Oxford Cambridge and RSA

Friday 14 June 2019 – Morning

A Level in Design and Technology: Design Engineering

H404/02 Problem Solving in Design Engineering

Resource Booklet

Time allowed: 1 hour 45 minutes

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INSTRUCTIONS
- You must read this Resource Booklet through before answering any questions.
- The recommended reading time for this Resource Booklet is **35 minutes**.
- This Resource Booklet is to be used when answering all questions.
- The question paper tells you when to refer to the information contained in this Resource Booklet.

INFORMATION
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- This document consists of **8** pages.

The stimulus in this booklet relates to issues and opportunities encountered when using technology to supply populations with a basic human need – access to water.

Water Scarcity

Water scarcity is the lack of sufficient available water resources to meet the demands of water usage within a region.

It already affects every continent and around 2.8 billion people around the world for at least one month out of every year. According to the World Health Organisation (WHO), more than 1.2 billion people lack access to clean drinking water.

Water scarcity may be caused by climate change such as altered weather patterns including droughts or floods, increased pollution and increased human demand and overuse of water.

Fig. 1

Water scarcity can be a result of two mechanisms: physical water scarcity and economic water scarcity. Physical water scarcity is a result of inadequate natural water resources to supply a region's demand and economic water scarcity is a result of poor management of the sufficient available water resources.

The reduction of water scarcity is a goal of many countries and governments. The United Nations (UN) recognises the importance of reducing the number of people without sustainable access to clean water and sanitation.

Africa

Africa faces huge challenges with multiple issues that adversely affect public health. One major challenge is the ability for both rural and urban Africans to access a clean water supply.

The WHO (2006) stated that in 2004 only 16% of people in sub-Saharan Africa had access to drinking water through a household connection (an indoor tap or a tap in the yard). Not only is there poor access to readily accessible drinking water, even when water is available in the small towns there are risks of contamination due to several factors. When wells are built and water sanitation facilities are developed, they are improperly maintained due to limited financial resources. Water quality testing is not performed as often as is necessary and lack of education among the people utilising the water source leads them to believe that as long as they are getting water from a well it is safe. Once a source of water has been provided, quantity of water is often given more attention than quality of water.

The implications of lack of clean water and access to adequate sanitation are widespread. Young children die from dehydration and malnutrition. Diseases such as cholera are spread during the wet season. Women and young girls who are the major role-players in accessing and carrying water are prevented from doing income-generating work or attending school as the majority of their day is often spent walking miles for their daily water needs. They are also at an increased risk of violence since they travel such great distances from their villages on a daily basis.

Water Sources

Rainwater is usually safe to drink unless it is found in an area with particularly severe air pollution. Catching rain is fairly simple and it is possible to collect and store rainwater from roofs or with other rain catchment systems. It is always necessary to have a clean storage vessel for rainwater and it is advisable to treat rainwater before drinking. It is also necessary to have the capacity to store large amounts of rainwater to assure adequate quantities are available during dry seasons.

Surface water is the most recognisable source of water and is easier to contaminate than groundwater. Rivers, streams and lakes are examples of surface water. Rainwater runoff is one of the major types of water contamination. Rain water runs along the ground and can pick up things like human and animal faeces and harmful chemicals and deposit them in rivers, streams and lakes. Any surface water that is to be used for drinking is often unsafe and must first be treated.

Groundwater is usually safer to drink than surface water and is a more reliable source during droughts. Water found underground has passed through several layers of soil. The soil acts as a natural filter removing harmful pathogens and chemicals. Groundwater found deep underground (more than 10 metres) may well be protected from many types of water contamination and be safe to drink. However, the high costs associated with drilling for water and the technical challenges in finding sources that are large enough to serve a population present challenges that limit accessing the resource. Groundwater is not a fail-safe resource when it comes to providing clean water. There may be contamination of the water with heavy metals and bacteria may be introduced by leaking septic systems or contaminated wells. For these reasons, it is important that groundwater is monitored frequently which is costly and requires technical abilities that may not be present in rural areas.

