MAKERERE UNIVERSITY

COLLEGE OF NATURAL SCIENCE

DEPARTMENT OF PHYSICS

MANUAL AUTOMATION OF THE BOREHOLE USING A PENDULUM

BY

SESSANGA RONALD

217001413

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SUPERVISOR : DR. TADDEO SSENYONGA

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Declaration

I hereby declare that this piece of work is to the best of my knowledge, has never been submitted to any university or any other higher institution of learning for the award of a degree or any other academic qualification and describe my involvement as a student of Bachelor of Science with Education at Makerere University and all information contained in this report is certain and true of me.

Signature:........Ronald........

Date:....18/12/2020........

SESSANGA RONALD
17/U/1086

Approval

The research project has been submitted for examination with my approval and done by SESSANGA RONALD, 17/U/1086 under my supervision.

Signature:..

Date: ....18/Dec/2020..........

Supervisor: **Dr. TADDEO SSENYONGA**

Dedication

I dedicate this research to my family and friends. May God bless you and grant you peace where ever you are.

Acknowledgment

First and foremost, I would like to thank the Almighty God for the protection, wisdom and guidance granted to me throughout these years of struggle for education. I wish to thank with gratitude my supervisor Dr. Taddeo Ssenyonga for the guidance, commitment and inspiration accorded to me for successive completion of this project.

To my brother Ssemambo Marvin, fellow colleagues in the struggle Balikuddembe Joseph, Chemonges Collins, and others thanks for the assistance rendered to me.

Abstract

This research is about the development of a borehole which operates in such a way that the pumping action is initiated by the swinging of the pendulum. The human arm, leg are used to operate the borehole by swinging the pendulum. Therefore less amount of energy is required to produce a reasonable output. According to the study, three machine parameters determine the amount of discharge obtained from the borehole and these parameters are length, mass and position of the pendulum. Generally, i found out that when the length of the pendulum is increased, the discharge obtained in a given time also increases and a graph of discharge against length is a curve which appears in an increasing manner. Further, when more weights are added to the pendulum, the discharge obtained in a given time increases and a graph of discharge against mass is a straight line with a positive gradient. Concerning the position of the pendulum, the more the angle the pendulum is displaced, the more the input energy and this inturn results into an increase in discharge obtained, the graph of discharge against input energy is a curve which appears in an increasing manner but less steep as compared to the graph of discharge against length obtained in the former case. A long meter rule was used to measure different length of the pendulum, known masses each of half kilogram were gradually added to the pendum, a protractor was used to measure the angle of displacement of the pendulum, a stop clock was used to determine the time at which readings were taken and a 100 ml measuring cylinder was used to determine the discharge obtained at all the three parameters. However due to the fact that most materials that i used in the project were wooden and othes plastic, further research need to be done when metallic materials which are more efficient are used so that even more weights can be added to the pendulum without breaking and hence large output of the liquid is obtained.

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Chapter 1

Introduction

1.1 Introduction

This chapter entails the general introduction about the whole project. It includes the project's background, problem statement, objectives, research questions, significance of the project, justification and scope of the study.

1.2 Background of the Study

A borehole is a deep round hole made by a special tool or machine, especially one that is made in the ground when searching for oil or water[1]. Typically, a borehole used as a water well is completed by installing a vertical pipe and well screen to keep the borehole from caving. This also helps prevent surface contaminants from entering the borehole and protects any installed pump from drawing in sand and sediment. Boreholes are usually narrow (typically 150 mm (6 inches) in diameter) and can be constructed quickly. Modern drilling machines use compressed air to drive a rotating hammer that smashes up the rock. The air exhaust from the hammer tool blows the broken rock chips, and any water in the hole, up to the ground surface[2]. Pumps are incorporated in boreholes to lift fluids.

A pump is a device that can be used to raise or transfer fluids (liquids or gases) by mechanical action [3]. Pumps are classified into three major groups according to the method they use to move the fluid and these include direct lift, displacement, and gravity pumps. Direct lift pumps are designed to operate within water and have an internal pipe that acts both as a piston and as a pump rod. As the pipe is raised, the piston valve closes so that the water inside the pipe is raised. Gravity pumps also known as water ram pumps work by using the potential energy of water at a higher level than the pump. The water flows down a pipe to the pump, and the kinetic energy of water is used to pump a fraction of that water to a height that can be several times higher than the height of the original water source. Displacement pumps also called positive displacement pumps moves a fluid by repeatedly enclosing a fixed volume and moving it mechanically through the system. The pumping action is cyclic and can be driven by pistons, screws, gears, rollers, diaphragms or vanes. There are three types of positive displacement pumps namely: rotary pumps, reciprocating pumps and linear pumps [4]. However a reciprocating pump is used in the manual automated borehole with a pendulum because it shows advantages such as compact size, simplicity of design, relatively low cost, light weight and wide spread availability of pumps and spare parts, which make it ideal for use in this project.

Reciprocating 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. They come in many sizes, from microscopic for use in medical applications to large industrial pumps.

World over, reciprocating water 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, irrigation to make dry lands agriculturally productive, chemical industry to transport fluids to and from various sites in the chemical plant, petroleum industry for use in every phase of processing petroleum, its transportation, and separation of the impurities, medical field to pump fluids in and out of the body [5].

In Africa, boreholes are changing lives and building business in developing economies for example Kickstart: a company that develops new irrigation technologies and then puts them into the hands of local entrepreneurs. It puts sustainable water-delivery to crops into hands of small farm owners in East and West Africa. Brlisen pumps which are largely used in Africa require a range of power between 0.37 kW to 4 kW to provide water for irrigation as well as domestic use[6].

In Uganda, various innovations have been made towards developing suitable pumps to provide water for irrigation, home use and industrial use. For example the solar pump designed by engineering students of Makerere university as part of an irrigation project [7]. However, the innovations made and technologies today on the Ugandan market require a source of power such as a solar panel which is about 5 million shillings to operate an expensive water pumping system worth 10 million shillings or hydro electric power which itself has not been installed in various districts in Uganda. The available manual boreholes require a lot of human power of about 750 W depending on the manufacturer to pump water for domestic as well as irrigation purposes[8]. This makes relatively weak people such as children and women to use these boreholes for only a short period of time and hence these have not satisfied the water needs of people in rural areas especially where electricity is a problem, people are poor and human power can't build up to 750 W to operate the manual boreholes.

1.3 Problem Statement

The rural installed boreholes in Uganda require sufficiently large effort depending on the manufacturer and the people operating them like women and children. Hence this calls for ways to improve the existing boreholes such that they can easily be used by women and children.

1.4 Objectives

1.4.1 General Objective

To automate a manual borehole using a pendulum.

1.4.2 Specific Objectives

i. To study the existing typical hand water boreholes.

ii. To select, size the material and develop machine layout.

iii. To determine machine parameters.

1.5 Research Questions

i. What are the specifications of a typical hand borehole?

ii. What are the machine parameters?

iii. What is the nature, size of material and machine components to be used in the design?

1.6 Significance of the Study

The successful development of the manual automated borehole with a pendulum has the following benefits to the community: Dry lands are made agriculturally productive since the borehole can be ued to pump water for irrigation purposes, Less man power is required to swing the pendulum inorder to initiate the pumping process, Continuous flow of water is achieved by swinging the pendulum, It can be operated without any external aid like a motor or electric or solar power and hence it is cheaper compared to other means of pumping water[9].

1.7 Justification

Relatively weak people like women and children cannot use the existing manual boreholes continuously for long time because of the increased fatigue experienced when operating these typical manual boreholes. Hence there is need to adopt the modified pendulum manual automated borehole to reduce the time and increase flexibility when pumping water.

1.8 Scope of the Study

The scope of research covers only the currently used boreholes in local communities and the pendulum operated borehole is developed.

Chapter 2

Literature Review

2.1 Introduction

This chapter consists of a working model diagram and working principle of the pendulum manual automated borehole, an illustration showing movement of water from underground in a typical borehole, overview of the reciprocating pump, working principle of the reciprocating pump, introduction to water pumps and types of water pumps in existence in rural communities.

2.2 Working Model Diagram of a Manual Automated Borehole with a Pendulum

The pendulum manual automated borehole has the following principal components as shown in figure 2.1: Pendulum bob, Pendulum rod, Arm joint, Link joint, Lever, Spring, Piston and Cylinder.
The pendulum bob shown by 1 on figure 2.1 is a weight suspended from a pivot so that it can swing freely, it is the main input given to the lever which further gives desired output. The pendulum rod shown by 2 on figure 2.1 is connected to the lever at the arm joint, its function is to provide support to the weights. The main function of arm joint shown by 3 in figure 2.1 is to hold the pendulum lever with counter weight. The link joint shown by 4 in figure 2.1 holds the spring firmly so that it does not move sideways during the reciprocating motion of the piston. The lever shown by 5 in figure 2.1 converts the oscillating motion of the pendulum into reciprocating motion of the piston in the cylinder. The spring is placed at position 6 as shown in figure 2.1.A spring is an elastic object which store mechanical energy. Both tension and compression springs are used to stretch and compress according

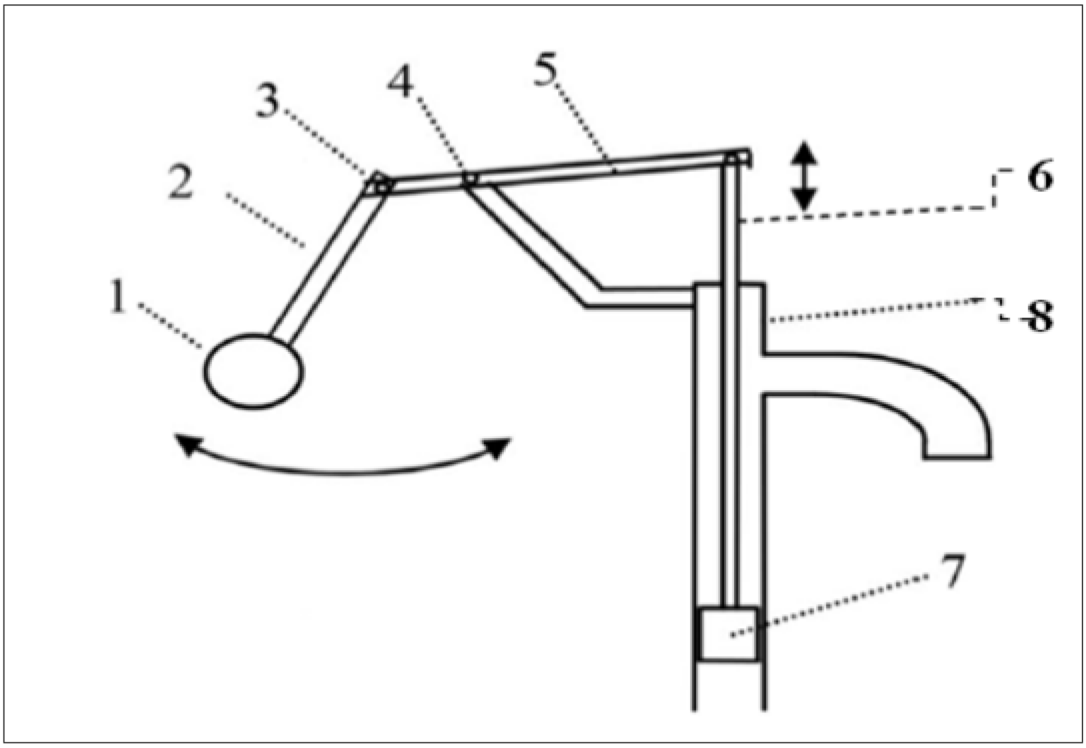

Figure 2.1: Working model of a manual automated borehole with a pendulum

to load applied. The piston shown by 7 in figure 2.1 is used to perform suction and deliverance of the liquid. The cylinder shown by 8 in figure 2.1 is a hollow metal where suction and delivery pipes are incorporated.

