Quiz 5

In industry cooling applications (e.g., cooling of nuclear reactors), a process called subcooled flow boiling is often employed. Subcooled flow boiling is susceptible to small bubbles that occur near the heated surface. The characteristics of these bubbles were investigated in Heat Transfer Engineering (Vol. 34, 2013). A series of experiments was conducted to measure two important bubble behaviors-bubble diameter (millimeters) and bubble density (liters per meters squared). The mass flux (kilograms per meters squared per second) and heat flux (megawatts per meters squared) were varied for each experiment. The data obtained at a set pressure are listed in the following table.

MassFlux	HeatFlux	Diameter	Density
406	0.15	0.64	13102.82
406	0.29	1.02	29117.38
406	0.37	1.15	123020.90
406	0.62	1.26	165969.10
406	0.86	0.91	254777.10
406	1.00	0.68	347952.70
811	0.15	0.58	7279.34
811	0.29	0.98	22565.97
811	0.37	1.02	106278.40
811	0.62	1.17	145586.90
811	0.86	0.86	224203.80
811	1.00	0.59	321019.10
1217	0.15	0.49	5095.54
1217	0.29	0.80	18926.30
1217	0.37	0.93	90991.81
1217	0.62	1.06	112101.90
1217	0.86	0.81	192902.60
1217	1.00	0.43	232211.10

diameter

Consider the multiple regression model of predicting the bubble diameter,

$$E(y_1) = \beta_0 + \beta_1 x_1 + \beta_2 x_2,$$

where y_1 = bubble diameter, x_1 = mass flux, x_2 = heat flux. To conduct a test of overall model utility at $\alpha = 0.05$. We conduct a test of overall model utility at $\alpha = 0.05$. The output is shown below.

```r
anova_alt(fit_diameter)
```

```
## Analysis of Variance Table
##
##        Df      SS       MS      F       P
## Source  2 0.11914 0.059570 1.0001 0.39111
## Error  15 0.89350 0.059567
## Total  17 1.01264 0.059567
```

```r
summary(fit_diameter)
```

```
##
## Call:
## lm(formula = Diameter ~ MassFlux + HeatFlux)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.34129 -0.23205  0.04017  0.15505  0.32121
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  1.0884141  0.1837825   5.922  2.8e-05 ***
## MassFlux    -0.0002343  0.0001737  -1.348    0.198
## HeatFlux    -0.0800181  0.1877160  -0.426    0.676
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2441 on 15 degrees of freedom
## Multiple R-squared:  0.1177, Adjusted R-squared:  7.021e-06
## F-statistic:     1 on 2 and 15 DF,  p-value: 0.3911
```

Exercise 5.1. What is the null hypothesis?

- ☐ $H_0 : \beta_0 = \beta_1 = \beta_2 = 0$.
- ☐ $H_0 : \beta_1 = \beta_2 = 0$.
- ☐ $H_0 : \beta_0 = 0$.
- ☐ $H_0 : \beta_1 = 0$.
- ☐ $H_0 : \beta_2 = 0$.

Exercise 5.2. What is the alternative hypothesis?

- ☐ $H_a : \beta_0 \neq 0, \beta_1 \neq 0, \beta_2 \neq 0$.
- ☐ $H_a : \beta_1 \neq 0, \beta_2 \neq 0$.
- ☐ $H_a : \beta_1 \neq 0$ or $\beta_2 \neq 0$.
- ☐ $H_a : \beta_1 \neq 0$.
- ☐ $H_a : \beta_2 \neq 0$.

Exercise 5.3. Find the value of F-statistic (round to 3 decimal places)

Exercise 5.4. Find the P-value for F-statistic (round to 3 decimal places)

density

Consider the multiple regression model of predicting the bubble diameter, $E(y_2) = \beta_0 + \beta_1 x_1 + \beta_2 x_2$, where y_2 = bubble density, x_1 = mass flux, x_2 = heat flux. We conduct a test of overall model utility at $\alpha = 0.05$. The output is shown below.

```
anova_alt(fit_density)
```

```
## Analysis of Variance Table
##
##        Df        SS        MS      F          P
## Source  2 1.9298e+11 9.6492e+10 121.31 5.4739e-10
## Error  15 1.1931e+10 7.9541e+08
## Total  17 2.0492e+11 1.2054e+10
```

```
summary(fit_density)
```

```
##
## Call:
## lm(formula = Density ~ MassFlux + HeatFlux)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -42636 -19706  -9202  26264  40453
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -1030.03   21237.16  -0.049   0.9620
## MassFlux       -57.90      20.08  -2.884   0.0114 *
## HeatFlux    332037.09   21691.71  15.307 1.46e-10 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 28200 on 15 degrees of freedom
## Multiple R-squared:  0.9418, Adjusted R-squared:  0.934
## F-statistic: 121.3 on 2 and 15 DF,  p-value: 5.474e-10
```

Exercise 5.5. What is the alternative hypothesis?

- ☐ $H_a : \beta_0 \neq 0, \beta_1 \neq 0, \beta_2 \neq 0.$
- ☐ $H_a : \beta_1 \neq 0, \beta_2 \neq 0.$
- ☐ $H_a : \beta_1 \neq 0$ or $\beta_2 \neq 0.$
- ☐ $H_a : \beta_1 \neq 0.$
- ☐ $H_a : \beta_2 \neq 0.$

Exercise 5.6. Which is correct? Use critical value method or p-value method to draw a conclusion.

- ☐ Because p-value $< \alpha$, we reject H_0. The overall model appears to be statitically useful for predicting bubble density.
- ☐ Because p-value $> \alpha$, we reject H_0. The overall model does not appear to be statitically useful for predicting bubble density.
- ☐ Because p-value $< \alpha$, we fail to reject H_0. The overall model appears to be statitically useful for predicting bubble density.
- ☐ Because p-value $> \alpha$, we fail to reject H_0. The overall model does not appear to be statitically useful for predicting bubble density.

Exercise 5.7. Which of the two dependent variables, diameter (y_1) or density (y_2), is better predicted by mass flux (x_1) and heat flux (x_2)?

- ☐ diameter (y_1)
- ☐ density (y_1)