Chapter 1

INTRODUCTION

The ever increasing demand for energy has led to the formation of various advanced resources which produces a certain part of the required energy. One principal consumer of a large amount of energy is our household itself. Large amount of electrical energy is wasted in pumping water, irrigation purposes etc. It is in this context the importance of pendulum pump arises, by the use of which a large amount of energy can be conserved and the conserved energy can be used for various other purposes.

A pump is a device that can be used to raise or transfer fluids. Pumps are selected for processes not only to raise and transfer fluids from one point to another, but also to meet some other criterion. This other criteria may be to obtain a constant flow rate or constant pressure according to the requirement.

Two-stage oscillator is a compound pendulum in which energy is transferred from one pendulum to another. Once the pendulum is provided with some input, it keeps on oscillating for some time thus transferring the energy to the other pendulum. In the year 1999, Sir Veljko Milkovic invented the two-stage oscillator mechanism. It was a new concept at that time. The highlight of the mechanism was the amount of energy input proved to be less than the energy obtained. The statement seems to be hypothetical but this was explained by carrying out various kinds of experiments. Nebojša Simin explained the phenomenon of increasing the input energy by operation of the pendulum-lever system [5]. Sir Jovan Bebic and Lujbo Panic also developed a relation between output and input energy of the system and found that the system has efficiency greater than unity [8, 9] .Jovan Marjanovic discussed the theory of gravity machines [9, 10] .The logic of this theory was also used to explain the two-stage mechanical oscillator of Veljko Milkovic and pointed out a way to improve its behavior. He also stated that the pivot point should have some lag before moving up or down until pendulum comes in position such that its pivot point and bob move in opposite directions. Jovan Marjanovic analyzed the factors affecting the free energy of the pendulum and various other factors [10]. He concluded that output energy was solely based on the mass of the bob of pendulum.

The main importance of a pendulum pump is that the initiation energy for starting the process of pumping, swinging of the pendulum, is considerably less when compared with the work required to operate hand pumps. Typical hand pumps require sufficiently large effort and an average person can use the pump continuously only for a short time, but the pendulum pump requires only minimum of the effort, because it is only required to oscillate the pendulum and can maintain these oscillation for several hours, without any fatigue. The advantage of this invention compared to present hand pump solutions are: less force to start the pump, less water consumption, and both arms can be used to fetch the water.

New and technically original idea - hand water pump with a pendulum - provides alleviation of work, because it is enough to move the pendulum occasionally with a little finger to pump the water, instead of large swings. Using the minimum of human strength in comparison to present classic hand water pumps enables efficient application in irrigation of smaller lots, for water -wells and extinguishing fires even by old people and children, which was proved by a large number of interested future consumers during the presentations.

Basically in villages and also in some town side areas, we could able to see the piston pumps which have been installed to suck the water from the ground, and this source of water from the ground is known as ground water. In pump the reciprocating motion is to be given by the people who access it. And by using that reciprocating motion, the suction is created and as a result water comes out from the ground. Hence no other method can easily replace it, due to its less maintenance, and easy accessibility. Hence it has been in the peak for several years. But we do not have the idea to replace those pumps. But we have the idea to reduce the human effort which is being given in these types of pumps. By saying particularly that, the reciprocating motion that is being given in the piston pump can be replaced by the oscillating motion obtained due to the oscillation of certain mass. New and technically original idea - hand water pump with a pendulum - provides alleviation of work, because it is enough to move the pendulum occasionally with a little finger to pump the water, instead of large swings.

Hand water pump with a pendulum is a realization of a new, original, and even unbelievable, by very simple solution for pumping water. Work is alleviated because easier, long-lasting and effortless use of the hand water pump has been enabled. Input energy for starting the process of pumping, in form of occasional pushing of the pendulum, is much less than with typical hand pumps. Hand water pump with a pendulum for pumping water out from wells or reservoirs consists of a cylinder with a piston, lever system, a seesaw, a pendulum, a reservoir and output water pipe.

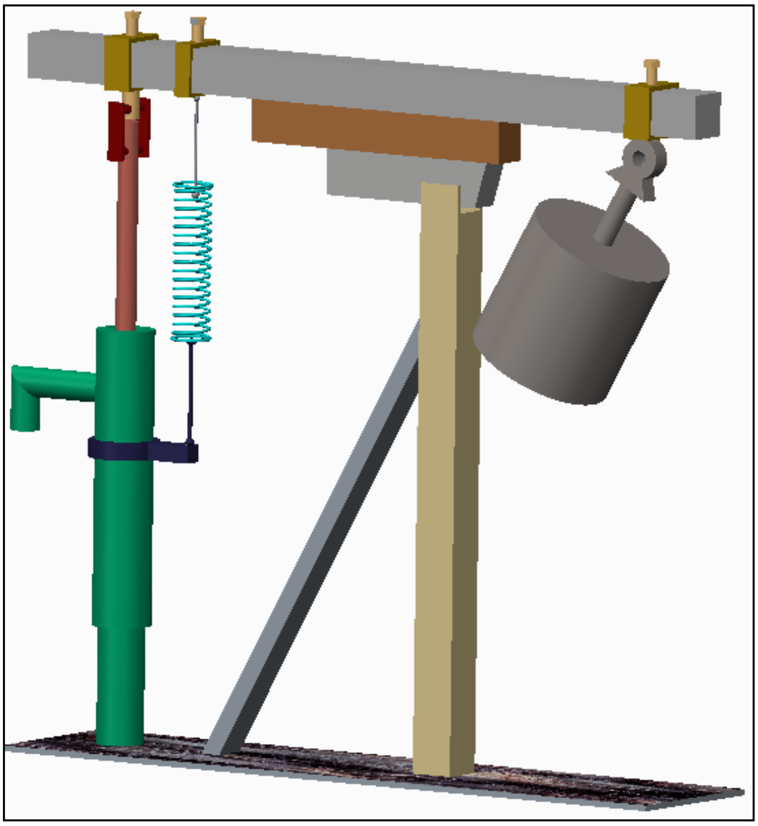


Figure 1.1 Creo Parametric Model of the Pendulum Pump

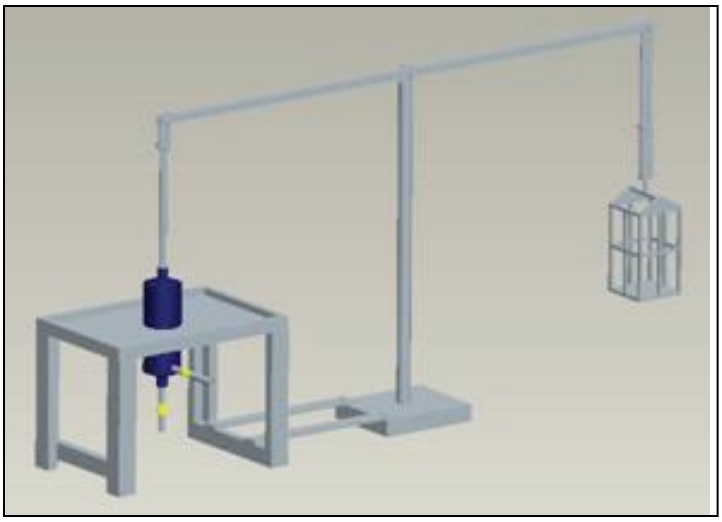


Figure 1.2 Model of the Pendulum Pump as suggested by K.Gowrishankar et al.

To get the water running out of the pump, the pendulum needs to be out of balance. After that, based on gravitational potential, the piston starts oscillating and the continuous stream of water is coming out of the output pipe. The pendulum should be occasionally pushed, to maintain the amplitude i.e. the stream of water. The pump works well with all sizes of the pendulum, but mainly with the amplitude of 90°. The advantage of this invention compared to present hand pump solutions are: less force to start the pump, less water consumption, both arms can be used to fetch the water. The invention is applicable on other devices that use lever mechanisms, such as a hand press etc.

1.1 Main components of pendulum operated piston pump:

1.1.1 Pump

A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action. Pumps can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement, and gravity pumps.

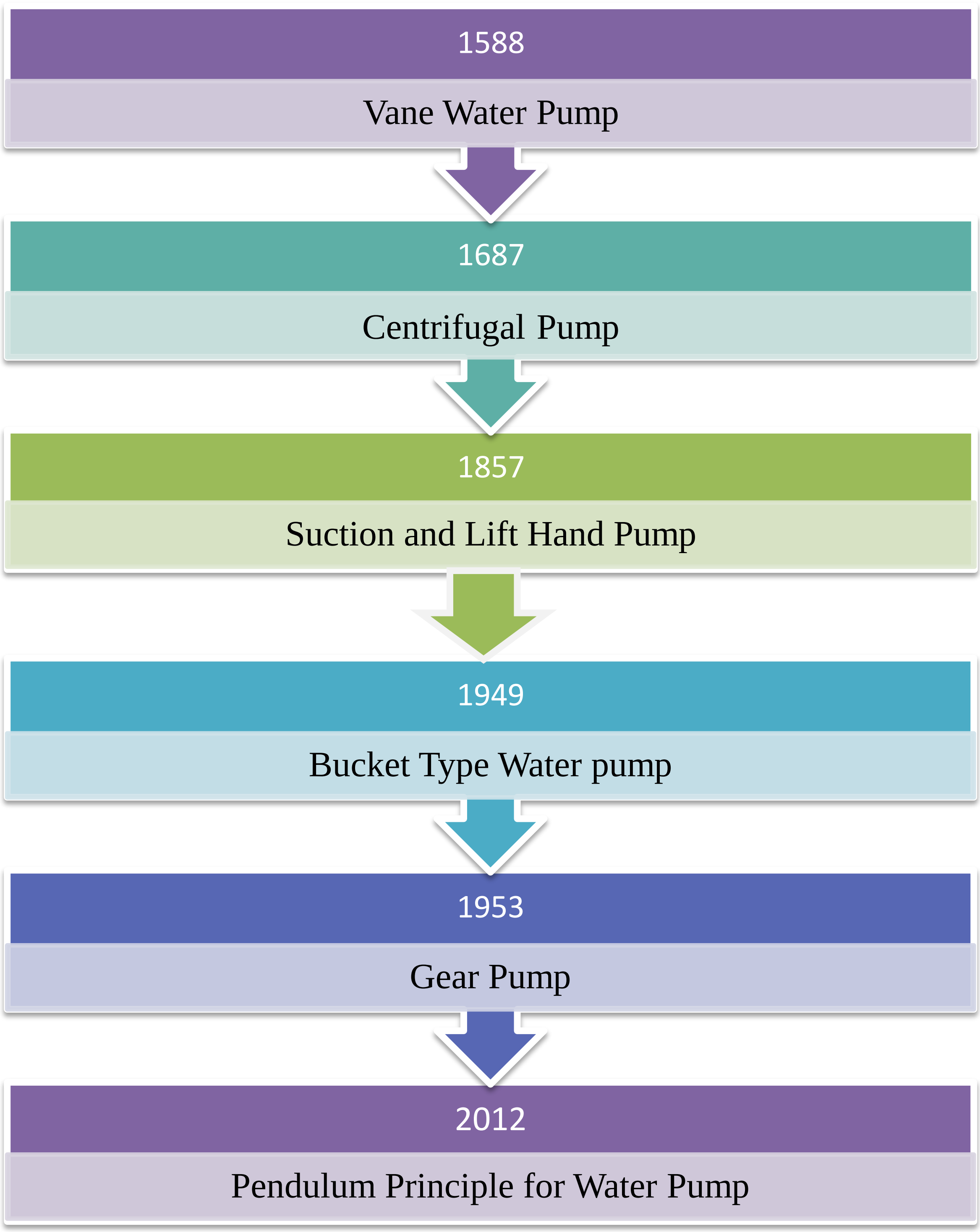
Pumps operate by some mechanism (typically reciprocating or rotary), and consume energy to perform mechanical work by moving the fluid. Pumps operate via many energy sources, including manual operation, electricity, engines, or wind power, come in many sizes, from microscopic for use in medical applications to large industrial pumps.