2.3 Operating Principle of a Manual Automated Borehole with a Pendulum

The borehole is made of pendulum, two-leg lever and cylinder with the piston which pumps the water as shown in figure 2.1. The working of pendulum operated borehole depends on its main parts like pendulum with suitable counter weight, main lever, oscillating mechanisms, reciprocating pump,and spring. Oscillation of the pendulum is maintained by periodical action of the human arm. When we apply the force on the pendulum, the pendulum starts to oscillate. This oscillatory motion of pendulum is transferred to the main lever. The main lever starts to oscillate due to movement of pendulum. The liver is mounted on the top of the cycle frame. The connecting rod of the piston is connected to the liver and hence the oscillating motion of liver is transferred to piston rod and then the motion of the piston rod is converted into reciprocating motion of piston. When the cylinder is fully filled by water then water goes out through outlet port where we get the output of the pump in the form of discharged water. The downward movement of piston is achieved by the spring. The spring is located at the end of lever at pump side. When the lever takes upward position then spring will expand and piston completes the suction stroke. The next movement of spring is compression, this movement is used to retract the liver. The spring also balances the weight of the pendulum.

Oscillation period of the pendulum is twice bigger than the period of the lever oscillation. The 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.

2.3.1 Flow Chart of a Manual Automated Borehole Operation

The flow chart in figure 2.2 clearly explains the working principle of the modified manual automated borehole as given in section 2.3.

2.4 Lifting Action in a Borehole

Figure 2.3 illustrates what happens when we begin to pump water out of the hole. The pump shown is an electrically-powered submersible borehole pump [10]. It has an electric motor at the bottom of the pump, above which is the water intake. The motor drives a shaft, which turns a series of propellers (technically termed 'impellers') which rotate inside pump bowls and push the water up the pipe to the surface. When the pump is turned on, it removes water from the hole, causing the water level in the hole to fall below the water level in the rock and soil. As a result, water starts to flow into the void from the transition zone at the top of the rock, the cracks in the upper rock, and from cracks in the rock below the water level in the hole. Water from cracks above the pump intake will flow down to the pump, and water from cracks below the pump intake will flow up the hole to the pump. All these

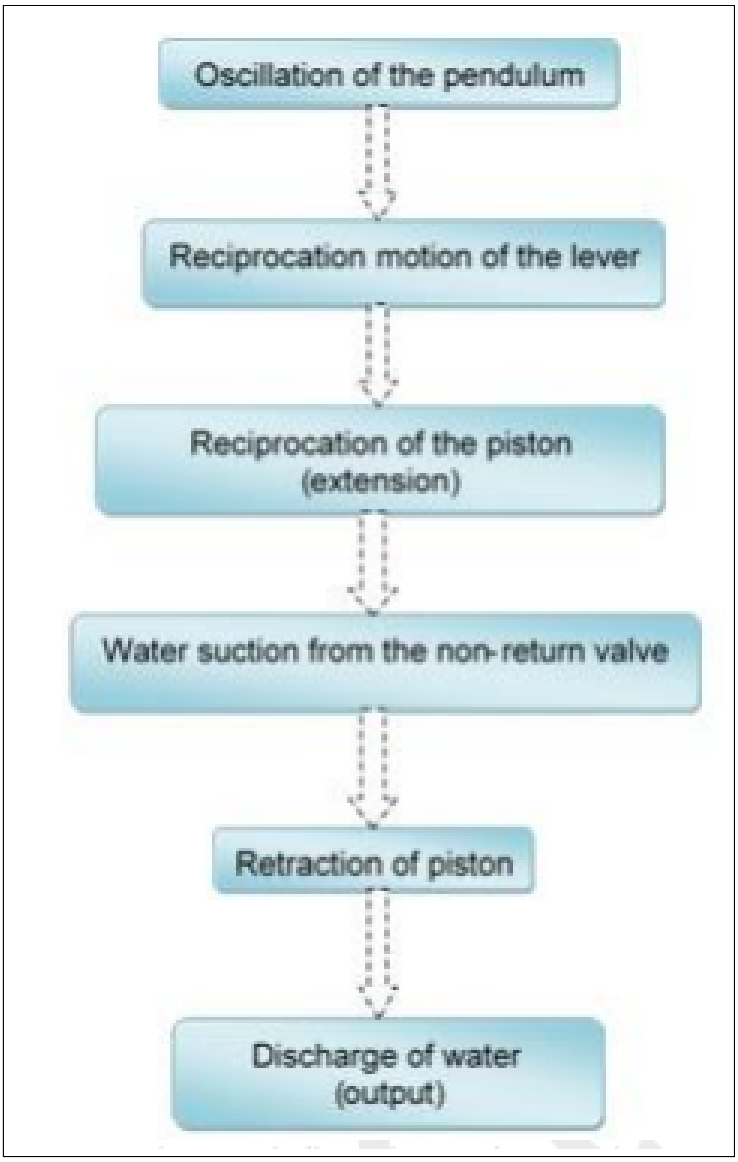

Figure 2.2: Flow chart of a manual automated borehole operation

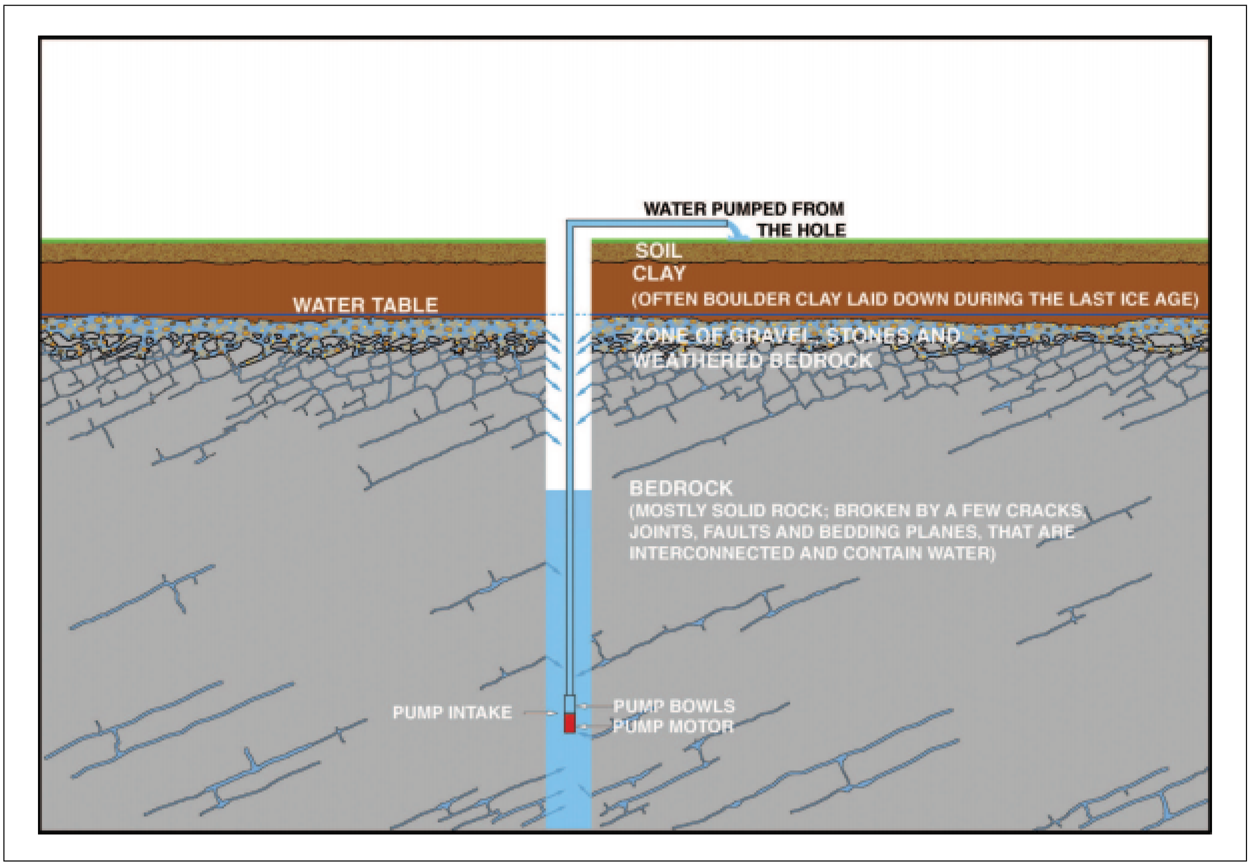

Figure 2.3: Movement of water from underground in a borehole

flows are driven by gravity that is by the difference in water level between the hole and the surrounding rock and soil [11].

2.5 Overview of the Reciprocating Pump

A reciprocating pump in figure 2.4 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. This type of pump operate by using a reciprocating piston. The liquid enters a pumping chamber via an inlet valve and is pushed out via an outlet valve by the action of the piston or diaphragm. Reciprocating pumps are generally very efficient and are suitable for very high heads at low flows. This type of pump is self priming as it can draw liquid from a level below the suction flange even if the suction pipe is not evacuated. The pump delivers reliable discharge flows and is often used for metering duties delivering accurate quantities of fluid [18].

