

Homework 10

Due November 13, 2009

272:

1.- A solenoid is made by winding a single layer of No. 14 copper wire on a cylindrical form 6 cm diameter. There are 5 turns per centimeter and the length of the solenoid is 30 cm. Consult wire tables and find what is the diameter of the No. 14 wire and find its resistance per meter at 75 degrees centigrade (the coil will run hot). If this solenoid is connected to a 24 V generator, what will be the magnetic field strength (in Tesla) in the solenoid and what its power dissipation (in Watts)?

2.- Calculate the self-inductance L of a cylindrical solenoid of diameter d and length $l=20d$. It has a single-layer winding containing a total of N turns. Assume as a first approximation that the magnetic field inside the solenoid is uniform right out to the ends. Estimate the magnitude of the error you incur. Is the true inductance L larger or smaller than your approximate result? Explain your reasoning.

272H (the previous problems and the following two):

3.- Supposed that the solenoid described in problem 1 is used to make a very strong field for a very short time by connecting it briefly to a high-voltage source, to force an enormous current through it. Putting all other limitations aside, consider the limit imposed by the tensile strength of the wire. The magnetic pressure, like pressure in a hose, will tend to split the solenoid open. If the tensile strength of the wire is 2×10^9 dynes/cm², what is the strongest field that could be contained in that solenoid?

4.- Consider two electrons in a linear accelerator which are moving on parallel paths, side by side, at the same speed v . The distance between them, a distance measured at right angles to their velocity, is r . What is the force that acts on one of them, owing to the presence of the other, as observed in the laboratory frames? If v were very small compared to c , you could answer $e^2/4\pi\epsilon_0 r^2$. However, v is not small and you have to be careful.

(a) The easiest way to get the answer is this: Go to a frame of reference moving with the electrons. In that frame the two electrons are at rest, the distance between them is still r , and the force is just $e^2/4\pi\epsilon_0 r^2$. Now transform the force into the laboratory frame using the appropriate force transformations. (Be careful about which is the primed system; is the force in the lab frame greater or less than the force in the electron frame?)

(b) It should be possible to get the same answer working entirely in the lab frame. In the lab frame, at the instantaneous position of electron 1, there are both electric and magnetic fields arising from electron 2. Calculate the net force on electron 1, which is moving through these fields with speed v , and show that you get the same result as in (a). Make a diagram to show the directions of the fields and forces.

(c) What can you say about the force between two side-by-side moving electrons (not being accelerated), in the limit as $v \rightarrow c$.