Final Exam

This exam is composed of 4 essays followed by 20 short answer questions (24 questions total). The essays are each worth 10% and the short answers are each worth 3%. Therefore the essays comprise 40% of the credit and the short answers comprise the other 60%. You have 2 hours. Divide your time accordingly, perhaps 10 minutes per essay and three minutes per short answer leaving 20 minutes of buffer for review at the end. When asked for an estimate, any answer correct to within 10% earns you full credit.

1. (10%)
- In robust design, what is a "dynamic" system?
- What is "ideal function" in a "dynamic" system?
- Give an example of "ideal function" in a "dynamic" system from an engineering context.

2. (10%)
- What are noise factors?
- What is a compound noise factor?
- Under what conditions would you recommend using a compound noise factor?

3. (10%)
- Describe an engineering example of a system integration problem caused by insufficient robustness of the system's components or subsystems.
- Explain what failure modes occurred, what noise factors were involved, and how system level interactions came into play.

4. (10%)

Your engineering team is involved in a product development project (imagine a project that is similar to those in your company). You decide to apply robust parameter design techniques to a critical subsystem. Based on the factor effect plots, you choose a set of control factor levels that are predicted to improve the S/N ratio by 12dB. Upon running the confirmation experiment, you find that the rise in signal to noise ratio is only 6dB.

- What might have caused this difference between prediction and confirmation?
- As the leader of the product development team, what would you do in this situation? Why?

Questions 5-10 below refer to the following scenario:

You are an engineer at ALDOA incorporated and you are concerned with the effects of precipitation heat treatment on the yield strength (Y) of a new aluminum alloy. Customer surveys indicate that perceived quality loss is inversely proportional to the square of Y. You wish to determine the effects on Y of the following control factors:

Oven temperature (high, medium, low)
Oven size (small, medium, large)
Position of the specimen in the oven (on the floor, on a low rack, on a high rack)
Aging time (short, medium, long)
Quenching liquid (water, oil)
Quenching liquid temperature (high, medium, low)

5. (3%) Which signal-to-noise ratio would you use to guide the design?

6. (3%) How many experiments are required if you want to determine the *main effects only* and you use a *one-factor-at-a-time* experimental design with three replicates of each experimental treatment?

7. (3%) If you want to determine the *main effects only* and you wish to use one of the *standard orthogonal arrays* listed in Appendix C of Phadke, which one would you choose?

8. (3%) How much more reliable is your estimate of the effect of oven temperature on S/N ratio when using the orthogonal array selected (problem 7) as compared to the one factor at a time experiment (problem 6)? Again, assume three replicates are performed for each experimental treatment.

9. (3%) In order to conduct a *full factorial* experiment, how many experiments would you would need to conduct? Again, assume three replicates are performed for each experimental treatment.

10. (3%) If it is likely that there is a significant interaction between quenching liquid and quenching liquid temperature. How will you ensure that your experimental plan will allow you to estimate this interaction?

The factor effect plots below represent the results of an orthogonal array based experiment. These plots are the basis of the questions 11-14 below.

11. (3%) Which control factor should be used as the scaling factor assuming the additive model holds?

12. (3%) What settings of the other control factors will maximize the S/N ratio assuming the additive model holds?

13. (3%) What will be the predicted S/N ratio at the optimal settings selected in problem 12 above? Estimate your answer from the graphs.

14. (3%) After optimizing the S/N ratio, what level should be selected for the scaling factor in order to place the mean response of the system at 31 Ohms? Assume an additive model holds for the mean response of the system.

