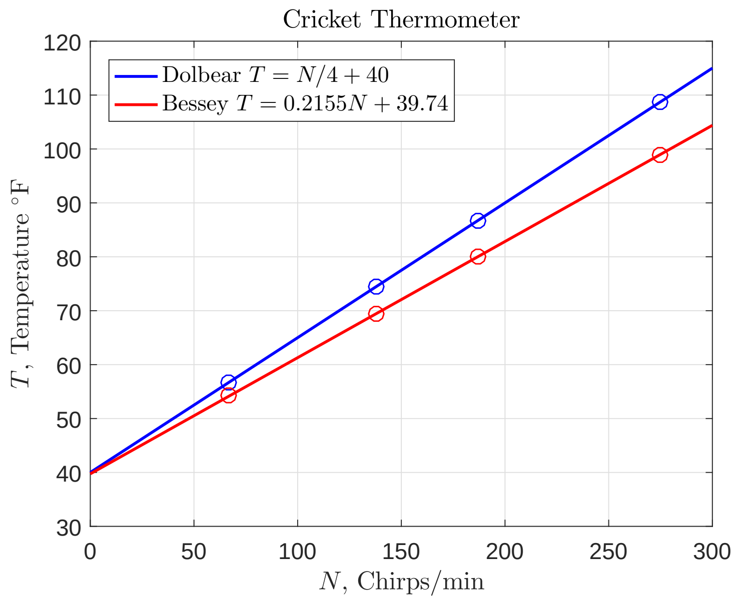
2. (7pts) d. The graph below shows the experimental data on chirps/min with the Bessey and Dolbear models. Graphs should span the domain and be at least 3 inches high and 4 inches wide. Any equations with variables should be labeled with appropriate variable names. Axes must be labeled.

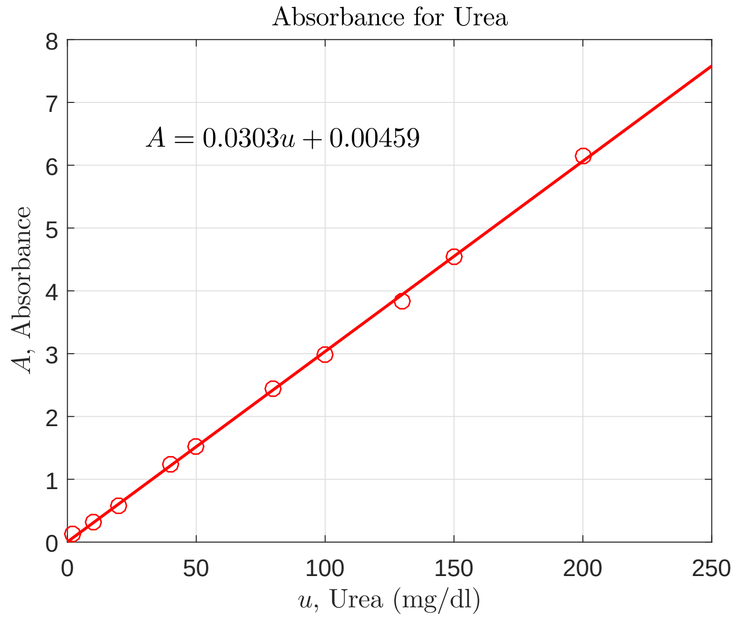


There are multiple ways to find the number of chirps/min in the audio clips for this problem. Most students will measure the length of the audio clips ($S = 5$ to 6 sec), then obtain the closest approximation to values listed in their problem. Some students employ computer software to slow down the recordings for greater accuracy, while some employ software that visualizes the sound waves and allows clear measurements. (The latter is the method I used for this problem.)

The primary source of error is the human error from counting the chirps on the recordings, especially at the higher chirp rates. Additional human error includes rounding error and the limitations of distinguishing precise chirps on the recordings or multiple crickets in the recording field. There are a number of potential biological errors that should be considered, including regional variations, different species, wind and humidity effecting the relative temperature, and imperfect rates of chirping of the specific cricket recorded.

The two models agree quite closely at low temperatures. However, the differences in the slopes result in almost 10°F difference at the highest chirp rate.

3. (10pts) c. The graph below shows the experimental data for the absorbance, A of test samples of urea, u. Graphs should span the domain and be at least 3 inches high and 4 inches wide. Any equations with variables should be labeled with appropriate variable names. Axes must be labeled. Models are solid lines, and data are represented by points.



The linear model fits the data very well, which can be seen from the very small sum of square errors. Since the model was found using the formula (`polyfit`) finding the least sum of square errors, any change in the slope, m, or the intercept, b would result in a larger sum of square errors and a poorer fit. The sum of square errors measures the vertical error between the data and the model.

