# ELIZADE UNIVERSITY, ILARA-MOKIN,
# ONDO STATE, NIGERIA
## DEPARTMENT OF MECHANICAL ENGINEERING

**SECOND SEMESTER EXAMINATION**

**2018/2019 ACADEMIC SESSION**

**COURSE:** MEE 518 – Turbomachinery (3 Units)

**CLASS:** 500 Level Mechanical Engineering

**TIME ALLOWED:** 3 Hours

**INSTRUCTIONS:** Answer five questions in ALL. **Question 1** is **compulsory**. Then, answer **two Questions each** from **SECTION B** and **SECTION C.**

HOD'S SIGNATURE

**Date:** July, 2019

**SECTION A (Answer all questions in this section)**

**Question 1 (General Questions)** **[12 Marks]**

a. Derive the following dimensionless numbers based on force ratios:
   i) Reynolds number
   ii) Froude number
   iii) Euler number
   iv) Weber number
   v) Mach number.

b. State the relationship between net positive suction head available and net positive suction head required.

c. Describe the shape of the characteristics curve for a centrifugal pump and positive displacement pump.

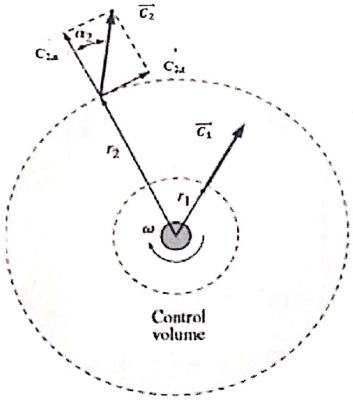
**SECTION B (Answer any two questions in this section)**

**Question 2 (Intro. to Fluid Machines/ Theory of Rotodynamic Machines)** **[12 Marks]**

a. Explain the following in relation to the course
   i) Fluid machines
   ii) Rotodynamic and Positive Displacement Machines

b. (i) State the conservation of mass, then write the continuity equation in cartesian coordinate form (ii) show that the power input as given by Euler's Turbomachine equation from the first principle is; $\boldsymbol{P = \rho\dot{v}(U_2C_{\theta_2} - U_1C_{\theta_1})}$

c. A centrifugal blower rotates at $N = 1750\,rpm(183.3\,rad/s)$. Air enters the impeller normal to the blades at $\alpha_1 = 0^0$ and exits at an angle of 40° from radial ($\alpha_2 = 40^0$) as sketched in Fig. below. The inlet radius is $r_1 = 4.0\,cm$, and the inlet blade width $b_1 = 5.2\,cm$. The outlet radius is $r_2 = 8.0\,cm$, and the outlet blade width $b_2 = 2.3\,cm$. The volume flow rate is $0.13\ m^3/s$. For the idealized case, i.e., 100 percent efficiency, calculate the net head produced by this blower in equivalent millimeters of water column height. Also calculate the required brake horsepower in watts. Take the density of air to be $\rho_{air} = 1.20\ kg/m^3$.




**Question 3 (Dimensional and Dimensionless Analysis/Similitude)** **[12 Marks]**

a. Write short note on the following terms:
   i) Dimensional Analysis
   ii) Distorted model
   iii) Scale effect

b. The thrust T of a screw propeller is dependent upon the diameter D, speed of advance V, revolutions per second N, fluid density ρ and the co-efficient of viscosity μ. Experiments were performed with various models of propellers. Derive on the basis of dimensional analysis suitable dimensionless groups to which the data should be plotted to present the thrust developed by a propeller?