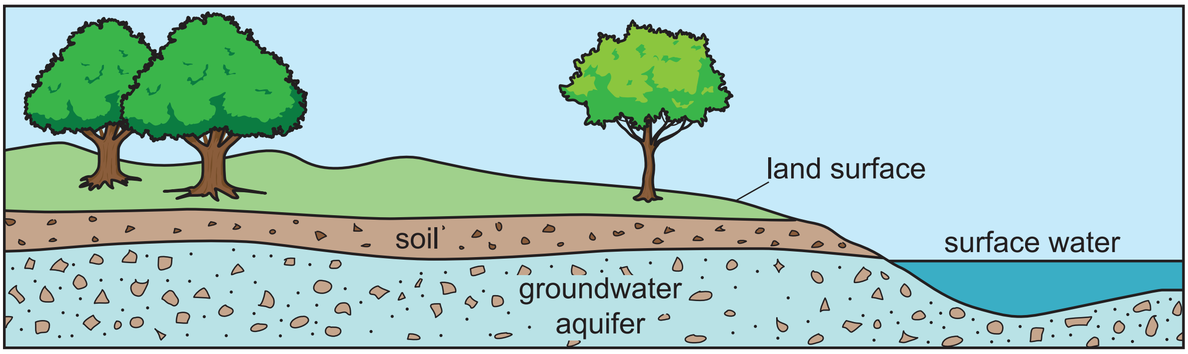

Fig. 2 – Groundwater and surface water

India MkIII Hand-Operated Water Pump

The hand-operated water pump in **Fig. 3** is commonly used throughout countries that require the means to collect groundwater suitable for use as drinking water from wells to a maximum depth of about 80 metres. The delivery height depends on the water level in the water well. It can be operated with the aid of human or animal power.

Fig. 3 – India MkIII water pump

The pump is designed to be built and used around the equator where the climate is arid and the temperatures are high. Whilst there are tropical monsoons the resulting water is quickly evaporated or lost to ground water and what surface water is left is often contaminated.

These pumps are located in or near to local villages (depending on the well location). They are designed to be built on unprepared land meaning that the pump could be located in open waste land or a prepared area. It also means a single well can be located and shared between several villages. This may mean villagers have to transport their water over large distances but in turn this may reduce the setup/running costs of the unit per village.

Constructed of a cast alloy the main parts of the pump are designed to last for many years of use and be able to withstand the harsh climate which they will be used in. Whilst the pump is simple, consisting of few moving parts, there are a few elements of the pump that require regular maintenance to keep it running as efficiently as possible. These parts will need regular lubrication and seals will require replacing. These parts are inexpensive to replace but can take time to source.

India MkIII Pump Operational Details

Fig. 4a and **Fig. 4b** illustrate the operation of the India MkIII hand-operated water pump through **one complete cycle**. When the handle is in the upper position (**Fig. 4a**) the piston is in the lower position and water floods the cylinder. When the handle is returned to the lower position (**Fig. 4b**) the piston rod pulls the piston up, forcing the water out of the water outlet. The pump is then refilled by raising the handle, moving the piston to the lower position and the cycle repeats. Pump dimensions are shown in **Fig. 5** in millimetres (mm**).**

