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PH 213

HIP 6

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, $b = 2.34\cdot10^{-6}$, $a = 5.67\cdot10^{17}$, and the beam has a radius of 1.73mm. The drift speed (v_d) of the protons is $1.00\cdot10^8$m/s.

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?

   J is in units of $C/(s*m^2)$. The value for b must be in m^2 and the value of a must be in $C/(s^4*m^4)$

b. What is the current in the beam at t=3ms?

   J = I/A → I = J*A → since J varies over radius and time we must take the integral → $I(t) = int((a(r^2-b)t^3)rdrd\theta)$ → $I(t)=int((ar^3-abr)t^3drd\theta)$ → $I(t)=2\pi((ar^4)/4 - (abr^2)/2)t^3$

c. How many protons are delivered to the tumor after 3ms?

To find how many protons that are delivered to the tumor we must find the amount of charge delivered over that time period and then divide that by the charge of a proton to find the number of protons.

$$I(t) = \iint (ar^2 - ab) t^3 \, r \, dr \, d\theta \longrightarrow \int_0^{2\pi} \int_0^{r} (ar^3 - abr) t^3 \, dr \, d\theta$$

$$\int_0^{4\pi} \left(\frac{ar^4}{4} - \frac{abr^2}{2} \right) t^3 \, d\theta$$

$$I(t) = 2\pi \left(\frac{ar^4}{4} - \frac{abr^2}{2} \right) t^3 = \frac{dQ}{dt}$$

$$I(t) = \frac{dQ}{dt} \longrightarrow \int dQ = \int I(t) \, dt$$

$$Q(t) = \int_0^t I(t) \, dt$$

$$Q(t) = \int_0^t 2\pi \left(\frac{ar^4}{4} - \frac{abr^2}{2} \right) t^3 \, dt$$

$$Q(t) = 2\pi \left(\frac{ar^4}{4} - \frac{abr^2}{2} \right) \frac{t^4}{4}$$

$$N_{proton} = \frac{Q(.003)}{p^+}$$

$$Q = \mathrm{abs}\left(2 \cdot \pi\left(\left(\frac{\left(a \cdot r^4\right)}{4} - \left(\frac{a \cdot b \cdot r^2}{2}\right)\right) \cdot \frac{t^4}{4}\right)\right)$$

$$Q = 0.0000910669927049$$

$$a = 5.67 \cdot 10^{17}$$

$$a = 5.67 \times 10^{17}$$

$$r = 1.73 \cdot 10^{-3}$$

$$0 \leq \theta \leq 12\pi$$

$$b = 2.34 \cdot 10^{-6}$$

$$b = 0.00000234$$

$$t = 3 \cdot 10^{-3}$$

$$t = 0.003$$

$$N = \frac{Q}{\left(1.6 \cdot 10^{-19}\right)}$$

$$N = 5.6916870441 \times 10^{14}$$

The number of protons delivered in this time period is estimated to be 5.69×10^{14} protons.

The reasonableness can be checked by comparing this value to that of a mole. A mole is $6.02*10^{23}$ units which is 9 orders of magnitude greater than the amount of protons delivered. This would be a reasonable amount in light of this comparison.

d. Neglecting relativity, how much energy is delivered to the tumor in those 3ms. The protons have a mass of $1.67*10^{-27}$ kg and they are travelling at $1*10^{8}$ m/s. With this information we can find the total kinetic energy delivered.

$K = ½*m*v^2 \rightarrow K = ½ * (1.67*10^{-27}*5.69*10^{14})*(1*10^{8})^2 \rightarrow$ **K = 4751 J**

GORY	PLARY (1.5)	MPLISHED (1)	LOPING (0.5)	GENT (0)
Statement and tion	arning tool for our class is written	blem is clearly presented for reader in h words.	blem is directly copied or is hard .	p into some calculation
	tch could be dropped into a novel as it stands.	a clear sketch, larger than a credit the problem set up with important and data noted	some sketch of the problem	etch?
Tools	iate physics tools are correlated ercise in textbook quality and	iate physics tools are correlated to the . Appropriate tools include: pictures, onservational laws utilized, etc...	hysics tools are correlated to the .	e a few equations written.
n Solution tation	is very clearly presented with g asides or annotations	is complete and clearly presented no significant intuitive demands on the	olution I have to read between	s version of solution with only nts present
	ution can serve as solution	g is larger than a credit card, tion is fluid, notation used is clear.	gure the path of your solution with	read it.
		correctly given	ons & quantities are presented s	hits at the results
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ableness	more than one type of ableness check.	ne clear rationale for appropriateness of tion in the setting	that the answer is reasonable but sn't given any evidence	ssion
Graded			e	t your self-assessment is from mine by at least two steps.