Magnetic Configuration of Magnetic Mirrors

Course: MPHYEC-01I Plasma Physics
(M.Sc. IV Sem)

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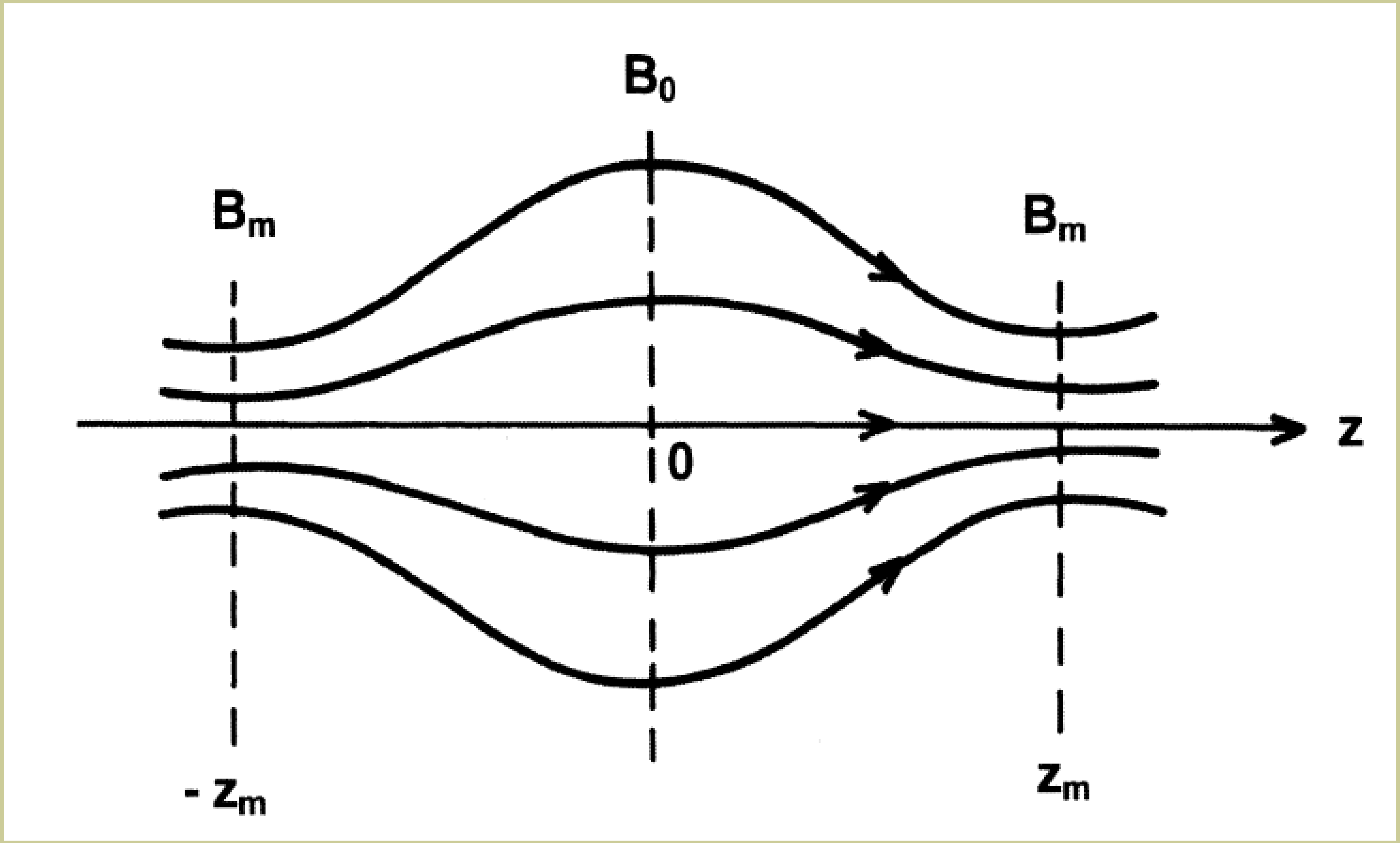
Lecture 7: Unit-I