Mechanical pumps serve in a wide range of applications such as pumping water from wells, aquarium filtering, pond filtering and aeration, in the car industry for water-cooling and fuel injection, in the energy industry for pumping oil and natural gas or for operating cooling towers. In the medical industry, pumps are used for biochemical processes in developing and manufacturing medicine, and as artificial replacements for body parts, in particular the artificial heart and penile prosthesis.

Single stage pump - When in a casing only one impeller is revolving then it is called single stage pump.

Double/ Multi stage pump - When in a casing two or more than two impellers are revolving then it is called double/ multi stage pump.

1.1.1.1 Pump Development Timeline



Reciprocating pumps move the fluid using one or more oscillating pistons, plungers, or membranes (diaphragms), while valves restrict fluid motion to the desired direction.

Pumps in this category range from simplex, with one cylinder, to in some cases quad (four) cylinders, or more. Many reciprocating-type pumps are duplex (two) or triplex (three) cylinder. They can be either single-acting with suction during one direction of piston motion and discharge on the other, or double-acting with suction and discharge in both directions. The pumps can be powered manually, by air or steam, or by a belt driven by an engine. This type of pump was used extensively in the 19th century—in the early days of steam propulsion—as boiler feed water pumps. Now reciprocating pumps typically pump highly viscous fluids like concrete and heavy oils, and serve in special applications that demand low flow rates against high resistance. Reciprocating hand pumps were widely used to pump water from wells. Common bicycle pumps and foot pumps for inflation use reciprocating action.

These positive displacement pumps have an expanding cavity on the suction side and a decreasing cavity on the discharge side. Liquid flows into the pumps as the cavity on the suction side expands and the liquid flows out of the discharge as the cavity collapses. The volume is constant given each cycle of operation.

Typical reciprocating pumps are:

- Plunger pumps - a reciprocating plunger pushes the fluid through one or two open valves, closed by suction on the way back.
- Diaphragm pumps - similar to plunger pumps, where the plunger pressurizes hydraulic oil which is used to flex a diaphragm in the pumping cylinder. Diaphragm valves are used to pump hazardous and toxic fluids.
- Piston pumps displacement pumps - usually simple devices for pumping small amounts of liquid or gel manually. The common hand soap dispenser is such a pump.
- Radial piston pumps

1.2 Spring

A spring is an elastic object used to store mechanical energy. Springs are usually made out of spring steel. There are a large number of spring designs; in everyday usage the term often refers to coil springs.

Small springs can be wound from pre-hardened stock, while larger ones are made from annealed steel and hardened after fabrication. Somenon-ferrous metals are also used including phosphor bronze and titanium for parts requiring corrosion resistance and beryllium copper for springs carrying electrical current (because of its low electrical resistance).

When a coil spring is compressed or stretched slightly from rest, the force it exerts is approximately proportional to its change in length (this approximation breaks down for larger deflections). The rate or spring constant of a spring is the change in the force it exerts, divided by the change in deflection of the spring. That is, it is the gradient of the force versus deflection curve. An extension or compression spring has units of force divided by distance, for example lbf/in or N/m. Torsion springs have units of torque divided by angle, such as N·m/rad or ft·lbf/degree. The inverse of spring rate is compliance, that is: if a spring has a rate of 10 N/mm, it has a compliance of 0.1 mm/N. The stiffness (or rate) of springs in parallel is additive, as is the compliance of springs in series.

Depending on the design and required operating environment, any material can be used to construct a spring, so long as the material has the required combination of rigidity and elasticity: technically, a wooden bow is a form of spring.

Springs can be classified depending on how the load force is applied to them:

- Tension/extension spring – the spring is designed to operate with a tension load, so the spring stretches as the load is applied to it.
- Compression spring – is designed to operate with a compression load, so the spring gets shorter as the load is applied to it.
- Torsion spring – unlike the above types in which the load is an axial force, the load applied to a torsion spring is a torque or twisting force, and the end of the spring rotates through an angle as the load is applied.
- Constant spring - supported load will remain the same throughout deflection cycle

- Variable spring - resistance of the coil to load varies during compression

Hooke's law

As long as they are not stretched or compressed beyond their elastic limit, most springs obey Hooke's law, which states that the force with which the spring pushes back is linearly proportional to the distance from its equilibrium length:

$$F = -kx$$

Where,

x is the displacement vector – the distance and direction the spring is deformed from its equilibrium length.

F is the resulting force vector – the magnitude and direction of the restoring force the spring exerts

k is the rate, spring constant or force constant of the spring, a constant that depends on the spring's material and construction. The negative sign indicates that the force the spring exerts is in the opposite direction from its displacement

Coil springs and other common springs typically obey Hooke's law. There are useful springs that don't: springs based on beam bending can for example produce forces that vary nonlinearly with displacement.

If made with constant pitch (wire thickness), conical springs will have a variable rate. However, a conical spring can be made to have a constant rate by creating the spring with a variable pitch. A larger pitch in the larger-diameter coils and a smaller pitch in the smaller-diameter coils will force the spring to collapse or extend all the coils at the same rate when deformed.

1.3 Roller Bearing

A roller bearing, also known as a rolling bearing, is a bearing which carries a load by placing rolling elements (such as balls or rollers) between two bearing rings called races. The relative motion of the races causes the rolling elements to roll with very little rolling resistance and with little sliding.

One of the earliest and best-known rolling-element bearings are sets of logs laid on the ground with a large stone block on top. As the stone is pulled, the logs roll along the ground with little sliding friction. As each log comes out the back, it is moved to the front where the block then rolls on to it. It is possible to imitate such a bearing by placing several pens or pencils on a table and placing an item on top of them. See "bearings" for more on the historical development of bearings.

A rolling element rotary bearing uses a shaft in a much larger hole, and cylinders called "rollers" tightly fill the space between the shaft and hole. As the shaft turns, each roller acts as the logs in the above example. However, since the bearing is round, the rollers never fall out from under the load.

Rolling-element bearings have the advantage of a good tradeoff between cost, size, weight, carrying capacity, durability, accuracy, friction, and so on. Other bearing designs are often better on one specific attribute, but worse in most other attributes, although fluid bearings can sometimes simultaneously outperform on carrying capacity, durability, accuracy, friction, rotation rate and sometimes cost. Only plain bearings are used as widely as rolling-element bearings

A particularly common kind of rolling-element bearing is the ball bearing. The bearing has inner and outer races between which balls roll. Each race features a groove usually shaped so the ball fits slightly loose. Thus, in principle, the ball contacts each race across a very narrow area. However, a load on an infinitely small point would cause infinitely high contact pressure. In practice, the ball deforms (flattens) slightly where it contacts each race much as a tire flattens where it contacts the road. The race also yields slightly where each ball presses against it. Thus, the contact between ball and race is of finite size and has finite pressure. Note also that the deformed ball and race do not roll entirely smoothly because different parts of the ball are moving at different speeds as it rolls. Thus, there are opposing forces and sliding motions at each ball/race contact. Overall, these cause bearing drag.

1.4 Non return valves

A check-valve, clack-valve, non-return valve or one-way valve is a valve that normally allows fluid (liquid or gas) to flow through it in only one direction.

Check valves are two-port valves, meaning they have two openings in the body, one for fluid to enter and the other for fluid to leave. There are various types of check valves used in a wide variety of applications. Check valves are often part of common household items. Although they are available in a wide range of sizes and costs, check valves generally are very small, simple, or inexpensive. Check valves work automatically and most are not controlled by a person or any external control; accordingly, most do not have any valve handle or stem. The bodies (external shells) of most check valves are made of plastic or metal.

An important concept in check valves is the cracking pressure which is the minimum upstream pressure at which the valve will operate. Typically the check valve is designed for and can therefore be specified for a specific cracking pressure.

Check valves are often used with some types of pumps. Piston-driven and diaphragm pumps such as metering pumps and pumps for chromatography commonly use inlet and outlet ball check valves. These valves often look like small cylinders attached to the pump head on the inlet and outlet lines. Many similar pump-like mechanisms for moving volumes of fluids around use check valves such as ball check valves. The feed pumps or injectors which supply water to steam boilers are fitted with check valves to prevent back-flow.

