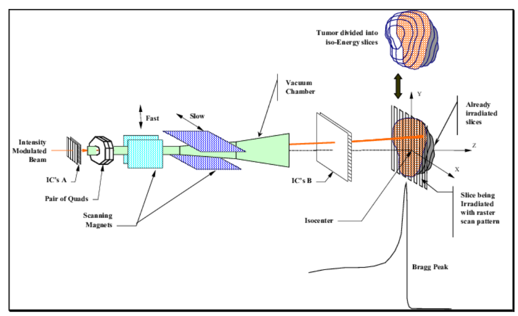
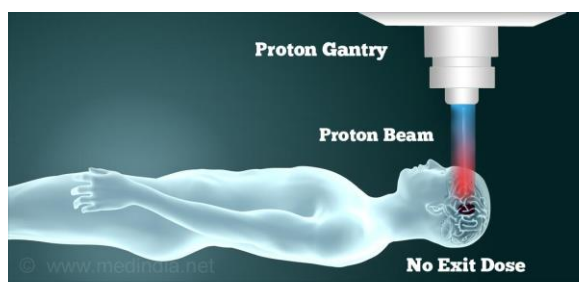
Hand-In Problem 6: Beginning of Solution Ph 213

Here are some hints to get you going on this problem.

Proton therapy is a relatively new way to treat some types of tumors. In proton therapy protons are accelerated to high speeds and then bombarded into cancerous cells.





A cylindrical beam of protons is aimed at a cancerous tumor. The beam current is non-uniform in both space and time and can be described by the current density function $J(r,t)=a(r^2-b)t^3$. One pulse of protons lasts for about 3.0ms.

a. What units should the variables a and b have in the above equation in order for the units to work out in SI units?
b. What is the current in the beam at t=3ms?
c. If the beam is 1.73mm in radius, how many protons are delivered to the tumor after 3ms?
   ($b = 2.34\cdot10^{-6}$, and $a = 5.67\cdot10^{17}$, both in standard units)
d. Each proton is traveling at $1.00\cdot10^{8}$m/s. Neglecting relativity, how much energy is delivered to the tumor in those 3ms.

a. a has units of $\frac{Amps}{m^4 s^4}$ which is the same as $\frac{C}{m^4 s^5}$

b has units of m^2

b. Remember that J is a current density which has the units of Amps/m^2. If we had a constant current density, then I would equal J·A. But, we are calculus literate individuals so we realize that

$$I = \int J(r,t)dA$$

$$I(t) = \int [a(r^2 - b)t^3]rdrd\theta$$

$$I(t) = 2\pi(\frac{1}{4}ar^4 - \frac{1}{2}abr^2)t^3$$

c. By definition $I = \frac{dQ}{dt}$ which means that:

$$Q(t) = \int_0^{0.003} 2\pi(\frac{1}{4}ar^4 - \frac{1}{2}abr^2)t^3 dt\Big|_{r=0}^{r=.00173m}$$

Possible Reasonableness tests you can run:

- Compare the number of protons to numbers we have used in class up to now.
- Compare the number of protons to the size of a mole and realize that it is much smaller than a mole.
- Calculate the temperature increase of the tumor and realize that it is pretty small.
- Let me know if you can come up with other reasonableness tests.