

## Nuclear Fusion

**In a popular science article on nuclear fusion it was claimed that two parallel electron beams could attract each other, i.e. be self-focussing. Is this claim valid?**

Answer

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The magnitude of the magnetic field from one beam (which carries current  $I$ ) at a perpendicular distance  $r$  is  $B = \mu_0 I / (2\pi r)$ .

The force on an electron from this magnetic field has a magnitude  $F = e v B$ , where  $e$  is the charge on the electron and  $v$  is its speed. Therefore, the magnetic force is attractive and has a magnitude

$$F_M = e \mu_0 I v / (2\pi r)$$

Let the charge per unit length of the beam be  $\lambda$ . The current  $I = \lambda v$ . This creates a radial electric field with magnitude

$$E = \lambda / (2\pi \epsilon_0 r)$$

This creates a repulsive force on the electron of magnitude

$$F_E = e \lambda / (2\pi \epsilon_0 r v)$$

Comparing the electric and magnetic forces

$$F_M / F_E = v^2 \epsilon_0 \mu_0$$

$$\text{But } c^2 = 1 / (\epsilon_0 \mu_0)$$

Therefore,  $F_M / F_E = v^2 / c^2$  and as  $v < c$  the net force is always outwards, i.e. de-focussing.