ME 6280 Design and Optimization of Energy Systems

End-Semester Examination

Time 3 hrs. Max Marks – 100

Instructions

1) Please follow the honor code and do not discuss the questions with anyone else.
2) You are allowed to use any internet resource, book, etc freely.
3) Make any assumptions necessary if you feel some data is missing. However, write down clearly all the assumptions you are making for the question
4) If you have used a code for a problem, that should be submitted as well. Name the code as ProblemX_CodeName_ROLLNO.m or ProblemX_CodeName_ROLL.py. You will be given credit for the question only if the code gives exactly the output that you have reported.
5) Even when you use a code, report the first, final iteration's answer, and the number of iterations by hand.
6) **Do not just submit the codes. Write down the formulation by hand for each answer clearly.**

Submission

1) A separate sheet for the final answers has been sent to you (ME6280_FinalAnswers_ROLLNO.docx). Rename it by replacing ROLLNO with your actual roll number. Fill in the final answers in the space provided.
2) Submit all the handwritten answers in a single file titled ME6280_ROLLNO.pdf
3) Include all your codes with the name ProblemX_CodeName_ROLLNO.m. For example, if you wrote a code for Fibonacci in Q1, you could name it Problem1_Fibonacci_ROLLNO.m
4) Zip all these files under the name ME6280_ROLLNO.zip and upload it to Learn.
5) **In case the upload is not working for some reason, immediately email the zip file to your respective TA.**

1) Consider a thermal system whose heat dissipation rate is given by $Q = 2.6 + 7.0v^{0.3}$, where Q is in kW and v is the velocity in *m/s* of the fluid being used as the medium for accomplishing the heat transfer. The accompanying pumping power is given by $P = 1.8 + 0.01v^{2.1}$. It is desired to **maximize the performance parameter Q/P. (15 marks)**

Conduct a one variable search in v to obtain the optimal velocity by using

a) Dichotomous Search. Choose an appropriate δ that will allow the final accuracy.
b) Fibonacci search
c) Golden Section search

Initial interval of uncertainty is 1 < v < 10 m/s. Obtain the final v to an accuracy of 3 decimal places. Report the following (in the final answers sheet)

	$a\ (v)$	$b\ (v)$	**Q/P at midpoint**	**Iterations for convergence**
Dichotomous				
Fibonacci				
Golden Section				

2) The first stage of a space shuttle consists of a **central liquid engine consisting of 3 nozzles** and **2 solid straps on external boosters**. For convenience, assume complete expansion in the nozzles i.e pressure at exit = ambient pressure. The exit gas velocities are $v_{e1} = 4000\ m/s$ and $v_{e2} = 1500\ m/s$. Based on the design of the nozzles $\dot{m}_1$ and $\dot{m}_2$ are the mass flow rates (in kg/s) for **each** of the central nozzles and external boosters respectively. **(15 marks)**

Optimize $\dot{m}_1$ and $\dot{m}_2$ for maximum total thrust. Recall that thrust for a single nozzle/booster is given by $\dot{m}v$.

The constraints are:

a) The maximum propellant weight that can be carried given by $6.2\ \dot{m}_1 + 2.4\ \dot{m}_2 \leq 6300$

b) The **total** fuel that can be carried in the main central tank is 650 tons and this has to burn for 8 mins.

c) In the external casings, the **total** (including both casings) fuel that can be carried is 900 tons and this has to burn for 2 mins.

d) Because of the nozzle geometry the constraint is $5.3\ \dot{m}_1 + 2.8\dot{m}_2 \leq 7800$

Solve the problem using the Simplex method. **Show all calculations by hand.**

Report the following (in the final answers sheet)

Optimal $\dot{m}_1$	**Optimal** $\dot{m}_2$	**Optimal Thrust**

3) The operating point of a centrifugal pump is to be determined. The pump performance curve is given by $\Delta P = a + bQ^n$. The following data is given for the pump performance **(35 marks)**

$Q(m^3/s)$	$\Delta P(N/m^2)$
1.4	232739.2
1.3	236731.8
2.7	212226.8
2.1	225390.2
3.1	193265.2
3.4	191154.2
4.4	151174.2
4.6	149267.2
5.7	99156.8
5.8	94750.8

The system load characteristics is given by $\Delta P = 40 \times 10^3 + 156.2 \times 10^3 Q^{1.8}$. Here, ΔP is the static pressure rise and Q is the discharge.

(a) Find the load characteristics of the pump starting from an initial guess of $a = 250 \times 10^3$, $b = -5000$, $c = 2.5$. Use appropriate tolerances for the question.
(b) Show the information flow in the system using an information flow diagram
(c) Obtain the operating conditions of the system by solving the appropriate information flow diagram starting from an initial guess of $\Delta P = 200 \times 10^3 N/m^2$ and $Q = 1\ m^3/s$

Report the following (in the final answers sheet)

	a	b	n
Pump characteristics			

	ΔP	Q
Operating conditions		

4) Most of the industries use Screw conveyors to transport a wide range of materials. As a part of your project, you are proposing a new screw conveyor network to optimize power consumption for the factory. As a part of the calculation process, you must calculate corrected material HP. Collected data for this is as follows: **(35 marks)**

Calculated HP (x)	Corrected HP (y)
0.201813	0.522508
0.549789	1.294212
0.865762	1.808682
1.288098	2.355305
1.741791	2.83119
2.222954	3.262058
2.806504	3.705788
3.389966	4.104502
3.961491	4.438907

For convenience, we wish to fit a curve to the above data.

(i) Pose the above as a least square problem for the following types of curves

a) Quadratic curve (b) Cubic curve (c) Power Law -- ax^b

(ii) For each of these curves determine the optimal coefficients using linear regression.

(iii) For the Power law in part (ii), reobtain the coefficients using Conjugate Gradient and Newton's Method for the optimization.

Report the following (in the final answers sheet)

	w_0	w_1	w_2	w_3
Quadratic				
Cubic				
Power Law				

The number of iterations it would take for the Conjugate Gradient and Newton to converge

	Conjugate	**Newton**
Quadratic		
Cubic		
Power Law		