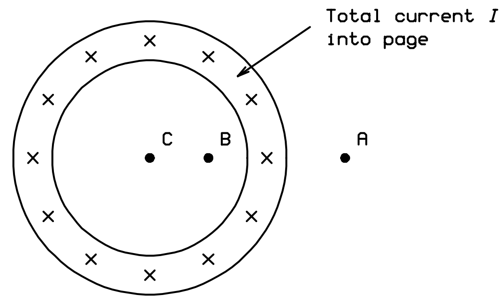
SOLUTIONS

Quiz Number 4 PHYSICS 102 February 27, 2002

Please **BOX** your answers.

$k = 1/(4\pi\epsilon_0) = 9 \times 10^9\,\mathrm{N\,m^2/C^2}$ $\epsilon_0 = 8.85 \times 10^{-12}\,\mathrm{C^2/N\,m^2}$ $\mu_0/4\pi = 10^{-7}\,\mathrm{T\,m/A}$

1. In high current applications, the "wires" are often made in the form of pipes so that cooling water can flow through the middle of the wire. The diagram shows a cross section of such a pipe. It is very long (perpendicular to the page) and has an inner radius $r_i = 5\,\mathrm{mm}$, and outer radius $r_o = 7\,\mathrm{mm}$, and carries a current $I = 100\,\mathrm{A}$ which is spread uniformly over the cross section of the pipe and flows into the page as indicated by the crosses.



(a) What are the magnitude and direction of the magnetic field produced by the current in the pipe at the point A, which is located $r_A = 10\,\mathrm{mm} = 0.01\,\mathrm{m}$ horizontally to the right of the centerline of the pipe, C? (3 points)

Ampere's law says that the sum of $B_\parallel \Delta L$ around a closed curve is μ_0 times the total current flowing through the closed curve. Since we have a symmetric situation, the lines of B are circles concentric with the pipe and lying in the plane of the page. $\sum B_\parallel \Delta L = B(2\pi r_A) = \mu_0 I$ and $B = \mu_0 I/2\pi r_A = 2(\mu_0/4\pi)I/r_A = 2 \times 10^{-7} \times 100/0.01 = \boxed{0.002\,\mathrm{T} = 20\,\mathrm{G}}$. Since the magnetic field lines are circles centered on the pipe, the question is whether the field points clockwise or counterclockwise. The right hand rule says stick your right thumb along the direction of the current (into the page) and then your fingers curl around the current in the direction of the field. This is clockwise, and at point A, the field points **down**.

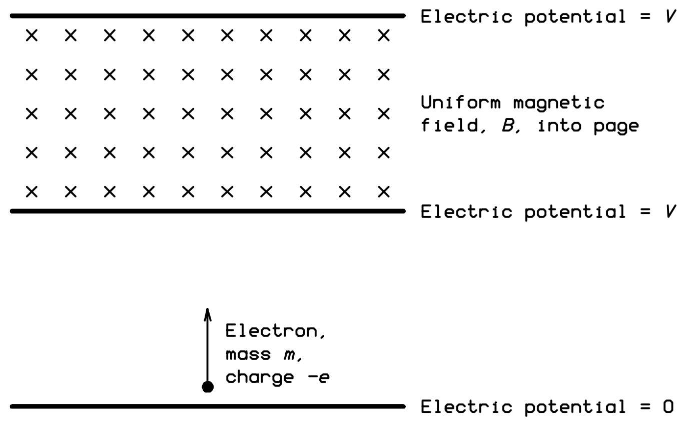
(b) What are the magnitude and direction of the magnetic field produced by the current in the pipe at the point B, which is located $r_B = 3\,\mathrm{mm} = 0.003\,\mathrm{m}$ horizontally to the right of the centerline of the pipe, C, and inside the pipe? (2 points)

An Ampere's law circular loop centered on the pipe and passing through B encloses no current. So $B = \boxed{0}$ and it has no particular direction.

Rewrite and sign the Honor Pledge: *I pledge my honor that I have not violated the Honor Code during this examination.*

Signature

(OVER)



2. The diagram shows a schematic of a small piece of a device which contains three plane conductors perpendicular to the page. The bottom conductor is held at potential 0. The top two conductors are held at potential $V > 0$. (So the region between the top two conductors is an equipotential volume and the region between the bottom two conductors is like a parallel plate capacitor.) Between the top two conductors is a uniform magnetic field with magnitude B. Its direction is into the page. An electron (charge $-e$, mass m) is released from rest at the bottom conductor. The potential difference between the middle and bottom conductors accelerates the electron towards the middle conductor and the magnetic field. It enters the region of uniform magnetic field and eventually comes out again, headed down through the middle conductor. Assume the device extends a long way left, right, into, and out of the page. Also assume the electron never reaches the top conductor before being turned around and assume that the conducting planes are actually wire meshes so the electron has no trouble passing through them!

Where does the electron come out? That is, how far to the left or right of where it enters the uniform field, does it return to the region between the bottom and middle conductors? Specify whether it comes out to the right or the left and give an expression (not a number) for the distance between the entry and exit points. Your answer may involve any or all of B, V, e, m, and physical and mathematical constants such as μ_0 or π. (5 points)

Upon entering the region of uniform magnetic field, the electron travels in a circle. The right hand rule tells us that magnetic force on a positive particle moving upwards is to the left. Since the electron charge is negative, the initial force is to the right and the electron comes out to the **right** of its entry point. The radius of the circle is found by stating that the magnetic force provides the required centripetal force $evB = mv^2/R$ or $R = mv/eB$. This expression contains the velocity which can be found by noting that the electron was accelerated from rest by the potential difference V. Conservation of energy gives $mv^2/2 = eV$ or $v = \sqrt{2eV/m}$. It comes out $2R$ to the right of where it entered or $\boxed{(2/B)\sqrt{2mV/e}}$.