1.a. $\beta_1$

1.b. Assumptions 1 and 2.

1.c. In general not. We estimate the sum of the direct effect of $X_2$ and the indirect effect of this variable through $X_3$ where the latter is the product of the effect of $X_2$ on $X_3$ and the effect of $X_3$ on $Y$. Only if the effect of $X_3$ on $Y$ is 0 or if $X_2$ and $X_3$ are not related is the OLS estimator an unbiased estimator of the direct effect.

1.d. $e_i = Y_i - \hat{\beta}_1 X_{1i} - \hat{\beta}_2 X_{12} - \hat{\beta}_3 X_{13}$. The sum of the OLS residuals over the observations is 0, because the model has an intercept. See (12) on the formula sheet.

1.e. Assumptions 1-4.

1.f. Assumptions 1-5.

2.a. If the price is increased by 1000$ the sales decrease by 12200000$.

2.b. Assumptions 1-5.

2.c. The t-statistic is $.127/.089 = 1.427$ which is smaller than the critical value 2.021 for the t-distribution with 40 degrees of freedom if we take $\alpha = .05$. The correct degrees of freedom is 37, but 40 is the closest available in the table. It is even smaller than the critical value 1.684 that corresponds to a test with $\alpha = .10$. So we cannot reject the hypothesis that $\beta_3 = 0$ at these levels of confidence.

2.d. $\tilde{Y}_{n+1} = 30.1 - 1.08 \times 15 = 13.9$

2.e. Use formula (21)

$$s^2_{n+1} = s^2 \left( 1 + \frac{1}{n} + \frac{(X_{n+1} - \bar{X})^2}{n \sum_{i=1}^{n} (X_i - \bar{X})^2} \right) = s^2 \left( 1 + \frac{1}{n} \right) + (X_{n+1} - \bar{X})^2 \text{ std}(\hat{\beta}_2)^2 =$$

$$= (3.9331)^2 \left( 1 + \frac{1}{40} \right) + (15 - 14)^2 (.191)^2 = 15.893$$

Using $t_{.05} = 2.021$, the prediction interval has lower bound $13.9 - 2.021 \times \sqrt{15.893} = 5.842$ and upper bound $13.9 + 2.021 \times \sqrt{15.893} = 21.958$.