

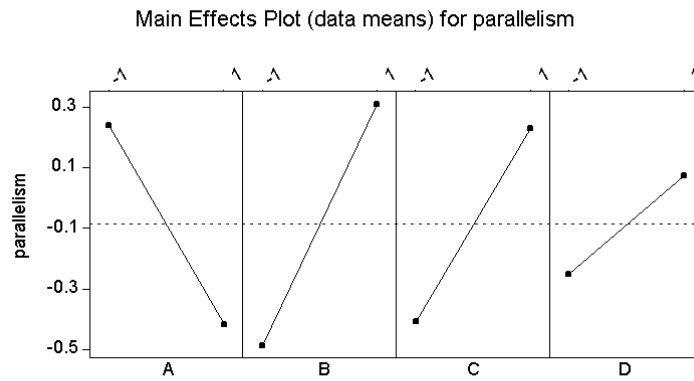
INSTRUCTIONS: You will have 1 hour and 30 minutes to complete the exam. There are 4 questions worth a total of 100 points. Not all questions have the same point value so gauge your time appropriately. Read the questions carefully and completely. Answer each question and show work in the space provided on the exam. Turn in the **entire** exam when you are done or when time is up. For essay questions, think before you write.

1. [35 pts] An automobile assembly plant uses an automated fixture to center a glove box door to the instrument panel. In order to improve door parallelism during assembly a 2^4 experiment with a single replicate is performed. The response is door parallelism in mm. Below are the factors, estimated full effects, and sums of squares for each estimated effect.

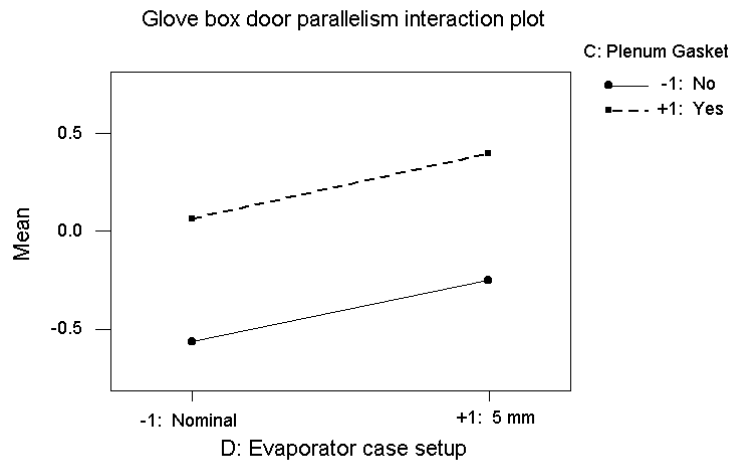
Factor	Low (-)	High (+)
A: RH cowl fore/aft movement	Nominal	5 mm
B: Center brace attachment sequence	Before	After
C: Plenum gasket	No	Yes
D: Evaporator case setup, fore/aft	Nominal	5 mm

Trmt. Comb.	A	B	C	D	Estimated Effect	Effect Name	SS_{Effect}
1	-	-	-	-	-0.0875	Mean	—
a	+	-	-	-	-0.6550	A	1.716
b	-	+	-	-	0.7975	B	2.544
ab	+	+	-	-	0.1475	AB	0.087
c	-	-	+	-	0.6375	C	1.626
ac	+	-	+	-	-0.1175	AC	0.055
bc	-	+	+	-	-0.1900	BC	0.144
abc	+	+	+	-	0.1750	ABC	0.123
d	-	-	-	+	0.3225	D	0.416
ad	+	-	-	+	-0.0325	AD	0.004
bd	-	+	-	+	-0.1550	BD	0.096
abd	+	+	-	+	0.1000	ABD	0.040
cd	-	-	+	+	0.0100	CD	0.000
acd	+	-	+	+	-0.1400	ACD	0.078
bcd	-	+	+	+	-0.1075	BCD	0.046
abcd	+	+	+	+	0.1225	ABCD	0.060

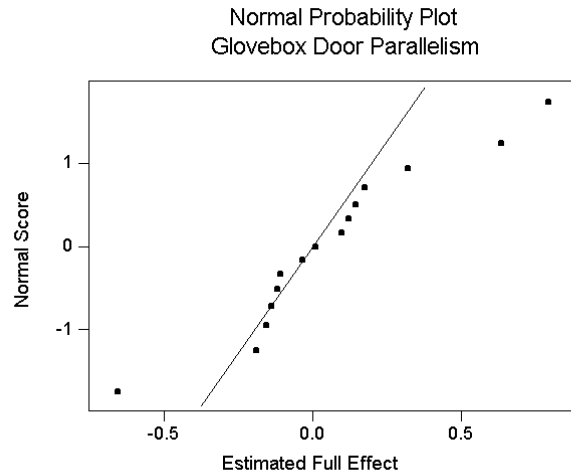
- (a) [5] Below is a main effects plot. Describe the effect on parallelism for each of the four factors in the experiment.



