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DESIGN AND CONSTRUCTION OF A DUAL POWERED BUCKET CENTRIFUGE

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Abstract:

The present high cost and fluctuation of electrical power call for research on alternatives to the existing centrifuge using local raw materials. The aim of this paper is to construct a dual powered bucket base centrifuge. This system consists of solar panel, rechargeable battery, electric motor, speed regulator. The components were fixed accordingly until functional equipment with speed setting of 600, 1200, 1800, 2400, 3000, 3600, 4200, 4800, 5400 and 6000 able to withhold power for 7 hours was produced. The locally made centrifuge was quality controlled using a foreign centrifuge (China L2-6k centrifuge) and was found to heave equivalent performance.The project particularly aimed to address its use as the solar power supply centrifuge with economically condition. The major difference in this system is relies on solar energy as a power source for rechargeable centrifuge. It is therefore recommended that construction of this type should be encouraged in other to bridge the gap for fluctuation of electric power, mostly in the rural area and to reduce the cost of the instrument and increase its availability in our laboratories. Further research should be carried out using liquid crystal display to monitor cell separation during centrifugation for different spin speed.

Keywords **—Cell separations, Solar panels, Inverter,Rechargeable, Voltage Regulator or speed control**

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I. INTRODUCTION

A centrifuge is a laboratory device use for separation particles from a solution according to their size, shape, density, viscosity of the medium and rotor speed, which are intended to aid in the diagnosis of blood disorders and diseases. The sample is kept in a rotor that is rotated about a fixed points (axis), resulting in strong force perpendicular to the axis. The centrifuge works using the sedimentation principle, where the centripetal acceleration causes denser substance and particles to move outward in the radial direction. At the same time, objects that are less dense are displaced and move to the centre. Hence, a centrifuge uses centrifugal force to separate two or more substances of different densities or masses from each other.

Generally, laboratory centrifuge is driven by an electric motor and some older one usually turns with hand, puts an object in a rotation around a fixed axis, applying a force perpendicular to the axis. In this paper, the proposed concept is to add rechargeable solar based system to the existing one. This solar is based on photovoltaic technology which converts solar energy into electrical energy to run a DC motor. The sun is a clean and renewable energy source, which are being increasingly implemented in many applications due to the growing concern of environmental pollution. The major distinguishing feature between centrifuge types is speed and capacity.

Aim and Objectives

The main aim of this project work is construction of Dual powered bucket base centrifuge. Specific objectives of this study are;
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i. To perform systematic review of past research works
ii. To design and fabricate a centrifuge for separating blood mixture mixtures using locally sourced materials.
iii. To maintain the speed and electrical power behaviour of the system during the separation of particles from the solution.
iv. To make it available for commercial uses at a low cost with solar base rechargeable power (backup) regulator that differ if from other centrifuge.

Statement of the problem

The present high cost and fluctuation of electric power call for research on an alternative to the existing centrifuge. The drawbacks have so much effect in some hospital in Nigeria, especially in a Rural Health Area with epileptic power supply. The centrifuge presented here is intended to add rechargeable solar based systempower backup to existing work flows, and this additional layer of the backup is quite practical. The construction of dual bucket base centrifuge will reduce the time consumed when there is a power failure in the laboratory during the separation process and instrument range in cost from hundreds of thousands for commercially use will be available to a few thousand.

Significance of the study

The most significant of this project is solving the power failure problem with engineering approach by constructing a solar base rechargeable system with power regulator attached to the centrifuge. Therefore bridging the gap between the system and power failure, mostly is a Rural Health Area. This is to help the Medical Laboratory Assistants (MLAs) to maintain state steady power who most of the time encounter power failure in the cost of separating the particles from a solution.

Limitation and scope of the study

The scope of this study is to improve on a centrifuge that is used in laboratories by constructing a rechargeable power backup to the centrifuge that is operating at the maximum speed of 6000 rpm.

II. DESIGN ANALYSIS OF THE DUAL POWERED CENTRIFUGE

Design Concepts and Consideration

The basic operation principle of the centrifuge designed is the sedimentation principle in which the rotator accelerates the centrifugal force to separate the heavy particles in the samples. This allows for separation of different reagents at different speeds to gives the result instantly.

