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Displacement current: Magnetic field due to changing electric induction

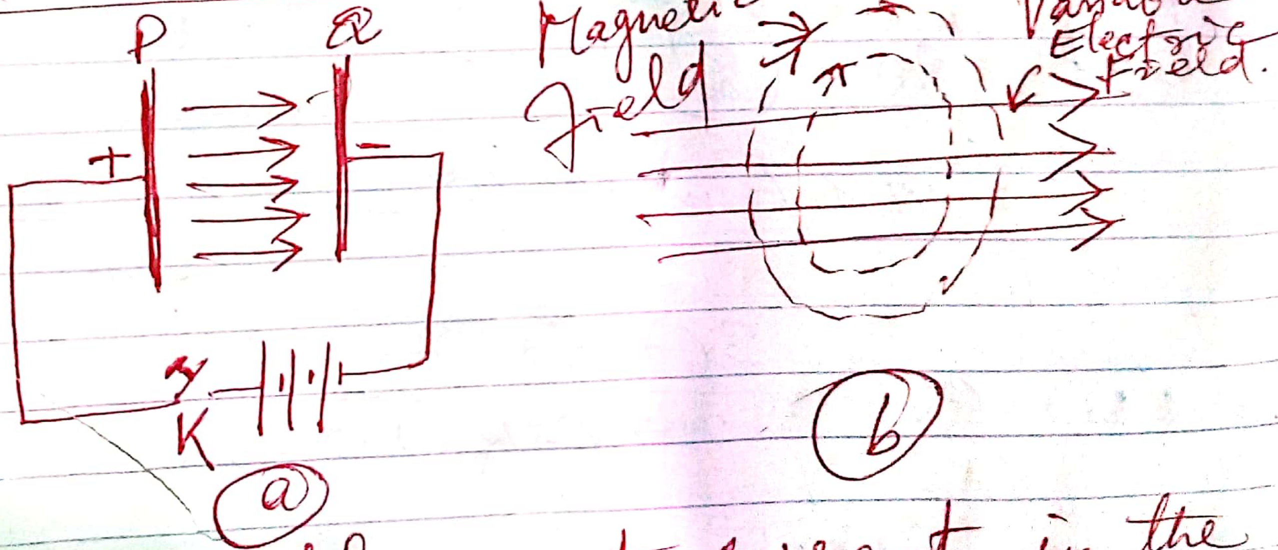

Fig (1) Displacement current in the dielectric between P and Q.

As soon as an electric field is applied between the two plates of a condenser, Fig. 1 (a), the electrons of the dielectric undergo a displacement within the atoms. This electronic movement constitutes a displacement current (a transient current) in the dielectric, which flows while the electric field is changing; it results from the polarising process mentioned above.

According to Maxwell, even though the two plates of the condenser are separated by free space, and there is no polarisation, the 'ether' undergoes a distortion due to the existence of the electric field, resulting in the flow of a space current which gives rise to the usual magnetic field, Fig. 1 (b). Thus we might expect to observe a changing magnetic field in the region between the plates of a condenser while it is charging or discharging (or when the plates are connected to an alternating voltage source), and this happens even though a vacuum exists between the plates.

(*) Space current:

Let

A = Area of and q = charge on each of the condenser plates

σ = surface density of charge

Total number of lines of electric force between the plates is

$\therefore K\epsilon_0 E = \sigma = q$, and since E changes during charging and discharging (or when plates are connected to an A.C. source) where K = Dielectric constant of the medium between the plates.

$$\therefore \frac{dE}{dt} = \frac{1}{\epsilon_0 KA} \cdot \frac{dq}{dt} = \frac{1}{\epsilon_0 KA} \cdot i$$

where i is the current passing in the condenser while being charged.

But $\frac{i}{A} = j$, where j is the space current density of the displacement current through the space between the plates.

$$\therefore \frac{dE}{dt} = \frac{1}{\epsilon_0 K} j \text{ or, } j = \epsilon_0 K \times \frac{dE}{dt} \rightarrow (1)$$

In free space;

$$K = 1, \text{ and } j = \epsilon_0 \cdot \frac{dE}{dt} \rightarrow (2)$$

Thus if at any instant, in free-space, the electric field E is changing with time, a hypothetical current of density j is produced.