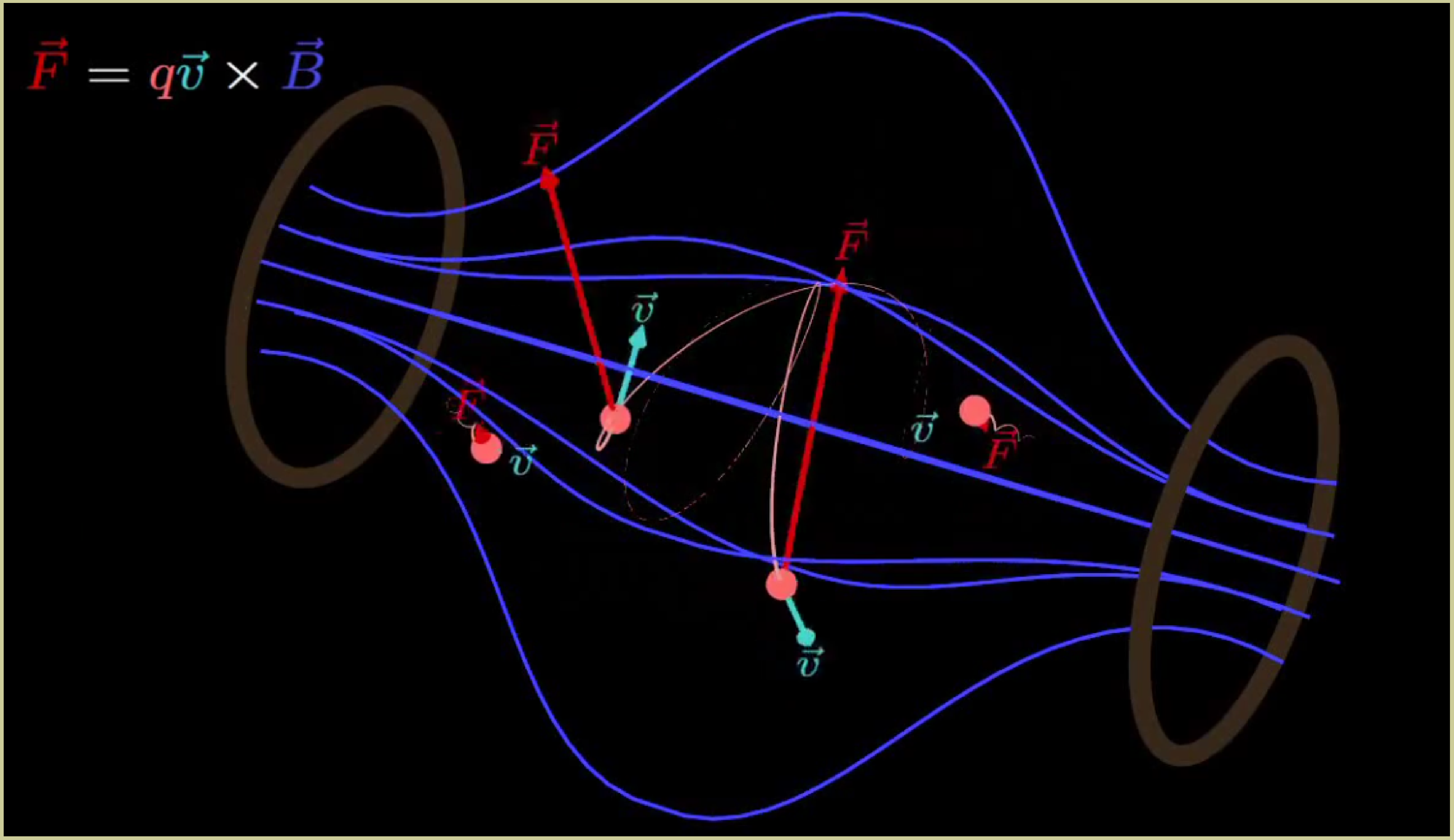
Magnetic Mirrors

- **Magnetic mirrors is a machine which is used to confine charged particles (plasma). Magnetic configuration of the machine is favorable for the confinement.**



Magnetic field line configuration for a system of two coaxial magnetic mirrors (coils) whose axis coincides with the z axis, being symmetrical about the plane z = 0.

3D view of Magnetic Mirrors



Expression of magnetic field along the z-axis is:

$$B_z(z)=\frac{\mu_0 NIR^2}{2\left(R^2+z^2\right)^{3/2}}$$

Where N, I and R represent the number of turns, current and radiu of both the coils (i.e., coils are identical) respectively.

If we assume the distance between the throats of the two coils is L, then
It can be easily demonstrated that for L>>R, the field at the center:

$$B_z(z=0)=\frac{\mu_0 NIR^2}{\left(R^2+L^2/4\right)^{3/2}}$$

And field at the throat

$$B_z(z=L/2)=\frac{\mu_0 NIR^2}{2\left(R^2\right)^{3/2}}$$

$$B_z(z=-L/2)=\frac{\mu_0 NIR^2}{2\left(R^2\right)^{3/2}}$$

$B_z(z=L/2)=B_z(z=-L/2)$

Then the ratio of the field at the throat and the center is:

$$\frac{B_z(z=L/2)}{B_z(z=0)} = \frac{L^3}{16R^3}$$

Clearly for $L>>R$, $L^3/16R^3 >>1$
and, therefore $B_z(z=L/2) = B_z(z=-L/2) >> B_z(z=0)$

It can be inferred that magnetic field at the center is minimum, i.e.,

$$B_z(z=0)=B_{min}$$

Field at a throat is maximum, i.e.,

$$B_z(z=L/2) = B_z(z=-L/2)=B_{max}$$

$$M_R = \frac{B_{max}}{B_{min}} = \frac{L^3}{16R^3}$$ → **Mirror ratio**

$$B_z(z) = B_{min}\left[1+(M_R-1)\frac{z^2}{L^2/4}\right]$$

- **Most suitable coordinate system to anaylze the magnetic mirror's field configuration is cylinderical.**

- **It can be considered that magnetic field is mostly pointed along z-direction and the field is axisymmetric**, $B_\theta = 0$ and $d/d_\theta = 0$.

- Therefore, $$\mathbf{B} = B_r\hat{\mathbf{r}} + B_z\hat{\mathbf{z}}$$

- From $\nabla \cdot \mathbf{B} = 0$ condition:

$$\frac{1}{r}\frac{\partial}{\partial r}(rB_r) + \frac{\partial B_z}{\partial z} = 0$$

$$=> \frac{\partial}{\partial r}(rB_r) = -r\frac{\partial B_z}{\partial z}$$

- With the assumption B_z does not vary much with r, we have

$$rB_r = -\int_0^r r\frac{\partial B_z}{\partial z}dr \approx -\frac{1}{2}r^2\left[\frac{\partial B_z}{\partial z}\right]_{r=0}$$

$$B_r = -\frac{1}{2}r\left[\frac{\partial B_z}{\partial z}\right]_{r=0}$$

Thanks!