The centrifuge is constructed in such a way that it has a switch which controls it's on and off, a speed control which determines the relative centrifuge force (RCF), the rotor which bears the centrifuge buckets, the bucket in which the centrifugation tubes are placed.

Materials

The design, material selection and development of the centrifuge were based on the following concepts and considerations:
80mm thick mild steel U-channel was used to fabricate the centrifuge frame in order to withstand vibrations that may arise from its operation.
The centrifuge comprises of two aspects which includes:

i. Mechanical Aspect and
ii. Electrical Aspect

Mechanical aspect

The mechanical aspect of the centrifuge is made of steel and is about 23cm in height with a depth of 14cm. Inside the centrifuge is a spindle with a centrifuge head which bears the bucket to which centrifuge tubes are placed in before centrifugation.

The following materials were bought in the market and were used to fabricate the mechanical part of the centrifuge:

i. **Metal Sheet and Metal Bowl:** The metal sheet is used to crave the base of the centrifuge that is housing the electric motor in position while the bowl is made of metal makes up the upper part with lid. This contains the shield shaft and the trunnion rings.
ii. **Bearing:** this is made up of a set of strong metal ball used to help in the rotation of the shaft so as to reduce friction.
iii. **Metal Rod** (As shaft)**:** it is a piece of metal rod used as a shaft that holds the shield and trunnion in position
iv. **Shield and Trunnion Rings:** This shield is a circular metal that holds the trunnion in four swing-out position
v. **Shears (Metal Cutter)** was used to remove unwanted(metal) material in the form of chips, from a block metal
vi. **Sand paper** is used to polish and smooth the surface of the metal.
vii. **Arc welding Machine** was hired and was used to create heat to melt and join metals.

Electrical aspect

The following electrical components were bought in the market and were used to construct the circuit of the centrifuge.

i. **Solar panels** are devices that allow for the input of sunlight, and convert this sunlight into electricity.
ii. **Inverter** (charge current: 10A, battery voltage: 6v/12v, input voltage: 220v) produce by SOOER High- Technology Enterprise was used to produce and maintain an un-interrupted 220V AC to the centrifuge.
iii. **Batteries** (12v 7.5AH, max initial current less than 2.25A**)** Produce by Stone-Tech was used to stores chemical energy and converts it to electricity energy.
iv. **Voltage Regulator or speed control** (voltage 200 – 250v, wattage 25 – 630w) produce by Zimlite was used to automatically "regulate" voltage level (regulates the speed of the rotor). It basically steps down the input voltage to the desired level and keeps that in that same level during the supply. This makes sure that even when a load is applied the voltage doesn't drop.
v. ***Switch:***It is used to switch the centrifuge on when centrifuging and to turn it off after centrifugation i.e. it controls the on and off of the electrical centrifuge.
vi. ***Cable:*** The cable ensures normal connections of the wires that generate electricity.
vii. ***Electric Motor:*** It drives the mechanical components of the centrifuge thereby bringing about a rotating movement around a fixed axis.
viii. ***Fuse:*** The fuse ensures protection of the equipment's
ix. ***Capacitor:*** It stores electric charges

All Electrical equipment and circuits shall conform to the standards in force and take account of any specific risks which may be present (for example dampness, explosion risk, fire risk, etc.). Equipment and circuits shall also comply with legislation in force relating to the protection and safety of the users.

The electrical component of the centrifuge is represented in the figure below:

