1. In an experiment designed to measure the magnitude of a uniform magnetic field, electrons are accelerated from rest through a potential difference of 350 V and then enter a uniform magnetic field that is perpendicular to the velocity vector of the electrons. The electron travel along a curved path because of the magnetic force exerted on them, and the radius of the path is measured to be 7.5 cm.

2. What is the magnitude of the magnetic field?

3. What is the angular speed of the electrons?

Solutions:

(a) From conservation of energy,

\[ \Delta K + \Delta U = 0 \]

or,

\[ \frac{1}{2} m_e V^2 + q \Delta U = 0 \]

\[ \Rightarrow V = \sqrt{\frac{-2q \Delta U}{m_e}} \]

\[ = \sqrt{\frac{-2(1.60 \times 10^{-19})(350)}{9.11 \times 10^{-31}}} \]

\[ = 1.11 \times 10^7 \text{ m/s} \]

Now, \[ BqV = \frac{m_e V^2}{r} \]

\[ \Rightarrow B = \frac{m_e V}{q r} = \frac{(9.11 \times 10^{-31})(1.11 \times 10^7)}{(1.60 \times 10^{-19})(0.075)} \]

\[ = 8.4 \times 10^{-4} \text{ T} \]

(b) Use, \[ V = \omega r \]

\[ \Rightarrow \omega = \frac{V}{r} = \frac{1.11 \times 10^7}{0.075} = 1.5 \times 10^8 \text{ rad/s} \]
What current is required in a winding of a long solenoid that has 1000 turns uniformly distributed over a length of 0.4 m to produce at the center of the solenoid a magnetic field of magnitude $1.00 \times 10^{-4}$ T?

**Solution:**

Ampere's law for solenoid is given by,

$$B = \mu_0 n I = \mu_0 \frac{N}{l} I$$

Here, $B = 1.00 \times 10^{-4}$ T, $N = 1000$, $l = 0.4$ m

$$n = \frac{1000}{0.4}$$

$$\Rightarrow I = \frac{B}{\mu_0 n}$$

$$= \frac{1.00 \times 10^{-4}}{(4\pi \times 10^{-7})(\frac{1000}{0.4})}$$

$$= 31.8 \text{ mA}.$$
(3) The coil in an AC generator consists of 6 turns of wire, each of area \( A = 0.090 \text{ m}^2 \), and the total resistance of the wire is 12.0 \( \Omega \). The coil rotates in a 0.5 T magnetic field at a constant frequency of 60.0 Hz.

(4) Find the maximum induced emf in the coil.

(5) What is the maximum induced current in the coil when the output terminals are connected to a low-resistance conductor?

**Solution:**

(4) The maximum induced emf is given by,

\[
E_{\text{max}} = N \varphi B \cos \omega t
\]

\[
= N A B \omega
\]

\[
\therefore \omega = 2\pi f
\]

where, \( N = 8 \), \( A = 0.090 \text{ m}^2 \), \( B = 0.5 \text{ T} \), \( f = 60.0 \text{ Hz} \)

So,

\[
E_{\text{max}} = 8(0.090)(0.5)(2\pi)(60.0)
\]

\[
= 136 \text{ V}
\]

(5) Again, \( E_{\text{max}} = I_{\text{max}} R \) where, \( R = 12.0 \Omega \)

\[
\Rightarrow I_{\text{max}} = \frac{E_{\text{max}}}{R} = \frac{136}{12} = 11.3 \text{ A}
\]
A 40.0 mA current is carried by a uniformly wound aircore solenoid with 450 turns, a 15.0 mm diameter and 12.0 cm length. Compute (a) the magnetic field inside the solenoid, (b) the magnetic flux through each turn and (c) the inductance of the solenoid.

Srn.: (a) From Ampere's law,

\[ B = \mu_0 n I = \mu_0 \frac{N I}{l} \]

\[ = (4\pi \times 10^{-7}) \left( \frac{450}{0.12} \right) (40 \times 10^{-3}) \]

\[ = 188 \mu T \]

(b) The magnetic flux is given by,

\[ \Phi_B = BA \] where, \[ A = \pi r^2 = (3.14) (0.75 \times 10^{-2})^2 \]

\[ = (188 \times 10^{-6}) (1.76 \times 10^{-4}) \]

\[ = 3.33 \times 10^{-8} T \cdot m^2 \]

(c) And inductance, \[ L = \frac{N \Phi_B}{I} \]

\[ = \frac{(450) (3.33 \times 10^{-8})}{(40 \times 10^{-3})} \]

\[ = 0.375 \text{ mH} \]
In figure, the battery has an emf of 12.0 V, the inductance is 2.81 mH, and the capacitance is 9.0 pF. The switch has been set to position a for a long time so that the capacitor is charged. The switch is then thrown to position b, removing the battery from the circuit and connecting the capacitor directly across the inductor.

(a) Find the frequency of oscillation of circuit.
(b) What are the maximum values of charge on the capacitor and current in the circuit?

