Biology 3550: Physical Principles in Biology
Fall Semester - 2016

Important Equations for the Mid-term Exam

The following are important equations that have been introduced during the first half of the semester and might (or might not) be useful for the mid-term exam. You are encouraged to review these equations, their meaning and applications as you study for the exam. These equations will also be provided on the exam, but without all of the explanations and variable definitions given here.

This list does not include every possible relationship that you might be expected to know. You should know, for instance, equations for calculating the areas or volumes of simple shapes; for calculating concentrations; and the basic rules of probability, such as when to add or multiply probabilities, how to calculate expected values and how to interpret continuous probability distribution functions.

Spend your time thinking and solving problems, not memorizing!

Derived SI units

- Force (newton or N)

$$1\,\mathrm{N} = 1\,\mathrm{kg}\cdot\mathrm{m}\cdot\mathrm{s}^{-2}$$

- Energy or work (joule or J)

$$1\,\mathrm{J} = 1\,\mathrm{N}\cdot\mathrm{m} = 1\,\mathrm{kg}\cdot\mathrm{m}^2\cdot\mathrm{s}^{-2}$$

Conversion factors

- L to cubic meters

$$1\,\mathrm{L} = 10^{-3}\,\mathrm{m}^3$$

Constants

- Avogadro's number, $N_\mathrm{A} = 6.02{\times}10^{23}$
- Gas constant: $R = 8.134\,\mathrm{L}\cdot\mathrm{kPa}\cdot\mathrm{K}^{-1}\mathrm{mol}^{-1} = 8.134\,\mathrm{J}\cdot\mathrm{K}^{-1}\mathrm{mol}^{-1}$
- Boltzmann constant: $k = 1.38{\times}10^{-23}\,\mathrm{J}\cdot\mathrm{K}^{-1}$

Probability

- Binomial coefficients (the number of ways to choose either k unlabeled items or k labeled items in a unique order), from a collection of n.

$$\binom{n}{k} = \frac{n!}{k!(n-k!)}$$

- The Gaussian (normal) probability distribution function for a random variable x with mean μ and standard deviation σ

$$p(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-(x-\mu)^2/(2\sigma^2)}$$

Random walks in one, two or three dimensions

- Parameters:

$$\delta = \text{fixed step length or root-mean-square length of random step lengths}$$
$$n = \text{number of steps}$$

- End-to-end distance, r

$$\langle r^2 \rangle = n\delta^2$$
$$\text{RMS}(r) = \sqrt{\langle r^2 \rangle}$$

- Mean-square net displacement along the x-axis in a two-dimensional random walk

$$\langle x^2 \rangle = n\delta^2/2$$

- Mean-square net displacement along the x-axis in a three-dimensional random walk

$$\langle x^2 \rangle = n\delta^2/3$$

Diffusion

- The diffusion coefficient, D

$$D = \frac{\delta_x^2}{2\tau}$$

where τ is the average time interval between direction changes of the diffusing molecule, and δ_x is the root-mean-square displacement along the x-direction between direction changes.

- Fick's first law:

$$J = -D\frac{dC}{dx}$$

where J is the flux (in moles or molecules per unit time per unit area), and dC/dx is the derivative of concentration with respect to x.

- Fick's second law:

$$\frac{dC}{dt} = D\frac{d^2C}{dx^2}$$

where dC/dt is the derivative of concentration with respect to time and d^2C/dx^2 is the second derivative of concentration with respect to x.

Kinetic energy and molecular motion

(to be covered on Wednesday, 5 Oct.)

- Kinetic energy, in the x-direction, of an object with mass m and velocity v

  $$E_{\mathrm{k},x} = mv^2/2$$

- Root-mean-square thermal kinetic energy, in the x-direction, of molecules of mass m at temperature T

  $$\mathrm{RMS}(E_{\mathrm{k},x}) = kT/2$$

- The Stokes-Einstein for calculating the diffusion coefficient for a spherical particle:

  $$D = \frac{kT}{6\pi\eta r}$$

  where η is the viscosity, in units of $\mathrm{N \cdot s\dot{m}^{-3}}$, and r is the sphere radius.