1.5 Pendulum

A pendulum is a weight suspended from a pivot so that it can swing freely. When a pendulum is displaced sideways from its resting, equilibrium position, it is subject to a restoring force due to gravity that will accelerate it back toward the equilibrium position. When released, the restoring force combined with the pendulum's mass causes it to oscillate about the equilibrium position, swinging back and forth. The time for one complete cycle, a left swing and a right swing, is called the period. The period depends on the length of the pendulum and also to a slight degree on the amplitude, the width of the pendulum's swing.

Chapter 2

LITERATURE REVIEW

2.1 Research papers followed

The following research papers were studied during the course of the project:

Rony K. Placid et al. in the research paper ***"FABRICATION AND ANALYSIS OF A PENDULUM PUMP"[1](April 2015)*** discussed the importance of a pendulum pump which can be used as a supplementary device for pumping water and is made to replace hand pumps.

- One important feature of a pump with a pendulum is that the work is alleviated or in simple terms it makes work rather easier when is compared with a traditional hand water pump.
- It is due to this underlined feature which enables the pendulum pump to be used as an efficient mode in the irrigation of smaller lots, water-wells and can also be used in extinguishing fires even by old people and children.
- By the use of pendulum based water pumping system we can increase the efficiency of the plant and reduce the effort, cost of production, production time, and manpower requirement.

Akshaj Adhikari in the research paper ***"DESIGN AND FABRICATION OF HAND WATER PUMP WITH PENDULUM" [2](***explained the effect of creating the free energy in the device made of a) Oscillating pendulum lever system, b) system for initiating and maintaining the oscillation of the pendulum, c) system which uses the energy of the device by damping the oscillations of the lever.

The operation of the machine is based on forced oscillation of the pendulum, since the axis of the pendulum affects one of the arms of the two armed lever by a force which varies periodically. Part of the total oscillation energy of the pendulum-lever system is changed into a work for operating a pump, a press, a rotor of an electric generation system. The creation of free energy was proved by a great number of physical models. The effect of creating the free energy is defined in this study as the difference between the energy which is the machine transfers to the user system by the lever and the energy which is input from the environment in order to maintain the oscillation of the pendulum. Appearance of the free energy is not in accordance with the energy conservation law.

The effect of creating the free energy results from the difference between the work of the orbital damping forces of the lever and the work of the radial damping force of the pendulum motion. This effect enables increase of the input energy.

Gowrishankar.K et al. in the research paper ***"Single Acting Piston Pump Using Oscillating Motion"*** [3] ***(October 2015)***investigated the project with an objective to reduce the human effort. The purpose of sucking the water from the ground, they were installing the piston pumps on every village. The reason behind the choice of piston pump is due to its less maintenance and less installation cost. Hence according to us, people were spending large effort on this in the way of giving continuous reciprocating motion to suck the water from the ground. Not only the continuous motion but also lot of time to be spent until the required amount of water is being sucked. In this type of pump the continuous reciprocating motion should be given only by the people, no other motion can replace that until now. But we were planned to replace that reciprocating motion with an oscillating motion. This method may be an already existing one, but the way of application is quite different in our project. A one who knew the concept of oscillating motion will know about the reciprocating motion present in it. Hence we can obtain two reciprocating motion from one single oscillation obtained due to oscillating a certain weight (a bob). Hence according to us by slight modification of an existing piston pump for adapting to the oscillating motioned piston pump, we can obtain the required amount of water with a minimum effort and with a low cost.

Ambe Verma et al. in the research paper ***"Swing Set Irrigation System"*** [4] ***(May 2015)*** discussed that in the coming days the demand for energy resources will be increasing everyday's the aim of this research is to develop the world by enriching. By utilizing its resources more. Now time has come for using this type of innovative ideas and it should be brought into practice. This operating system is design to process a mechanism which is capable of powered water for irrigation for agriculture.

A "Swing Set Irrigation system" is a mechanism used to generate power for lifting water from one place to another place with the help of reciprocating pump. This

Project is completely based on "SIMPLE PENDULUM". There are many sources to convert the mechanical energy into various other forms. In this system no man power and electrical energy is used.

This project gives the overview for the challenges and opportunity for energy lasting in coming decades due to this project we are going to make the best use of existing technology to ensure reliability and efficiency under changing condition. By such arrangement, this mechanism has more simplified structure, more environments friendly and provides stable energy output. It is full independent system. It outlines the need for cost effective technology in rural region.

Nebojša Simin in the research paper ***"FREE ENERGY OF THE OSCILLATING PENDULUM-LEVER SYSTEM"*** [5] ***(September, 2007)*** explains the effect of creating the free energy in the device made of: a) oscillating pendulum-lever system, b) system for initiating and maintaining the oscillation of the pendulum, and c) system which uses the energy of the device by damping the oscillation of the lever. Serbian inventor Veljko Milkovic has invented, patented and developed series of such machines based on two-stage oscillator for producing energy.

The operation of the machine is based on forced oscillation of the pendulum, since the axis of the pendulum affects one of the arms of the two-armed lever by a force which varies periodically. Part of the total oscillation energy of the pendulum-lever system is changed into work for operating a pump, a press, rotor of an electric generator or some other user system.

The creation of free energy was proved by a great number of physical models. The effect of creating the free energy is defined in this study as the difference between the energy which is the machine transfers to the user system by the lever and the energy which is input from the environment in order to maintain the oscillation of the pendulum. Appearance of the free energy is not in accordance with the energy conservation law. The effect of creating the free energy results from the difference between the work of the orbital damping forces of the ever and the work of the radial damping force of the pendulum motion. This effect enables increase of the input energy. The coefficient of efficiency of the machine can be more than one.

The free energy of the machine based on oscillation pendulum-lever system, is defined in this study, as a difference between the resulting energy of the machine and the energy input from the environment in the same time interval. Existence of the free energy defined in this way is not in accordance with the energy conservation law, but it has been verified experimentally and it can be explained.

Appearance of the free energy is necessarily a consequence of the reverse action of the user system on the lever since the lever has no oscillation energy of its own and the momentum of the orbital damping force of the lever is greater than the momentum of the radial damping force of the pendulum at any phase of oscillation. The same effect appears in case of all two-stage oscillators which fulfill these conditions, for example, in case of eccentric flywheel which rotates on the edge of a wheel. The wheel has no oscillation energy of its own, and the momentum of the orbital damping force of the wheel is greater than the momentum of the radial damping force of the eccentric flywheel at any time, except in two phases when the mentioned moments of the orbital and radial damping forces are equal.

Bojan Petkovic in the research paper ***"MODELLING AND SIMULATION OF A DOUBLE PENDULUMWITH PAD"*** [6] investigated the results of the simulation of a double pendulum with a horizontal pad are presented. Pendulums are arranged in such a way that in the static equilibrium, small pendulum takes the vertical position, while the big pendulum is in a horizontal position and rests on the pad. Motion during one half oscillations is investigated. Impact of the big pendulum on the pad is considered to be ideally inelastic. Characteristic positions and angular velocities of both pendulums, as well as their energies at each instant of time are presented. Obtained results proved to be in accordance with the motion of the real physical system. Double pendulum with pad refers to the two-stage mechanical oscillator that is invented, Patented and constructed by Serbian inventor Veljko Milkovic.

Joseph et al. ., ***"GRAVITATIONAL ENERGY"*** [7] this is a sobering reality check for a project such as the current Mahadaga Pump Project. Almost all of the data is somewhat dated, as most of the hand pump work was done in the 1980's, but because hand pumps are a low technology product, there is reason to believe that the findings presented below are still valid.

Milkovic et al. in the research paper" ***THE SECRET OF FREE ENERGY OF THE PENDULUM"***[8], **(Sep 2003)** said some information about the pendulum pump which is as follows. Hand water pump with a pendulum is a realization of a new, original, and even unbelievable, by very simple solution for pumping water. Work is alleviated because easier, long-lasting and effortless use of the hand water pump has been enabled. Input energy for starting the process of pumping, in form of occasional pushing of the pendulum, is much less than with typical hand pumps.

Matos et al. in the research paper **"*PENDULUM PUMP"***[9] **(Jan 2010)** He said about the pendulum pump is as follows The Milkovic's pendulum –lever system does work only in one direction, when the working of lever side goes up. To return it to the initial point he needs to use a spring or a weight in the lever to push it down. This is the method used to pulse the lever. When the pendulum is in its lower position is when maximum work is achieved. Some energy is used in the spring or to lift the weight. In his proposal the pendulum works in the same direction of the load,and the amplitude is independent of work done or load applied.

Nikhade G.R. et al. in the research paper ***"TWO-STAGE OSCILLATOR MECHANISM FOR OPERATING A RECIPROCATING PUMP"*** [10] ***(August, 2013)*** presented the the conceptual mechanism to run the reciprocating pump by the two-stage oscillator. It provides the energy required to lift the water from a tank placed approximately 2.5 meter below the ground level. Basic application of the mechanism will be for watering the garden which will be operated by means of opening and closing of entrance gate. Paper consists of basic concept, design of pump and two-stage oscillator mechanism and fabrication of the model.

The research done till now concentrated only on the working and the effectiveness of the mechanism. This paper presents the possibility of using this mechanism in real world application. Considering all of the advantages of the mechanism it was decided to use it for lifting water with the help of a reciprocating pump such that the input to the mechanism would be given with the help of entrance gate of the garden for watering the plants without electricity.

Chapter 3

PROPOSED METHODOLOGY

3.1 Formulation and Presentation of Problem

The ever increasing demand for energy has led to the formation of various advanced resources which produces a certain part of the required energy. One principal consumer of a large amount of energy is our household itself. Large amount of electrical energy is wasted in pumping water, irrigation purposes etc. It is in this context the importance of pendulum pump arises, by the use of which a large amount of energy can be conserved and the conserved energy can be used for various other purposes.

