Problem 1

(a) Let's look at the ANOVA table output from SAS.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	6026.83333	2008.94444	6.97	0.0022
Error	20	5767.00000	288.35000		
Corrected Total	23	11793.83333			

The p-value for the F-statistic is 0.0022, much less than 0.05. Hence we reject the hypothesis and conclude that there are treatment differences.

(b) Since the experiment is a balanced design, two contrasts are orthogonal to each other iff their inner product is 0. Let $\mathbf{C}_1$, $\mathbf{C}_2$ and $\mathbf{C}_3$ be respectively the contrasts for "Hormone I vs Hormone II", "Low Level vs High Level" and "Equivalence of Level". Then

$$\begin{aligned}
\mathbf{C}_1^t\mathbf{C}_2 &= 1*1+1*(-1)+(-1)*1+(-1)*(-1) = 1-1-1+1 = 0, \\
\mathbf{C}_1^t\mathbf{C}_3 &= 1*1+1*(-1)+(-1)*(-1)+(-1)*1 = 1-1+1-1 = 0, \\
\mathbf{C}_2^t\mathbf{C}_3 &= 1*1+(-1)*(-1)+1*(-1)+(-1)*1 = 1+1-1-1 = 0.
\end{aligned}$$

Hence the three contrasts are orthogonal to each other.

(c) The SAS output for contrast sums of squares and contrasts testing is as follows.

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
C1	1	864.000000	864.000000	3.00	0.0989
C2	1	5162.666667	5162.666667	17.90	0.0004
C3	1	0.166667	0.166667	0.00	0.9811

From the table, Contrast $\mathbf{C}_1$ is nearly significant but not significant (p-value $= 0.0989$), which indicates that the average effect of hormone I and the average effect of hormone II on are not different from each other; Contrast $\mathbf{C}_2$ is very significant (p-value $= 0.0004$), which indicates the average effect of the high levels of the hormones and the average effect of the low levels of the hormones are quite different; Contrast $\mathbf{C}_3$ is not significant at all (p-value $= 0.9811$), so the difference between the high-level and low-level of hormone I is the same as that between the high-level and low-level of hormone II. ∎