- (b) [4] Below is an interaction plot for plenum gasket and evaporator case set up. What does this plot tell you about interaction between these two variables? Be sure to mention what you see in the plot that supports your answer.



- (c) [4] On the normal plot of estimated full effects identify and label those effects that appear to be significant.



- (d) [8] Using one of the methods discussed in class, come up with an estimate of error variability, and a standard error of an estimated full effect.

- (e) [4] Which effect(s) is(are) statistically significant?

- (f) [4] Give a prediction equation using only those effects that are statistically significant.

- (g) [6] Using your equation in (f), give a predicted value and prediction interval (use $t=2$) for the glove box door parallelism where the RH cowl fore/aft movement is nominal, the center brace is attached after, there is no plenum gasket and the evaporator case setup, fore/aft is nominal.

2. [25 pts] An experiment is performed to determine if there is any difference in mean hardness readings for four types of tips used on a hardness tester. Five test coupons from a particular type of alloy are used as blocks and each tip is tested once on each coupon. The testing is non-destructive so that coupons can be tested several times. The data from the experiment are summarized below:

	Type of Tip			
	1	2	3	4
number	5	5	5	5
mean hardness	9.4	9.5	9.3	9.8

Source	df	Sum of Squares
Rep Error	16	1.76
Blocks	4	1.52

- (a) [5] For a randomized complete block design explain explicitly how you would randomize the runs. Be sure to state how many runs there are.
- (b) [4] What size difference in mean hardness readings will you be able to detect with $\alpha = 0.10$ and $\beta = 0.10$?
- (c) [6] If we ignore blocking (this is the wrong analysis but do it anyway), compute the LSD (use $t=3$) for comparing the types of tips. Which tips are significantly different?

- (d) [6] If we incorporate blocking (as we should) in our analysis, compute the LSD (again use $t=3$) for comparing the types of tips. Which tips are significantly different?
- (e) [4] What do parts (c) and (d) indicate about paying attention to how the data are collected when it comes to data analysis?
3. [10 pts] The three basic principles of sound experimental design are control of outside variables, randomization and replication. Failing to include any one of these principles will result in difficulties with the analysis of the resulting data.
- (a) [4] What difficulties are encountered if one fails to replicate?
- (b) [6] What difficulties are encountered if one fails to control outside variables? How does randomization help with these difficulties?

4. [30 pts] An experiment is conducted on the silencing ability of a filter added to the exhaust system of a vehicle. Three factors are investigated, each at two levels (the data are given below in standard Yates order). There are two replicates for each treatment combination. The response is the noise level reading in decibels. One objective of the experiment is to verify that the type of filter has no affect on the noise level.

A: Vehicle Size	B: Filter Type	C: Side Monitored	Noise Level	Mean \bar{Y}	Var. s^2
small(-1)	standard(-1)	right(-1)	810, 820	815	50
large(+1)	standard(-1)	right(-1)	780, 790	785	50
small(-1)	Octel(+1)	right(-1)	820, 820	820	0
large(+1)	Octel(+1)	right(-1)	775, 775	775	0
small(-1)	standard(-1)	left(+1)	835, 835	835	0
large(+1)	standard(-1)	left(+1)	760, 770	765	50
small(-1)	Octel(+1)	left(+1)	825, 825	825	0
large(+1)	Octel(+1)	left(+1)	770, 760	765	50

- (a) [5] For a completely randomized design, explain explicitly how you would randomize the runs. Be sure to indicate how many runs there are.

- (b) [3] What is the $MS_{repError}$ for this experiment?

- (c) [6] Complete the following table of estimated full effects.

Effect Name	Estimated Full Effect	Effect Name	Estimated Full Effect
Mean		C	-1.25
A	-51.25	AC	-13.75
B	-3.75	BC	
AB	-1.25	ABC	6.25

- (d) [6] Which effects are statistically significant? Be sure to give the critical effect size using $t=3$. According to this analysis, does the type of filter make a difference in terms of average noise level?
- (e) [4] Using a prediction equation containing only significant terms, what would you recommend for the vehicle size, filter type and monitoring side to produce the lowest noise level?
- (f) [6] Give the predicted noise level and prediction interval (use $t=2$) for your recommendation in (e)