Factor Effects on the S/N Ratio

Factor Effects on the Mean
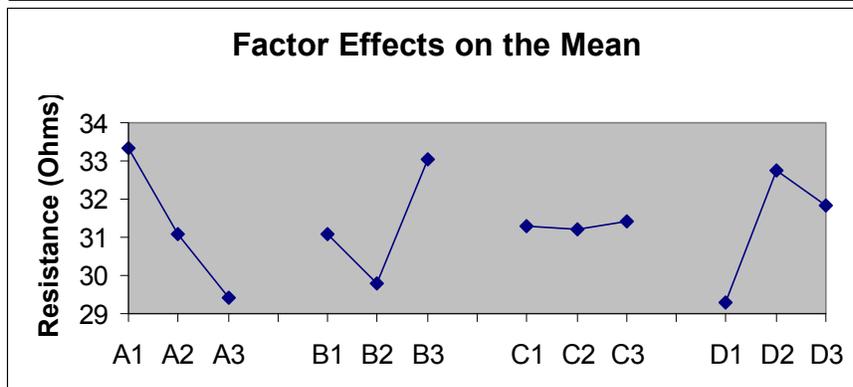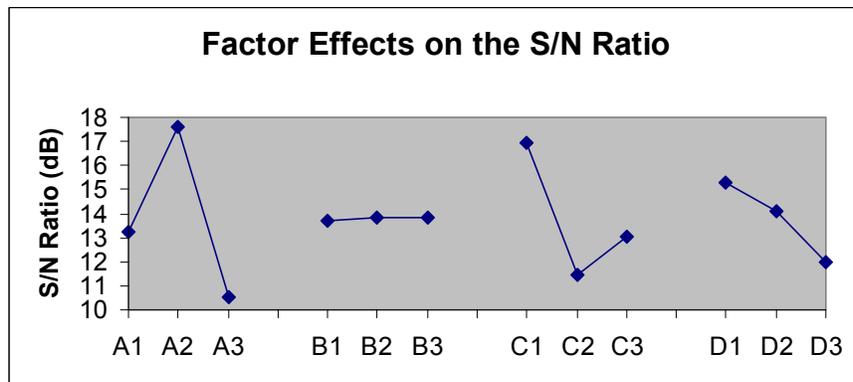
The data below represent the results from an L_4 (2^3). The third column was left unassigned. This data is the basis of questions 15-17 below.

Exp no.	Control Factors			η
	A	B	e	
1	1	1	1	7 dB
2	1	2	2	17 dB
3	2	1	2	5 dB
4	2	2	1	19 dB

15. (3%) Sketch the AXB interaction plot.

16. (3%) If you pool the variance due to the unassigned column (the third column), what will be the F ratio of control factor B?

17. (3%) Do you judge the interaction between factors A and B to be significant?

Questions 18 and 19 refer to the scenario described below:

The circuit below is an amplifier circuit including an op amp with a finite input resistance R_i. The gain (v_2/v_s) of the circuit is known to be

$$\frac{v_2}{v_S} = \frac{-k \cdot R_2 \cdot R_i}{R_2 \cdot R_i + R_1 \cdot R_i + R_1 \cdot R_2 + k \cdot R_1 \cdot R_i}$$

Amplifier
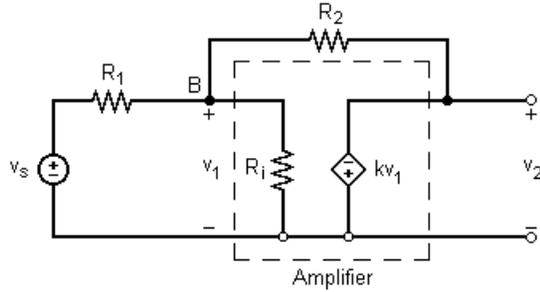
The noise factors are:

$R_1 = 1k\Omega \pm 1\%$
$R_2 = 1k\Omega \pm 1\%$
$R_i = 50k\Omega \pm 1\%$
$k = 100 \pm 10$

18. (3%) Estimate the standard deviation of the gain (v_2/v_s). Remember, any answer within 10% gets you full credit.

19. (3%) The average quality loss per circuit is $0.05 and is due entirely to variance in the gain (v_2/v_s) (assume the average gain is very close to the target value). Loosening the tolerance to 5% on any resistance will save $0.01 per circuit. Which tolerances would you relax?

Questions 20-24 refer to the following scenario:

You are designing a high-bypass turbofan engine for a small commercial transport. Pilots seem to fly more safely and efficiently when the thrust delivered by the engine is consistent for any given throttle position under a wide range of angles of attack.

Your design team performs a continuous-continuous dynamic signal to noise analysis with throttle position as the signal factor and thrust as the response. Angle of attack (α) is the only noise factor induced in the experiment. The following data were collected:

Throttle position	α=5 degrees	α=10 degrees	α=20 degrees
½	7.9 x10³lbs	7.0x10³lbs	6.1x10³lbs
¾	11.0x10³lbs	10.5x10³lbs	9.9x10³lbs
1 (full throttle)	16.0x10³lbs	14.1x10³lbs	12.1x10³lbs

20. (3%) **Estimate** the slope of the least squares regression line (β). (Remember to include units).

21. (3%) Estimate the continuous-continuous dynamic signal to noise ratio.

22. (3%) In this scenario, which factor contributes to the dynamic signal to noise ratio more, the effect of angle of attack or the effect of non-linearity in the response?

23. (3%) If the experiment were conducted **only** at the ¾ throttle position, estimate what the continuous-continuous dynamic signal to noise ratio would be.

24. (3%) What is the primary cause of the difference between the S/N ratio estimated in problem 22 and the S/N ratio estimated in problem 23?