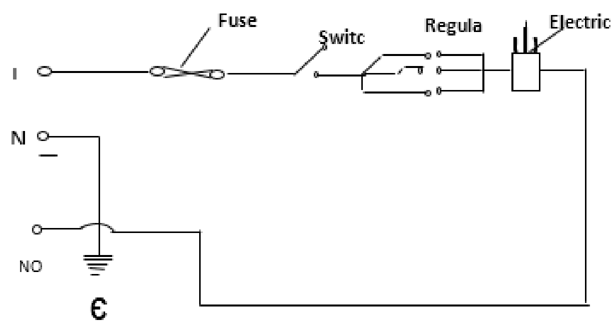

Fig.1: ***Electrical Circuit Diagram***

Design Analysis of Motor Driver Power Dissipation

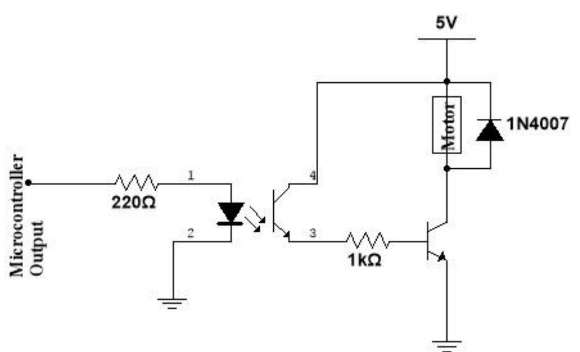

Fig 2: ***Circuit diagram of driver unit.***

The total power dissipation is calculated as follows:

$P_{TOT} = (2\times P_{RDS}) + (2\times P_{SW}) + P_{IVM} + P_{LDO}$

The factorof 2 on the P_{RDS} and P_{SW} terms comes from the fact that there are two H-bridge sin the DRV8825, each driving one phase of the stepper motor, and one side of each H-bridge is being pulse-width modulated to regulate winding current. Calculating the components step-by-step, using data from the DRV8825 data sheet:

$P_{RDS}=$ (**HS-R**$_{DS(ON)}$)$\times$ (**I**$_{OUT(RMS)}$))2) + (**LS-R**$_{DS(ON)}$)$\times$ (I_{OUT}($_{RMS}$))2)

$P_{RDS}= (0.25\Omega\times (1.5A)2) + (0.25\Omega\times (1.5A)2)$

$P_{RDS} = 1.125$ W

$P_{SW}= P_{SW\_RISE} + P_{SW\_FALL}$

$P_{SW}= (½\times V_M\times I_{OUT}\times t_R\times f_{SW}) + (½\times V_M\times I_{OUT}\times t_F\times f_{SW})$

$P_{SW}=$ (½× 24V × 1.5A × 200ns× 30kHz)+ (½× 24V × 1.5A × 200ns× 30kHz)

$P_{SW}= 0.216W$

$P_{IVM}= V_M\times I_{VM}=$ 24V × 5 mA

$P_{LDO}= I_{LDO\_OUT}\times (V_M - V_{OUT})$ = 2 mA× (24V – 3.3V) = 0.04 W

Finally,

$P_{TOT}= (2\times P_{RDS}) + (2\times P_{SW}) + P_{IVM} + P_{LDO}$

$P_{TOT}=$ 2 × 1.125W + 2 × 0.216W + 0.12W + 0.04 W= 2.84W

This is the approximate amount of power dissipated in the IC

Design Analysis of Rechargeable Unit.

Here, the calculation of the Battery Charging Time and Battery Charging current is been done

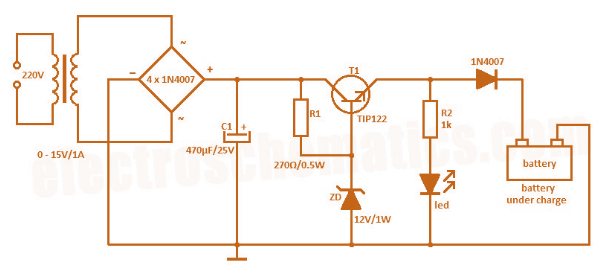

Fig 3: ***Circuit diagram of the rechargeable unit.***

Here is the formula of charging time of a lead acid battery.

Charging time of battery = Battery Ah / Charging Current T = Ah / A

Where, Batteries use = 12v 7.5Ah + 12v 7.5Ah connected in Parallel = 12v 15Ah

- T = Time hrs.
- Ah = Ampere Hour rating of battery **= 15Ah**
- A = Current in Amperes

First of all, we will calculate charging current for 15 Ah batteries. As we know that charging current should be 10% of the Ah rating of battery.

Therefore, Charging current for 15Ah Battery = **15 Ah x (10/100) = 1.5 Amperes.**But due to some losses, we may take **1.5 – 2** Amperes for batteries charging purpose instead of **1.5 Amp.**

Charging time for 15Ah battery **= 15 / 1.5= 10 Hrs.**

Practically, it has been noted that 40% of losses occurs in case of battery charging. Then 15 x (40 / 100) = 6 …..(15Ah x 40% of losses)

Therefore, 15 + 6 = 21 Ah (15 Ah + Losses)

Now Charging Time of battery = Ah / Charging Current

Putting the values; 21 / 1.5 = 12.92 or 13 Hrs (in real case)

Therefore, a**15Ah battery** would take **13 Hrs** to fully charge in case of the required **1.5A** charging current.