Solution:
(a) To find frequency, \( \omega = 2\pi f \)

\[ f = \frac{\omega}{2\pi} = \frac{1}{2\pi \sqrt{L/C}} \]

\[ = \frac{1}{2\pi \sqrt{(2.81 \times 10^{-3}) (9.00 \times 10^{-12})}} \]

\[ = 1.00 \times 10^6 \text{ Hz} \]

(b) To find charge, \( \Phi_{\text{max}} = CV \)

\[ = (9.00 \times 10^{-12})(12) \]

\[ = 1.08 \times 10^{-10} \text{ C} \]

To find current, \( I_{\text{max}} = \omega \Phi_{\text{max}} \)

\[ = 2\pi f \Phi_{\text{max}} \]

\[ = (2\pi)(1.00 \times 10^6)(1.08 \times 10^{-10}) \]

\[ = 6.79 \times 10^{-4} \text{ A} \]
An electricity-generating station needs to deliver energy at a rate of 20 MW to a city 10 km away. A common voltage for commercial power generation is 22 kV, but a step-up transformer is used to boost the voltage to 230 kV before transmission. If the resistance of the wire is 2.0 \Omega and the energy costs are about 10 cents per kWh, compare the total cost before and after stepping up the voltage for one day.

**Before:**

\[ I_{rms} = \frac{P_{avg}}{V_{rms}} = \frac{20 \times 10^6 \text{W}}{22 \times 10^3 \text{V}} = 910 \text{A} \]

Rate at which energy is delivered to resistance wire,

\[ P = I_{rms}^2 R = (910 \text{A})^2 (2.0 \Omega) = 1.7 \times 10^3 \text{ kW} \]

Total energy = power \times time

\[ = (1.7 \times 10^3 \text{ kW}) \times (24 \text{h}) = 4.1 \times 10^4 \text{ kWh} \]

Cost = ($4.1 \times 10^4 \text{ kWh}) (10 \text{ cents/kWh})

\[ = $4.1 \times 10^3 \]

**After:**

\[ I_{rms} = \frac{P_{avg}}{V_{rms}} = \frac{20 \times 10^6 \text{W}}{230 \times 10^3 \text{V}} = 87 \text{A} \]

Power delivered to wire,

\[ P = I_{rms}^2 R = (87 \text{A})^2 (2.0 \Omega) = 15 \text{ kW} \]

Total energy = power \times time

\[ = (15 \text{ kW}) (24 \text{h}) = 360 \text{ kWh} \]

Total cost = ($360 \text{ kWh}) (10 \text{ cents/kWh})

\[ = $36 \]
A series RLC circuit has \( R = 425 \, \Omega, \, L = 1.25 \, H, \, C = 3.50 \, \mu F \). It is connected to an AC source with \( f = 60.0 \, Hz \) and \( \Delta V_{\text{max}} = 150 \, V \).

(a) Determine the inductive reactance, the capacitive reactance, and the impedance of the circuit.

(b) Find the maximum current in the circuit.

(c) Find the phase angle between the current and voltage. (d) Find maximum voltage across each element.

Semi: (a) For angular frequency, \( \omega = 2\pi f \)

\[
\omega = 2\pi (60.0) = 377 \, s^{-1}
\]

Inductive Reactance, \( X_L = \omega L = (377)(1.25) = 471 \, \Omega \)

Capacitive reactance, \( X_C = \frac{1}{\omega C} = \frac{1}{(377)(3.50 \times 10^{-6})} = 758 \, \Omega \)

Impedance, \( Z = \sqrt{R^2 + (X_L - X_C)^2} \)

\[
= \sqrt{(425)^2 + (471 - 758)^2} = 513 \, \Omega
\]

(b) Maximum current, \( I_{\text{max}} = \frac{\Delta V_{\text{max}}}{Z} = \frac{150}{513} = 0.292 \, A \)

(c) To calculate the phase angle,

\[
\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)
\]

\[
= \tan^{-1}\left(\frac{471 - 758}{425}\right) = -34.0^\circ
\]

(d) To calculate the maximum voltages,

Across \( R \), \( \Delta V_R = I_{\text{max}} R = (0.292)(425) = 124 \, V \)

Across \( L \), \( \Delta V_L = I_{\text{max}} X_L = (0.292)(471) = 138 \, V \)

Across \( C \), \( \Delta V_C = I_{\text{max}} X_C = (0.292)(758) = 221 \, V \)
8. An AC voltage of the form \( \Delta V = (100 \text{V}) \sin(1000t) \) is applied to a series RLC circuit. Assume the resistance is 400 \( \Omega \), the capacitance is 5.00 \( \mu \text{F} \), and the inductance is 0.500 \( \text{H} \). Find the average power delivered to the circuit.

\[ \Delta V = (100 \text{V}) \sin(1000t) \]

Comparing with, \( \Delta V = \Delta V_{\text{max}} \sin(\omega t) \)

\[ \Delta V_{\text{max}} = 100 \text{V}, \quad \omega = 1000 \text{ rad/s}, \quad R = 400 \Omega \]

\[ C = 5 \times 10^{-6} \text{F}, \quad L = 0.500 \text{H} \]

So, \( X_L = \omega L = (1000)(0.500) = 500 \Omega \)

\[ X_C = \frac{1}{\omega C} = \frac{1}{(1000)(5 \times 10^{-6})} = 200 \Omega \]

Impedance,

\[ Z = \sqrt{R^2 + (X_L - X_C)^2} \]

\[ = \sqrt{(400)^2 + (500 - 200)^2} = 500 \Omega \]

Maximum current, \( I_{\text{max}} = \frac{\Delta V_{\text{max}}}{Z} = \frac{100}{500} = 0.20 \text{ A} \)

The average power dissipated in the circuit is,

\[ P = I_{\text{rms}}^2 R = \left( \frac{I_{\text{max}}}{2} \right)^2 R \]

\[ = \left( \frac{0.20}{2} \right)^2 (400) \]

\[ = 8.0 \text{ W} \]