Basic Muscle Physiology
1. Define the terms sarcolemma, sarcoplasm, myofibril, and sarcomere.
2. Define isometric, concentric, and eccentric contractions, and agonist, antagonist, and synergist muscles.
3. Explain (in your own words) the events that influence the width of each band of a sarcomere when a muscle goes through the sequence of being stretched, contracting, and relaxing.
4. Design an experiment to test the following hypothesis: muscle A has the same number of motor units as muscle B. Assume you could stimulate the nerves that innervate skeletal muscles with an electronic stimulator and monitor the tension produced by the muscles.

Core Engineering Skills
5. Outline the steps needed to solve an ordinary, linear differential equation using the method of undetermined coefficients.
6. Solve the following differential equation using the method of undetermined coefficients:
   \[ \frac{dx}{dt} + ax = u(t) \]
   where \( u(t) \) is the unit step function, and \( x(0) = 0, \ a > 0 \)
7. Plot the solution to 6, define the term “time constant”, and label the time constant on your plot.
8. Write the one-dimensional equations of motion (i.e. the differential equation describing the dynamics) for a linear spring, a mass, and a linear, viscous damper

Muscle Mechanics
9. The parallel elastic element in the Hill Model represents the mechanical effect of connective tissue, which is made of collagen. Given that collagenous tissues exhibit a stiffness proportional to force plus a constant, derive the form of the force-length relationship for the parallel elastic element.
10. In some enhanced versions of the Hill Model, the series elastic element is modeled as two springs in series. One spring represents tendon stiffness, with a stiffness independent of activation. The other spring represents the stiffness of the crossbridges in the muscle, with a stiffness proportional to overall muscle activation.
   a) Explain why crossbridge stiffness would be expected to increase with muscle activation.
   b) Prove that as muscle activation increases, the net series stiffness will approach that of the tendon element.
11. Hill’s equation describes the nonlinear relationship between the tension \( T \) in a muscle and its shortening velocity: \( (T+a)(v+b) = (To+a)b \)
   a) Derive an expression for the maximum muscle shortening velocity \( V_{\text{max}} \)
   b) Show that Hill’s equation can be written in normalized form \( v' = (1-T')(1+T'/k) \), and provide an expression for \( k \) in terms of the constants in Hill’s equation.
   c) For most muscles, \( .15 < k < .25 \). Plot the normalized force-velocity relationship for \( k = 0.1, 0.2, 0.3, 0.4 \).
12. Assume a linearized version of the Hill Model with \( B = 10 \) grams-sec/cm and \( K = 500 \) gram/cm and no parallel elastic element. Model the excitation to the muscle (i.e. the “active
state”) as a short pulse 10 msec in duration with magnitude \( F_0 \). Determine and sketch the resulting twitch force \( F(t) \) if the muscle is held isometric.

13. Does your model in 12 predict rate coding? (Hint: the model in 12 is a linear system – what is the precise mathematical definition of a linear system)

**Huxley Model of Muscle**

14. Using qualitative reasoning, sketch crossbridge distributions \( n(x) \) predicted by the Huxley Model at \( v = 0 \), \( v = v_{\text{max}} \), and \( v < 0 \) (i.e. muscle lengthening).

15. Why is the plateau in the force-length relationship for an individual sarcomere a strong point of evidence in favor of the concept that crossbridges generate the force in a muscle.

**PROBLEM REQUIRED FOR GRADUATE STUDENTS ONLY:**

16. Using the first-order-kinetic scheme (Huxley 1957 model), derive the crossbridge distribution function \( n(x) \) for isotonic lengthening at a constant velocity \( v \).

**Food for Thought: Deep Learning**

“Someone ought to tell students how unimportant good grades are once they leave the campus. Grade-obsessed students probably assume that high grades lead to better jobs and more money, things they care about. [However,] what is correlated with success is what is called "engagement," genuine involvement in courses and campus activities. Engagement leads to what's called "deep learning," or learning for understanding. That's very different from just memorizing stuff for the exam and then forgetting it. As Russ Edgerton of the Pew Forum on Undergraduate Learning notes, ‘What counts most is what students DO in college, not who they are, or where they go to college, or what their grades are.’”

From, GRADE INFLATION: IT'S NOT JUST AN ISSUE FOR THE IVY LEAGUE, by John Merrow, Tomorrow’s Professor Msg. #584