Answer on Question 55899, Physics, Electromagnetism

What is the self-inductance of an air-core solenoid, $1m$ long and $0.05m$ in diameter, if it has 1400 turns?

a) $5.23mH$

b) $4.84mH$

c) $3.63mH$

d) $2.42mH$

Solution:

We can find the self-inductance of an air-core solenoid from the formula:

$$L = \mu_0 \frac{N^2 A}{l} = \mu_0 \frac{N^2 \frac{\pi d^2}{4}}{l} = \mu_0 \frac{N^2 \pi d^2}{4l},$$

where, μ_0 is the permeability of free space, N is the number of turns, $A = \frac{\pi d^2}{4}$ is the cross-sectional area, d is the diameter of the wire, l is the length of solenoid.

Let's calculate the self-inductance of an air-core solenoid:

$$L = 4\pi \cdot 10^{-7} \frac{H}{m} \cdot \frac{(1400)^2 \cdot \pi \cdot (0.05m)^2}{4 \cdot 1m} = 4.84 \cdot 10^{-3} H = 4.84mH.$$

Answer:

b) $4.84mH$

17. Which of the following is not correct:

a) A changing electric field can produce a changing magnetic field.

b) A steady magnetic field produces a steady current.

c) A changing magnetic field can produce a changing current.

d) A changing magnetic field can produce a steady electric field.

Answer:

A static magnetic field relative to a wire induces a zero current.

Therefore, the false statement is b) A steady magnetic field produces a steady current.

18. A rectangular coil of dimensions $20cm$ by $15cm$ lies with its plane parallel to a magnetic field of $0.5\frac{W}{m^2}$. The coil, carrying a current of $10A$ experiences a torque of $4.5Nm$ in the field. How many loops has the coil?

a) 100

b) 60

c) 30

d) 20

Solution:

Let us consider a rectangular loop of coil carrying a current I in the presence of a uniform magnetic field B directed parallel to the plane of the loop:

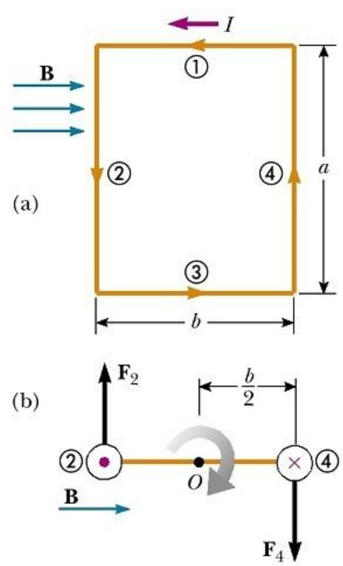

Figure 1.

We see in the Fig. 1a, that no magnetic forces act on sides 1 and 3 because these wires are parallel to the field. However, magnetic forces do act on sides 2 and 4 because these sides are oriented perpendicular to the field. We can obtain the magnitude of this forces from the equation $\boldsymbol{F}_B = I\boldsymbol{L} \times \boldsymbol{B}$, where $\boldsymbol{F}_B$ is the magnetic force, I is the current in the wire, $\boldsymbol{L}$ is a vector that points in the direction of the current I and has a magnitude equal to the length L of the wire, $\boldsymbol{B}$ is the magnetic field. So, the magnitude of this forces is:

$$F_2 = F_4 = IaB$$

The direction of F_2, the force exerted on wire 2 is out of the page in the view shown in the Fig. 1a, and that of F_4, the force exerted on wire 4, is into the page in the same view. If we view the loop from side 3 and sight along sides 2 and 4, we see the view shown in Fig. 1b, and the two forces F_2 and F_4 are directed as shown. So, these two forces produce about point O a torque and the magnitude of this torque τ is:

$$\tau = F_2\frac{b}{2} + F_4\frac{b}{2} = (IaB)\frac{b}{2} + (IaB)\frac{b}{2} = IabB$$

where the moment arm about point O is $\frac{b}{2}$ for each force.

Because the torque increases proportionally according to number of loops N we obtain:

$$\tau = NIabB$$

Finally, we can find the number of loops of a rectangular coil:

$$N = \frac{\tau}{IabB} = \frac{4.5Nm}{10A \cdot 0.2m \cdot 0.15m \cdot 0.5\frac{W}{m^2}} = 30\ loops.$$

Answer:

c) $30\ loops$