done for two way function as autonomous and manual mode for manual tracking or adjustments. So the whole code was written in the C language and converted to hex file using keil microvision software. After getting hex file required virtual circuit board was created in the proteus and then that file got tested which was very successful. The actuator motors are made of plastic fiber gears which stop the excessive rotation of the shaft, as in the case of metallic gear in the motor cause’s excessive rotation. The belts used here are made of rubber which causes some inaccurate motion of the parts.

6. CONCLUSION & FUTURE SCOPE

6.1. CONCLUSION

The original idea came after seeing a cooking device used for cook food inside the shelter. After observing the food quality it was found that the food was partially uncooked so to find the reasons behind this, the device used was analyzed. It was found that the device uses a chamber to collect the thermal radiation from sun and then transfers the thermal radiations to cooking pot.

Another idea came from the light pipe that uses total internal refraction to illuminate dark rooms using sun light from roof top to the inside of the house. So the idea was that to bring solar radiation from outdoor to inside the room. A deep literature review had done to find different existing solar cookers and devices that are somehow related with solar energy conservation.

Material selected for Fresnel lens was acrylic sheets, polycarbonates and rigid vinyl. Each of them has their own limitations for transmittance of wavelength. The solar radiation consists of a wide range of wavelengths in which major part of heat is available near the visible light and infrared rays. After doing literature review it was found that the lens material filters some of wavelengths because of their transmittance property, but it would not affect much because most of energy is infrared and near visible light which is in the transmittance range of material.

Initial designs of the system were totally dependent on the modules of the system and with their application too. So firstly modules were identified like-

a) Ray guiding system
b) Support frame
c) Refractors and reflectors
d) Passage for radiation
e) Load setup
f) Storage system

So the first challenge was to design some part by which consequent parts could be designed. For the first trial it was checked whether these lens arrangements are able to collect energy and able to concentrate the ray. For designing part, CAD tool was used and then random sizes were chosen and simultaneously assembly had been done so that if there any change in dimension is required it could be changed. Later on it was scaled for a prototype system.

All the parts were printed in a rapid prototyping machine using ABS material; after getting parts printed they were physically assembled. Now the main task was to find out if the lens arrangement is able to make concentrated radiation or not. For a Fresnel lens of 1 m^2 availability of energy was 5.68kWh/m^2/day; also with assuming 100 % efficiency for all lenses and considering average atmospheric condition of water, it is calculated that it could boil 65 liter of water in a day. As the maximum size availability of Fresnel was 0.09m^2 so it can only boil 5.86 liter in a day.

After first testing it was found that the lens arrangement was able to transfer the concentrated radiation, but not for a longer distance; it is because of improper lenses. Following is the lens requirement ($\frac{D1}{F1} = \frac{D2}{F2}$) where D2 is the diameter of concentrated beam radiation; D1 is required solar radiation area to harness solar rays; F1 is focal length of Fresnel lens and the F2 is the focal length of small lens. Based on above relation a standard lens combination tried to be carried out. It is like if 1m^2 Fresnel with 1.8m focal length is used with 0.1 m diameter lens then it should be must of 0.128m focal length. Similarly for a 0.09m^2 Fresnel lens with 280 mm focal length a lens of 97.73 diameter with 64.5 focal length is required.

In this trial three lenses were used because of unavailability of proper lenses. These were in sequence of Fresnel, concave and convex. For the positions of lenses lens formula were used and the distance of concave and convex from the Fresnel is 243.04mm and 376.28 mm. In the same trial it was found that few mechanisms selected were not proper so in the second trial mainly frame design and mechanism were changed. The lens combination remains same for the second trial.

In second trial a bearing is used in the place of printed support part which discussed earlier. The ray guiding system which transports the concentrated beam inside the hollow pipe was also changed, as shown in topic “design modification based on first trial”. The solar tracking was supposed to accomplish using gears but it wasn’t working with printed part and also it was found more complex so instead off that a new solar tracking system was developed and installed in second trial. The tracking system was tested using proteus simulator.

In the solar tracking light dependent resistors is used as input for the microcontroller which controls the gear motors to track sun. The simulation is done for two way function as autonomous and manual mode for manual tracking or adjustments. So the whole code was written in the C language and converted to hex file using keil microvision software. After getting hex file required virtual circuit board was created in the proteus and then that file got tested which was very successful. This board was developed for 12 volt power supply which can be easily supplied using a small battery and solar charging kit. Now the LDR were modified with new body as discussed in the topic modeling of modified sensor. The main concept is that to use LDR as a input signal to microcontroller for that an arrangement were done in figure 3.7.3 and the whole body of LDR were painted black so that no reflection of light can disturb the sensitivity of LDR. The working of LDR is that they are attached with Fresnel lens making itself free from sun light so as when the solar rays are normal to the Fresnel lens light coming from the sun would not activate the LDR and similarly the sun will move then light will also get an angle to the lens surface so as well it would enter to the sensor body and activate them. After getting the light it will lose its resistivity and release a supply of voltage as input to the microcontroller which further activates the actuator till the light entering to the sensor body will stop and signal as well.

Testing part was executed to test the radiation guiding principle discussed in the topic principle of transporting solar rays. It was found that if lenses are not parallel to each other with very high precision then concentrated radiation would not travel for a longer distance. In this test some blue and orange shades were found which shows also the lack of parallelism. So to get long range concentrated radiation parallel plane is very essential.

