

Mutual Inductance

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The problem:

Inside an infinite solenoid with n windings per unit length, there is a closed planar loop of area S which is placed at an angle to the axis of symmetry of the solenoid.

What is the mutual inductance of the system?

The solution:

Lets define a few parameters:

1. n - the density of windings per unit of length
2. θ - the angle that the z axis creates with the solenoid
3. S - the surface of the solenoid

The magnetic field in the solenoid is

$$\vec{B} = \mu_0 I n \hat{z} \tag{1}$$

And the flux is

$$\Phi = \vec{B} \cdot \vec{s} = \mu_0 I n \hat{z} \cdot S \hat{n} = \mu_0 I S \cos \theta \tag{2}$$

Thus the induced e.m.f is

$$\epsilon = -\dot{\Phi} = -\mu_0 n S \cos \theta \dot{I} \tag{3}$$

Therefore, the mutual inductance coefficient is

$$M = \mu_0 n S \cos \theta \tag{4}$$