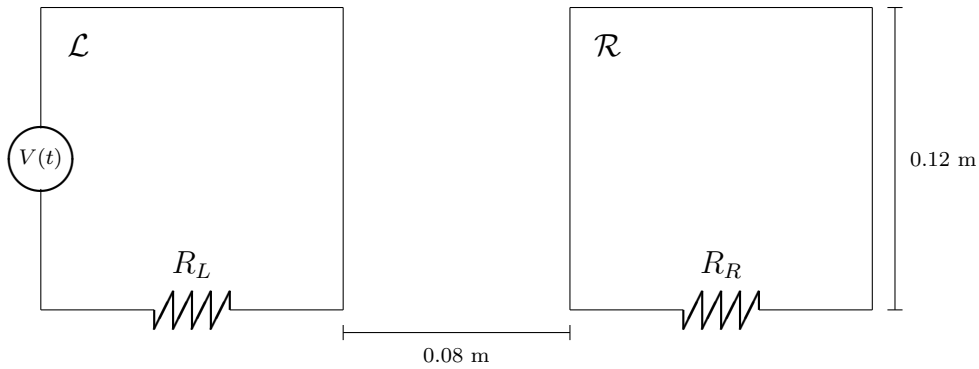
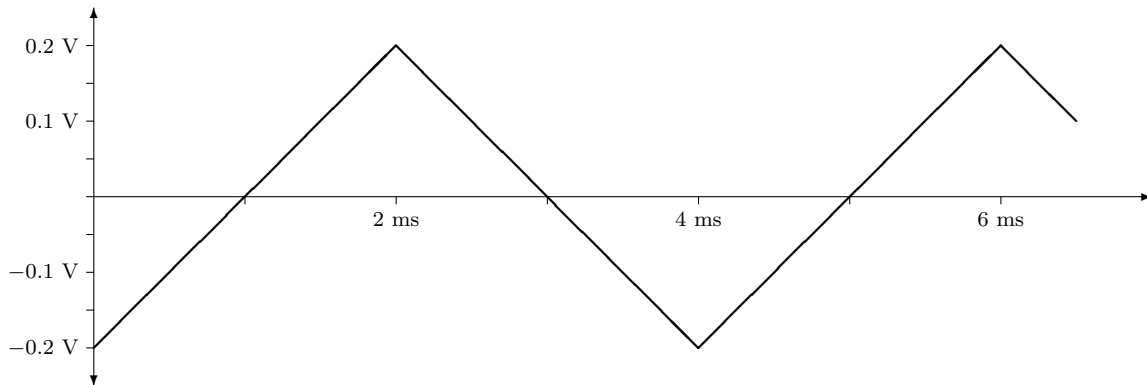


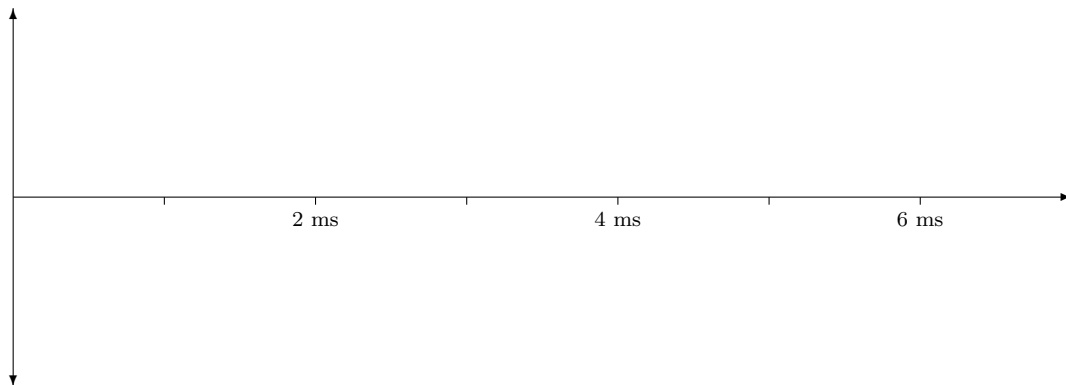
1. (40 points) You have two circuits next to each other:



Each circuit is square with 0.12 m sides, and 0.080 m separates the right edge of the left circuit (\mathcal{L}) from the left edge of the right circuit (\mathcal{R}). Both have the same resistance values $R_L = R_R = 0.50 \Omega$, and \mathcal{L} has a voltage source which produces a sawtooth waveform $V(t)$, which looks like the following on an oscilloscope:



(a) Sketch the shape of the waveform you will see if you measure the voltage across R_R with an oscilloscope. Don't put in any voltage numbers—just sketch the waveform.



- (b) Now let's make some approximations to estimate the amplitude of the voltage waveform induced in \mathcal{R} . There are four wire segments in \mathcal{L} : the left, top, right, and bottom on the diagram. The current in each wire produces a magnetic field through \mathcal{R} . Only one of the following makes the largest contribution to the magnetic flux through \mathcal{R} —we will just take that and ignore the rest. Circle your answer:

The right wire The top and bottom wires The left wire

Brief explanation:

The magnetic field produced by the wire segment you picked will not be uniform through \mathcal{R} . But we are looking for a rough estimate, so we will assume that it is uniform. The magnitude of B at what part of \mathcal{R} will be a representative value to use in this uniform approximation?

The right edge The center The left edge

Brief explanation:

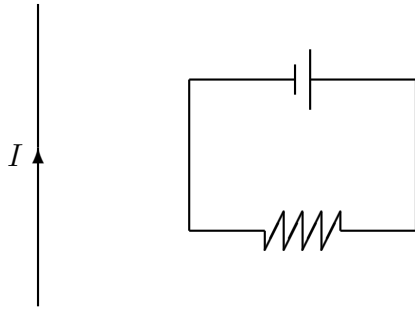
Now we need an equation that will help us get the magnetic flux:

$$\text{Loop: } B = \frac{\mu_0 I}{2r} \quad \text{Long wire: } B = \frac{\mu_0 I}{2\pi r} \quad \text{Wire: } F = ILB$$

Brief explanation:

Finally, use all this and estimate the *amplitude* of the waveform sketched in part (a).

2. (20 points) You have a long current-carrying wire, and a circuit next to it:

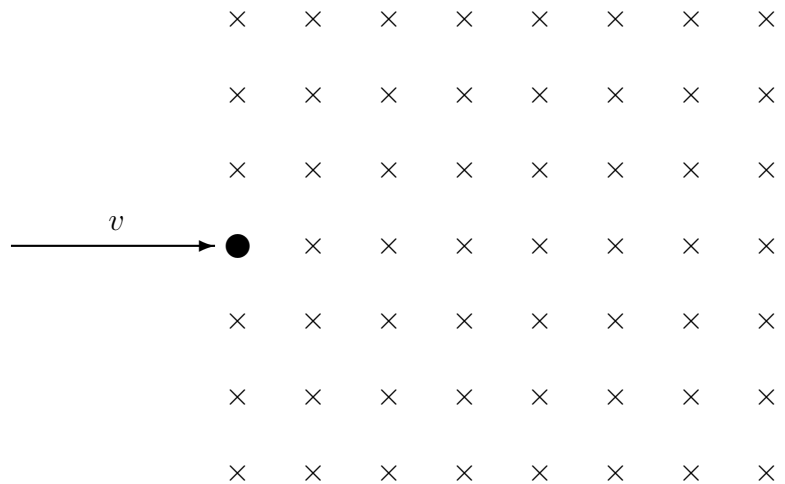


- (a) In the picture, draw in the magnetic field produced by the long wire with current I , and indicate the current direction in the circuit.
- (b) Will the circuit be attracted to the long wire, repelled by it, or will it feel no force? State your reasoning.
- (c) If you let the circuit move according to the total magnetic force that might be acting on it, will any extra voltage V_{extra} be induced in the circuit? State your reasoning.

