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KINEMATIC MODEL FOR MAGNETIC NULL-POINTS IN 2 DIMENSIONS

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ABSTRACT. The adjacent configurations of two-dimensional magnetic null point centers are analyzed by an immediate examination about the null. The configurations are classified as either potential or non-potential. By then the non-potential cases are subdivided into three cases depending upon whether the component of current is less than, equal to or greater than a threshold current. In addition the essential structure of reconnection in 2D is examined. It unfolds that the manner by which the magnetic flux is rebuilt. In this paper, we center on the ramifications of kinematic arrangements; that is, we fathom just Maxwell's conditions and a resistive Ohm's law.

Key words and phrases: Magnetic reconnection; Null point; Kinematic Solution.

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1. INTRODUCTION

Magnetic reconnection assumes a focal job in numerous wonders that happen in plasmas. For instance, in space, in the arrangement of x-ray bright points and solar flares on the Sun and in the interaction between the earth's magnetosphere and the solar wind and, in the laboratory, in spheromaks. In the course of the most recent twenty years numerous parts of two-dimensional reconnection have been widely contemplated. In two measurements the magnetic field evaporates at a nonpartisan point which might be either X type or O type. To find the nearby magnetic structure about a null point we should consider the magnetic field in the area of a point where the field evaporates $\mathbf{B} = \mathbf{0}$. In the event that, without loss of consensus, we take the null point to be arranged at the cause and, what's more, expect that the magnetic field approaches zero straightly. In this paper we methodically examine the framework $\mathcal{M}$. Besides, an unfaltering arrangement is accepted, so Faraday's equation $\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial \mathbf{t}}$ infers that $\mathbf{E} = \mathbf{E}\hat{\mathbf{z}}$ in 2D. One further prerequisite which is forced is that the non-ideal region, for example the area where the term on the right-hand side of (Ohm's law) is non-zero, must be limited. We consider a limited non-ideal area (D) as the nonexclusive circumstance for astrophysical plasmas, since these plasma shave amazingly high attractive Reynolds numbers, and dissemination is upgraded just in very much restricted locales, for instance when the nearness of solid electric flows may drive miniaturized scale dangers. In the accompanying area, the impact of various kinds of reconnection on magnetic flux tube will be depicted. Because of the effortlessness of the magnetic fields utilized in the models, these flux tubes are for the most part at first untwisted, despite the fact that when all is said in one flux tubes with a limited measure of contort would be conventional in two measurements. The reconnection of segregated curved and untwisted motion tubes has been explored in a progression of numerical examinations [1], [2], [3]. The outrageous instance of a very contorted transition cylinder would be a flux tube in which the magnetic flux is absolutely toroidal.

2. TWO-DIMENSIONAL NULL POINTS STRUCTURE

A magnetic null point is a point in an magnetic field where every one of the components of the field are zero. In two measurements:

$$B_x = B_y = 0$$

This tells us little in itself about the local magnetic structure; the topology of the field in the immediate vicinity of one null point may be quite different near another. However, if we assume that the magnetic field near a null point approaches zero linearly, we can approximate the components of the magnetic field in this region by means of a two variable, first order Taylor expansion about the neutral point X_0,Y_0. Consider the x component:

$$B_X \approx B_X(X_0, Y_0) + \frac{\partial \mathbf{B_X}}{\partial Y}_{X_0,Y_0}(X - X_0) + \frac{\partial \mathbf{B_X}}{\partial X}_{X_0,Y_0}(Y - Y_0)$$

Retain only the first order, linear terms

$$B_X \approx \frac{\partial \mathbf{B_X}}{\partial X}_{X_0,Y_0}(X - X_0) + \frac{\partial \mathbf{B_X}}{\partial Y}_{X_0,Y_0}(Y - Y_0)$$

Choose an origin such that $X_0 = Y_0 = 0$

$$B_X \approx \frac{\partial \mathbf{B_X}}{\partial X}_{0,0} + \frac{\partial \mathbf{B_X}}{\partial Y}_{0,0}$$

