A SUMMARY OF TOPICS THAT WILL BE HELPFUL WHEN TAKING BIOEN 316

Programming

MATLAB

General topic	**Example functions**	
Array generation	`Ones, zeros, linspace, logspace,` `x = [1 1 2 3 5]; t = 1:0.5:10; y = 5*t;`	
Array indexing	`x2 = x(2:5);  x3 = x(3:end);`	
Array arithmetic	`+ - / * .* ./ ^ .^` `A .* B` *versus* `A * B`	
Plotting	`Plot, plot3,` **`polar`**`, imagesc` We will also use `abs, imag, real, angle`	
Programming	`While` and `for` loops. Object-oriented programming is optional.	

Mathematics

Algebra

Basic equation manipulation and solution methods, especially the quadratic formula.

Trigonometry

Radians vs. degrees, definition of sine, cosine, tangent, and their inverses.
Conversion between rectangular (Cartesian) and polar coordinates.
Addition, dot product, and cross product of 2-D vectors.

Calculus

Definite integrals of sine, cosine, and exponential functions.
Integration by parts.

Summations

Notation for finite and infinite series and summations

e.g.

$$f(x) = \sum_{n=0}^{\infty} a_n x^n = a_0 + a_1 x^1 + a_2 x^2 \dots$$

Logarithms

Let $\log(x) \equiv \log_{10}(x)$. Convert each of the following expressions to the form $k \log(x)$, if possible:

$\log(100x)$

$\log(x/\sqrt{10})$

$\log(100+x)$

$20 \log(x^2)$

$20 \log(x) - 10 \log(1/x)$

Natural log and e are defined such that $\ln(e^x) = e^{\ln(x)} = x$; $\ln(x) = \log_{10}(x)/\log_{10}(e)$.

Log(x) is defined only for positive x, where x is simply a number (no units). It is legitimate to calculate the logarithm of a ratio of two numbers with the same units; this is done when converting sound pressure level to decibels: Loudness in dB = 10 log(I / I_0) where I and I_0 are both in W/m^2. (Section 15-3 of Physics book)

Complex numbers

Let $j^2 = -1$. Label each of the following as real, imaginary, complex, or none of these.

27	$\sqrt{-6}$	$\sqrt{j}$ (hint: what is j in terms of e?
4 + 5j	$2e^{2j}$	
$7e^{\pi j}$	e^{-j}	
$2e^{-j\pi/2}$	$2e^{\pi/4}$	
$e^{3j} + e^{-3j}$	$e^2\, e^{-5j} - e^{5j+2}$	

In the following questions let z^* be the complex conjugate of the complex number z. That is, $(a+jb)^* = (a-jb)$. Write an equivalent form for each of the following expressions.

$(3 - 2j)^*$

$(3 - 2j)^*(3 - 2j)$ i.e. the product of z and z^*.

$(x + 3 - 2j)^2$

Is $(x + 3 - 2j)^*(x + 3 - 2j)$ ….

a) Real

b) Imaginary

c) Complex

d) Depends on x

Add the following by converting to rectangular coordinates and back to polar.

$6e^{j\pi/6} + 2e^{-j\pi/6}$

Divide the following by converting to polar form and back.

$\frac{2-3j}{7+4j}$ $\qquad \frac{14+8j}{2}$ $\qquad \frac{12j}{3-2j}$

L'Hopital's rule

The limit of a ratio of two functions is equal to the ratio of the derivatives of the numerator and denominator, each taken to the same limit. This can be used to determine the value of the ratio of some functions that would otherwise be undefined (tend toward infinity) as the limit is approached.

$$\lim_{x\to\infty}\left(\frac{f(x)}{g(x)}\right) = \frac{\lim\limits_{x\to\infty}\left(\frac{df(x)}{dx}\right)}{\lim\limits_{x\to\infty}\left(\frac{dg(x)}{dx}\right)}$$

Statistics

Definition of mean, standard deviation, variance, and median.

Biology

Terminology

Cardio = heart; myo = muscle; cephalo = head; oculo = eye;

Anatomy

Basic layout of the heart: atria, ventricles, septum, apex, aorta, valves.

Neurophysiology

Action potential: how an electrochemical impulse travels along a neuron.

Physics

Electromagnetics

Definition of electric charge (Q), voltage (V or v), and current (I or i).

The following list includes topics that you should know conceptually, and examples that you should be able to solve if given a similar problem. The section and example numbers refer to the appropriate sections in the PHYS 121-2-3 book by Tipler & Mosca.

Sect 21.1 – Charge; 1 Coulomb = 6.25×10^{18} electrons.

Sect 23.1 - Potential difference, units for voltage (J/C) and E field (V/m)

Sect 24.1 - Capacitance, capacitors, farads. A capacitor is a discrete component that accumulates charge, where the charge is calculated as the product of voltage and capacitance. "Discrete component" means that all of the capacitance is in one place and the connectors (wires) do not contribute any capacitance. It also means that the component ideally has only capacitance, with infinite resistance and no inductance.