Calculation of the Battery Life

Formula and Equations for Battery Life Calculator is giving by;

Battery life = (Battery Capacity/ Load Current) × 0.7
Where; Battery life = in Hours

Battery Capacity = in mAH (milli Ampere hours)
Load Current = Consumption of device in Amperes
0.7 = Battery Cycle life considerations (Run Time)
Battery Life =(**Ah**rating of Battery / Amp) x Run Time %
Battery Life = (15 / 1.5) x 0.7%
= 7 Hours

Estimating Solar Charge Time for Batteries from Solar

The average wattage of solar panel need to charge 12v 7.5Ah battery

12v at 7.5 ***x*** *2*

12v ***x*** *15 = 180 watt-hours*

Charging Time = Battery capacity (in Watt hours)/ Panel power (in Watts) **x** 2
Battery capacity in watts hour Formula is (mAh)*(V)/1000 = (15)*(12)/1000 = 0.18 watts

Charging Time = 0.18/ 180 ***x*** *2*
Charging Time = 0.18/ 360 = 5 Hour

To Calculate Solar Panel Output

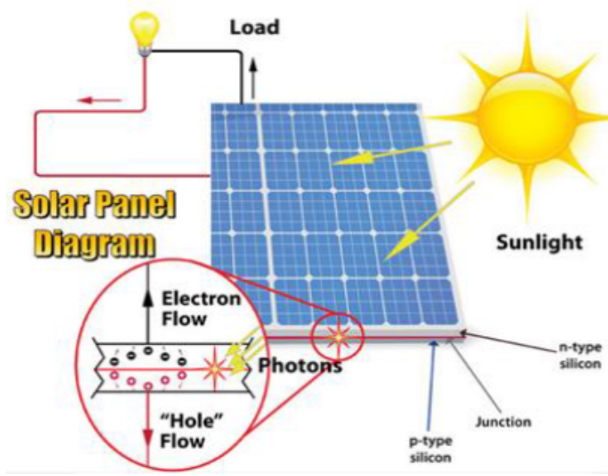

Fig 4: ***Solar panel diagram.***

Solar panel watts x average hours of sunlight x 75% = daily watt-hours.
180 watts solar panels and live in a place where you get 5hours of sunlight per day
180watts x 5hours x 75 = 67,500 daily watts hours
67500/1000 = 67.5 = 68 kilowatt-hours per solar panel.

III. DEVELOPMENTAL PROCEDUREE / DECRIPTION OF THE CENTRIFUGE

The body is divided into two compartments that is the upper part, which was made of metal bowl, and the base made of metal sheet carved in cylindrical shape to house the electric motor. The lid was attached to the body by means of electrical welding with a constructed hinges for essay pivoting. The lids functions as the cover. The bowl was drilled at the centre of its bottom using electric driller to make a hole for the shaft to pass through it. A pair of bolt and nut was then attached to the bottom by electric welding to hold the bowl and base firmly together. The base constructed from a flat metal sheet was carved in cylindrical shape using electrical welding to join edges together. The base was designed to house the electric motor and also to serve as the stand for the entire body. The bottom of the base was covered with mesh to allow free entry of air so as to reduce the heat generated by the motor. The electric motor with an AC voltage of 240V was held in position by means of bolt and nuts tightened firmly to the base. The metal rod known as shaft which measured 90mm in length and 80mm in thickness was attached to the rotating shaft of the electric motor by means of electric welding and a bearing was attached to the rotating shaft of the electric motor by means of electric welding and a bearing was attached to the base of the shaft to provide smooth rotation and also to reduce friction. The shaft was then passed through the hole of the shaft to provide smooth rotation and also to reduce friction. The shaft was then passed through the hole made at the centre of the bowl to be in position. The shield made of a thick metal sheet has its circumference measured at 350mm. the shield was then cut in square shape measuring 37mm by 10mm. The trunnion was fixed to the shield with pin attached to the shield by electric welding hold the trunnion in a swinging position.