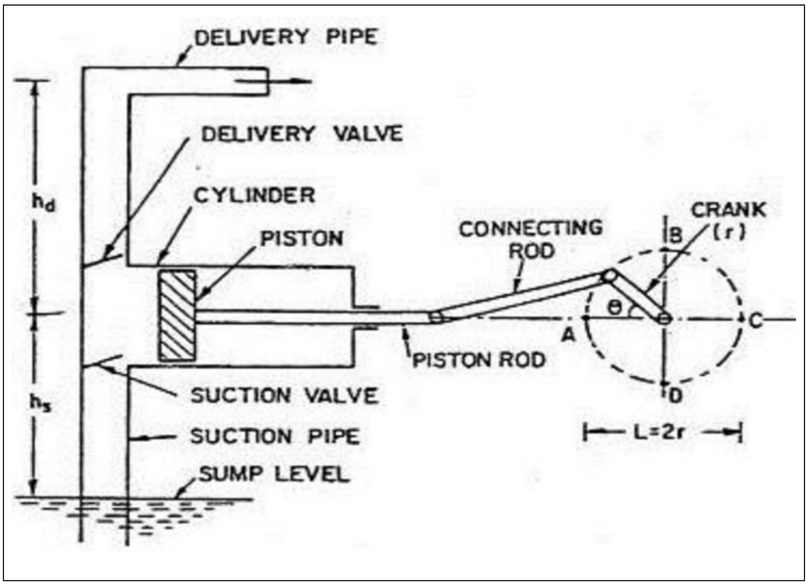

Figure 2.4: Reciprocating pump

The reciprocating pump has the following components: cylinder, piston, piston rod, crank, connecting rod, suction valve, suction pipe, delivery valve and delivery pipe. The functionality of each component is described below. The Cylinder is hollow and made up of steel alloy or cast iron. Arrangement of the piston and piston rod is inside the cylinder. Suction and release of the liquid takes place in the cylinder and so both suction and delivery pipes together with valves are connected to the cylinder. The piston is a solid type cylinder part that moves backward and forward to perform suction and deliverance of the liquid. The piston rod helps the piston to achieve its linear motion. The crank is a solid circular disc which is connected to a power source like a motor, engine etc for its rotation. The connecting rod connects the crank to the piston as a result of the rotational motion of the crank gets converted into linear motion of the piston. Suction pipe connects the source of the liquid to the cylinder of the reciprocating pump. the liquid is suck by this pipe from tthe source to the cylinder. The suction valve is a one way valve that is a non-return valve. It allows the liquid to flow in one direction only that is, it permits the liquid from the suction pipe to the cylinder. Delivery pipe is connected to the cylinder and it is the passage of liquid out of the cylinder. Delivery valve is also one way non-return valve. It permits the liquid to flow in one direction only that is, it allows the liquid from the cylinder to the delivery pipe.

2.6 Working Principle of a Reciprocating Water Pump

In a reciprocating pump, liquid acts on one side of the piston only. A reciprocating pump has one suction pipe and one delivery pipe. It is usually placed above the liquid level in the sump [19].

A reciprocating pump consists of two strokes namely; suction and delivery

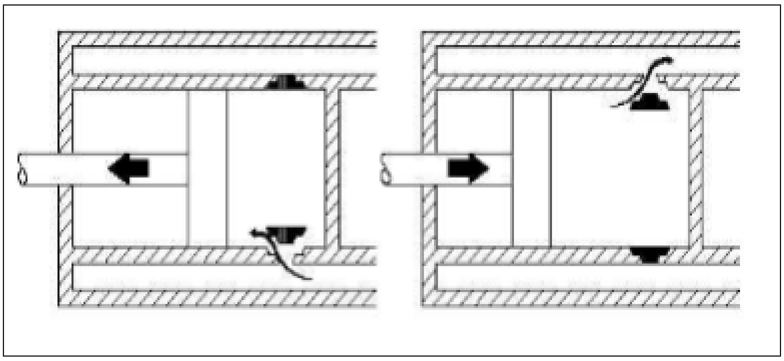

Figure 2.5: Working principle of a reciprocating water pump.

strokes.

2.6.1 Suction Stroke

The suction stroke is indicated by an arrow moving towards the left in figure 2.5. During suction stroke, when the lever moves up, the piston moves upwards in the cylinder. In this case the volume covered by the piston within the cylinder increases. On the free surface of water in the sump, atmospheric pressure acts and thus there is a pressure difference at the two ends of the suction pipe which connects the sump and the cylinder. This pressure difference between the free surface and inside of the cylinder causes the flow of water from the sump into the cylinder through the suction valve, which is kept open. During this stroke, the non-return valve at the delivery side will be closed by the atmospheric pressure existing in the delivery pipe. At the end of the suction stroke, the cylinder will be full of water, and the piston reaches the right end which is called outer dead centre since the water is continuously sucked into the cylinder and this stroke is called suction stroke.

2.6.2 Return Stroke or Delivery Stroke

The delivery stroke is indicated by an arrow moving towards the right in figure 2.5. During delivery stroke, when the lever moves down, the piston from its extreme upward position starts moving downwards in the cylinder. The movement of piston downwards increases the pressure of the liquid inside the cylinder to a pressure more than atmospheric pressure. Therefore, the suction valve closes and the delivery valve opens and the liquid inside the cylinder is forced into the delivery pipe through the delivery valve. Consequently, the liquid is raised to the required height and the liquid is discharged at every alternate stroke.

2.7 Components Used

The following are the components that i used in this project.

2.7.1 Cycle Frame

The cycle frame 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 slider-crank mechanism is an arrangement of mechanical parts designed to convert straight-line motion, as in a reciprocating piston engine, or to convert rotary motion to straight-line motion, as in a reciprocating pump [20].

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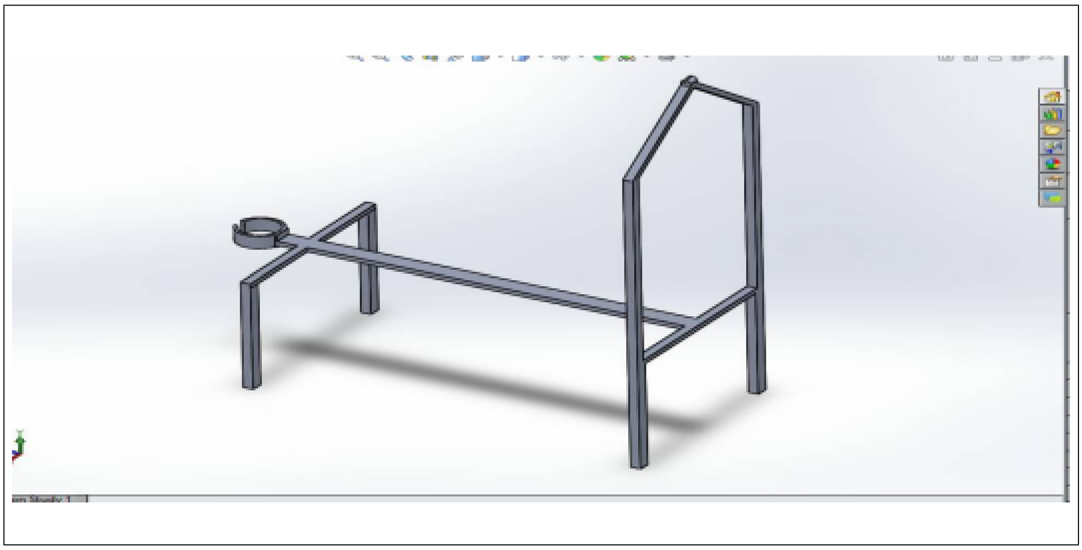

Figure 2.6: Cycle frame.

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 slider-crank mechanism is an arrangement of mechanical parts designed to convert straight-line motion, as in a reciprocating piston engine, or to convert rotary motion to straight-line motion, as in a reciprocating pump [20].

2.7.2 Spring

A spring is an elastic object used to store mechanical energy. In the machine design, tension spring was used. It is the function of this tension spring to stretch according to the load applied. When a conventional spring, without stiffness variability features, is compressed or stretched from its resting position, it exerts an opposing force approximately proportional to its change in length. 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 [21]. An extension or compression spring's rate is expressed in units of force divided by distance, for example N/m or lbf/in. A torsion spring is a spring that works by twisting; when it is twisted about its axis by an angle, it produces a torque proportional to the angle. A torsion spring's rate is in units of torque divided by angle, such as Nm/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 [22].

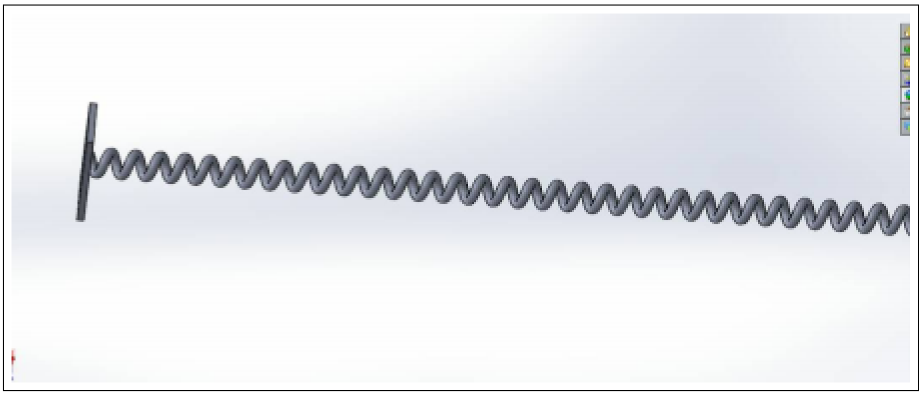

Figure 2.7: Tension spring.

2.7.3 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[12]. In the design of a single acting reciprocating pump used in this project, inlet and outlet check valves are used. A non-return valve is fitted to ensure that a medium flows through a pipe in the right direction, where pressure conditions may otherwise cause reversed flow. Non-return valves show advantages such as they are available in a wide range of sizes and costs, they are generally small, simple and inexpensive. They also protect pumps and compressor equipment from damage caused by backflow and reverse flow. They reduce down time and loss of production due to the failure of unsuitable valves. They increase energy savings and are very effective in preventing water hammer[13].