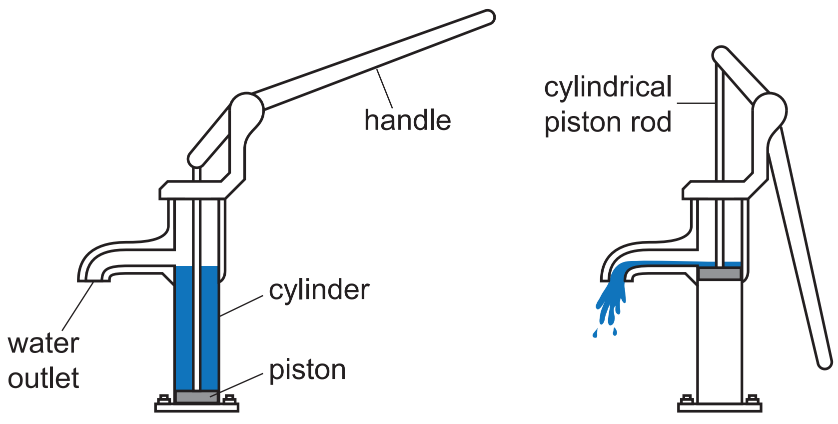

Fig. 4a **Fig. 4b**

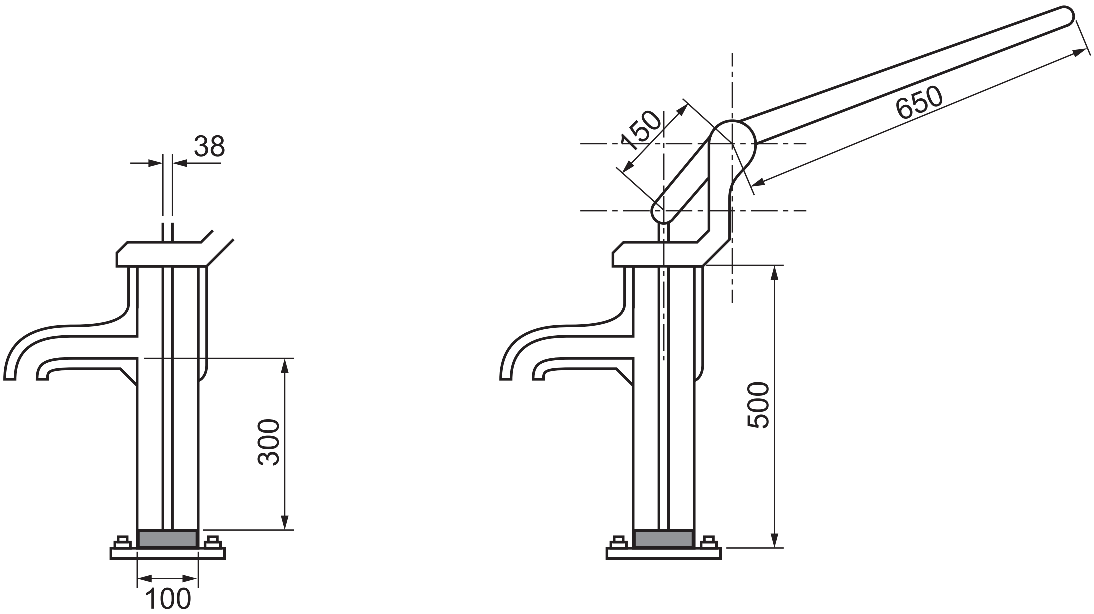

Fig. 5
(not to scale)

RB500 Photovoltaic Panel

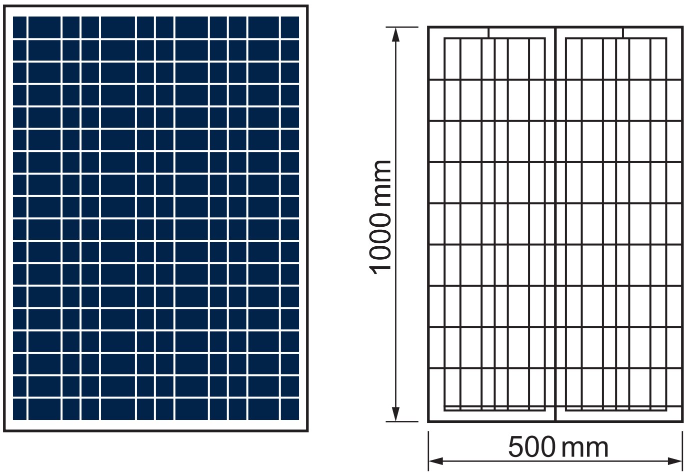

Fig. 6 – Photovoltaic panel
(not to scale)

Specification for photovoltaic panel	
Size of photovoltaic panel (mm)	1000 × 500
Operating temperature range (°C)	–40 ~ 85
Solar cells	Polycrystalline 3 bus bar
Photovoltaic panel yield	0.15
Performance ratio, coefficient of losses	0.75
Mass (kg)	8.78

Specification for photovoltaic panel location	
Annual average solar irradiation ($kWh\,m^{-2}$)	2100
Average annual rainfall (mm)	100
Average daily sunlight (hours)	7
Maximum daily temperature (°C)	41

Construction/maintenance team: Throughout the life span of the RB500 it will need to be accessed, whether this is by the construction team responsible for retrofitting the unit to the existing pumps or the maintenance team. Whilst it is envisaged that the RB500 will require little maintenance there will be small amounts of input required to keep it running as efficiently as possible (cleaning the cells, checking alignment, etc.).

Villagers: The collection of water from wells is currently done mainly by the women and children of the village. It is, however, a physically demanding task not only the journey to and from the water source which often involves miles of walking in the difficult climate but also the pumping of the water once there. With a new system coming online there will need to be some education given to the villagers on how it is operated. They will also have to be made aware of any safety issues that may arise during the RB500's use.