Similarly for y:

$$B_Y \approx \frac{\partial \mathbf{B_Y}}{\partial X}_{0,0} + \frac{\partial \mathbf{B_Y}}{\partial Y}_{0,0}$$

We may then express the magnetic field near a null point (to lowest order) as

$$\mathbf{B} = \mathcal{M} \cdot \mathbf{r}$$

where $\mathcal{M} = \begin{bmatrix} \frac{\partial B_X}{\partial X} & \frac{\partial B_X}{\partial Y} \\ \frac{\partial B_Y}{\partial X} & \frac{\partial B_Y}{\partial Y} \end{bmatrix}$, and $r = (X, Y)^T$
For simplicity, we rewrite the above matrix as

$$\mathcal{M} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$$

However, this matrix can be simplified and rewritten in a form that will lend itself more readily to meaningful analysis. First, we impose the solenoidal constraint

$$\nabla \cdot \mathbf{B} = \mathbf{0} \Longrightarrow \frac{\partial \mathbf{B_X}}{\partial \mathbf{X}} = \frac{\partial \mathbf{B_Y}}{\partial \mathbf{Y}} \Longrightarrow \mathbf{a_{11}} = \mathbf{a_{22}} = \mathbf{0} \Longrightarrow \mathbf{a_{11}} = -\mathbf{a_{22}}$$

The diagonal entries are associated with the potential part of the field (they do not show up in the expression for the current below), so we let $a_{11} = p, a_{22} = -p$
Consider now the current

$$\mathbf{J} = \frac{\mathbf{1}}{\boldsymbol{\mu_0}} \boldsymbol{\nabla} \times \mathbf{B} = \frac{\mathbf{1}}{\boldsymbol{\mu_0}} \boldsymbol{\nabla} \times \begin{bmatrix} p & a_{11} \\ a_{22} & -p \end{bmatrix} = \frac{\mathbf{1}}{\boldsymbol{\mu_0}} (\mathbf{0}, \mathbf{0}, \mathbf{a_{21}} - \mathbf{a_{12}})$$

We can conveniently rewrite

$$a_{12} = \frac{1}{2}(q - J_z)$$

Thus for a current free null point, where $J_z = 0, a_{12} = a_{21} = \frac{q}{2}$. Therefore the parameter q is associated with the potential field. The matrix $\mathcal{M}$ may now be stated in its final form

$$\mathcal{M} = \begin{bmatrix} p & \frac{1}{2}(q - J_z) \\ \frac{1}{2}(q + J_z) & -p \end{bmatrix}, \tag{2.1}$$

parameter q is associated with the potential field. The matrix $\mathcal{M}$ may now be stated in its final form.

2.1. **The Threshold Current.**

From the square root of the discriminant of the characteristic equation of the symmetric part of $\mathcal{M}$, we define a threshold current,

$$\mathcal{M}_S = \frac{1}{2}(\mathcal{M} + \mathcal{M}^T)$$

$$J_{thresh} = \sqrt{4p^2 + q^2} \tag{2.2}$$

which we note is only dependent on parameters associated with the potential part of the field The proof proceeds as follows

$$\mathcal{M}_S = \frac{1}{2}(\mathcal{M}+\mathcal{M}^T) = \begin{bmatrix} p & \frac{1}{2}(q - J_z) \\ \frac{1}{2}(q + J_z) & -p \end{bmatrix} + \begin{bmatrix} p & \frac{1}{2}(q + J_z) \\ \frac{1}{2}(q - J_z) & -p \end{bmatrix} = \frac{1}{2} \begin{bmatrix} p & \frac{1}{2}q \\ \frac{1}{2}q & -p \end{bmatrix}$$

$$det(\mathcal{M}_s - \lambda) = -p^2 + \lambda^2 - \frac{q^2}{4} = 0$$

$$\lambda^2 - (p^2 + \frac{q^2}{2}) = 0$$

This yields a discriminant

$$d = 4p^2 + q^2$$

Then

$$J_{thresh} = \sqrt{d} = 4p^2 + q^2$$

as given above.