The following are all typical styles of Non-Return Valves: Ball NRVs: Have a closing member, the movable part to block the flow, that is a spherical ball. This is sometimes spring-loaded to help keep it shut, or otherwise reverse flow is required to move the ball toward the seat and create a seal. The interior surface of the main seats of ball NRVs are conically-tapered to guide the ball into the seat and form a positive seal when stopping reverse flow. Ball check valves are often very small, simple, and cheap[14].
Diaphragm NRVs: Use a flexing rubber diaphragm to create a normally-closed valve. Pressure on the upstream side must be greater than the pressure on the downstream side (pressure differential) for the NRV to open and allow flow. Once positive pressure stops, the diaphragm automatically flexes back to its original closed position[14].
Swing Check NRVs: Have a movable part to block the flow, which swings on a hinge or trunnion on to the seat to block reverse flow or off the seat to allow forward flow. The seat opening cross-section may be perpendicular to the centerline between the two ports or at an angle. Although swing check NRVs can come in various sizes, larger NRVs are often swing check valves[14].
Stop Check NRVs: Have override control to stop flow regardless of flow direction or pressure. As well as closing in response to insufficient forward pressure or backflow, it can also be deliberately shut by an external mechanism. This can prevent any flow regardless of forward pressure[15].
Lift Check NRVs: Feature a disc, sometimes called a lift, which can be lifted up off its seat by higher pressure of inlet or upstream fluid to allow flow to the outlet or downstream side. When the pressure drops, gravity or higher downstream pressure causes the disc to lower onto its seat, shutting the valve to stop reverse flow[15].
In-line NRVs: Are similar to a lift-check NRV but generally has a spring that lifts when there is pressure on the upstream side of the valve. The pressure needed on the upstream side of the valve to overcome the spring tension is called the 'cracking pressure'. When the pressure goes below the cracking pressure, the spring will close the valve to prevent back-flow[16].

Figure 2.8: One-way inlet valve.

Figure 2.9: One-way outlet valve.

2.7.4 Nylon Tubes

Nylon tubing is a unique kind of tubing made from polyamide resin. This material is known for its outstanding chemical, abrasion, impact, and moisture resistance and dimensional stability. It also offers higher corrosion resistance than other types of nylon tubing[17]. Nylon tubes are connected to the delivery and suction ends of the reciprocating pump for the passage of water from the pump and the delivery tank.

Figure 2.10: Nylon tubes.

2.7.5 Weight Hanger

The weight hanger is used to hold the weights and it is the oscillating part of the system and thus it acts like a pendulum. When a pendulum is displaced from its equilibrium position, it is subjected to a restoring force due to gravity that will accelerate back towards the equilibrium position. When released, the restoring force combined with the pendulum mass causes it to oscillate about the equilibrium position swinging back and forth. The time to complete one cycle, a left and right swing is called the period. The period depends on the length of the pendulum and also to a slight degree the amplitude, the width of the swing.

Figure 2.11: Weight hanger.

2.8 Types of Existing Hand Water Pumps

Pumps can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement, and gravity pumps. In order to be successful in this project, the pendulum hand water pump must offer a significant advantage over the existing technology.
Communities should be able to choose from a range of water pumps, and each option should be presented with its advantages, disadvantages and implications. The following are some of the hand water pumps in existence.

2.8.1 Rope and Bucket Pump

This device is mainly used with hand-dug wells. A bucket on a rope is lowered into the water. When the bucket hits the water it dips and fills, and is pulled up with the rope. The rope may be held by hand, run through a pulley, or wound on a windlass. Sometimes, animal traction is used in combination with a pulley. Improved systems use a rope through a pulley, and two buckets – one on each end of the rope. For water less than 10 m deep, a windlass with a hose running from the bottom of the bucket to a spout at the side of the well can be used. However, the hygiene of this system is poorer, even if the well is protected. It has a Range of depth of 0–15 m (or more sometimes) and it yields 0.25 litres/s at 10 m. It is commonly used all over the world.

Potential problems associated with this type of water pump are; poor-quality rope deteriorates quickly (e.g. sisal rope lasts for only a few months); the bucket falls into the well – to prevent this, communities can keep a spare bucket and fit the bucket into a protective cage, such as that described by (Morgan, 1990); the hose breaks frequently in windlass-and-hose systems; poor hygiene, especially when the rope or bucket touches users' hands or the ground; communal wells tend to become more contaminated than family-owned wells, and the latter should be promoted whenever possible; the rope-and-bucket system is only suitable for limited depths.

Figure 2.12 below shows the schematic diagram of the rope and buket pump.

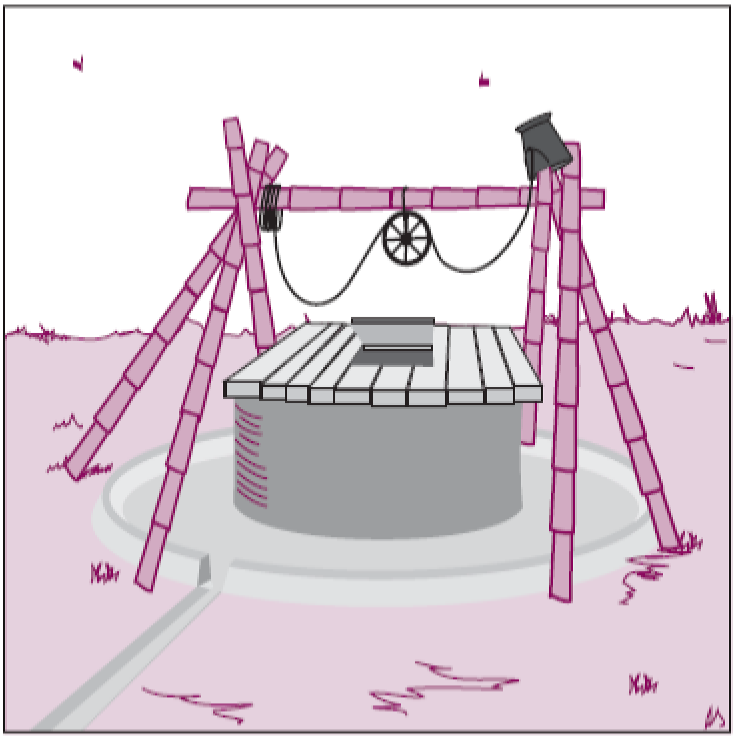

Figure 2.12: Rope and bucket pump

2.8.2 Bucket Pump

The bucket pump is mainly used in drilled wells. It consists of a windlass over a 125 mm PVC tube, down which a narrow bucket with a valve in the base is lowered into the water on a chain. When the bucket hits the water, the valve opens and the water flows in. When the bucket is raised, the valve closes and the water is retained in the bucket. To release the water, the pump operator rests the bucket on a water discharger, which opens the valve in the base. The windlass bearings are made of wood. It has a range of depth of 0–15 m and its yield is relatively low and depends on well depth. It is commonly used in Zimbabwe and elsewhere.
Potential problems associated with this type of water pump are; loose valve parts; broken chain; stones thrown in the well by children; low discharge rates; contamination especially with communal wells; chlorine for disinfecting

the well may not be locally available.
Figure 2.13 below shows the schematic diagram of the buket pump.

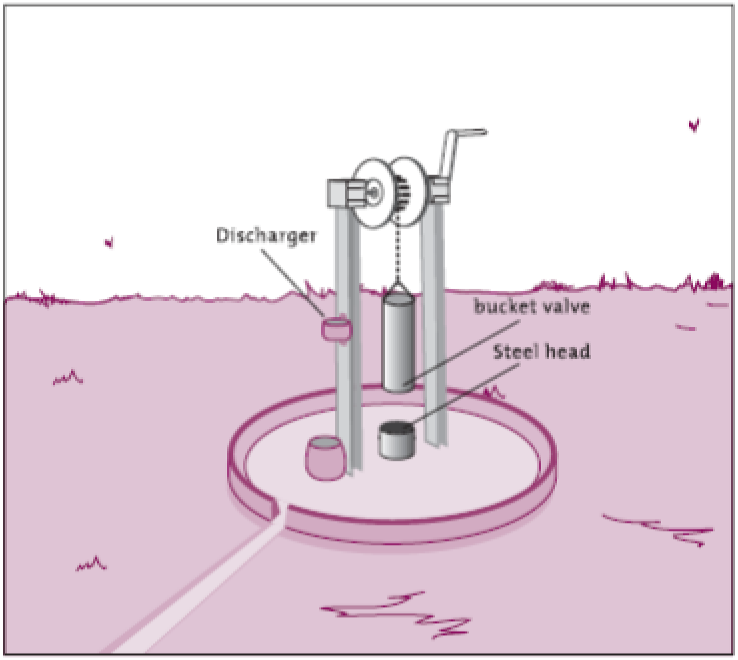

Figure 2.13: Bucket pump

2.8.3 Rope Pump

The basic parts of a rope pump are a pulley wheel above the well, a riser pipe from under the water level to an outlet just under the wheel, and a rope with rubber or plastic washers. The rope comes up through the pipe, over the wheel, back down into the well and into the bottom of the pipe, completing the loop. When the wheel is turned, the washers move upwards and lift water into the pipe towards the outflow. Other important parts are an underwater rope guide that directs the rope and washers back into the pipe, and a frame that holds the pulley wheel. The rope pump can be made at village level using wood, rope and PVC tubing (or bamboo canes with the centres bored out). In Nicaragua, local industries produce an improved type of rope pump that has a metal wheel and frame, industry-made washers, and a guide block of concrete with ceramic and PVC tubes. About 25000 of these pumps have been installed in Nicaragua. Water can be lifted from as deep as 50 m and raised to 5m above ground level. Special models with 3-inch boreholes, and powered by windmills, bicycles, animal traction, electric motors

or small gasoline engines and all power sources give good results. The rope pump yields 0.6 litres/s at 10 m, 0.15 litres/s at 50m. It is usually used in rural and peri-urban areas of Nicaragua, Bolivia, Indonesia, Ghana, Burkina Faso and other countries.
Potential problems associated with this type of water pump are; the rope becomes worn because it is exposed to the sun (exposed rope needs to be protected), or because it is used heavily; the installation of the rope pump was poorly done and its performance is suboptimal; the pulley wheel malfunctions; the pistons, frame and guide block are of poor quality and do not function properly; traditional rope pumps have a lift of only about 10 m; users need to exercise care when using the pump as it is susceptible to contamination; although design and quality of construction may differ significantly, the rope pump can be low-cost, and operated and maintained at the village level.

Figure 2.14 below shows the schematic diagram of the rope pump.

