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**PRESIDENCY UNIVERSITY**

**Bengaluru**

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| **Ph.D. Course Work End Term Examinations – JAN-FEB 2025** |
| **Date:** 30 – 01-2025 **Time:** 09:30 am – 12:30 pm |

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| **School:** SOE | **Program:** Ph.D. | |
| **Course Code:** MEC 821 | **Course Name:** Thermal Systems Design | |
| **Semester**: | **Max Marks**: 100 | **Weightage**: 50% |

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| **CO - Levels** | **CO1** | **CO2** | **CO3** | **CO4** | **CO5** |
| **Marks** |  |  | **50** | **50** |  |

**Instructions:**

1. *Read all questions carefully and answer accordingly.*
2. *Do not write anything on the question paper other than roll number.*
3. ***Books, notes and data handbooks are allowed.***
4. *Make suitable assumptions wherever required with justification.*

**1.** The operating point of a centrifugal pump is to be determined. The pump performance curve and the system load characteristics are given as follows.

Pump: ΔP = 240 x 103 – 43.8 x 102 Q2

Load: ΔP = 40 x 103 + 156.2 x 103 Q1.8

Where ΔP is the static pressure rise in Pa and Q is the discharge in m3/s.

(1) Using the successive substitution method for 2 unknowns, determine the operating point of the pump. Start with an initial guess value of Q = 0.4 m3 /s.

Decide on your own stopping criterion.

(2) At the operating point, if the pump efficiency is known to be 86%, what is the electrical power required for the pump?

**[30 M] (CO3) [Application]**

**2.** An engineer requires 4800, 5810 and 5690 m3 of sand, fine gravel and coarse gravel respectively for a building project. There are three pits from where these materials can be sourced. The composition of these pits is

A table with numbers and text

Description automatically generated

Determine how many m3 must be hauled from each pit to meet the engineer’s needs, using the Gauss Seidel method. For uniformity you may denote the quantity hauled from Pits 1, 2 and 3 as x, y and z. Start with an initial guess value of x=y=z=2000 m3. Perform at least 8 iterations and report the sum of the squares of the residues of the three variables at the end of very iteration. Show the entire process on a Tabular column.

**[30 M] (CO3) [Application]**

**3.** A supersonic military aircraft engine typically employs an after burner after the combustor where additional fuel is injected to increase the thrust. The total energy, E, at the exit of the afterburner is to be maximized for maximum work output. One such aircraft is flying at 600 m/s and intakes air at 10.5 kg/s (Cp for air is 1005 J/kg-K). The temperature at the inlet of the engine is -25°C and the calorific value of the fuel is 44000 kJ/kg. The fuel flow rate to the combustor is **x1** kg/s and that to the after burner is **x2** kg/s. Due to spraying limitations, a constraint in the form of **8x1+ 6x2 ≤ 3** arises. The combustor can withstand more heat than the afterburner and so **x1-x2 ≥ 0.1**. Furthermore, due to limitations in fuel storage and distribution **2x1 + 5x2 ≤ 1.2**.

(a) Set up the optimization problem for maximizing energy at the exit (Note: Due to high velocities, kinetic energy term may not be negligible!) of the afterburner as a Linear Programming (LP) problem.

(b) Solve the LP using the graphical method.

(c) Solve the LP using the method of slack variables and compare the solutions obtained in (b) and (c).

**[40 M] (CO4) [Application]**