1 Induction and AC Circuits

1.1 Formulas

Faraday's law of induction: $\Delta V = -N\Delta\varphi_B/\Delta t$ where the magnetic flux $\varphi_B = BA\cos\theta$

Induced emf in a wire moving $\perp$ to a magnetic field (Hall Effect): $\Delta V = \epsilon = Blv$

Induced emf in a wire moving in a magnetic field: $\Delta V = Blv\sin\theta$

Maximum emf in a generator: $\Delta V = NBA\omega$

Definition of self inductance L: $\Delta V = -L\Delta I/\Delta t$

Energy stored in an inductor: $U = LI^2/2$

RL circuit with $I_0 = 0$: $I(t) = I_{\mathsf{max}}(1 - e^{-Rt/L})$

AC current RMS value: $I_{\mathsf{rms}} = I_{\mathsf{max}}/\sqrt{2}$

AC voltage RMS value: $\Delta V_{\mathsf{rms}} = \Delta V_{\mathsf{max}}/\sqrt{2}$

Reactance of a capacitor: $X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$

Reactance of an inductor: $X_L = \omega L = 2\pi fL$

Impedance of a series RLC circuit: $Z = \sqrt{R^2 + (X_L - X_C)^2}$

Amplitudes: $V_R = IR, VL = IX_L, V_C = IX_C$, and $\epsilon = IZ$

Angular frequency at resonance: $\omega_0 = 2\pi f = \frac{1}{\sqrt{LC}}$

AC transformer: $I_1/I_2 = \Delta V_2/\Delta V_1 = N_2/N_1$

1.2 Dropped Steel Beam Problem

A 11.5 m long steel beam is accidentally dropped by a construction crane from a height of 5.41 m. The horizontal component of the Earth's magnetic field over the region is 12.9 μT. The acceleration of gravity is 9.8 m/s^2.

What is the induced emf in the beam just before impact with the Earth, assuming its long dimension remains in a horizontal plane, oriented perpendicularly to the horizontal component of the Earth's magnetic field? Answer in units of mV.

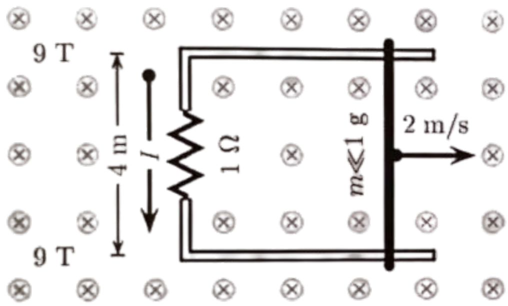
1.3 Energy Stored in Inductor Problem

An inductor of 140 turns has a radius of 5 cm and a length of 28 cm. The permeability of free space is 1.25664×10^{-6} N/A^2.

Find the energy stored in it when the current is 0.4 A. Answer in units of J.

1.4 Force on a Bar Problem

In the arrangement shown in the figure, the resistor is 1Ω and a 9 T magnetic field is directed into the paper. The separation between the rails is 4 m. An applied force moves the bar to the right at a constant speed of 2 m/s.



Calculate the applied force required to move the bar to the right at a constant speed of 2 m/s. Assume the bar and rails have negligible resistance and friction. Neglect the mass of the bar. Answer in units of N.

1.5 Rate of Change of Current in Inductor Problem

An inductor in the form of an air-core solenoid contains 183 turns, is of length 22.7 cm, and has a cross-sectional area of 1.2 cm^2. The permeability of free space is 1.25664×10^{-6} N/A^2.

What is the magnitude of the uniform rate of change in current through the inductor that induces an emf of 275 μV? Answer in units of A/s.

1.6 Change in Field of Rectangular Coil Problem

The plane of a rectangular coil, 6.9 cm by 3.6 cm, is perpendicular to the direction of a uniform magnetic field B.

If the coil has 75 turns and a total resistance of 8.9Ω, at what rate must the magnitude of B change to induce a current of 0.04 A in the windings of the coil? Answer in units of T/s.

1.7 Inductor with Series in Lamp Problem

A 0.834 H inductor is connected in series with a fluorescent lamp to limit the current drawn by the lamp.

If the combination is connected to a 67 Hz, 125 V line, and if the voltage across the lamp is to be 46.2 V, what is the current in the circuit? (The lamp is a pure resistive load.) Answer in units of A.