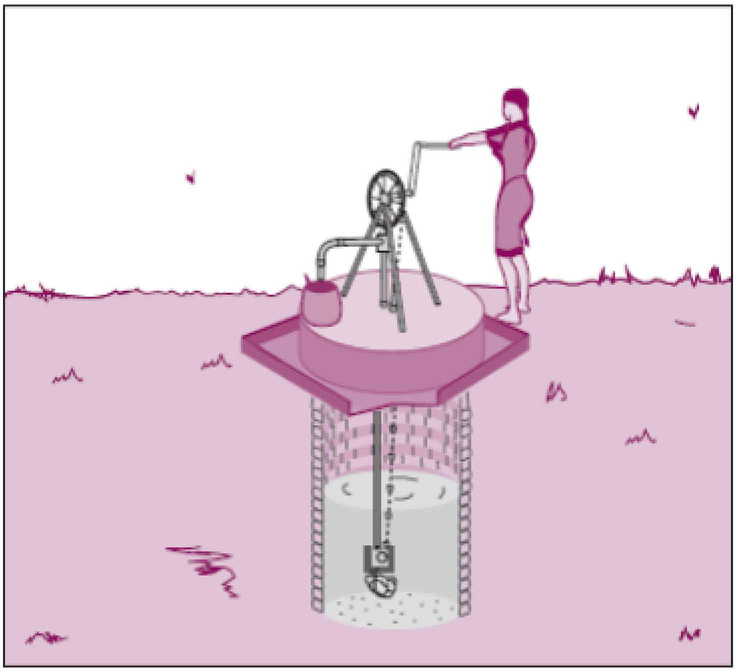

Figure 2.14: Rope pump

2.8.4 Suction Plunger Hand Pump

A suction plunger handpump has its cylinder and plunger (or piston) located above the water level, usually within the pump stand itself. These pumps must be primed by pouring water on the plunger. On the up-stroke of the plunger, the pressure inside the suction pipe is reduced and atmospheric pressure on the water outside pushes the water up into the pipe through the inlet valve. On the down-stroke, a check valve at the inlet of the suction pipe closes and water passes the plunger through an opened plunger valve also called the outlet valve. With the next upstroke, the plunger valve closes and the water is lifted up by the plunger and flows out at the top of the pump, while new water flows into the suction pipe. The operational depth of this type of hand pump is limited by barometric pressure and the effectiveness of the plunger seals to about 7 m at sea level, less at higher altitudes. It yields 0.4–0.6 litres/s at 7 m and commonly used in rural and low-income peri-urban areas where groundwater tables are within 7 m of the surface.
Potential problems associated with this type of hand water pump are; worn

out washers, cupseals and bearings; excessive corrosion that causes pump rods to break, and leaks to appear in the rising mains; many pumps are of poor quality; the biggest drawback of suction pumps is that they can lift water to only about 7 m, and if the water table falls below that level, the pump becomes inoperable and must be replaced with a deep-well pump; contaminated water is often used to prime suction pumps; most pumps are designed for family use and are not sturdy enough for communal use.
Figure 2.15 below shows the schematic diagram of the suction plunger hand-pump.

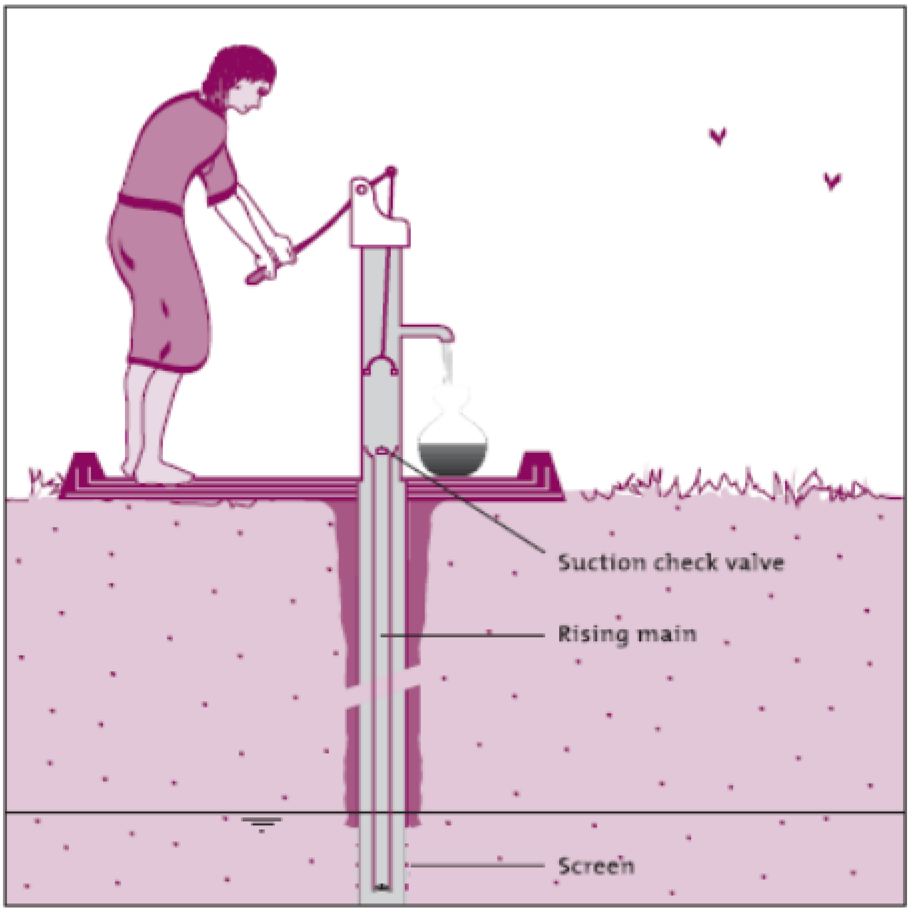

Figure 2.15: Suction plunger hand pump

2.8.5 Direct Action Hand Pump

Direct action hand pumps are usually made of PVC and other plastics, and are installed on boreholes of limited depth. A plunger is attached to the lower end of a pump rod, beneath the groundwater level. The user moves the pump rod in an up-and-down motion, using a T-bar handle. On the up-stroke, the plunger lifts water into the rising main, and replacement water is drawn into the cylinder through the foot valve. On the down stroke, the foot valve closes, and water passes through a one-way valve in the plunger and is lifted on the next up-stroke. Because direct action handpumps have no mechanical advantage, such as the lever or fly-wheel of a deep-well hand pump, direct action pumps can only be used to depths from which an individual can physically lift the column of water (about 12 m). However, the mechanical simplicity, low cost and light weight construction makes these pumps well equipped to meet O&M objectives at the village level. It yields 0.25–0.42 litres/s at 12 m depth and commonly used in rural and low-income peri-urban areas, where groundwater tables are within 12 m of the surface.

Potential problems associated with this type of hand water pump are; worn washers, plungers and foot valve parts; abrasion of the seal on the PVC cylinder and between the pump rod and rising main; broken or damaged handles; the maximum lift is limited to about 12 m; the force needed to pump the water may be too great for children, especially if the water table is below 5 m.

Figure 2.16 below shows the schematic diagram of the direct action hand-pump.

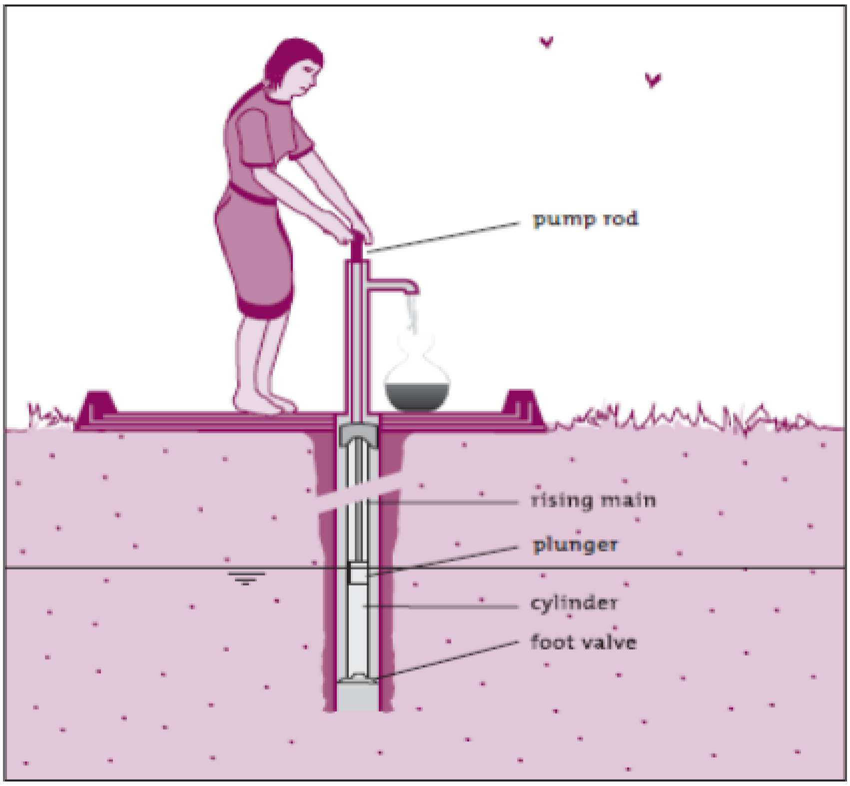

Figure 2.16: Direct action hand pump

2.8.6 Deep-well Diaphragm Pump

Inside a cylindrical pump body at the bottom of the well, a flexible diaphragm shrinks and expands like a tube-shaped balloon, taking the water in through an inlet valve and forcing it out through an outlet valve. The cylindrical pump is connected to a flexible hose which leads the water to the surface. Movement of the diaphragm is effected by a separate hydraulic circuit that consists of a cylinder and piston in the pump stand, and a water-filled pilot pipe, which is also a flexible hose. The piston is moved, usually by pushing down on a foot pedal, although conventional lever handles may also be used. When foot pressure is removed, the elasticity of the diaphragm forces water out of it, back up the pilot pipe, and lifts the foot pedal. Deep-well diaphragm pumps are still being improved, but most imperfections have been corrected.

The principle of the pump is attractive because it allows thin flexible hoses to be used, making the pump easy to install or remove without the need for special tools or equipment. Replacing spare parts is usually easy; only the replacement of the diaphragm may need the assistance of a skilled mechanic. It is possible to install several pumps in a single well or borehole. It yields 0.50 litres/s at 10 m depth; 0.32 litres/s at 30 m; and 0.24 litres/s at 45 m and a useful life of eight years.
Potential problems associated with this type of water pump are; pedal rod guides and plunger seals need to be replaced frequently, and the plunger guides may wear out quickly; drive hoses often need to be re-primed because water leaks past the plunger seals, and the foot pedal then needs to be raised by hand; if solid particles enter the down hole pumping element it must be cleaned, since this will cause the diaphragm to stop working or even rupture.

Figure 2.17 below shows the schematic diagram of the deep-well diaphram pump.

