General Physics - E&M (PHY 1308) Lecture Notes

Homework004

SteveSekula, 13 September 2010 (created 12 September 2010)

no tags

Homework 4

Expectations for the quality of your handed-in homework are available at http://www.physics.smu.edu/sekula/phy1308/HomeworkPolicy.pdf. Failure to meet these guidelines will result in loss of points as detailed in that document. This assignment covers material from Wolfson Chapter 22. Each problem is worth 20 points, and the total assignment is worth 60 points.

This homework is due by 9am (start of class) on Monday, September 20

Reading Assignment:

Chapter 22

Problem SS-10

Medical facilities, such as hospitals, often contain a device known as a "particle accelerator" for use in cancer therapies. Particle accelerators use electric fields to accelerate electrically charged particles to high speeds. They were originally developed for use in the study of subatomic particles, but have found many uses in industry and medicine.

Particles accelerators by a medical linear accelerator are used to penetrate the body and deposit their energy, gained during acceleration, into tumor material. For instance, Greenwich Hospital in New York boasts on its website that it has " . . . one of the newest generations of linear accelerators used in radiation therapy." (http://www.greenhosp.org/medicalservices_cancer-treatment-radiation-treatment.asp).

1. Electrons are the typical particle of choice in such cancer therapy, as they are cheap to obtain in large quantities and easy to accelerate. If, during medical therapy, a beam of electrons strikes the skin with an energy of $10.0 \mathrm{MeV}$ (million electron-Volts): (a) Through what potential was it accelerated to reach this energy? (b) If a medical linear accelerator brings electrons from rest (zero energy) up to $10.0 \mathrm{MeV}$ in 2.0 meters, what is the magnitude of the electric field used in acceleration?

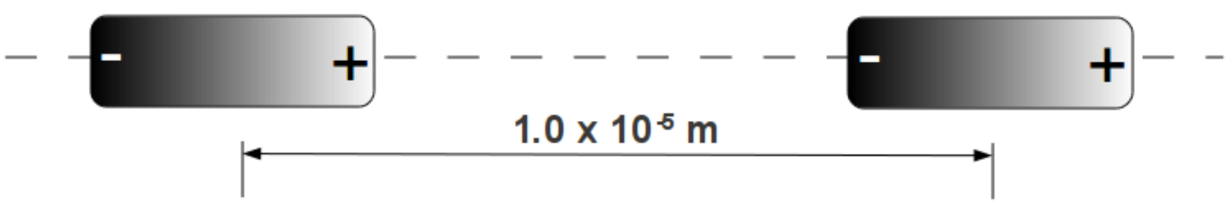
(More about medical accelerators: http://www.radiologyinfo.org/en/info.cfm?pg=linac)

Problem SS-11

As mentioned in class, the tiny air sacs in our lungs (the "alveoli") are the microscopic source of expansion and contraction that enable our breathing. The insides of those sacs is lined with a layer of water. Water is a dipole, and dipoles tend to align each other along their electric fields, exerting a tiny force on one another called the "Van der Waals Force." Infant Respiratory Distress Syndrome (IRDS) results when an infant is born before sufficient pulmonary surfactant has been produced to overcome the van der Waals force in the lungs.

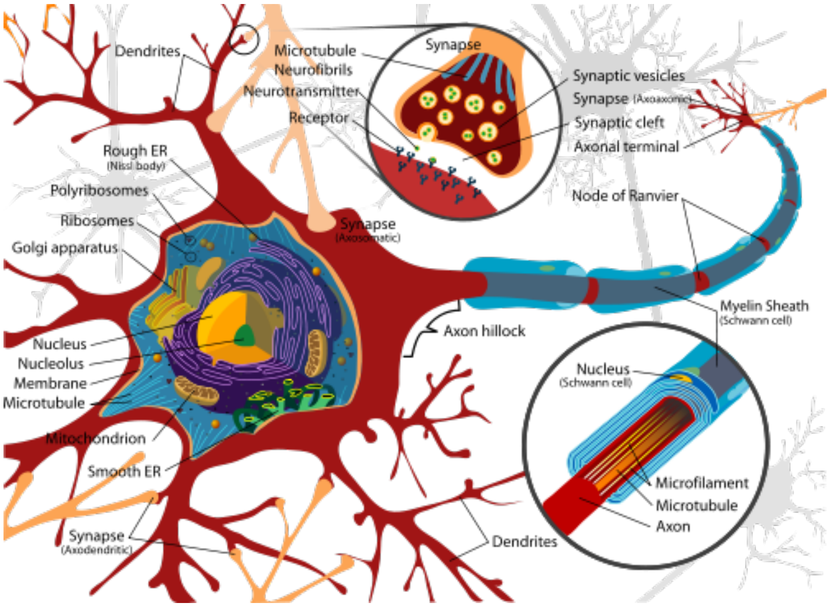
Let's note some basic information about water, and about water in an alveolus (a single sac). Water has a dipole moment of $p = 6.2 \times 10^{-30}\mathrm{Cm}$. The average separation between water molecules in the surface layer of water in the alveolar sac is about $1.0 \times 10^{-5}\mathrm{m}$. The magnitude of the charge on each end of the water dipole is about 10.0 elementary charges.

