Answer Key - Quantitative Question from Lecture #1

Diffusion coefficient (D) represents the rate at which a molecule or particle will move in a solution. D will depend on the size/shape of the molecule (and also on the nature of the solution because any solvent molecules tightly bound / "permanently affixed" to the surface of the particle creates a boundary layer that increases the effective size of the particle) and on the viscosity of the solvent (because the more viscous the solution, the more frictional drag on the particle). You were given the equation (Fick's Law) for calculating D, namely $D = kT/f$, and the equation (Stokes' Law) for calculating (for a sphere) the value of f, namely $f = 6\pi r\eta$. You were given the size/shape of the particle (a roughly spherical protein molecule with a diameter of 65 Å) and given the nature of the solution (an aqueous buffer containing 20% sucrose at 4˚C). So, you had to worry about the units (the value of D is usually given in cm^2/sec) and were asked to look up the viscosity of the solution.

D = k (Boltzman's constant) x T (˚K) / 6 x π x r (radius of the particle) x η (viscosity)

k = 1.381×10^{-23} J (Joules)/˚K, where 1 J is 1 $kg\text{-}m^2/s^2$
= 1.381×10^{-23} $kg\text{-}m^2/˚K\text{-}s^2$

T = 4˚C, and ˚K = ˚C + 273
= 277 ˚K

π = 3.14159265 (dimensionless)

r = 65 Å / 2 = 32.5 Å, where 1 Å is 10^{-10} m
= 32.5×10^{-10} m

η = ~3.240 cP (centipoise)*, where 1 cP is 10^{-3} Pa-s (Pascal-second) and where 1 Pa-s is 1 kg/m-s
= 3.24×10^{-3} kg/m-s

*Based on extrapolation from data I found in the "CRC Handbook of Biochemistry (with selected data for Molecular Biology)," 2nd Ed, copyright 1970, Tables on p. J-288-to-J-289. Viscosity of 20% sucrose in H_20 (at T ˚C): 3.774 (0 ˚C); 3.135 (5 ˚C); and, 2.642 (10 ˚C).
Viscosity of 20% sucrose at diff. temps. can also be determined at—
http://www.seas.upenn.edu/courses/belab/be309/SucroseCalculator.html#refs

D = 3.825×10^{-21} $kg\text{-}m^2/s^2$ / 1.984×10^{-10} kg/s = 1.928×10^{-11} m^2/s

D = 1.928×10^{-7} cm^2/s