Sect 24.3 - Batteries and circuits

Example 24-4 shows that the combined capacitance of capacitors in parallel is the sum of the capacitances.

Example 24-5. When capacitors are in series, there is equal charge on both capacitors, and the voltages of the two capacitors add to make one total series voltage. Derivation:

$Q_1 = Q_2 = Q_{\mathrm{SERIES}}$

$V_{\mathrm{SERIES}} = V_1 + V_2$

$Q_{\mathrm{SERIES}} = C_{\mathrm{SERIES}} * V_{\mathrm{SERIES}} = C_{\mathrm{SERIES}} * (V_1 + V_2) = C_{\mathrm{SERIES}} * (Q/C_1 + Q/C_2)$,

$C_{\mathrm{SERIES}} = (1/C_1 + 1/C_2)^{-1}$.

Example 24-6, a series Capacitor problem.

Example 24-7. The sum of the voltages around a closed loop is zero. This is called Kirchhoff's Loop Law or Kirchhoff's Voltage Law.

Problem 24.67 on neuron capacitance is a good biological application, but not required for BIOEN 316.

Chapter 25: Resistance. A resistor is a discrete component that allows current to pass, proportional to the applied voltage. Given the resistance R of a resistor, $V=IR$. "Discrete component" means that all of the resistance is in one place and the connectors (wires) do not contribute any resistance. In reality all electrical connections have some resistance, but usually it is very low. In fluid systems, the connections contribute a lot of the resistance. It is useful to know the following equations:

25-1	$I = \Delta Q/\Delta t$
25-2	1 amp = 1 coulomb/second
25-7,9	$R = V/I$, $V = IR$
25-8	1 Ω = 1 V/A, *i.e.* a 1-ohm R allows 1 A through with 1 V across it.
25-10	$R = \rho L/A$, where ρ is resistivity (a material property), L = length and A = cross-sectional area of conductor
25-14	$P = V^2/R = IV = I^2R$
25-20	$R_{\mathrm{SERIES}} = R_1 + R_2$ ← note that this is opposite from series capacitors.
25-25	$R_{\mathrm{PARALLEL}} = (1/R_1 + 1/R_2)^{-1}$

Note the resistivity of some materials in table 25-1. We will use the resistor value color code in table 25-3, but most students do not memorize it. For example, red-orange-yellow means numbers 2-3-4, indicating 23×10^4 Ω = 230 kΩ.

Understand example 25-8 (identify series and parallel connections in a circuit diagram).

Problem: Refer to the figure in example 25-12, which shows a loop that contains a) a battery, b) a resistor, and c) two resistors in parallel. If $v_a - v_b$ = 64 V, what is the current through the 4 Ω resistor? Answer: i_4 = 6 A.

Sect. 25.5 - Kirchhoff's rules. Example 25-16, which is a figure-8 circuit (two loops that share a resistor) with a total of two batteries and three resistors.

Vocabulary: Ammeter, Voltmeter, Ohmmeter. Combined, they make a Multimeter.

Sect. 25.6, RC Circuits: Recognize that the circuit behavior can be represented by a first-order differential equation, $RC\frac{dv_C}{dt} + v_C = v_{in}$. The voltage across the capacitor is either a rising exponential (charging) or a falling exponential (discharging).

Chapter 28.

Moving charge produces a magnetic field. *Note: The text has much more detail than is needed for BIOEN 316.*

Coils of wire are used to concentrate a magnetic field inside the coil; this forms an electromagnet. Iron cores are sometimes inserted in the coils to increase the density of the magnetic field. The number of turns in the coils and the current through the wire determine the magnetic field strength.

Sect. 28.6 - Concept of inductance, especially self-inductance. Inductance L of a coil is the ratio between the magnetic flux (the integral of the magnetic field) and the current through the coil. L is also the ratio of the voltage across an inductor to the rate of change of current through the coil.

An inductor is a discrete component that accumulates current by integrating voltage. The faster the current is changing, the greater the voltage. An inductor can be energized (building up the magnetic field), similar to charging a capacitor. When energizing, the current follows an exponential rise; when de-energizing, the current follows an exponential decay.

A resistor, capacitor, and inductor can be combined into one circuit, in which the current or voltage can oscillate, following a sinusoidal function of time.

Waves

Let x, y and z define the Cartesian coordinate system.

Traveling wave: $p = A\cos(kx - \omega t + \varphi)$, crests moving in the +$x$ direction

Stationary wave: $p = A\cos(kx + \varphi)$

Stationary oscillation: $p = A\cos(\omega t + \varphi)$

ω is in radians/second, $\omega = 2\pi f = 2\pi/T$, where f is frequency in Hz and T is period.

k is in radians/meter, $k = 2\pi/\lambda$, where λ is spatial period (wavelength).

Optics

Concepts: refraction, reflection, diffraction, concave and convex lenses, focal point, real and virtual images, index of refraction, total internal reflection.

Formulas: Snell's law.

$$\frac{\theta_1}{n_1} = \frac{\theta_2}{n_2}$$