Consider the picture below of two water dipoles, lined up next to one another in electrostatic equilibrium. How much work is needed to increase the separation between two dipoles by a factor of 2.0? *HINT: consider the electric field of one of the dipoles, and then consider how much work is needed to move each of the charges on the other dipole by the specified amount. The total work is the sum of the work required to displace each one separately.*



Problem SS-12

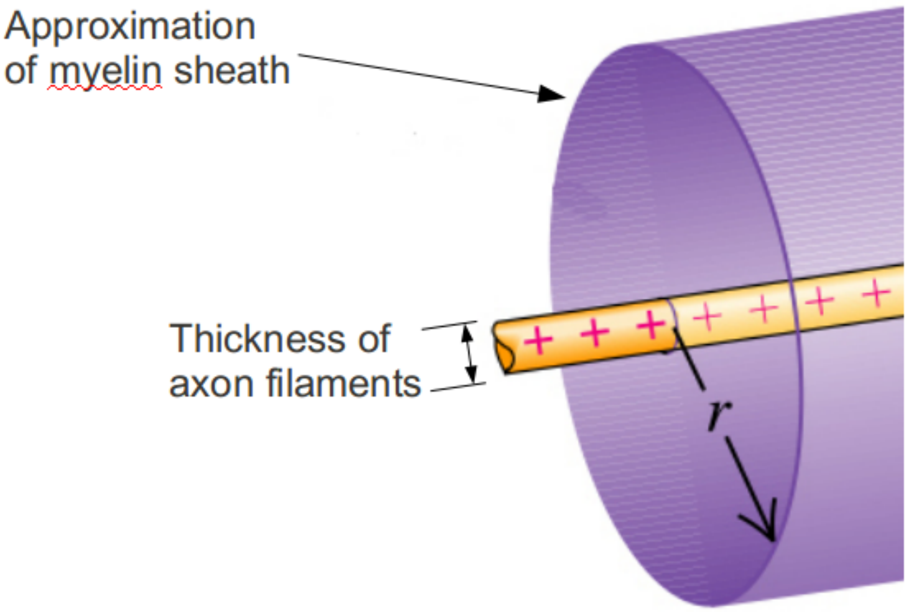
The neuron is a complex cellular structure whose job is to transmit information, in the form of electrical impulses, throughout the nervous system of a living organism, such as a human. Neurons consist of dendrites, which connect one neuron to another, the soma (central cell body of the neuron which processes information from the dendrites), the axon (the long "cable" behind the soma that transmits impulses to the axon terminal), and the axon terminal, which connects via synapses to other dendrites on other neurons. See image below. The complex interaction of neurons plays a central role in decision making, learning, memory, and is likely the cellular foundation of consciousness.



The axon is essentially an example of a "coaxial cable" - a conductor in the center of a cylindrical "sheath." In the axon, the sheath is a chemical called "myelin," which results from glial cells.

Let us treat the axon as a very long coaxial cable (this is not unreasonable - some axons, as in the spine, can be up to a few feet long). This is illustrated below. The myelin sheath can be treated as a thin-walled cylindrical enclosure with a diameter of $1.0\mu\text{m}$. The axon filaments in the center can be treated as a wire of thickness $1.0 \times 10^{-8}\text{m}$ running along the central axis of the myelin cylinder. Treat the filament and the myelin as conductors.

Given that the potential difference in a typical neuron is 50.0 mV, what is the linear charge density on the conductors?


Approximation
of myelin sheath
Thickness of
axon filaments
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