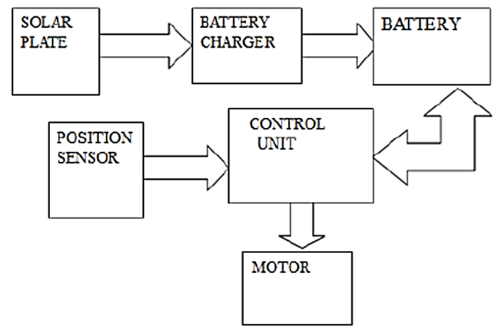

Fig 5: The Block Diagram and Inner Layout of a centrifuge

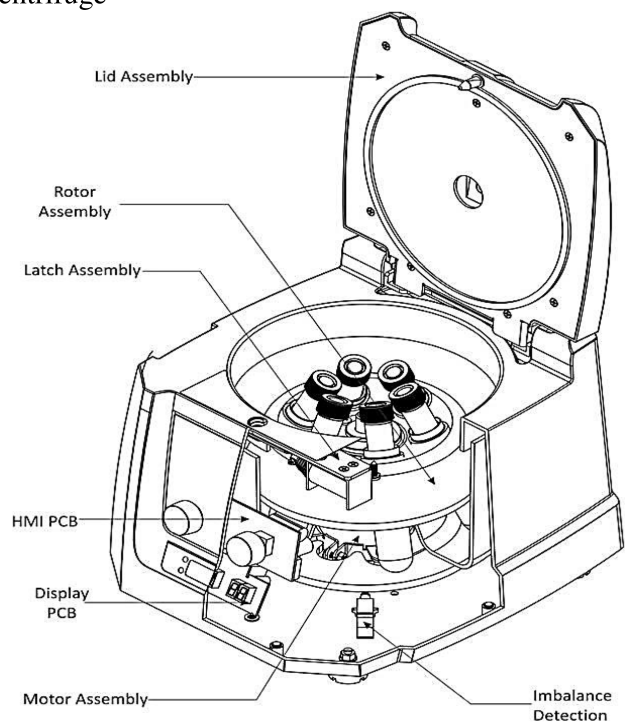

Fig. 6: *Block diagram and Inner Layout of Centrifuge*

Performance Evaluation

On completion of the Construction, a thorough test and assessment of the locally made centrifuge was quality controlled using a foreign China L2-6k centrifuge and was found to have equivalent performance. We demonstrated the system by monitoring cell separations during centrifugation for different spin speeds, concentrations, separation time and vibration.**See Appendix 1.**

IV. RESULTS AND DISCUSSION

The Dual powered centrifuge performance test results shown in Table 1 and 2 revealed that its respective throughput and efficiency is 92.5% when electrically powered and 95.5% when solar powered with rechargeable. The test performance indicators include; optimal speed and specific energy consumption. The optimal speed of the centrifuge is the safest speed required to separate a given mixture in the shortest possible time while the specific energy consumption, *SE* is defined as the ratio of the total energy consumed by the centrifuge to the mass of the mixture separated in one operational cycle.**See Appendix 2.**

Optimal Separation time.

Optimal separation time of the centrifuge was determined from the result of five experimental runs at speeds of 600rpm, 1200rpm, 1800rpm and 2400rpm respectively tabulated in Table 1

Table 1: Result of Optimal Separation time.

Parameters	1st run	2nd run	3rd run	4th run	5th run
Centrifuge speed (rpm)	600	1200	1800	2400	3000
Velocity ratio	1:2	2:3	1:1	1.3:1	1.5:1
Separation time	90	70	40	30	30
Vibration (pulse/s)	368	411	750	1250	1663

Plots of centrifuge speed against separation time are shown in Figures below.