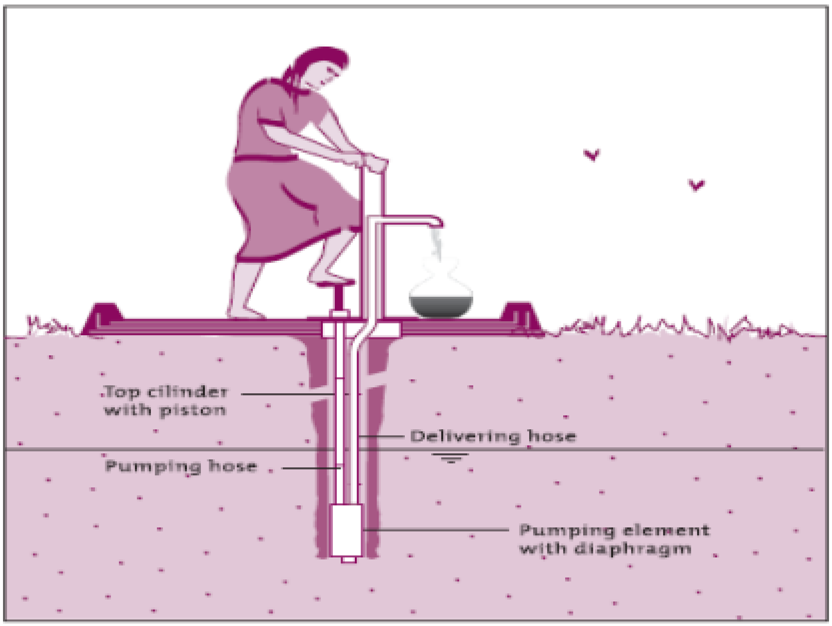

Figure 2.17: Deep-well diaphragm pump

2.8.7 Deep-well Piston Hand Pump

With a deep-well piston hand pump, the piston is placed in a cylinder below the water level, which is usually 15–45 m below the ground. The pumping motion by the user at the pump stand is transferred to the piston by a series of connected pumping rods inside the rising main. On the upstroke, the plunger lifts water into the rising main, and replacement water is drawn into the cylinder through a foot valve. On the down-stroke, the foot valve closes, and water passes the plunger and is lifted on the next up-stroke. The pumping height is limited only by the effort needed to lift the water to the surface. Nowadays, most pump cylinders have an open top. This allows the piston and foot valve to be removed through the rising main for servicing and repairs, while the rising main and cylinder stay in place.

Potential problems associated with this type of water pump include: the most common repair is replacing the plunger seals; there can be problems with the quality control of local manufacturers, especially in African countries; the hook-and-eye connectors of the pump rods tend to break more often than conventional connections, and the rods may also become disconnected, or bend spontaneously; corrosion is a problem, especially where the groundwater is aggressive, and it can affect the pump rods if they are not made of stainless steel, the rising main (if not galvanized iron tubing), the cylinder, the housing for the pump head bearing, and other pump stand parts; handles become shaky or broken, mainly because of worn-out bearings; the number of problems usually increases with increasing depth of the groundwater (the maximum lift for a pump varies according to the brand, but is usually 45–100 m).

Figure 2.18 below shows the schematic diagram of the deep-well piston handpump.

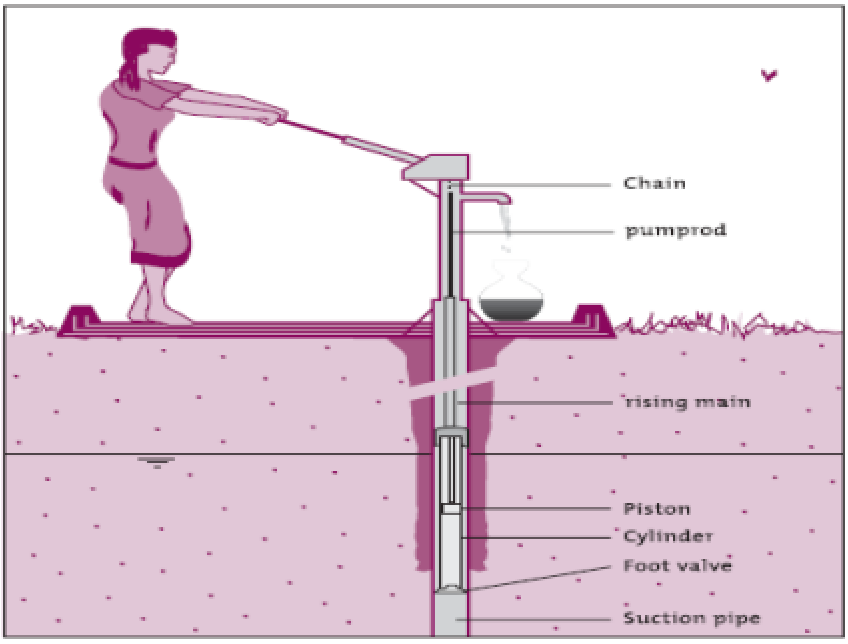

Figure 2.18: Deep-well piston handpump

2.8.8 Submersible Pump

For deep-well applications, centrifugal pumps are housed with the electric engine in a single unit that is designed to be submerged. Usually, a multiple-stage pump is used. The multiple-stage pump is placed above a motor and under a check valve that leads to the rising main. Submersible pumps are self-priming, if they do not run dry. To prevent the pump from running dry, the water level in the well must be monitored, and pumping must be stopped if the water level drops to the intake of the pump.
Power is delivered through a heavily insulated electricity cable connected to a switch panel at the side of the well. The power may come from an AC mains connection, a generator, or a solar power system. They have a range of depth of7–200 m or more and efficiency range of 40– 70%.
Potential problems associated with this type of water pump are; sand or other particles may enter the pump and cause abrasion damage; the rising main may corrode; the pipeline system can be damaged by the severe pressure surges that result when the pump is started or stopped abruptly; the main

limitations of a submersible centrifugal pump are its price, the need to maintain a reliable supply of electricity or fuel, and the high level of technology involved.

Figure 2.19 below shows the schematic diagram of the submersible pump.

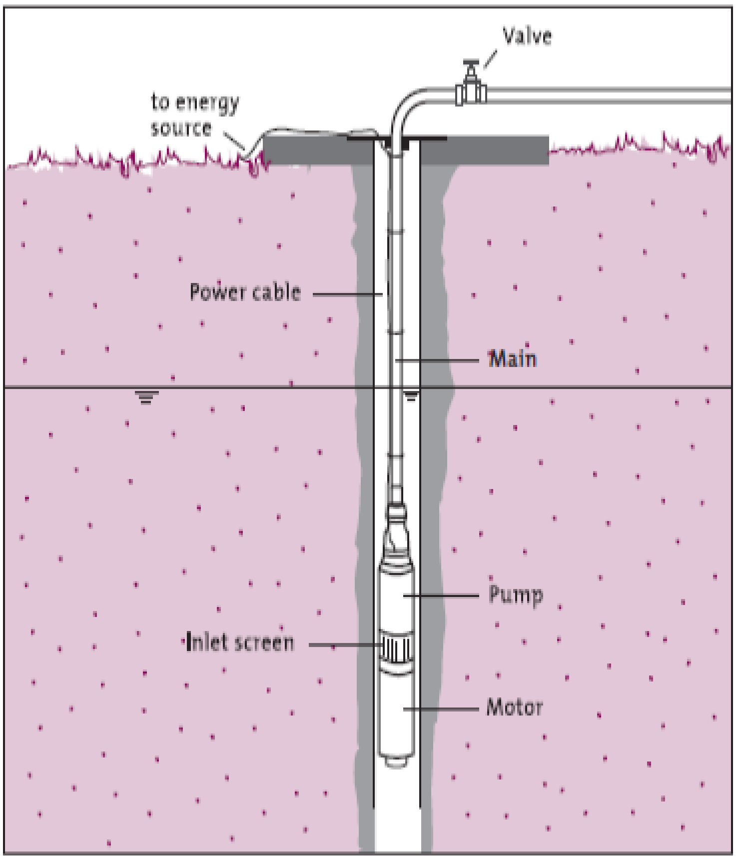

Figure 2.19: Submersible pump

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Chapter 3

Methods and Results

3.1 Introduction

This chapter presents the methodologies and instruments which were used in the project to execute each specific objective.

3.2 Research Area

The project is based on modification of a typical hand borehole by automating a manual borehole with a pendulum.

3.3 Data Sources

Data was collected using different sources which include; the primary data source and secondary data source.

3.3.1 Primary Data Source

The primary data is the raw data which is collected from the experimental setup. The data is inform of the discharged liquid obtained by varying the machine parameters namely: length of the pendulum, mass of the pendulum and the swing angle of the pendulum.

3.3.2 Secondary Data Source

The secondary data is derived from different write ups by different authors, which include: journals, internet, library, and other relevant literature reviews.

3.4 Data Collection Methods/ Tools

In this project, various tools and techniques were used during data collection and among these include: experimentation, desk search, internet search, library search, and consultation.

3.4.1 Desk Search

This is the method of data collection which involves the use of relevant published books, internet, libraries, articles, journals and other relevant literature reviews to obtain the required information about boreholes. This information required involve; the types of existing boreholess, their specifications, advantages and disadvantages, how they are used in Uganda, Africa and world at large. The aim of doing this is to compare the existing boreholes with the modified one hence determining the efficiency and effectiveness of the modified machine.

3.4.2 Experimentation

This is the process of performing a scientific procedure, especially in a laboratory to determine something. While using this method, i was able to determine the amount of discharged water at different intervals by varying the length of the pendulum, mass of the pendulum and the angle of swing of the pendulum. The discharged water was recorded in units of litres/second.

3.4.3 Internet Search

This refers to the use of the internet to collect data. While using this method, i was able to achieve some of my objectives such as using the internet to study the various existing typical hand boreholes in order to understand their mode of operation as well as their advantages and disadvantages to people living in the community. In so doing i was able to obtain the relevant information required for the successful completion of this project.

3.4.4 Library Search

This is a method of data collection that allows to search for items owned by a specific library, including books, movies, journals, magazines among others. I used this method to determine the nature and size of materials that i used to come up with the layout of the machine. This was achieved by watching videos on youtube concerning the research area to observe the steps taken to design and fabricate the borehole layout.

3.4.5 Consultation

This refers to a conference for the exchange of information and advice. Using this method, i was able to inquire from spare parts dealers in order to guide me on how to select different materials to be used in this project such as the size and cost of reciprocating pump.

3.4.6 Formulae

Using Bernoulli's equation to determine the power required by the pump;

$$Power, P = \frac{\Delta PQ}{\eta}$$

Where;
ΔP is the change in total pressure between the inlet and outlet (in Pa).

Q, the fluid flow rate is given in $\frac{m^3}{s}$.

η is the pump efficiency, and may be given by the manufacturer's information.

3.5 Studying the Existing Hand Water Boreholes

Determining the power required to operate the existing manual water boreholes is important for both their efficiency and to match the prime mover.