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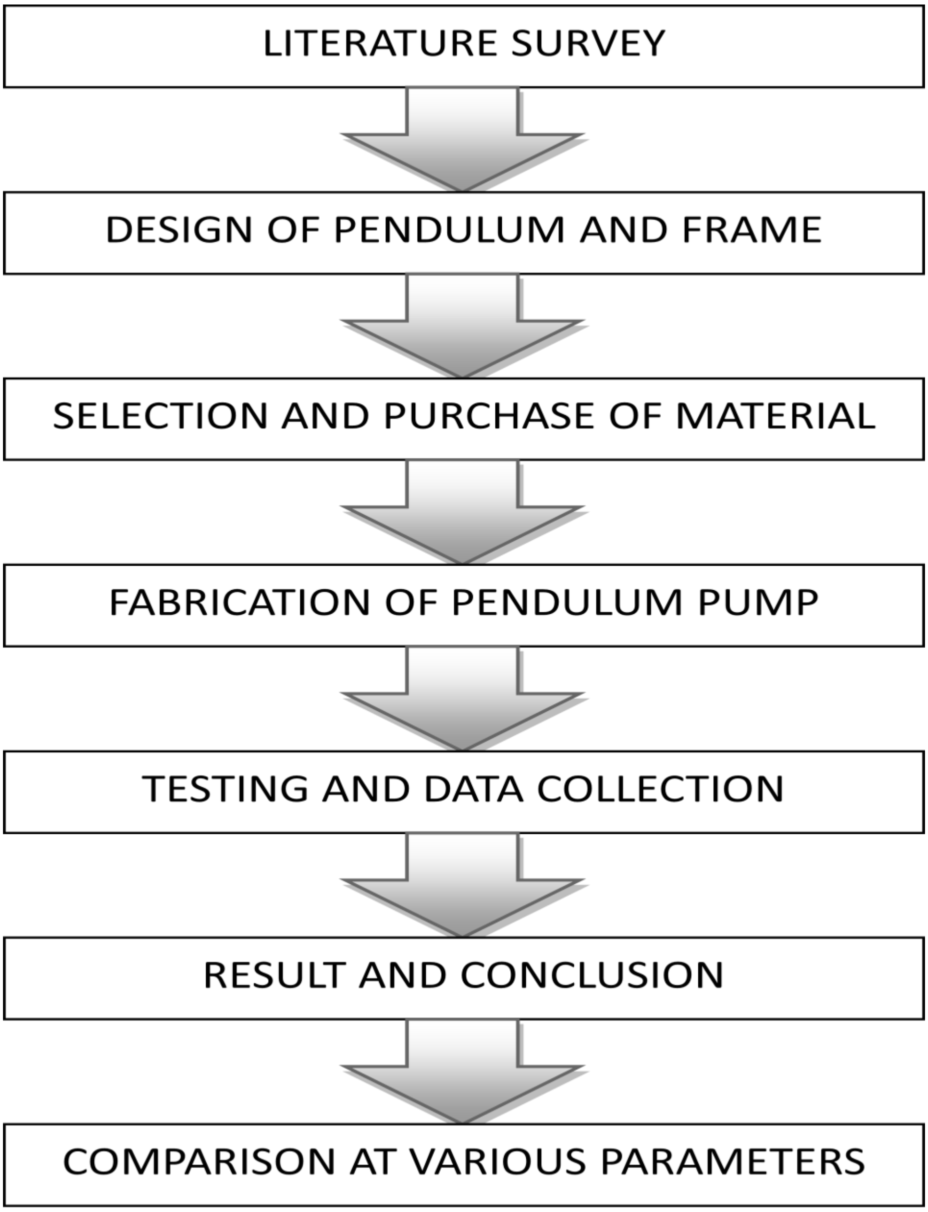
Using the minimum of human strength in comparison to present classic hand water pumps enables efficient application in irrigation of smaller lots, for water-wells and extinguishing fires even by old people and children. Hand water pump with a pendulum is a realization of a new, original, and even unbelievable, by very simple solution for pumping water. Work is alleviated because easier, long-lasting and effortless use of the hand water pump has been enabled. Input energy for starting the process of pumping, in form of occasional pushing of the pendulum, is much less than with typical hand pumps. To get the water running out of the pump, the pendulum needs to be out of balance. After that, based on gravitational potential, the piston starts oscillating and the continuous stream of water is coming out of the output pipe. The pendulum should be occasionally pushed, to maintain the amplitude. The pump works well with all sizes of the pendulum, but mainly with the amplitude of 90°.

3.2 Solution Approach



3.3 Software and Hardware Requirements and Specifications

3.3.1 Hardware Requirements

a) Pump specification:

i) Bore diameter (D) = 3.75” = 9.525 cm

ii) Stroke length (L) = 6.50” = 16.51 cm

iii) Plunger length (l) = 22.5 cm

iv) Plunger length with bucket (l’) = 30 cm

v) Total cylinder length = 32 cm

vi) Weight of plunger with bucket = 500 g

b) Spring specification:

i) Helical Extension type spring

ii) Number of coils = 75

iii) Solid length = 10” = 25cm

iv) Diameter of coil = 2cm

c) Ball Bearing :

i) Material : Mild steel

ii) Inner diameter = 16mm

iii) Outer diameter = 28mm

d) Pendulum :

i) Material : welded cast iron plates

ii) Weight = 20 kg

iii) Arm length = 38.1 cm

Table 3.1 Material Specification of components used

S.no	Components	Material	Specification
1.	Single Acting Pump	Mild Steel	Bore Diameter = 3.75” , Stroke = 6.5”
2.	Helical Spring	Mild Steel	Number of coils = 75 ,Solid length=25cm
3.	Ball Bearing	Mild Steel	Inner Dia. = 16mm , Outer Dia.=28mm
4.	Piston	Cast Iron	Weight = 500g
5.	Pendulum	Cast Iron	Weight = 23kg

3.3.2 Software Requirements:

1. Solid Works V-2012
2. MS Excel 2010

Chapter 4

EXPERIMENTAL SETUP

4.1 Principal Components

4.1.1 Frame

It is the main component of the pump system and is made up of steel. The principal mechanism used for the construction of the pendulum pump is the slider crank mechanism and the frame converts the oscillating movement of the pendulum on one side to the reciprocating motion of the piston to the other side. The cycle frame consists of seven rigid links which converts the pendulum movement into the piston movement. Tension and compression springs are properly fixed to the frame.

4.1.2 Reciprocating Pump

It is a positive displacement pump. It operates on the principle of actual displacement or 'pushing' of liquid by a piston or a plunger that executes a reciprocating motion in a closely fitting cylinder.

4.1.3 Springs

The spring is an elastic object used to store mechanical energy. Here in the pendulum pump both tension and compression springs are used. It is the function of these tension and compression springs to stretch and compress according to the load applied.

4.1.4 Tension/Extension Spring

The spring is made to operate with a tension load, so that the spring stretches freely as the load is applied to it.

4.1.5 Compression Spring

This is made to operate with a compressive load, so that the spring gets shorter as the load is applied to it.

4.1.6 Non Return Valves

A non-return valve or a check valve or one-way valve is a valve that normally allows fluid (liquid or gas) to flow through it in only one direction

4.1.7 Nylon Tubes

Nylon tubes are connected to the delivery and suction ends of the reciprocating pump for the passage of water from the sump and the delivery tank.

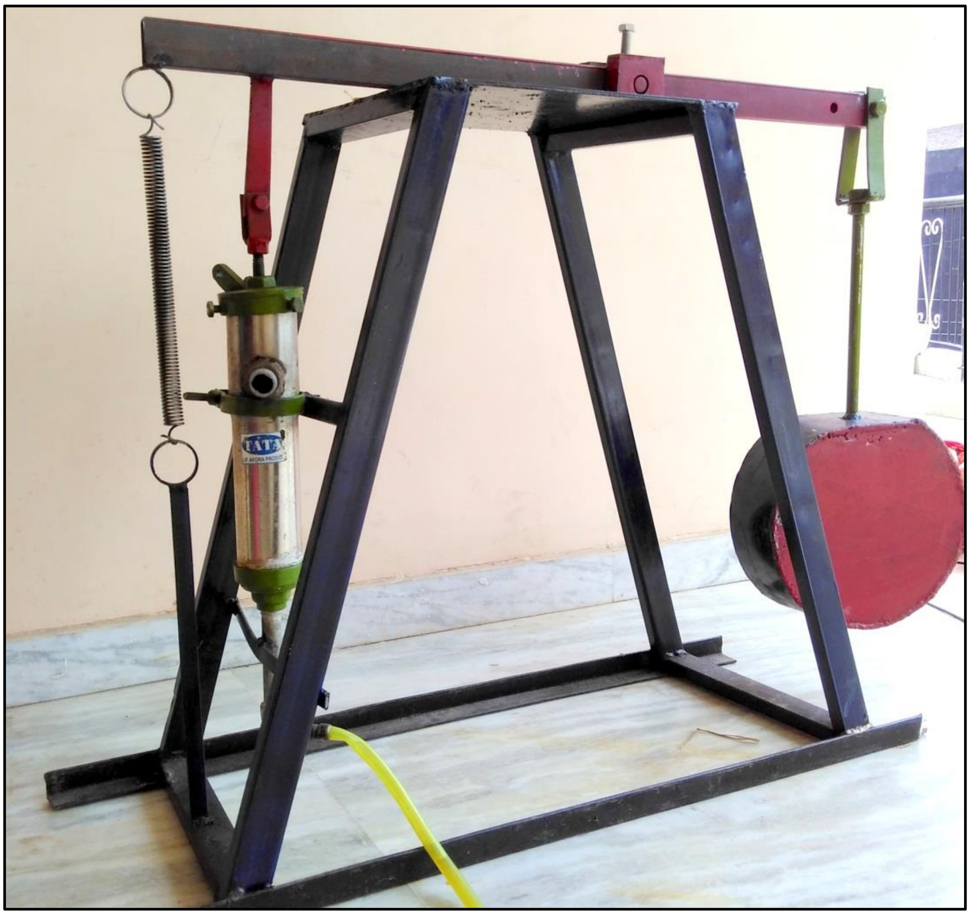


Figure 4.1 Experimental setup of pendulum operated piston pump

4.2 Working principle

The parts of Hand water pump with pendulum are:

1. Load of the pendulum,
2. Handle of the pendulum

3. Axis of the pendulum
4. Axis of the two-leg lever
5. two-leg lever
6. Water pump
7. Piston of the pump

The pump is made of pendulum, two-leg lever and cylinder with the piston which pumps the water. Oscillation of the pendulum is maintained by periodical action of the human arm. Oscillation period of the pendulum is twice bigger than the period of the lever oscillation. Piston of the pump has reverse effect on the lever and damps its oscillation. Damping of the lever motion causes damping of the pendulum, but the work of the force damping the pendulum is less than the work of the forces which damp the lever. Equilibrium position of the lever is horizontal, and the equilibrium position of the pendulum is vertical. Oscillation of the lever and the pendulum takes place in the same plane, vertical in reference to the ground. Physical model of this type of water pump was shown at a number of exhibitions, in some publications and on the Internet

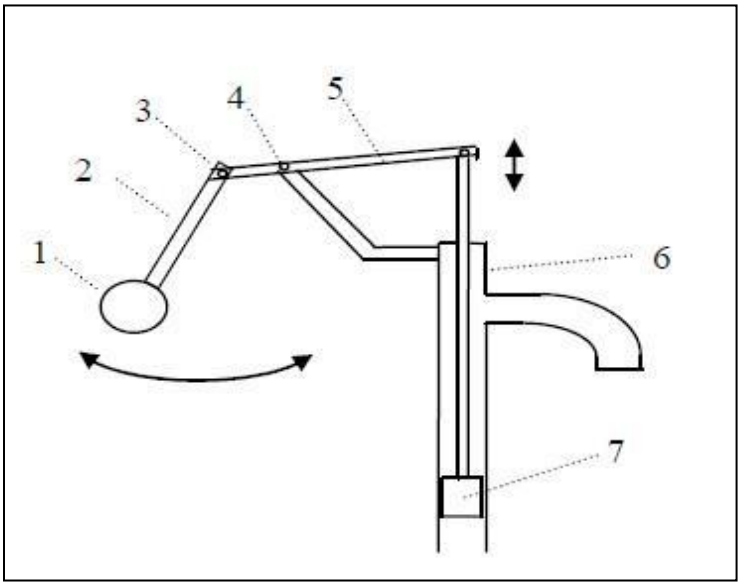


Figure 4.2 Schematic hand water pump with pendulum

4.3 Force Analysis of a Pendulum

The vibrating is acted upon by a restoring force. The restoring force causes the vibrating object to slow down as it moves away from the equilibrium position and to speed up as it approaches the equilibrium position. It is this restoring force that is responsible for the vibration. So what forces act upon a pendulum bob? And what is the restoring force for a pendulum? There are two dominant forces acting upon a pendulum bob at all times during the course of its motion. There is the force of gravity that acts downward upon the bob. It results from the Earth's mass attracting the mass of the bob. And there is a tension force acting upward and towards the pivot point of the pendulum. The tension force results from the string pulling upon the bob of the pendulum. In our discussion, we will ignore the influence of air resistance - a third force that always opposes the motion of the bob as it swings to and fro. The air resistance force is relatively weak compared to the two dominant.

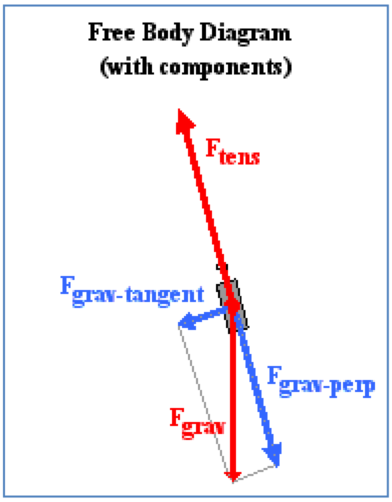


Figure 4.3 Free body diagram of force analysis of pendulum

The gravity force is highly predictable; it is always in the same direction (down) and always of the same magnitude - mass*9.8 m/s^2. The tension force is considerably less predictable. Both its direction and its magnitude change as the bob swings to and fro. The direction of the tension force is always towards the pivot point. So as the bob swings to the left of its equilibrium position, the tension force is at an angle - directed upwards and to the right. And as the bob swings to the right of its equilibrium position, the tension is directed upwards and to the left. The diagram below depicts the direction of these two forces at five different positions over the course of the pendulum's path.

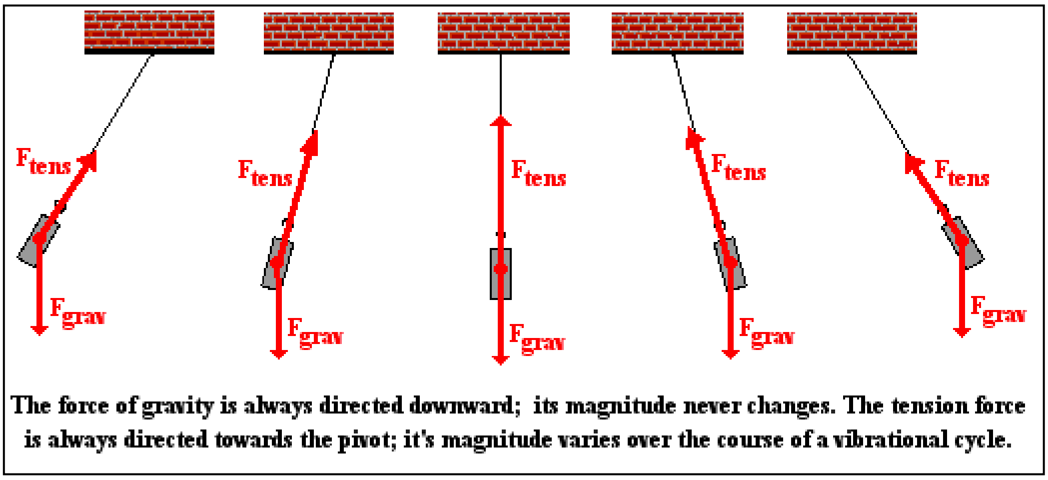


Figure 4.4 the direction forces at different positions in the pendulum's path

In physical situations in which the forces acting on an object are not in the same, opposite or perpendicular directions, it is customary to resolve one or more of the forces into components. This was the practice used in the analysis of sign hanging problems and inclined plane problems. Typically one or more of the forces are resolved into perpendicular components that lie along coordinate axes that are directed in the direction of the acceleration or perpendicular to it. So in the case of a pendulum, it is the gravity force which gets resolved since the tension force is already directed perpendicular to the motion. The diagram at the right shows the pendulum bob at a position to the right of its equilibrium position and midway to the point of maximum displacement. A coordinate axis system is sketched on the diagram and the force of gravity is resolved into two components that lie along these axes. One of the components is directed tangent to the circular arc along which the pendulum bob moves; this component is labeled $F_{grav\text{-}tangent}$. The other component is directed perpendicular to the arc; it is labeled $F_{grav\text{-}perp.}$ You will notice that the perpendicular component of gravity is in the opposite direction of the tension force. You might also notice that the tension force is slightly larger than this component of gravity. The fact that the tension force (F_{tens}) is greater than the perpendicular component of gravity ($F_{grav\text{-}perp}$) means there will be a net force which is perpendicular to the arc of the bob's motion. This must be the case since we expect that objects that move along circular paths will experience an inward or centripetal force. The tangential component of gravity ($F_{grav-tangent}$) is unbalanced by any other force. So there is a net force directed along the other coordinate axes. It is this tangential component of gravity which acts as the restoring force. As the pendulum bob moves to the right of the equilibrium position, this force component is directed opposite its motion back towards the equilibrium position.

The above analysis applies for a single location along the pendulum's arc. At the other locations along the arc, the strength of the tension force will vary. Yet the process of resolving gravity into two components along axes that are perpendicular and tangent to the arc remains the same. The diagram below shows the results of the force analysis for several other positions.

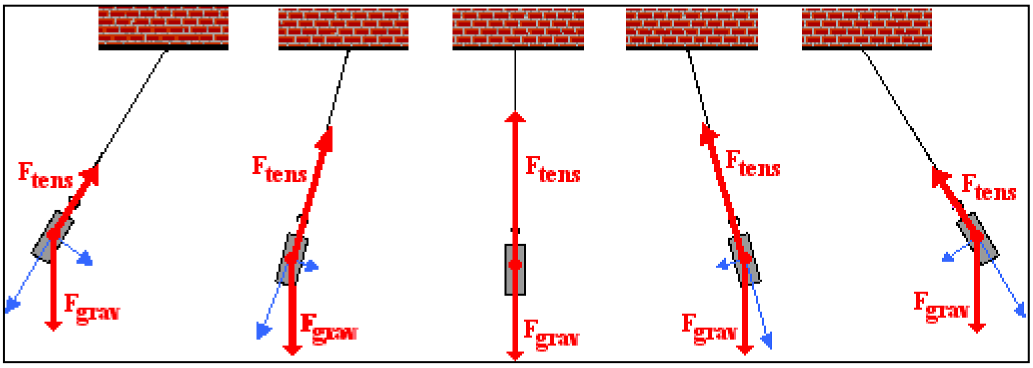


Figure 4.5 the direction of forces along the axis of pendulum at different positions

There are a couple comments to be made. First, observe the diagram for when the bob is displaced to its maximum displacement to the right of the equilibrium position. This is the position in which the pendulum bob momentarily has a velocity of 0 m/s and is changing its direction. The tension force (F_{tens}) and the perpendicular component of gravity ($F_{grav-perp}$) balance each other. At this instant in time, there is no net force directed along the axis that is perpendicular to the motion. Since the motion of the object is momentarily paused, there is no need for a centripetal force.

Second, observe the diagram for when the bob is at the equilibrium position (the string is completely vertical). When at this position, there is no component of force along the tangent direction. When moving through the equilibrium position, the restoring force is momentarily absent. Having been restored to the equilibrium position, there is no restoring force. The restoring force is only needed when the pendulum bob has been displaced away from the equilibrium position. You might also notice that the tension force (F_{tens}) is greater than the perpendicular component of gravity ($F_{grav\text{-}perp}$) when the bob moves through this equilibrium position. Since the bob is in motion along a circular arc, there must be a net centripetal force at this position.