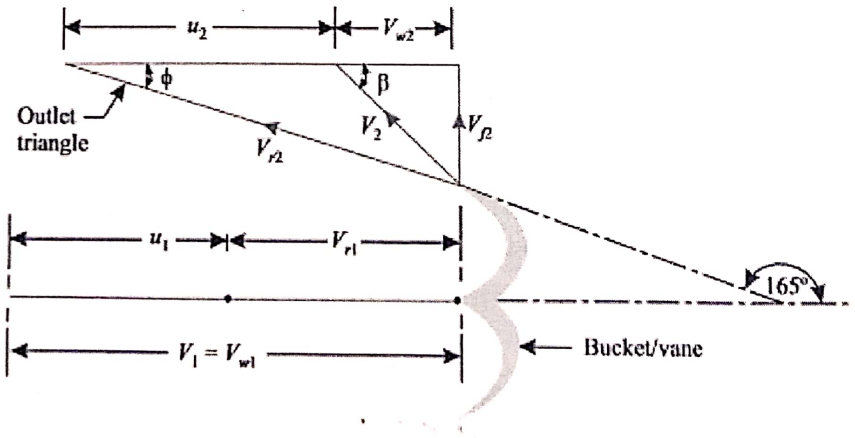
c. The characteristics of a propeller of 4.8 m diameter and rotational speed 120 rpm. are examined by means of a geometrically similar model of 600 mm diameter. When the model is run at 480 rpm by a torque of 30 Nm, the thrust developed is 300 N and the speed of advance is 3 m/s. Determine the following for the full- scale propeller: (i) Speed of advance, (ii) Thrust, and (iii) Torque.

**Question 4 (Water Turbines, Performance characteristics Losses and Efficiencies) [12 Marks]**

a. Write short note on the following: (i) Water Turbine (ii) Reaction Turbine (iii) Impulse Turbine (iv) overall efficiency and specific speed

b. Explain the construction and working of a Pelton wheel/turbine

c. A Pelton wheel is receiving water from a penstock with a gross head of 510 m. One-third of gross head is lost in friction in the penstock. The rate of flow through the nozzle fitted at the end of the penstock is 2·2 $m^3/s$. The angle of deflection of the jet is 165°. Determine: (i) The power given by water to the runner, and (ii) Hydraulic efficiency of the Pelton wheel. Take $C_v$ (co-efficient of velocity) = 1·0 and speed ratio = 0·45.



## SECTION C(Answer any two questions in this section)

**Question 5 (Centrifugal Pump)** **[12 Marks]**

a. State the purposes of the following centrifugal pump components:
   i) Impeller
   ii) Diffuser
   iii) Volute

b. Using velocity diagram, show that Head theoretical of Impeller ($H_{th}$). Take $U_2 = \pi DN$.

$$(H_{th}) = \frac{\pi^2 D^2 N^2}{g} - \frac{1}{g}\left(\frac{\pi DN}{A} . \cot\beta_2\right) Q$$

Where: $D$ *is the outer diameter of impeller in* "m", $Q$ *is the flow rate in* "$m^3/s$",

$N$ *is the speed of the impeller in* rpm, $g$ *is acceleration due to gravity in* "$m/s$",

$\beta_2$ *is the angle between tangential velocity and absolute velocity of water in* "degree",

$A$ *is the cross sectional area of the impeller in* $m^3$,

$U_2$ *is the tangential velocity at outlet in* $m/s$.

c. The following details refer to a centrifugal pump. Outer diameter: 30 cm, Eye diameter: 15cm, Blade angle at inlet: 30°, Blade angle at outlet: 25°, Speed: 1450 rpm. The flow velocity remains constant and the whirl at inlet is zero. Determine:
   i) the work done per Kilogram (Kg)
   ii) the work done head, if the width at the outlet is 2 cm.
   iii) the power. Given that Overall efficiency ($\gamma_o$) = 76%

**Question 6 (Positive Displacement Pump)** **[12 Marks]**

a. Differentiate between the following:
   i) Rotary and reciprocating pump working principles
   ii) Fluid coupling and Torque converter

b. Categorize the following pumps as either rotary or reciprocating and Explain their working principle:
   i. Vane pump
   ii. Lobe type pump
   iii. Piston pump
   iv. Plunger pump

c. A single acting reciprocating water pump of 180 mm bore and 240 mm stroke operates at 40 rpm. Determine the discharge if the slip is 8%. What is the value of coefficient of discharge? If the suction and delivery heads are 6 m and 20 m respectively determine the theoretical power. If the overall efficiency was 80%, what is the power requirement?

**Question 7 (Pumping and Piping Systems)** **[12 Marks]**

a. Explain the series and parallel operation of centrifugal pumps stating their mode of operation.

b. Differentiate between Air entrainment, Cavitation and Vortexing in pump system. (Include how they can be detected and avoided)

c. Mention the types of test required to determine the integrity of a pump and explain how the two most important of these tests could be carried out.