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

Homework003

SteveSekula, 8 February 2011 (created 5 September 2010)

no tags

Homework 3

Expectations for the quality of your handed-in homework are available at http://www.physics.smu.edu/sekula/phy1308/homework.pdf. Failure to meet these guidelines will result in loss of points as detailed in that document.

Reading Assignment:

Chapter 22, Chapter 23

Practice Problems:

These are not required; they are odd-numbered problems from Wolfson that may help you to warm up for the required problems.

- CH22-21
- CH22-49
- CH23-22 (Answer: $C = 2.2 \times 10^{-8}\text{F}$)

Required Problems:

- SS-8 [20 Points]
- SS-9 [20 Points]

- CH23-30 [10 Points]
- CH23-32 [10 Points]

Problem SS-8

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.

Medical linear accelerators are used to make a beam of particles that can penetrate the body. The particles then deposit the energy gained during acceleration into tumor material. 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).

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 10.0MeV (million electron-Volts):

1. Through what potential was it accelerated to reach this energy?

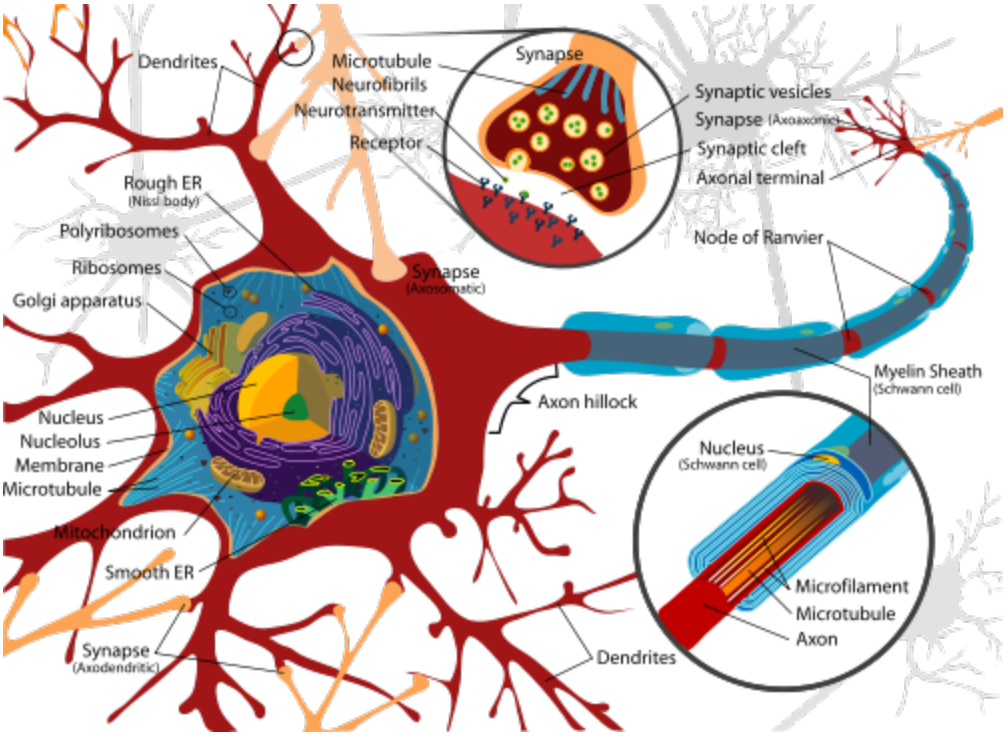
2. If a medical linear accelerator brings electrons from rest (zero energy) up to 10.0MeV in 4.0 meters, what is the magnitude of the electric field used in acceleration?

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

Problem SS-9

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" - this is a cable made from a small wire running along the central axis of a larger cylindrical conductor (the "sheath"). In the axon, the sheath is a chemical called "myelin," which is produced by 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 with a diameter of $1.0 \times 10^{-8}\text{m}$; this filament wire runs along the central axis of the myelin cylinder and carries a uniform linear charge density. Treat the filament and the myelin as conductors.

1. What is the formula for the electric field inside the cylinder due to the filament? *HINT: what is the electric field outside of a cylinder carrying a linear charge density, λ?*

2. What is the electric potential difference between the outer surface of the filament, located at r_A, and the inner surface of the sheath, located at r_B?

3. The resting electric potential difference in a typical neuron is -70.0 mV. What is the linear charge density on outer surface of the central filament?

4. What is the capacitance of this axon if its length is 1.0m?