4.4 The Sinusoidal nature of pendulum motion

The sinusoidal nature of the motion of a mass on a spring. We will conduct a similar investigation here for the motion of a pendulum bob. Let's suppose that we could measure the amount that the pendulum bob is displaced to the left or to the right o f its equilibrium or rest position over the course of time. A displacement to the right of the equilibrium position would be regarded as a positive displacement; and a displacement to the left would be regarded as a negative displacement. Using this reference frame, the equilibrium position would be regarded as the zero position. And suppose that we constructed a plot showing the variation in position with respect to time. The resulting position vs. time plot is shown below. Similar to what was observed for the mass on a spring, the position of the pendulum bob (measured along the arc relative to its rest position) is a function of the sine of the time.

Now let's try to understand the relationship between the position of the bob along the arc of its motion and the velocity wit h which it moves. Suppose we identify several locations along the arc and then relate these positions to the velocity of the pendulum bob. The graphic below shows an effort to make such a connection between position and velocity.

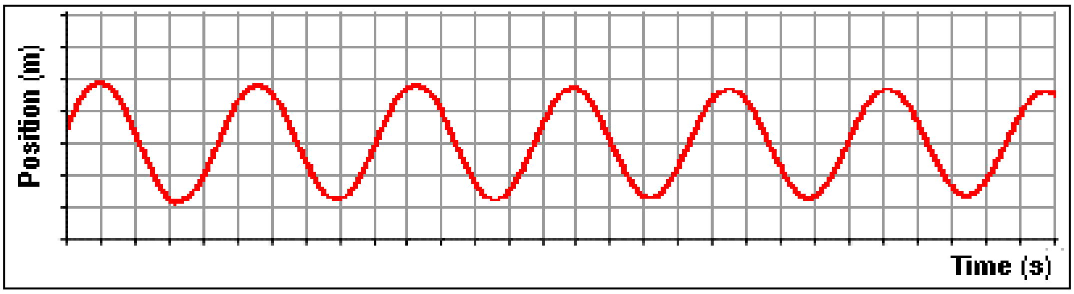


Figure 4.6 position v/s time graph of the pendulum

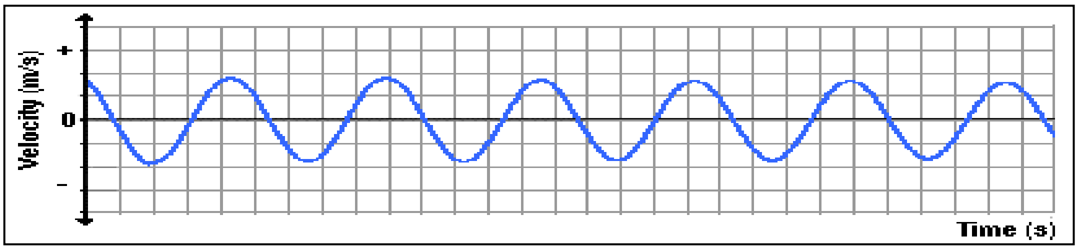


Figure 4.7 Velocity v/s Time graph of the pendulum

As is often said, a picture is worth a thousand words. Now here come the words. The plot above is based upon the equilibrium position (D) being designated as the zero position. A displacement to the left of the equilibrium position is regarded as a negative position. A displacement to the right is regarded as a positive position. An analysis of the plots shows that the velocity is least when the displacement is greatest. And the velocity is greatest when the displacement of the bob is least. The further the bob has moved away from the equilibrium position, the slower it moves; and the

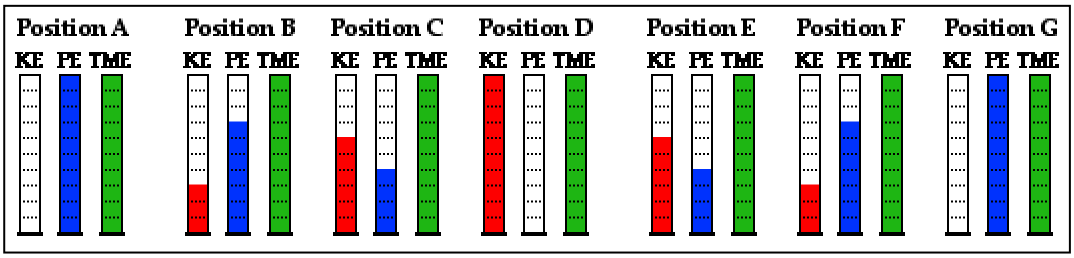


Figure 4.8 Bar graph Kinetic energy, Potential energy and Time of the pendulum at different positions

closer the bob is to the equilibrium position, the faster it moves. This can be explained by the fact that as the bob moves away from the equilibrium position, there is a restoring force that opposes its motion. This force slows the bob down. So as the bob moves leftward from position D to E to F to G, the force and acceleration is directed rightward and the velocity decreases as it moves along the arc from D to G. At G - the maximum displacement to the left - the pendulum bob has a velocity of 0 m/s. You might think of the bob as being momentarily paused and ready to change its direction. Next the bob moves rightward along the arc from G to F to E to D. As it does, the restoring force is directed to the right in the same direction as the bob is moving. This force will accelerate the bob, giving it a maximum speed at position D - the equilibrium position. As the bob moves past position D, it is moving rightward along the arc towards C, then B and then A. As it does, there is a leftward restoring force opposing its motion and causing it to slow down. So as the displacement increases from D to A, the speed decreases due to the opposing force. Once the bob reaches position A - the maximum displacement to the right - it has attained a velocity of 0 m/s. Once again, the bob's velocity is least when the displacement is greatest. The bob completes its cycle, moving leftward from A to B to C to D. Along this arc from A to D, the restoring force is in the direction of the motion, thus speeding the bob up. So it would be logical to conclude that as the position decreases (along the arc from A to D), the velocity increases. Once at position D, the bob will have a zero displacement and a maximum velocity.

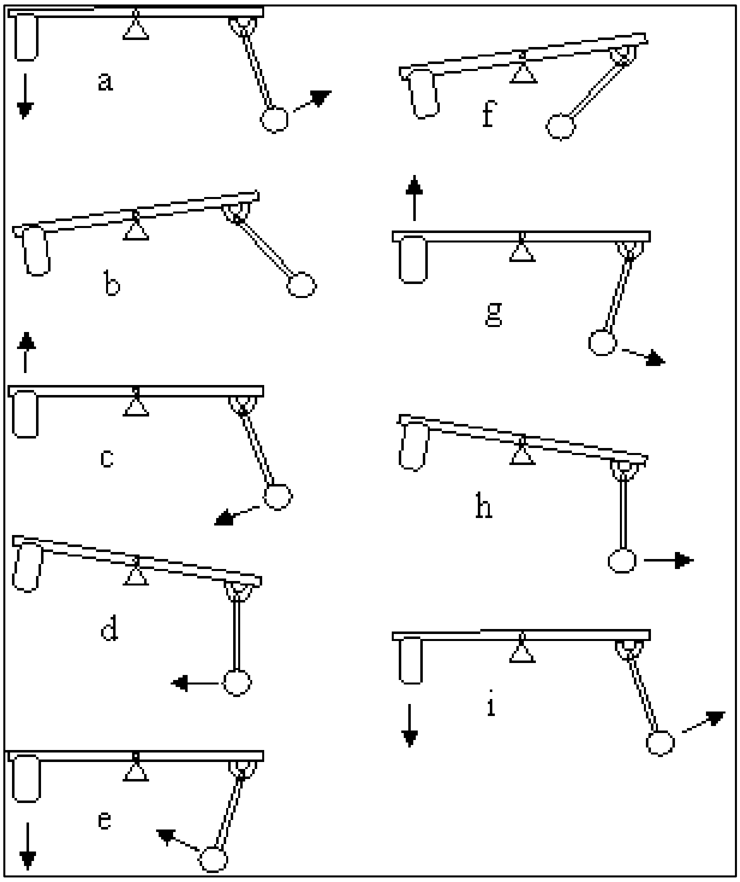


Figure 4.9 Relative positions of pendulum and piston

The velocity is greatest when the displacement is least. The acceleration vector that is shown combines both the perpendicular and the tangential accelerations into a single vector. You will notice that this vector is entirely tangent to the arc when at maximum displacement; this is consistent with the force analysis discussed above. And the vector is vertical (towards the centre of the arc) when at the equilibrium position. This also is consistent with the force analysis discussed above.

4.5 Energy Analysis

The energy possessed by a pendulum bob was discussed. We will expand on that discussion here as we make an effort to associate the motion characteristics described above with the concepts of kinetic energy, potential energy and total mechanical energy.

The kinetic energy possessed by an object is the energy it possesses due to its motion. It is a quantity that depends upon both mass and speed. The equation that relates kinetic energy (KE) to mass (m) and speed (v) is

$$KE = \frac{1}{2}mv^2 \tag{4.1}$$

The faster an object moves the more kinetic energy that it will possess. We can combine this concept with the discussion above about how speed changes during the course of motion. This blending of concepts would lead us to conclude that the kinetic energy of the pendulum bob increases as the bob approaches the equilibrium position. And the kinetic energy decreases as the bob moves further away from the equilibrium position.

The potential energy possessed by an object is the stored energy of position. Two types of potential energy are discussed in The Physics Classroom Tutorial - gravitational potential energy and elastic potential energy. Elastic potential energy is only present when a spring (or other elastic medium) is compressed or stretched. A simple pendulum does not consist of a spring. The form of potential energy possessed by a pendulum bob is gravitational potential energy. The amount of gravitational potential energy is dependent upon the mass (m) of the object and the height (h) of the object. The equation for gravitational potential energy (PE) is

$$PE = mgh \tag{4.2}$$

Where g represents the gravitational field strength (sometimes referred to as the acceleration caused by gravity) and has the value of 9.8 m/s^2

The height of an object is expressed relative to some arbitrarily assigned zero level. In other words, the height must be measured as a vertical distance above some reference position. For a pendulum bob, it is customary to call the lowest position the reference position or the zero level. So when the bob is at the equilibrium position (the lowest position), its height is zero and its potential energy is zero joules. As the pendulum bob does the back and forth, there are times during which the bob is moving away from the equilibrium position. As it does, its height is increasing as it moves further and further away. It reaches a maximum height as it reaches the position of maximum displacement from the equilibrium position. As the bob moves towards its equilibrium position, it decreases its height and decreases its potential energy.

