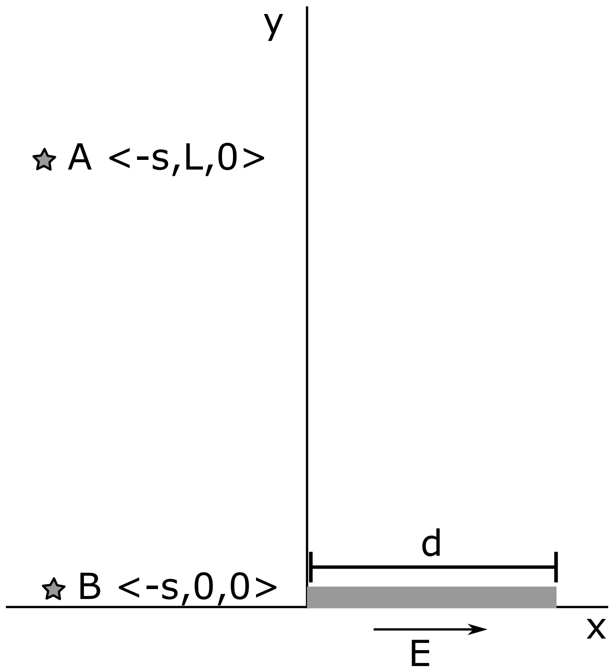
PHYS 2250 Exam II

Due: Wednesday, November 25, 2020 at 11:59 PM

Instructions*: You have until 11:59 PM on Wednesday to submit your exam. Please answer only one problem per page, and clearly label which problem you are working on. The exam must be submitted on Canvas as a single PDF via a scanner, or a smart-phone scanner app. Partial credit may be awarded, so you are encouraged to clearly and legibly show your work for each problem. Email me if you have questions.*

Academic Integrity*: The exam is open-book and open-note, but you are not allowed to discuss anything on the exam with your classmates (until after Wednesday night). Evidence of collaboration with classmates constitutes a violation of the University's academic honesty policy and may result in the complete forfeiture of your exam grade. This applies if you receive help from others or if you provide help to others*

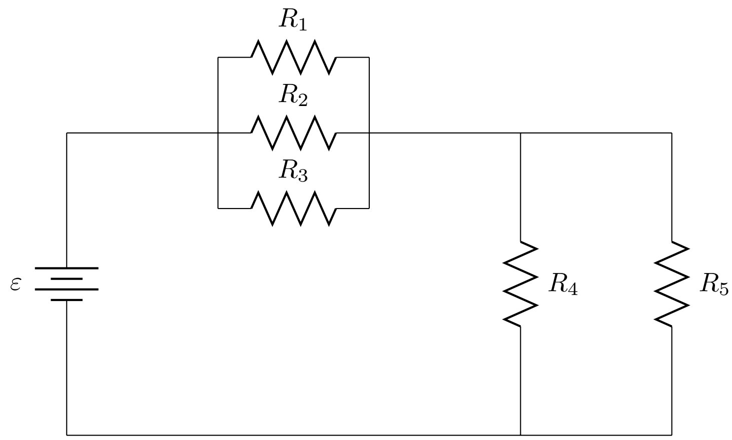
1. In the figure, there is an electric field in the conducting wire due to a battery which is not shown. The wire has a mobile electron density of n, an electron mobility of u, a length d and a cross-sectional area A. The electric field $\vec{E} = E\hat{x}$, and the charge carriers are electrons.



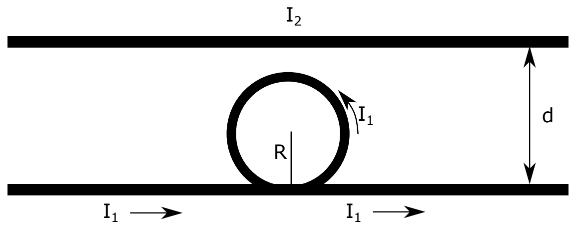
   (a) What is the magnetic field $\vec{B}$ of this section of wire (both magnitude and direction) at location A? You may leave your answer in the form of an integral, but make sure to evaluate any cross products that arise.