The power capabilities of humans at various ages and the durations are shown in table 3.1 on page 35 and intrest is put on lifting 20 to 40 litres at a time.

Table 3.1: Power capabilities of human beings

Age(Years)	**Human Power(Watt)& Duration(minutes)**					
	5min	10min	15min	30min	60min	180min
20	220	210	200	180	160	90
35	210	200	180	160	135	75
60	180	160	150	130	110	60

3.5.1 Review of Water Lifting Techniques and Listing of Candidate Pumps

There are four different mechanical principles of transferring water from one location to another and these are shown in table 3.2 on page 35.

Table 3.2: The four mechanical means of lifting water

Technique	**Operation**
Direct lift	By using a container to physically lift the water
Displacement	Water can be regarded as incompressible and can therefore be displaced
Creating a velocity head	Flow or pressure can be created by propelling water at high speed
Using the buoyancy of a gas	Passing air bubbles through water will raise the level of the surface

3.6 Cost Analysis for the Project

Table 3.3 on page 36 shows the components, quantity, size and cost that i used inorder to come up with the machine layout.

Table 3.3: Cost estimate of the project

Component	**Quantity**	**Size**	**Cost(Ug.shs)**
Reciprocating pump	1	check vaives,piston	20000
Cylindrical pipe	1	pvc pipe	10000
Cycle frame	1	wood(10 m)	20000
Pendulum rod	1	Thread(2 m)	1000
Tension spring	1	5 N/m	5000
Lever	1	wood(1 m)	15000
Weights	6	1/2 kg each	14000
Jerrycan	1	5 litres	3000
Total	-	-	88000

From the table, it is clear that i used cheap and affordable materials such as wood because it is readily available. Further, i did not include the labour costs since all the work was done by me with the help of a friend.

3.7 Methods Used to Achieve the Set Objectives

Table 3.4 on page 38 summarizes the methodologies and instruments that are used in the project for each specific objective.

3.8 Results Obtained by Varying the Mass of the Pendulum

Table 3.5 on page 39 shows the discharge obtained by varrying Mass on the pendulum while keeping Length of the pendulum and the swing angle fixed.

3.9 Results obtained by Varying the Length of the Pendulum

Table 3.6 on page 39 shows the discharge obtained by varrying Length of the pendulum while keeping Mass on the pendulum and the maximum swing angle fixed.

3.10 Results Obtained by Changing the Position of the Pendulum

Table 3.7 on page 39 shows the discharge obtained by varying the displacement angle of the pendulum while keeping maximum weight on the pendulum and the maximum length of the pendulum fixed.

Table 3.4: Methodology and data instruments for each specific objective.

OBJECTIVES	TOOLS/TECHNIQUE	DESCRIPTION	OUTCOMES
1.To study the existing types of hand water boreholes	Internet search	Through visting the internet and read about various hand water boreholes and their mode of operation.	Effectiveness and Efficiency of the machine will be determined.
2. To determine machine parameters.	Experimentation Consultation	Through setting up experimental procedures and carrying them out precisely.This will enable to determine how discharge is obtained from various parameters.	Accurate machine parameters were determined.
3. To select, size and develop machine layout.	Desk search	Through use of drawing skills with the help of knowledge from different textbooks to develop the actual design. Obtaining components from spare parts dealers.	A clear layout and design mechanism will be determined.

Table 3.5: Discharge in millitres obtained at different weights

Mass(kg)	**Discharge(ml/30s)**	**Discharge(ml/s)**
0.5	60	2.0
1.0	120	4.0
1.5	190	6.3
2.0	250	8.3
2.5	340	11.3
3.0	420	14.0

Table 3.6: Discharge in millitres obtained at different length of the pendulum

Length(m)	**Discharge(ml/30s)**	**Discharge(ml/s)**
0.1	50	1.67
0.2	80	2.67
0.3	120	4.00
0.4	150	5.00
0.5	160	5.33
0.6	175	5.83

Table 3.7: Discharge in millitres obtained by varying the position of the pendulum

Swept angle(°)	**Input Energy(J)**	**Discharge(ml/30s)**	**Discharge(ml/s)**
0°	14.715	210	7.0
30°	16.991	420	14.0
45°	20.810	540	18.0
60°	29.43	780	26.0
90°	44.145	1020	34.0

Chapter 4

Presentation and Data Analysis

4.1 Introduction

This chapter includes the diagram of the borehole developed. It also includes the Analysis of the machine parameters such as Length of the pendulum, Mass of the pendulum and the swing angle of the pendulum.

4.2 Diagram of the Developed Borehole

4.3 Analysis of the Machine Parameters

The machine parameters which were analysed in this section include: Mass of the pendulum, Length of the pendulum and the swing or displacement angle of the pendulum mass.

4.3.1 Analysis of the Mass of the Pendulum

Here, the discharge is found out by changing the weights on the pendulum while maintaining the maximum swing angle and maximum length of the pendulum. Figure 4.2 on page 42 illustrates how Discharge (ml/s) varies with Mass of pendulum (kg). Here, the amount of liquid discharged was measured using a 100 ml measuring cylinder and the readings were taken after 30 seconds. Then further computations involving converting the discharge obtained in 30 seconds to the discharge collected in one second were done by dividing the latter by a number 30.

The nature of the graph in figure 4.2 on page 42 indicates that as more weights are added to the wire hanger(pendulum), the discharge increases.

Figure 4.1: Diagram showing the developed borehole

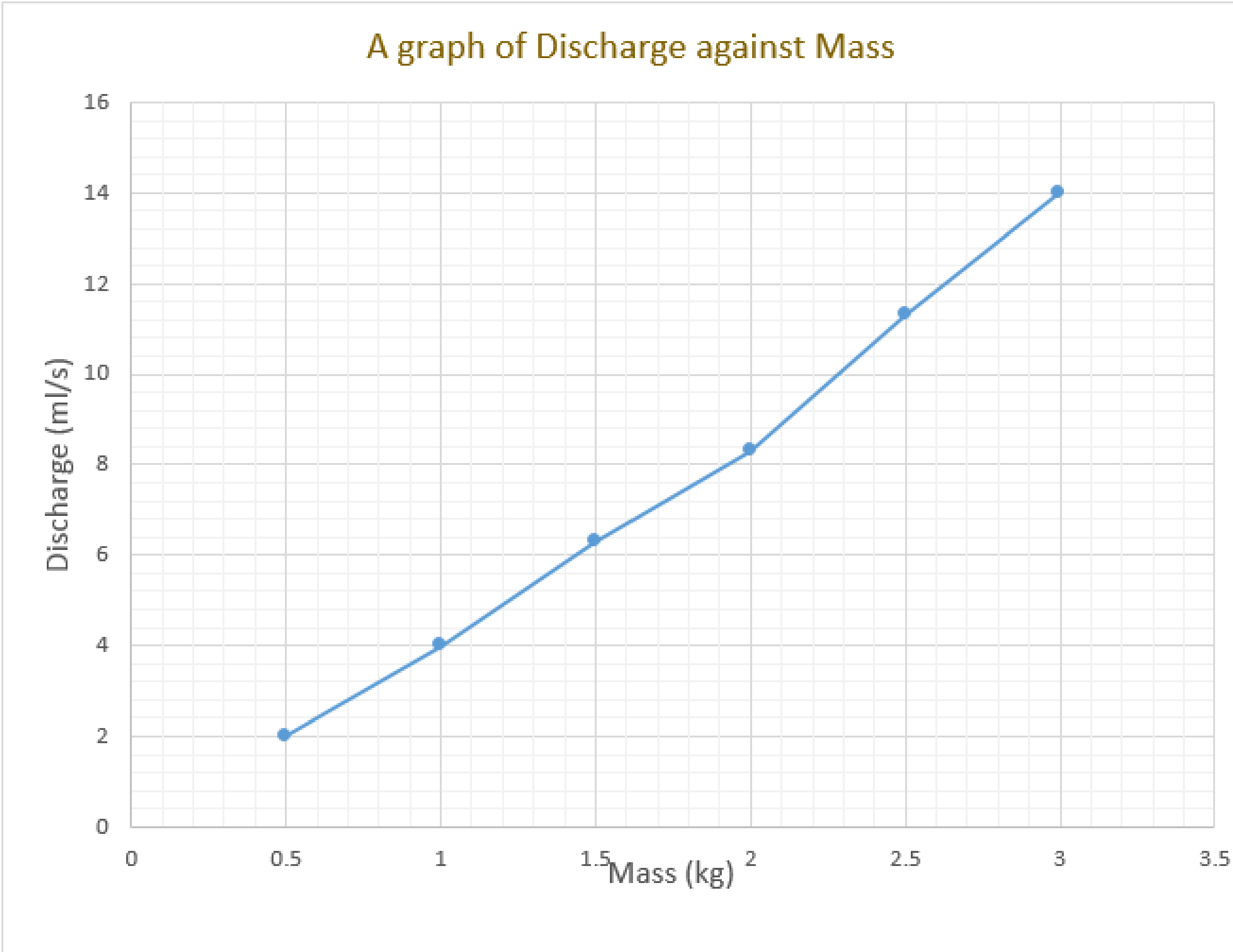

Figure 4.2: Analysis of the mass of the pendulum

This is because a large weight on the pendulum will provoke large oscillations of the pendulum which will inturn lead to maximum out put inform of the discharged water. The maximum discharge is 14 ml/s obtained when the mass on the pendulum is 3 kg while the minimum out put is 2 ml/s obtained when the mass on the pendulum is 0.5 kg.

4.3.2 Analysis of the Length of the Pendulum

Here, the discharge is found out by varrying the length of the pendulum while maintaining the maximum swing angle and the weight on the pendulum. Figure 4.3 on page 43 shows how Discharge (ml/s) varies with the

Length of pendulum (m). The amount of liquid discharged was measured using a 100 ml measuring cylinder and the readings were taken after 30 seconds. Then further computations involving converting the discharge obtained in 30 seconds to the discharge collected in one second were done by dividing the latter by a number 30.

