Do problem 8.5 in the text

Solution:

Let $A^−$ denote the dissociated form of the acid. Let $x = [H^+]$ and $y = [A^−]$. Then we can find $[OH^-]$ by charge neutrality: $[H^+] = [OH^-] + [A^-]$. The two dissociation equilibria give

\[
x(x - y) = 10^{-14}
\]

\[
xy/(0.1 \text{ M} - y) = 10^{-4.76}
\]

\[
10^{-14} = x^2 - (0.1 - y)10^{-4.76} \approx x^2 - 0.1 \times 10^{-4.76}
\]

Thus $x \approx 0.0013$. We justify the approximation above by noting that then $y = x - 10^{-14}/x \approx x \ll 0.1$.

Thus the pH is $-\log_{10} 0.0013 = 2.9$.

Do problem 8.7 in the text.

Solution:

Use the Stokes drag formula and 1 eV $\approx 40k_BT$:

\[
\frac{(10e)(200 \text{ volt/m})}{(6\pi)(10^{-3} \text{ J s m}^{-3})(3 \times 10^{-9} \text{ m})} = \frac{2000(40k_BT)(1 \text{ m}^{-1})}{(6\pi)(3 \times 10^{-12} \text{ J s m}^{-2})} = 5.8 \mu \text{m s}^{-1}
\]

Do problem 10.2 in the text.

Solution:

**Part (a)** If the cross-sectional area of a resting muscle is $10 \text{ cm}^2$, then the maximum force of all those myofibrils
in parallel is \((5.3 \times 10^{-12} \text{ N}) \times 100 \times (10^{-3} \text{ m}^2)/(1.8 \times 10^{-15} \text{ m}^2) = 300 \text{ N}\). A 30 kg mass weighs about this much. The maximum weight you can lift from the elbow is somewhat less than the maximum force generated by your biceps because of the leverage of the arrangement (see Fig. 10.1). So yes, it’s reasonable. Notice that the length of the muscle didn’t enter. Longer muscles will be able to contract a greater distance, but the force exerted involves only the rate of momentum transfer across any cross-section, and hence only the cross-sectional area.

**Part (b)** Geometric similarity means that the two creatures have roughly similar leverage (mechanical advantage), and that the big one’s muscles have a cross-sectional area of \((L_1/L_2)^2\). But the creatures’ weights, and hence the burdens they are required to lift, have weights differing by a factor of \((L_1/L_2)^3\). So the little creature has an advantage in this contest, and indeed, ants readily lift more than their body weight whereas the mighty elephant cannot.

An alternate argument involves work. The maximum relative contraction (strain) of any muscle, \(\Delta l/l\), is determined by the microscope geometry and hence is universal (it’s about 0.25). Taking the product of the strain times the maximum force per area found above (about \(3 \times 10^5 \text{ Pa}\)) gives another universal quantity with the units of work per volume; it’s the volume-specific work of one muscle stroke, \(7.5 \times 10^4 \text{ J m}^{-3}\). Checking the dimensions we see that the maximum work per stroke in the big creature is larger by a factor of \((L_1/L_2)^3\). But the work that we are requiring that the creature perform is its weight times its height, which for the big creature is larger by a factor of \((L_1/L_2)^4\)!