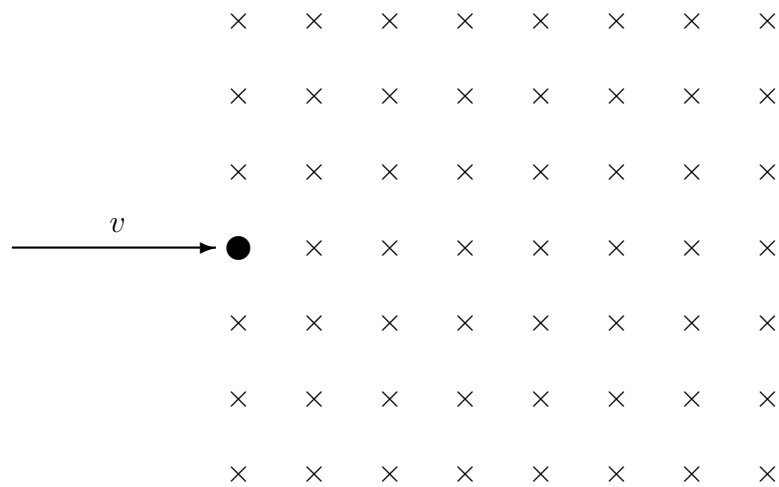
3. (40 points) This question is about charges in electric and magnetic fields.

(a) Magnetic fields act on moving charges. To get electrons moving at high speed, we can accelerate them by using a high voltage. Say an electron with charge $-e$ and mass m starts at rest, and gains kinetic energy by accelerating through a voltage difference of $-V_a$. What is v , its final speed, in terms of e , m , and V_a ?

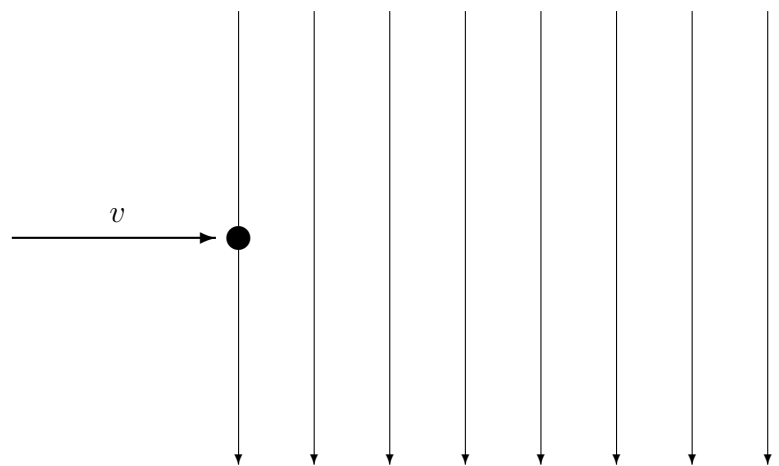
(b) An electron with speed v , moving toward the right, enters a region with a uniform magnetic field with magnitude B . The magnetic field points into the page. What is the magnitude of the magnetic force on the electron, F_B , in terms of B , e , m , and V_a ? Draw its direction as the rightward-moving electron just enters the region with the uniform magnetic field into the page.



- (c) Draw a diagram showing the *trajectory* of the electron in the same magnetic field. (The black dot is, once again, the electron entering the magnetic field.)



- (d) Now say that the electron, instead of emerging into a magnetic field, enters a region with a uniform electric field. The electron with speed v , moving toward the right, comes in between the plates of a parallel plate capacitor that produces an electric field with magnitude E . The field points downward on your page. Draw a diagram showing the trajectory of the electron in the uniform electric field.



- (e) The capacitor has a voltage difference of V_c across its plates, which are separated by a distance d . What is E , the magnitude of the electric field in this capacitor, in terms of V_c and d ?
- (f) Now say that the electron with speed v emerges into a region where *both* a uniform magnetic field and a uniform electric field exists in the ways described in (b) and (d). If the magnitude B is just right, the electric force and magnetic force will cancel each other out and the electron will not be affected. Find this value of B in terms of V_c , V_a , e , m , and d .