The Lambert-Beer Law states that the absorbance of light is proportional to the concentration in a sample. This varies with different chemicals and different wavelengths. This law implies that the linear relationship should have an intercept, $b = 0$. We see that the intercept is nearly 0, so satisfies the Lambert-Beer law quite well. There are two primary sources of error for why $b \neq 0$: 1. Theoretically, the model is obtained from a least squares fit that is derived by experiments, so fluctuations shift the intercept from zero, 2. Experimentally, the spectrophotometer user may not have properly zeroed the machine with the blank water only ($u = 0$) sample or samples might have other impurities.

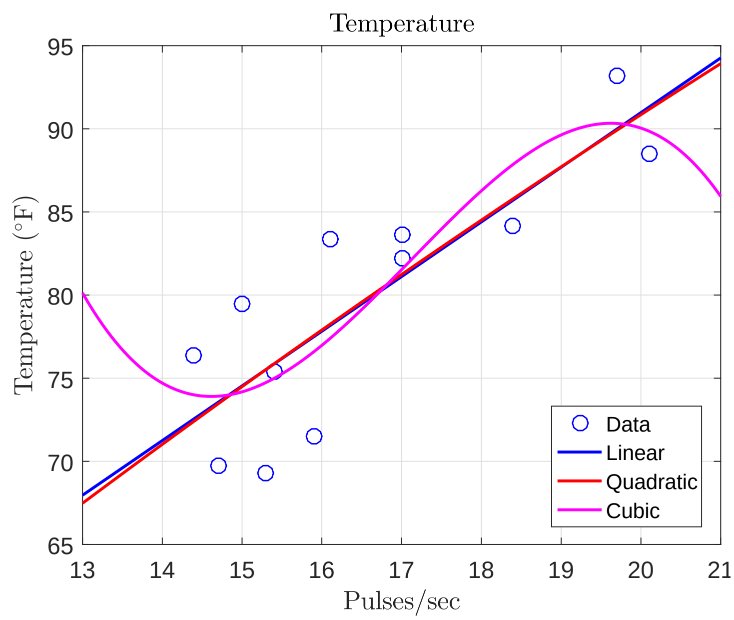
f. The experiments show a higher concentration of urea at higher temperatures. Biologically, animals must balance the conservation of their water and energy. At higher temperatures the hummingbirds need to conserve water (as the water is needed to assist in cooling (evaporative loss)), so the urea is concentrated more. The higher temperature gives the birds more energy to use in this process. It takes more energy to concentrate the urea, so at lower temperatures the hummingbirds conserve energy by not concentrating the urea and water is not a limiting quantity.

Torpor is a state hummingbirds use each night to conserve energy. They significantly reduce their metabolism, including heart and breathing rates. With lower metabolism little nitrogen waste is produced, which would lower excretion of urea. However, some animals shut down the filtration of kidneys, so there could be a slight build up in the blood. Thus, it is inconclusive if hummingbird urine is more or less concentrated immediately following torpor.

h. There should be a discussion of any pattern found between the different animal excretion patterns. The only animal close to a hummingbird in urea concentration is the frog, which lives in an aqueous environment and has a semi-permeable skin allowing easy water exchange.

Hummingbirds feed on nectar, which has a very high water content, so water is easily available also. When the environment and diet have less water available, then the animal needs to expend more energy to concentrate the urine and conserve water. Thus, the tortoise has the most concentrated urea, which is natural because of its arid climate, while the frog with the lowest concentration resides in water and has direct absorption of water, so it is not a limiting resource.

4. (8pts) h. Below is a graph of the cricket data with the linear, quadratic, and cubic best fitting models. The cricket data is fairly spread, so the models do not fit the data that well, especially over the limited range of pulse/sec data. One sees little distinction between the linear and quadratic, while the cubic clearly tries to hit the points, but obviously extends poorly beyond the extreme values of the pulses/sec.



Below is a Table listing the least sum of square errors for each model. These SSEs clearly are monotonically decreasing for the three model. The Table also includes values for the Akaike Information Criterion and the Bayesian Information Criterion. These information criteria show that the increase in number of parameters is not justified, which means that the linear model is the best.

	SSE	AIC	BIC
Linear	184.42	70.84	37.76
Quadratic	184.31	72.84	40.24
Cubic	172.15	74.02	41.90

Since the domain of the data is quite limited, the best improvement of the model would be to find more data with higher and lower pulse rates. As seen in the earlier Cricket Thermometer from class, it is unlikely that any model other than a linear one is likely to really show much improvement.