The final system enables user to guide concentrated solar radiation to the load point for example in cooking application. Usually a person who uses solar cooker needs to go out of the kitchen and cook food for long time into sun light or in a shelter, but this enables solar light to travel inside the kitchen and cook food easily. This radiation can also be made to fall on a heat storage device that can be used for late night or when sun is not available. A heat storage device can store energy for 4-5 days that depends on the salt used.

Hence, the two modes of the system are: (a) Cook food inside kitchen and (b) Store heat into a heat storage device. With the help of this system a person can save energy in the form of electricity and fuel which is totally eco friendly and cost effective.

6.2FUTURE SCOPE

- The bigger lens to collect more energy with calculated focal lengths can be added.
- System can be improved with good robustness.
- Tracking sensors can be enhanced to get more accurate and précised tracking.
- More function can be added to make it fully automated.

References

1. *Experimental determination of energy and exergy efficiency of the solar parabolic-cooker.* **ozturk, Hassan huseyin.** 2004, solar energy 77, pp. 67-71.

2. *Modeling and design of a solar thermal system for hybrid cooking application.* **U.R, Prasanna, L. Umanand.** 2011, applied energy 88, pp. 1740-1755.

3. [Online] http://www.benefits-of-recycling.com/advantagesofsolarenergy/.

4. *Thermal performance of a solar cooker integrated vacuum-tube collector with heat pipes containing different refregerants.* **esen, mehmet.** 2004, solar energy 76, pp. 751-757.

5. *A compressive review on solar cookers.* **Erdem Cuce, Pinar Mert Cuce.** 2013, Applied Energy102, pp. 1399-1421.

6. *Solar thermal colleectors and applications.* **Kalogirou, Soteris A.** 2004, progress in energy and combustion science, pp. 231-295.

7. *Durability of solar reflector materials for secondary concentrators used.* **Aránzazu Fernández-García a, n, M.Elena Cantos-Soto a, Marc Röger b, Christian Wieckert c,.** 2014, Solar Energy Materials & Solar Cells, pp. 51–63.

8. *cogeneration solar system using themoelectric module and fresnel lens.* **M.Hasan Nia, A. Abbas Nejad A.M. Goudarzi, M.Valizadeh, P. Samadian.** 2014, enrgy conversion and management 84, pp. 305-310.

9. *Performance investigation on a linear fresnel lens solar collector using cavity receiver.* **M.Lin, K. Sumathy , Y.J.Dai , x.K. Zhao.** 2014, Solar energy 107, pp. 50-62.

10. [Online] http://www.3dlens.com/.

11. *Antifogging antireflective coating on fresnel lenses by intrgrating solid and mesoporous silica nanoparticles.* **Gang Zhou, Junhui He, Ligang Xu.** 2013, microporooys and mesoporous materials 176, pp. 41-47.

12. *Robust antifogging antireflective coatings on polymer substrates.* **Tong li, Junhui He, Lin Yao, Zhi Geng.** 2015, Journal of Colloid and Interface Science 444, pp. Pages 67–73.

13. [Online] http://solarjourneyusa.com/sunlight.php.

14. [Online] http://www.fresneltech.com/materials.html.

15. [Online] http://www.fresneltech.com/pdf/POLYIR.pdf.

16. [Online] http://en.wikipedia.org/wiki/File:Solar_Spectrum.png.

17. [Online] http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/wien3.html.

18. *Study of light pipes for the use of sunlight in road tunnels: from a scale model to real tunnels.* **L.M. Gil-Martina, A. Pena-Garcia b, A. Jimenez a, E. Hernandez-Montes.** 2014, tunnelling and Undergrouond Space Technology 41, pp. 82-87.

19. *A srudy on a ventilation stack integrated with a light pipe.* **Thanyalak Taengchum, Surapong chirarattananon, Robot H.B.Exell, Kuskana Kubaha, Pipat Chaiwiwatworakul.** 2013, Applied Thermal Engineering 50, pp. 546-554.

20. *Tracing of daylight through circular light pipes with anidolic concentrators.* **Thanyalak taengchum, Surapong chirarattananon, Robert H.B.Excell, Pipat Chaiwiwatworakul.** 2014, Solar energy 110, pp. 818-829.

21. *A novel application of a fresnel lens for a solar stove and solar heating* . **M.M. Valimki, Peiwen Li, javier heyer, Matthew morgan, Abdulla Albinali, Kamal Alhamidi , Jeremy Wagoner.** 2011, Renewable energy 36, pp. 1614-1620.

22. *Charging of a heat storage coupled with a low-cost small-scale solar parabolic though for cooking purpose.* **Maxime Mussard, Ole jorgen nydal.** 2013, Solar Energy 95, pp. 144-154.

23. *Model of a thermal energy storage device intefrated into a solar assisted heat pump system for space heating.* **Badescu, Viorel.** 2003, Enrgy conversion & Management 44, pp. 1589-1604.

24. *Latent heat based high temperature solar thermal energy.* **Bruno Cárdenas*, Noel León.** 2014 , Energy procedia 57, pp. 580-589.

25. [Online] http://www.synergyenviron.com/tools/solar_insolation.asp?loc=Jaipur%2CRajasthan%2CIndia.

26. **Gogia, K.L. Gomber&.** *Fundamental physics.* s.l. : Pradeep publisher, 2004.

27. [Online] http://large.stanford.edu/courses/2010/ph240/barile2/.

28. [Online] http://www.eolss.net/ebooks/sample%20chapters/c08/e3-14-02-00.pdf.