   (b) What is the magnetic field $\vec{B}$ of this section of wire (both magnitude and direction) at location B? You may leave your answer in the form of an integral, but make sure to evaluate any cross products that arise.

2. In the circuit shown below, the battery has an emf $\varepsilon = 9$ V. $R_1 = 40\ \Omega$, $R_2 = 60\ \Omega$, $R_3 = 20\ \Omega$, $R_4 = 30\ \Omega$, and $R_5 = 60\ \Omega$. Find the current through each resistor (I_1=current through R_1, I_2=current through R_2, etc...)

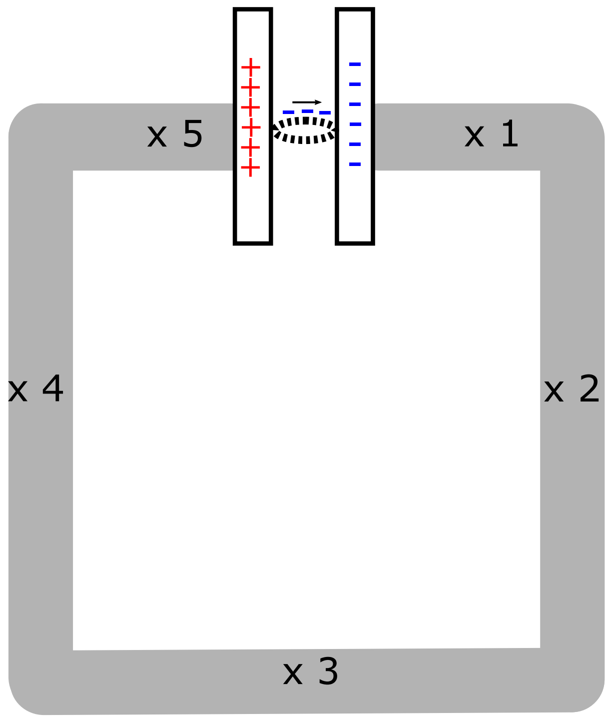


3. In the figure below, two very long, thin wires run parallel to each other. A conventional current $I_1 = 0.3$ A flows through the bottom wire in the directions indicated. The loop in the wire has a radius $R = 5$ cm, and the distance d between the wires is 12 cm. What current I_2 is required in the top wire (both direction and magnitude) in order to cancel the magnetic field at the center of the loop?



4. A 3 V battery is short-circuited (connected to a circuit with zero resistance), and the current is found to be 6 A. Now, an uncharged capacitor with a capacitance of 500 μF is connected to the same battery. How much time will it take for the capacitor to reach 50% of its final charge?

5. The figure shows a section of wire connected to a battery. Every part of the wire is made of the same material and has the same cross-sectional area. The circuit is in the steady state.



(a) On the figure (or on your own copy of the figure): sketch (using arrows) the electric field $\vec{E}$, electron current i, and drift velocity v at each labeled location of the circuit. Be sure that your arrows indicate direction and relative magnitude.

(b) In locations 2-5 of the wire, how does the electron current i compare to the current at location 1 (i_1)? (Equal to, less than, greater than)

(c) In locations 2-5 of the wire, how does the drift velocity v compare to the drift velocity at location 1 (v_1)?

(d) In locations 2-5 of the wire, how does the magnitude of the electric field E compare to the magnitude of the field at location 1 (E_1)?

(e) We can approximately treat the battery as an electric dipole, which has a weaker electric field at greater distances ($|\vec{E}_{\text{batt}}| \propto 1/r^3$). Is your result from part (d) consistent with the electric field of a dipole? If not, explain the discrepancy.

(f) Suppose the wire in this circuit is a 10-cm long copper wire with a cross-sectional area of 2×10^{-5} m^2. For copper: the mobile electron density is 8.5×10^{28} electrons per m^3, and the electron mobility is $4.5 \times 10^{-3} \frac{\text{m/s}}{\text{N/C}}$. If the battery has an emf $\varepsilon = 3$ V, what is the drift velocity of the moving electrons at location 3?