

# Chapter 5

## Electromagnetic Induction

Answer the following Questions :

1. A coaxial cable consists of two thin coaxial cylinders electrically connected at one end; an inner cylindrical conducting tube of radius  $a$  carrying a steady current  $I$  which is screened by an outer cylindrical conducting sheath of radius  $b$  which provides a return path. There is no dielectric medium present.

Use Ampere's theorem to derive the total magnetic energy stored in the space between the conductors. show that the inductance of a length  $l$  of the cable is

$$L = \frac{\mu_0 I^2 l}{2\pi} \ln\left(\frac{b}{a}\right)$$

If this cable ( $a = 5$  mm,  $b = 10$  mm,  $l = 1000$  m) is now employed in a (resistanceless) LC circuit containing a capacitance  $C = 1000$   $\mu\text{F}$ , determine the period of oscillations (neglect the capacitance of the cable itself).

2. A vertical square loop of copper wire with sides of length 10 cm is falling as shown from a region where the magnetic field is horizontal and of magnitude 1.2 T into a region where the field is zero, as shown in figure. The wire has a diameter of 1 mm.



- (i) Calculate the magnitude of the current round the loop in terms of the velocity  $v$  of fall, and indicate its sense.  
(ii) What is the magnetic force acting on the loop, again expressed in terms of  $v$ ?  
(iii) If the velocity of fall reaches a steady value whilst the upper arm of the circuit remains in the field, calculate this velocity.

(The resistivity of copper is  $1.7 \times 10^{-8} \Omega \text{ m}$ ; the density is  $8960 \text{ kg m}^{-3}$ .)

3. Two parallel rectangular superconducting plates of length  $l$ , width  $b$  and separation  $a$  ( $l \gg b \gg a$ ) are joined at each end to form a one-turn coil of negligible resistance. What is its self-inductance? How much energy is stored in the magnetic field when a steady current  $I$  flows? The separation  $a$  increases by a small amount  $\Delta a$ . Calculate the various energy changes (a) when the coil includes in its circuit a lossless battery which maintains a constant current  $I$ , and (b) when the circuit consists of the coil alone. Deduce the magnitude and direction of the force per unit area between the two plates.

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