Photovoltaic Panel Control System

PICAXE–18M2 microcontroller pinout diagram

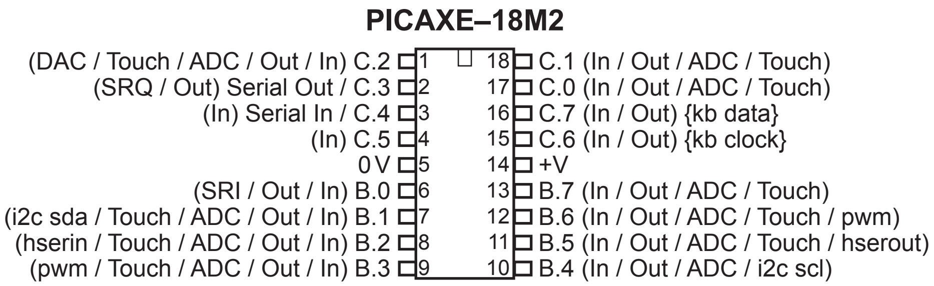

Fig. 7 – Chosen microcontroller

Microcontroller circuit operation

The circuit in **Fig. 8** uses two light dependent resistors (LDRs), positioned either side of the photovoltaic array to detect the position of the sun. When one LDR receives more light intensity than the other the system will turn the motor, connected through a gearbox, to rotate the photovoltaic array into a position where both LDRs receive the same level of light. This operation will always position the photovoltaic array in the optimum position.

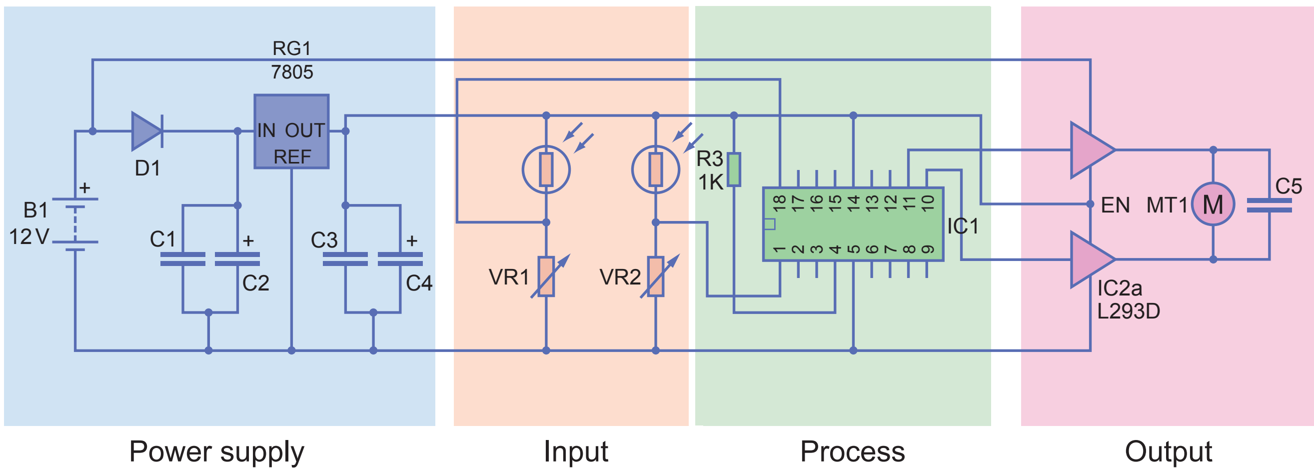

Fig. 8 – Microcontroller circuit

Gearbox

The table below shows details of the spur gears that are available for use in the gearbox to move the photovoltaic array.

Number of teeth	Number in stock
160	2
80	3
40	2
20	3

Fig. 9 – Spur gear

Water Container

Model	DP4b
Container volume (l)	20
Material	PP food grade
Size (mm)	330 × 280 × 280

Strong and durable 20 litre water container with a solid carry handle for easy movement. The container comes with a tap which can be inserted into a bung hole in the base.

Fig. 10 – Water container (not to scale)

Trolley Design

Specification point	DLR-90
Handle adjustable height (mm)	1090–1400
Max Load Capacity (kg)	90
Tyre type	Solid
Unit weight (kg)	10
Wheels (mm)	150 diameter
Carrying bed size (mm)	380 × 250
Frame material	Aluminium
Axle material	Steel
Unit cost (£)	39

Fig. 11 – Trolley

The trolley has an extendable handle.

The carrying bed is made from ABS and is available in a range of colours.