There is an increase in potential energy to accompany this decrease in kinetic energy. Energy is being transformed from kinetic form into potential form. Yet, the total amount of mechanical energy is conserved. This explains principle of energy conservation.

4.6 Solid Modelling

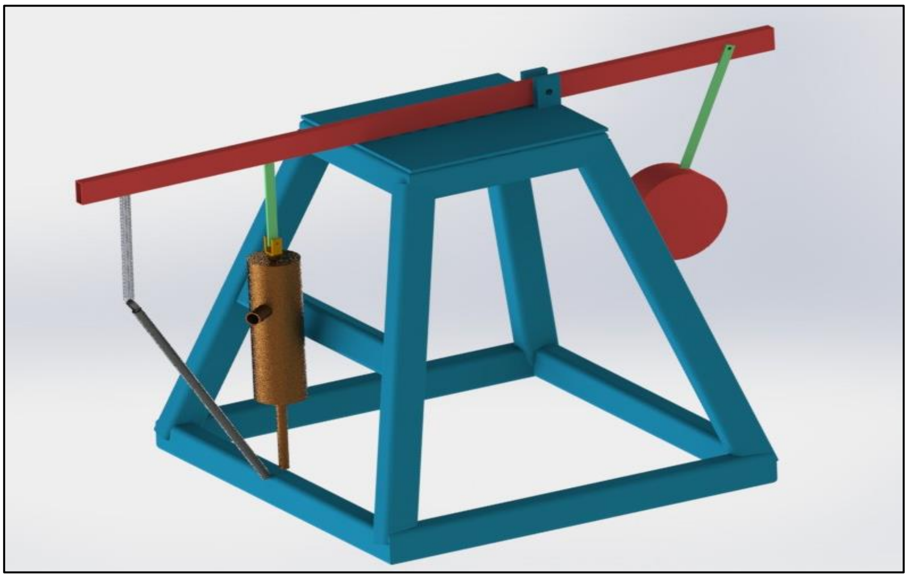


Figure 4.10 Solid model 1

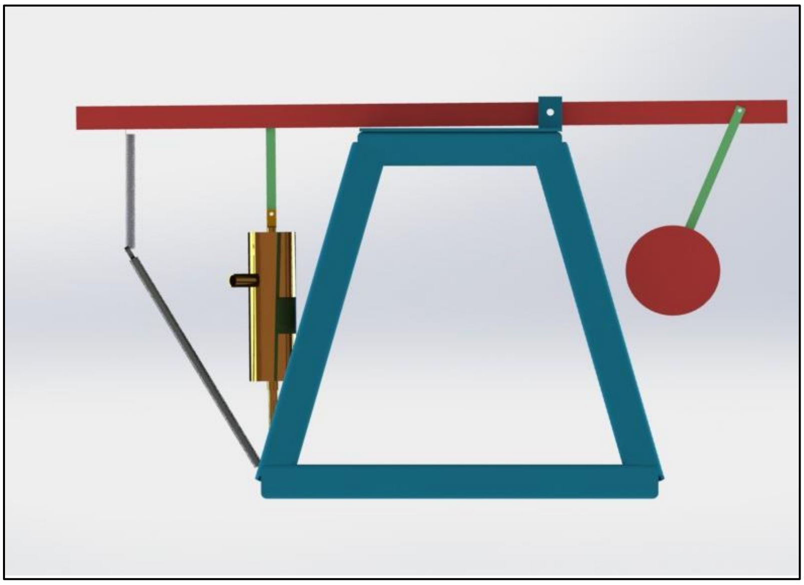


Figure 4.11 Solid Model 2

Figure 4.12 Reciprocating Pump

Figure 4.13 Helical Spring

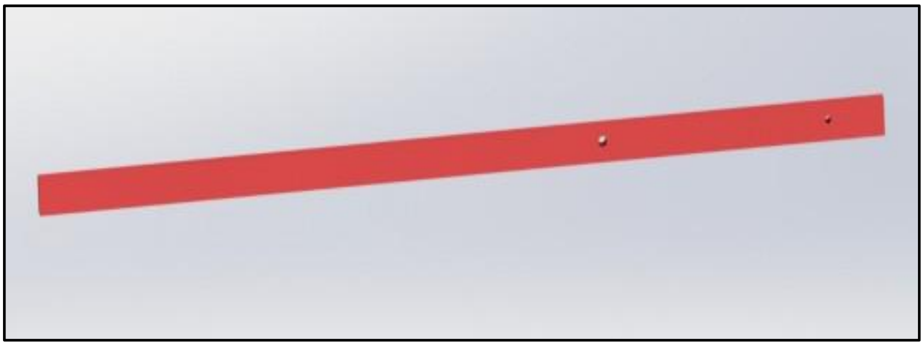


Figure 4.14 Connecting rod

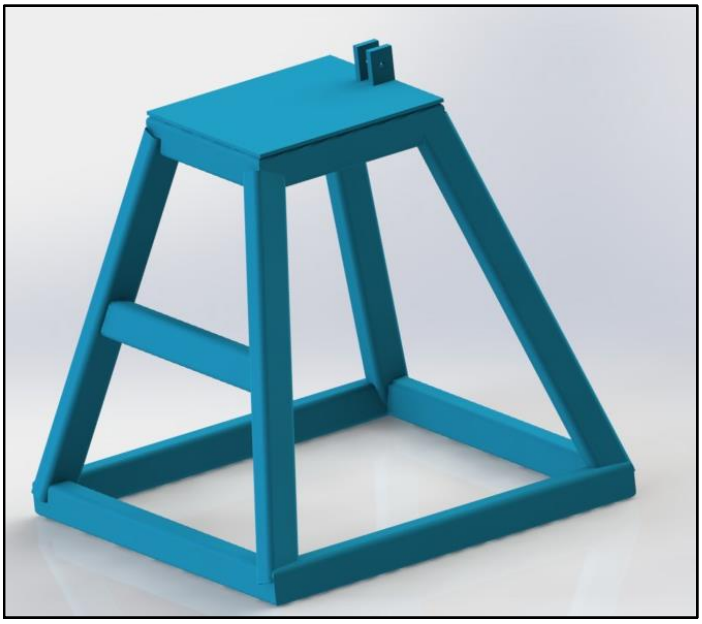


Figure 4.15 Frame

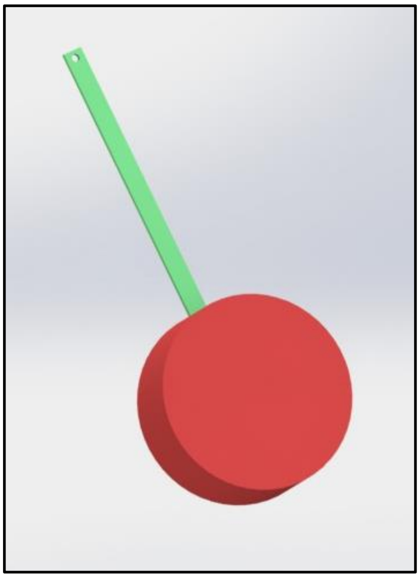


Figure 4.16 Pendulum

Chapter 5

RESULT AND ANALYSIS

5.1 Specification of components

5.1.1 Pump specification

i. Bore diameter (D) = 3.75” = 9.525 cm
ii. Stroke length (L) = 6.50” = 16.51 cm
iii. Plunger length (l) = 22.5 cm
iv. Plunger length with bucket (l’) = 30 cm
v. Total cylinder length = 32 cm
vi. Weight of plunger with bucket = 500 g
vii. Number of strokes per minute = 45

5.1.2 Spring specification

i. Number of coils = 75
ii. Solid length = 10” = 25.4cm
iii. Diameter of coil = 2cm

5.2 Mathematical Calculations

i. Area of the cylinder $(A) = \pi \frac{d^2}{4}$ = 0.0071255 m^2

ii. Volume of cylinder (V) = Area*stroke length = 0.0071255*0.1651
= 1.17643 x 10^{-3} m^3

iii. Weight of water per stroke = 9810*1.17643*10^{-3} = 11.5368 N

iv. Load acting along the length of the spring $(F) = \frac{yGd^4}{8D^3i} = \frac{90*75*10^3*20^4}{8*75*254^3}$

= 109.843 N

[Modulus of rigidity for mild steel = 75 GPa]

v. Friction Force (F_F) = μR

a) R = 11.5368 + (9.81*0.5) = 16.44N

b) μ = 0.15 (for contact between mild steel and cast iron)

F_F = 2.466N

vi. Net force acting downward during suction stroke

= (2.466+11.5368+4.905+109.843) = 128.751 N

vii. Minimum weight of pendulum required = 128.751/9.81 = 13.12 kg

This weight of the pendulum will keep the system in equilibrium condition. But to make the pumping feasible, the weight needs to be increased due other factors and additional losses.

5.3 Observation and Result

During the working of pendulum operated piston pump following observations have been taken and corresponding graphs have been plotted.

