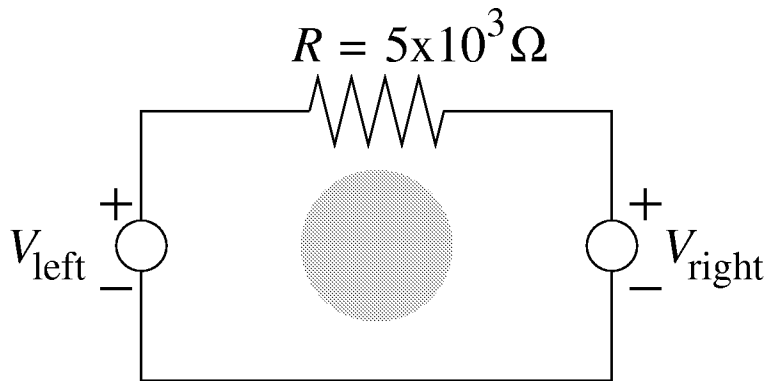


Problem 13 (6 points)

Two voltmeters, V_{right} and V_{left} , each with an internal resistance of $10^4 \Omega$ are in series with a resistor R of $5 \times 10^3 \Omega$. They are connected through wires of negligible resistance (see the circuit below). The “+” side of both voltmeters is up as shown. A changing magnetic field is present in the shaded area. At a particular moment in time V_{left} reads +0.1 Volt.

- (3) At that moment in time, what is the reading of V_{right} ?
- (3) What, at that moment, is the current (in A) in the circuit (magnitude and direction), and what is the induced EMF?



(c) 100% Reflection \implies **no** energy is absorbed.

Problem 11

(a) In the $\omega = 0$ steady state, all currents are constant in time. The self-inductor acts as a wire with zero resistance, shorting out the capacitor and ensuring $I_C = 0$ (there would be no current in this branch even if we replaced the capacitor with a resistor). Thus we effectively have a resistor R in series with a zero-resistance wire, and $I_L = I_R = V_0/R$. (Notice, even though it is irrelevant here, that the reactance of the capacitor ($1/\omega C$) is infinitely high.)

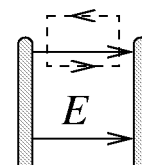
(b) With ω infinitely high, the reactance of the self-inductor (ωL) becomes infinitely large and thus $I_L = 0$. The reactance of the capacitor ($1/\omega C$) goes to zero. We effectively have a resistor R in series with a zero-reactance capacitor, and our peak current values are simply $I_C = I_R = V_0/R$.

(c) We would expect the peak value of I_R to **decrease** from the value V_0/R found in part (a) as we increase ω to non-zero values. The effective impedance of the parallel combination of the capacitor and the self-inductor was zero with $\omega = 0$. For $\omega \neq 0$ it can only increase, as the self-inductor will no longer act as zero-Ohm wire and the reactance of the capacitor ($1/\omega C$) will also be non-zero. (This expectation can be confirmed by an exact calculation, if you are feeling ambitious.)

(d) The frequency is $\omega = 1/\sqrt{LC}$. (What else could it be?) This is the natural oscillation frequency of the LC sub-circuit alone. We will have an oscillating current in the LC sub-circuit that dissipates no energy. The voltage across the capacitor will be exactly offset by the power supply voltage at all times, so that there will never be any voltage across the resistor. Hence, $I_R = 0$. (None of this is very intuitive.)

Problem 12 (See homework problem 5.7 and Exam 2, problem 4)

Assuming an abrupt drop to zero, integrating around the dashed path shown gives $\oint \mathbf{E} \cdot d\mathbf{l} \neq 0$, for there is an E -field between the plates. Since this is a static situation, we have $d\Phi_B/dt = 0$ for the rate of change of magnetic flux through the open surface bounded by our loop, and thus Faraday's law asserts $\oint \mathbf{E} \cdot d\mathbf{l} = 0$. Therefore the E -field *cannot* drop abruptly to zero outside the capacitor.



Problem 13

(a) V_{right} will read -0.1 Volt, since it has the same internal resistance as V_{left} but has its terminals oppositely oriented with respect to the current in the circuit.

(b) If V_{left} reads $+0.1$ Volt, then the current must enter through the positive terminal. Thus the current flows counterclockwise. From Ohm's law,

$$I = V_{\text{left}}/R_{\text{left}} = (0.1)/(10^4) = 10^{-5} \text{ Amperes.}$$

The induced EMF is counterclockwise as well, and is given by

$$\mathcal{E} = I(R + R_{\text{left}} + R_{\text{right}}) = (10^{-5})(2.5 \times 10^4) = 0.25 \text{ Volts.}$$