1. Using the fact that sum of squares and degrees of freedom add to give the totals, we have

Source	Sums of squares	Degrees of freedom	Mean square	F	p-value
Between treatments	64.42	3	21.47	8.98	.000866
Within treatments	40.63	17	2.39		
Total	105.05	20			

2. The null hypothesis $H_0 : \mu_1 = \mu_2 = \mu_3 = \mu_4$ is rejected. There is significant evidence of different population mean tensile stengths. The ANOVA table is summarized below. Note that the p-value is less than $\alpha = .05$.

```
y = c(3129 , 3000 , 2865 , 2890 ,
      3200 , 3300 , 2975 , 3150 ,
      2800 , 2900 , 2985 , 3050 ,
      2600 , 2700 , 2600 , 2765 )
x = as.factor(c(rep(1,4),rep(2,4),rep(3,4),rep(4,4)))
anova(lm(y~x))
          Df Sum Sq Mean Sq F value    Pr(>F)
x          3 489740  163247  12.728 0.0004887
Residuals 12 153908   12826
```

3. (a) The estimates for the μ_i are the $\overline{Y}_{i\cdot}$: 29.4, 29.6, and 28.0. The estimate for σ^2 is $MSE = 9.7$.

   (b) The standard error for $\overline{Y}_{i\cdot}$ is $\sqrt{MSE/n_i} = \sqrt{9.7/5} = 1.39$. Since the sample sizes are equal, this is the same for each group.

   (c) The null hypothesis is $H_0 : \mu_2 - \mu_3 = 0$ (versus the 2-sided alternative). The test statistic is

$$t = \frac{29.6 - 28}{\sqrt{9.7(\frac{1}{5} + \frac{1}{5})}} = 0.81$$

   which is not significant since $0.81 < 2.18 = t_{12}(.05/2)$. So, we cannot claim a difference between the green and orange groups.

   (d) The contrast is $L = \mu_1 - .5(\mu_2 + \mu_3)$, and the null hypothesis is $H_0 : L = 0$ (versus the 2-sided alternative). The test statistic is

$$t = \frac{29.4 - .5(29.6 + 28)}{\sqrt{9.7(\frac{1}{5} + \frac{.5^2}{5} + \frac{.5^2}{5})}} = 0.35$$

   which is not significant (same critical value as above).

```
data = read.table('CH16PR08.txt')
y = data[,1]
x = as.factor(data[,2])
ybar = tapply(y,x,mean)
anova(lm(y~x))
```

4. (a) The completed ANOVA table is below. Since $7.22 > 3.01$, this is significant evidence that the population mean bioactivity levels are not equal.

Source	SS	df	MS	F
Drug	56.10	3	18.7	7.22
Error	62.12	24	2.59	
Total	118.22	27		

(b) With four groups, there are six possible pairs.

(c) The individual critical value is $t_{24}(.05/2) = 2.06$.

(d) Tukey's critical value would be $q_{4,24}(.05)/\sqrt{2} = 2.76$, Bonferroni's value would be $t_{24}(.05/6/2) = 2.88$, and Scheff'e's value would be $\sqrt{(4-1)f_{3,24}(.05)} = 3.00$.

(e) First note that in all cases, the standard error is $\sqrt{MSE(1/n + 1/n)} = \sqrt{2.59(2/7)} = 0.86$. The Tukey LSD is $2.76(0.86) = 2.37$, the Bonferroni LSD is $2.88(.86) = 2.48$, and the Scheff'e LSD is $3.00(.86) = 2.58$. Similar to 1(b) above, two groups are declared significantly different if the sample means differ by more than the LSD. Using Tukey's approach, insignificant pairs are joined (underlined) together.

```
Group   3      4      2      1
Mean  62.63  63.65  65.75  66.10

      ------------  ------------
             ------------
```

With Bonferroni and Scheff'e's approach, groups 1 and 4 are found insignificant.

```
Group   3      4      2      1
Mean  62.63  63.65  65.75  66.10

      ------------
             -------------------
```

(f) We see that Tukey's approach found one additional significant difference, which reflects its additional power (smaller critical) value than the other two approaches. Tukey's procedure is designed for pairwise comparisons and is most appropriate in this case.