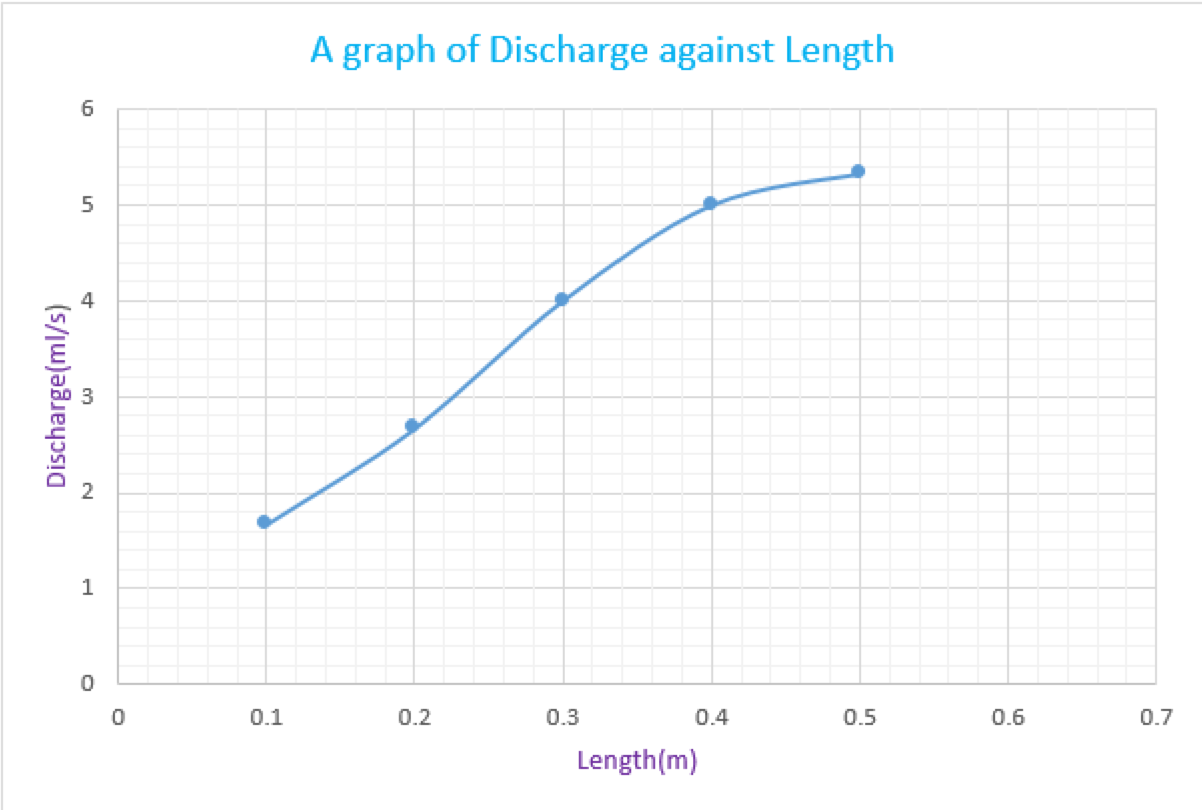

Figure 4.3: Analysis of the length of the pendulum

The nature of the graph in figure 4.3 on page 43 indicates that as the length of the pendulum rod is increased, the amount of discharged water increases. This is because a longer pendulum rod will lead to large oscillations of the pendulum which will inturn lead to maximum out put inform of the discharged water. The maximum discharge is 5.5 ml/s obtained when the length of the pendulum rod is 0.5 m while the minimum out put is 1.8 ml/s obtained when the length of the pendulum is 0.1 m.

4.3.3 Analysis of the Swept Angle by the Mass

Table 4.1: Analysis of the swept angle by the mass

Position of the mass with respect to the lever	**Mathematical formula**	**Energy input to the pump**
Initially(At 0°)	$E_{\mathrm{p}} = mgl$	$E_{\mathrm{p}} = 14.715$
At 30°	$E_{\mathrm{p}} = \frac{2}{\sqrt{3}}mgl$	$E_{\mathrm{p}} = 16.991$
At 45°	$E_{\mathrm{p}} = \sqrt{2}mgl$	$E_{\mathrm{p}} = 20.810$
At 60°	$E_{\mathrm{p}} = 2mgl$	$E_{\mathrm{p}} = 29.430$
At 90°	$E_{\mathrm{p}} = 3mgl$	$E_{\mathrm{p}} = 44.145$

In order to effectively analyse the swept angle by the mass, i used the maximum weight which was 3 kg and the maximum length of the pendulum rod which was 0.5 m. The energy input to the pump was determined at different positions of the pendulum using the idea that potential energy is equivalent to mass multiplied by acceleration due to gravity which is 9.81 m/s^2 and then the product is multiplied by the length of the pendulum. The input energy is given interms of potential energy because the position of the pendulum determines the amount of energy input to the pump. As evidenced from table 4.1 on page 44, the input energy is maximum at the greatest angle and it is minimum at the least angle. This means that maximum discharge is obtained when the angle of swing of the pendulum is maximum and minimum discharge is obtained when the angle of swing of the pendulum is minimum. Hence a graph of Discharge(ml/s) against energy input(J) is plotted.

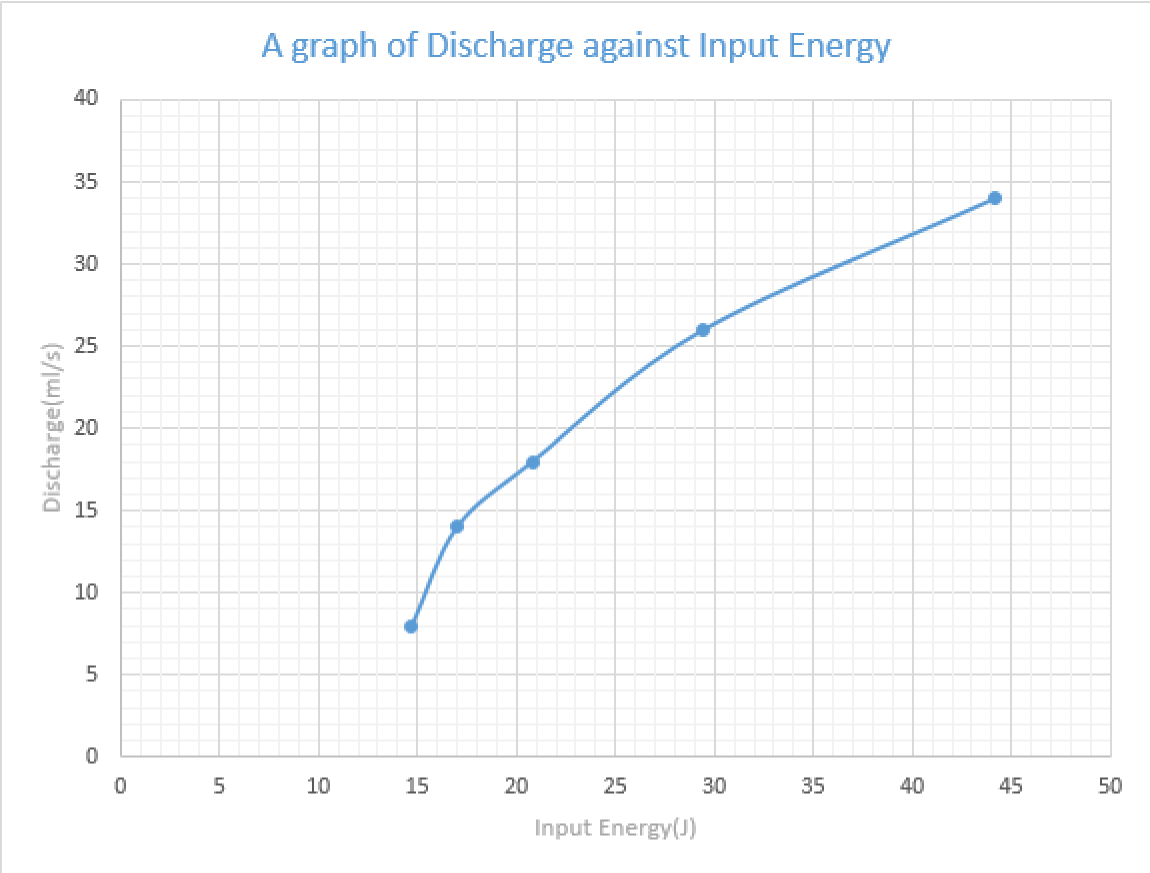

Figure 4.4: Swept angle graph

The nature of the graph in figure 4.4 on page 45 indicates that as the position of the pendulum is raised, the amount of discharged water increases. This is because a raised pendulum position will lead to large oscillations of the pendulum since the pendulum has to move a long distance which will inturn lead to maximum out put inform of the discharged water. The maximum discharge is 34.0 ml/s obtained when the input energy to the pendulum is

44.145 J while the minimum out put is 7.0 ml/s obtained when the input energy to the pendulum is 14.715 J.

Chapter 5

Conclusion and Recommendation

5.1 Introduction

This chapter consists of the conclusions drawn from the project and the recommendations.

5.2 Conclusion

This project was about development of a manual automated borehole which uses a pendulum to pump water and should be used in rural communities where there exists no electricity and other means of pumping water are expensive for the poor families. Basing on the findings of the study, the following conclusions have been drawn;

- With reference to the objectives of the project, the existing pumping methods were successfully reviewed which was achieved with the help of library search, internet and local information.
- The different components were designed and selected and pendulum manual automated borehole was assembled.
- The modified manual automated borehole with a pendulum requires only a minimum mass on the pendulum to generate a large power input to the pump and to oscillate the pendulum and maintain these oscillations for about 45 strokes per minute.
- From the design of pendulum operated borehole, we have reduced the human effort by providing the pendulum bob which is attached in the

hand lever. While pumping, the pendulum oscillates to and fro and provides continuous energy to the hand lever which pressurizes the water and lifts the water from lower head to higher head and provides the continuous flow of liquid. This is one of the methods that help the rural people to access liquids easily for spraying pesticides, gardening purposes and for Drip irrigation.

5.3 Recommendation

With regard to the process undertaken in the compilation of this document, the observations made and the system developed, the following recommendations have been drawn;

i. The design should be improved by using metallic materials instead of wooden and plastic so that heavy weights can be added to the pendulum without breaking of the lever.

ii. Apart from using pendulum water pump for pumping water for irrigation, it can further be applied in other fields. These include; sewage plants used in the collection and treatment of sewage, Chemical Industry to transport fluids to and from various sites in the chemical plant, Petroleum Industry for use in every phase of processing of petroleum, its transportation and separation of the impurities, Medical Field to pump fluids in and out of the body.

iii. Further research should be carried out as far as pendulum based hand borehole is concerned as this could solve many problems in the agriculture and fisheries, health and energy sectors for this nation, with the majority of areas lacking access to electricity.

iv. A proper maintenance schedule should be adhered to so as to get the best output of the machine. Necessary repairs need to be done in time such that the borehole is efficient all the time.

v. Development of operating, service, catalogue manuals for routine maintenance should be carried out.

vi. For large scale applications, the frame used should be metallic so as to be able to handle large weights applied on the pendulum side.

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