5.3.1 Effect on discharge when suction head is varied.

5.3.1.1 When suction head is 66 cm

Table 5.1 Effect on discharge when suction head is 66 cm

s.no	**time (seconds)**	**discharge (mL)**	**discharge (Litre/sec)**	**Average Discharge (Lit/sec)**
1	10	260	0.026	0.0264
2	10	260	0.026	
3	10	270	0.027	
4	10	270	0.027	
5	10	260	0.026	

5.3.1.2 When suction head is 58 cm

Table 5.2 Effect on discharge when suction head is 58 cm

s.no	time (seconds)	discharge (mL)	discharge (Litre/sec)	Average Discharge (Lit/sec)
1	10	320	0.0320	0.0319
2	10	315	0.0315	
3	10	320	0.0320	
4	10	320	0.0320	
5	10	320	0.0320	

5.3.1.3 When suction head is 52 cm

Table 5.3 Effect on discharge when suction head is 52 cm

s.no	time (seconds)	discharge (mL)	discharge (Litre/sec)	Avg Discharge (Lit/sec)
1	10	350	0.035	0.0356
2	10	350	0.035	
3	10	360	0.036	
4	10	360	0.036	
5	10	360	0.036	

5.3.1.4 When suction head is 40 cm

Table 5.4 Effect on discharge when suction head is 40 cm

s.no	time (seconds)	discharge (mL)	discharge (Litre/sec)	Avg Discharge (Lit/sec)
1	10	510	0.051	0.051
2	10	510	0.051	
3	10	500	0.050	
4	10	520	0.052	
5	10	510	0.051	

5.3.1.5 When suction head is 33 cm

Table 5.5 Effect on discharge when suction head is 33 cm

s.no	time (seconds)	discharge (mL)	discharge (Litre/sec)	Avg. Discharge (Lit/sec)
1	10	600	0.060	0.06
2	10	590	0.059	
3	10	610	0.061	
4	10	600	0.060	
5	10	600	0.060	

5.3.1.6 Suction head vs. average discharge

Table 5.6 Suction head vs average discharge

S.no	Suction Head (cm)	Avg. Discharge (Lit/sec)
1	33	0.0600
2	40	0.0510
3	52	0.0356
4	58	0.0319
5	66	0.0264

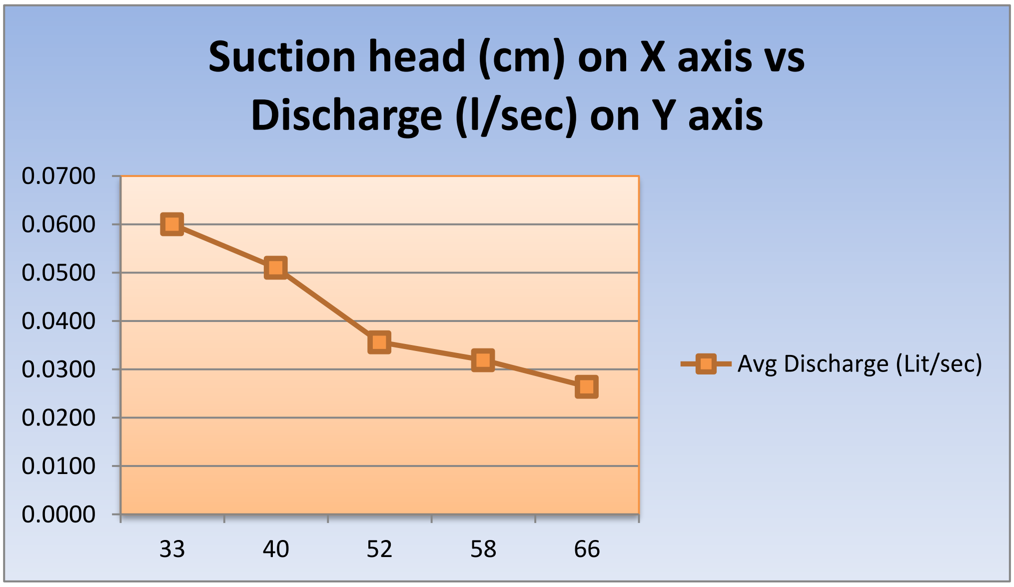


Figure 5.1-Graph showing variation of Suction head with Discharge

5.4 Effect on discharge when angle of swing is changed

Table 5.7 Variation of discharge with angle of swing

S.no	angle of swing (degree)	discharge (l/sec)
1	45	0.0616
2	55	0.0659
3	60	0.0685
4	70	0.0718
5	75	0.0739

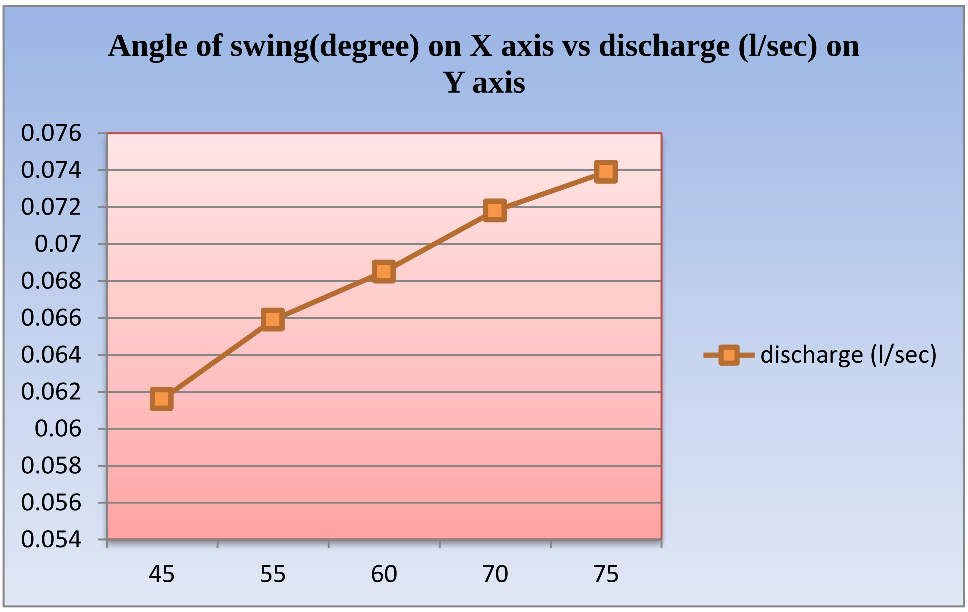


Figure 5.2 Graph showing variation of Angle of swing with discharge

5.5 Effect on discharge when mass of pendulum is varied

Angle of swing is kept constant at 70° and suction head at 30 cm.

Table 5.8 mass of pendulum vs. discharge

Mass (kg)	time (sec)	discharge (L/sec)
20	10	0.064
24	10	0.066
28	10	0.069
32	10	0.070

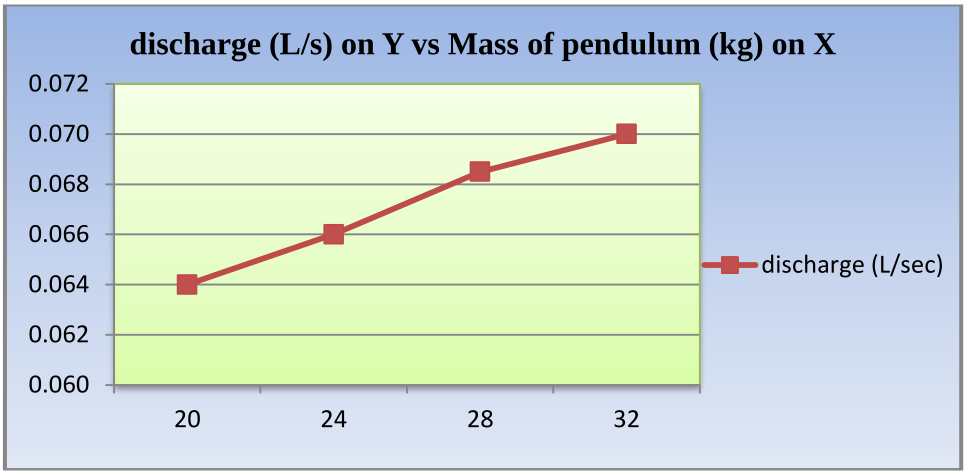


Figure 5.3 Graph showing variation of mass of pendulum with discharge

Chapter 6

APPLICATION, ADVANTAGES AND LIMITATIONS

6.1 Advantages

1. **Swing Set Irrigation System :**

   A "Swing sets water pump" is a mechanism used to power or supply water with the help of swing set in garden. In this system when a person start swing on its play set with the help of Grasshopper Law a link is connected to water source from when they suck the water through a inlet valve and flow out through an exit valve.

Figure 6.1 Model of a Swing Set Irrigation system

2. Hand water pump with pendulum can be widely used in rural areas. As the installation cost of hand water pump with pendulum is low it is useful for poor people. It can be installed in all the public places. It can be operated by children or old people as the force required by the pump is low.

3. It uses the minimum of human strength in comparison to present classic hand water pumps.

4. In comparison to the hand pumps the energy required to initiate the pumping process is significantly less for the pendulum pump.

5. It requires less water consumption.

6. Since maintaining the oscillation of the pendulum does not request any special training or dexterity, both parts of the pump can be used to draw fluid from the source.

7. Compact size, easy to relocate, less moving parts, hence less maintenance cost

6.2 Applications

1. **Drainage:** Used to control the level of water in a protected area.

2. **Sewage:** Used in the collection and treatment of sewage.

3. **Irrigation:** Used to make dry lands agriculturally productive.

4. **Chemical Industry:** Used to transport fluids to and from various sites in the chemical plant.

5. **Petroleum Industry:** Used in every phase of processing of petroleum, its transportation, and separation of the impurities.

6. **Medical Field:** Used to pump fluids in and out of the body.

7. **Steel Mills:** Cooling water in steel mills can be transported using a pendulum pump.

6.3 Limitations

The limitations include:

1. Less efficiency when compared to other device.
2. Air leakage can affect the entire working of the whole unit.

Chapter 7

CONCLUSION AND FUTURE SCOPE

7.1 Conclusion

1. On increasing the suction head, discharge of the given pendulum system decreases.
2. On increasing the mass of pendulum, discharge of the given pendulum system increases.
3. On increasing the angle of swing, the discharge of the given pendulum system increases.
4. It was concluded that human effort is considerably reduced while pumping water by a pendulum operated pump compared to a regular pump.

7.2 Future Scope

1. It can be used where the shortage of power or electricity is a major issue.
2. From experimentation it can be concluded that the system is practically feasible.
3. Implementing a pendulum pump setup which uses gravitational force only, leads to large amount of energy conservation
4. This system is more efficient, considering the minimum efforts required.