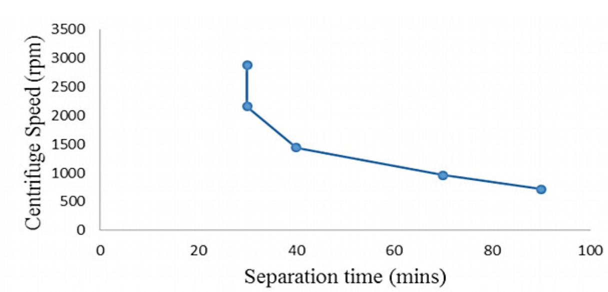

Fig 7: *Variation of separation time with centrifuge speed.*

Table 2: Comparing of the L2-6k with the new prototype

Model	L2-6k	Prototype U-6k
Max RPM (rpm)	6000rpm	6000rpm
Max. RCF	4430 × g	4430× g
Max Capacity	4*100ml	4*100ml
Timer	1min – 99min	No timer
Max Power consumption	150w	**300w**
Voltage	AC 220V±22V，50/60Hz，10A	AC 220V±12V，50/60Hz，10A
Speed	100 – 4,400 rpm (100 rpm steps)	100 – 6000 rpm (100 rpm steps)
Volume range	4 × 100 mL	400 mL
Rotors available	6	6
Noise level	< 52 dB(A) with Rotor A-4-38	<46 dB(A) with Rotor A-4-38
Net weight	45kg	50kg
Dimensions (W x D x H)	38 × 58 × 27 cm / 15 × 22.9 × 10.6 in	32 × 40 × 24 cm / 12.6 × 15.6 × 9.6 in

From the result obtained, it can be concluded that this centrifuge has been fairly constructed and it gave an impressive result, which compares favourably with the China L2-6k centrifuge.

Cost Analysis of the Research Project

The total expenses made at the cause of the design and implementation of this project is analyzed below which cost the total sum of **₦ 108,200**

Table 3: Summary of the Research Project Cost, **(BEME)**

S/N	ITEM	QUANTITY	UNIT PRICE	TOTAL AMOUNT (#)
1	Resistors	5	20	100
2	Capacitors	3	100	300
3	Diode(IN4007)	6	50	300
4	Transistors	8	250	2000
5	Relay (12v)	2	100	200
6	Electrical Motor DC	1	35,000	35,000
7	Rotor	1	4000	4000
8	Bucket	6	500	3000
9	Fuse box	1	300	300
10	Transformer(12v)	1	2000	2000
11	DC Battery 12v 7AH	2	7500	15000
12	Vero board	2	150	300
13	Switch	2	250	500
14	**IC**	1	2000	2000
15	Soldering Iron	1	1500	1500
16	Pilot Lamp	2	250	500
17	Transportation	1	1200	1200
18	Soldering lead	5yards	100	500
19	Connecting wires	10yards	50	500
20	Heat sink	1	2000	2000
	TOTAL			**71,200**
	STRUCTURAL /CASING			
	Flat sheet Pan 18mm			5000
	Marking			1000
	Bending / folding			2000
	Joining / Welding and Riveting			2500
	Filler			1000
	Washing / Sand Papering			1500
	Painting			4000
	Solar Panel			20,000
	TOTAL			**37,000**
	COST IMPLICATION (71,200 + 37,000)			**₦ 108,200**

V. CONCLUSION AND RECOMMENDATION

A dual powered Rechargeable Centrifuge was designed and developed at Enugu State University of Science and Technology, ESUT Enugu using locally sourced standard materials. The centrifuge was used in centrifuging different samples of liquid and accurate centrifugation was achieved. From the observation, there is no power interruption during the centrifugation, it maintain it power level during separation time without reduction in voltage.

Since accurate centrifugation was achieved with the use this rechargeable dual powered centrifuge, saving users time, providing power backup and from the result obtained, it can be concluded that this centrifuge has been fairly constructed and it gave an impressive result, which compares favourably with the China L2-6k centrifuge.

It is therefore recommended that possible future studies in increasing the solar panel efficiency, and reducing the system size should be carried out.

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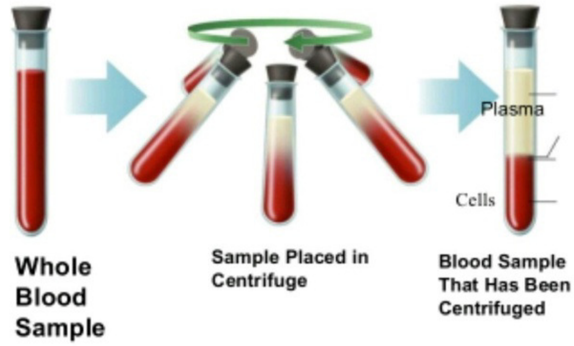
Appendix 1



Appendix 2