Pinch Effect: Magnetic Confinement:

We have seen that if we consider a conducting fluid (Plasma) in an electromagnetic field and if $\vec{J}$ is the current density & P is the fluid pressure then the force acting on unit volume of the fluid is:

$$\boxed{\vec{F} = \vec{J} \times \vec{B} - \nabla P}$$

For equilibrium: $\vec{F} = 0$

For a plasma fluid in equilibrium in an electromagnetic field $\nabla P = \vec{J} \times \vec{B}$ — (1)

Taking the scalar product of eq^n (1):

$$\vec{B} \cdot \nabla P = \vec{B} \cdot (\vec{J} \times \vec{B})$$

In the R.H.S ; $\vec{J} \times \vec{B}$ is a vector $\perp^r$ to $\vec{J}$ & $\vec{B}$ both let $\vec{J} \times \vec{B}$ is $\vec{C}$ and $\vec{C}$ is $\perp^r$ $\vec{B}$. Therefore the dot product of $\vec{B}$ with $\vec{C}$ is zero.

ie $\vec{B} \cdot \nabla P = 0$ — (2)

If we take the scalar product of eq^n (1) with $\vec{J}$

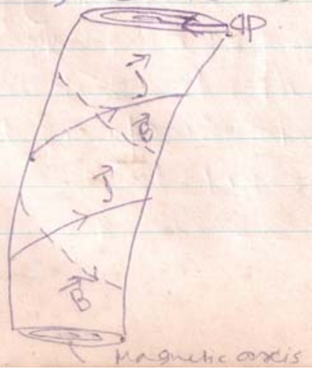
$$\vec{J} \cdot \nabla P = \vec{J} \cdot (\vec{J} \times \vec{B})$$
$$= \vec{J} \cdot \vec{C}$$

$\vec{C}$ being perpendicular to $\vec{J}$ & $\vec{B}$, the dot product of $\vec{J}$ & $\vec{C}$ is zero.

$\therefore$ $\vec{J} \cdot \nabla P = 0$ — (3)

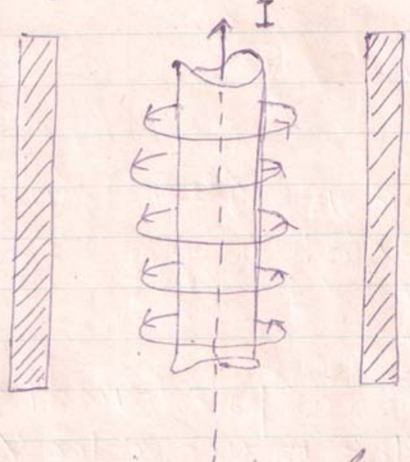
Equation (2) and (3) implies that both $\vec{J}$ & $\vec{B}$ are perpendicular to the vector ∇P otherwise $\vec{J} \times \vec{B}$ will be zero, which is not true.

In these Isobaric Surfaces the pressure increases from outside towards the axis ; the force $\vec{J} \times \vec{B}$ also points towards the axis. This means that the plasma is contained by the force (per unit volume) $\vec{J} \times \vec{B}$ (this force prevents the plasma fluid from flowing out and therefore it keeps the fluid confined in the Isobaric Surface). This is known as Magnetic confinement



A Simple example can explain how the magnetic field can affect the dynamic state of plasma. In the fig.

is shown a cylindrical plasma with an electric current flowing through it axially. Associated with this column there will be a magnetic lines of force or $\vec{B}$ lines encircling the cylinder and the force $\vec{J} \times \vec{B}$ is directed towards the axis which tends to pinch or squeeze the plasma.



Under the action of this force the plasma contracts. Until the compressing electrodynamical force compensated by increased kinetic pressure ($P = NKT$). This phenomenon is known as

PINCH EFFECT

If we imagine surface surrounding the plasma fluid; at every point of which the fluid pressure P can be assumed to be constant i.e. an Isobaric Surface; the ∇P will be perpendicular to that surface.
$\vec{J}$ and $\vec{B}$ being perpendicular to ∇P; $\vec{J}$ & $\vec{B}$ will lie on that Isobaric Surface.

If these surface happen to be closed surface, then since no $\vec{B}$ lines or $\vec{J}$ lines can cross them and therefore they may be viewed as made up from a winding of $\vec{B}$ lines and of $\vec{J}$ lines as shown in the fig. The lines $\vec{B}$ & $\vec{J}$ can not be shown parallel to each other in the Isobaric Surface, because then $\vec{J} \times \vec{B} = 0$; which is not true.