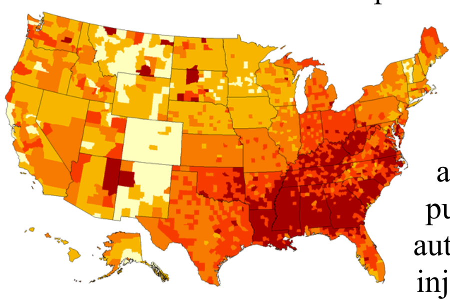
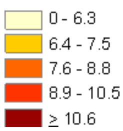
Special Problem 6
BYU ChE 436: Process Dynamics and Control

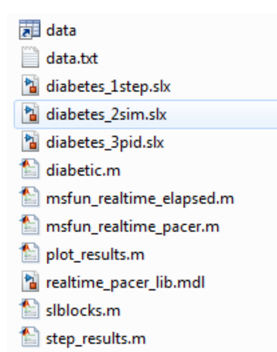
This assignment is to design an artificial pancreas for a Type-I diabetic. A Type-I diabetic has no insulin production in the pancreas. Insulin production in the pancreas is used to regulate a person's blood glucose level. When that natural production does not exist, glucose is monitored at regular intervals and insulin is injected as needed. With the recent development of continuous blood glucose monitors and the established success of continuous insulin pumps, it is now possible to create a controller that automatically regulates blood glucose by adjusting the injection rate of insulin. This development is needed because of the increased rates of diabetes within the U.S. as tracked by the Center for Disease Control (CDC). The incidence of diabetes mellitus is shown for the year 2008 with predictions for average rates of 33% by 2050 if the trend continues. Currently 8-9% or 26 million Americans are affected by this condition with yearly direct medical costs of $116 billion and even higher indirect costs.





The set point for blood glucose concentration is expected to remain within a specified range that is typical of a healthy individual. A typical range for a healthy individual is between 64 and 104 mg/dL (3.6 and 5.8 mmol/L) with a target of 80 mg/dL. Blood glucose values that are out of range are undesirable but values that are too low are much more serious and can lead to hospitalization or death if left untreated.

The insulin pump is a continuous injection into the person's body. It can deliver flow rates between 0.0 and 10.0 μU/min with a typical base value of 3.0 μU/min. The controller must restrict values of the flow to this range during the controller testing although it is typical with these devices to allow small one-time injections when needed.



a) Perform the necessary open loop dynamic modeling studies to determine a first order plus dead time (FOPDT) model which describes process operation near the design operation conditions (use diabetes_1step.slx Simulink model to generate step response data). *Report values of* K_p, τ_p, *and* θ_p.

b) Using the K_p, τ_p, and θ_p from part *a*, compute the tuning parameters for a PID controller from the IMC tuning correlation. This tuning correlation can be found on page 76 in the PPC packet. *Report the tuning parameters.*

c) Using your K_C, τ_I, and τ_D from part *b*, implement a PID controller with anti-reset windup (use diabetes_3pid.slx Simulink model and adjust PID parameters). Test the disturbance rejection capability of this controller by plotting the response of the process to steps in disturbance. Comment on how the nonlinear behavior of this process impacts our observed disturbance rejection performance. *Turn in a plot for the default IMC parameters, along with comments.*

e) Determine a "best" tuning by adjusting K_C, τ_I, and τ_D by trial and error until the controller response is improved (use quantitative measures like time outside the limits). Plot this best disturbance rejection response. *Turn in final plot and values of tuning parameters.*

f) Run a matrix of six more tuning cases and plot the response of each. The first two cases should use your best K_C from part *e,* but should use double and then half of your best τ_I. The next two cases should use your best τ_I from part *e,* but should use double and then half of your best K_C. Repeat τ_D as well. Comment on how the three tuning parameters interact and impact controller performance. *Turn in plots along with comments. Put all trends for each parameter on one plot for the sake of comparison.*