2.2. **The Flux Function.**
We now determine the flux function A an expression that characterizes the geometry of the magnetic field, defined to obey the solenoid constraint). It satisfies

$$B_X = \frac{\partial A}{\partial Y}, B_Y = \frac{\partial A}{\partial X}$$

Since

$$\mathbf{B} = \mathcal{M} \cdot \mathbf{r}$$

$B_X = pX + \frac{1}{2}(q - J_z)$, and $B_Y = pX + \frac{1}{2}(q + J_z)$
Hence

$$A = \int B_X dY = pXY + \frac{1}{4}(q - J_z)Y^2 + f(X)$$

$$A = -\int B_Y dY = -\left(\frac{1}{4}(q - J_z)X^2 - pXY\right) + f(X)$$

Therefore,

$$A = \frac{1}{4}\left((q - J_z)Y^2 - (q + J_z)^2 X^2\right)$$

This expression can be further simplified by a rotation of the XY axes, allowing us eventually to rewrite it as

$$A = \frac{1}{4}\left[(J_{thresh} - J_z)y^2 + (J_{thresh} + J_z)x^2\right] \quad (2.3)$$

ie. a function of the two parameters J_{thresh} and J_z. The proof proceeds as follows:
Rotate XY-axes through an angle θ,

$$\begin{bmatrix} X \\ Y \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix}$$

to give

$$A = \frac{1}{4}\left((q - J_z)(x\sin\theta + y\cos\theta)^2 - (q + J_z)^2(x\cos\theta - y\sin\theta)^2\right) + p(x\cos\theta - y\sin\theta)$$
$$(x\sin\theta + y\cos\theta)$$

Expanding, and factorizing in x^2, y^2 and xy, yields

$$A = x^2\left[\frac{1}{4}(q - J_z)\sin^2\theta - \frac{1}{4}(q + J_z)\cos^2\theta + p\sin\theta\cos\theta\right] + y^2\left[[\frac{1}{4}(q - J_z)\cos^2\theta - \frac{1}{4}(q + J_z)cos^2\theta\right]$$
$$+xy\left[q\sin\theta\cos\theta + p(\cos^2\theta - \sin^2\theta)\right]$$

Now let $\tan 2\theta = -2\frac{p}{q}$. Firstly, consider the xy term:

$$q\sin\theta\cos\theta + p(\cos^2\theta - \sin^2\theta) = \frac{q}{2}\sin 2\theta + p\cos 2\theta = -p\cos 2\theta + p\cos 2\theta$$

ie. the xy term vanishes. Next, consider the x^2 term:

$$x^2[\frac{1}{4}(q - J_z)\frac{1}{2}(1 - \cos 2\theta) - \frac{1}{4}(q + J_z)\frac{1}{2}(1 + \cos 2\theta) + \frac{1}{2}p\sin 2\theta]$$
$$= -\frac{x^2}{4}(q\cos 2\theta - 2p\sin 2\theta + J_z) = -\frac{x^2}{4}(q\cos 2\theta + \frac{4p^2}{q}\cos 2\theta + J_z)$$

$$= -\frac{x^2}{2}\left(\frac{1}{(4p^2+q^2)^{\frac{1}{2}}}(4p^2+q^2) + J_z\right) = -\frac{x^2}{2}(J_{thresh} + J_z)$$

Finally, consider the y^2 term:

$$\frac{y^2}{8}\left[(q-J_z)(1+\cos 2\theta) - (q+J_z)(1-\cos 2\theta) - 4p\sin 2\theta\right]$$
$$= \frac{y^2}{8}\left(q\cos 2\theta - 2p\sin 2\theta - J_z\right) = \frac{y^2}{8}\left(q\cos 2\theta + \frac{4p^2}{q}\cos 2\theta - J_z\right)$$
$$= \frac{y^2}{4}\left(\frac{1}{(4p^2+q^2)^{\frac{1}{2}}}(4p^2+q^2) - J_z\right) = \frac{y^2}{4}\left(J_{thresh} - J_z\right)$$

And hence,

$$A = \frac{1}{4}\left[(J_{thresh} - J_z)y^2 - (J_{thresh} + J_z)x^2\right]$$

2.3. **The Eigenvalues.**

Now, we determine a general expression for the eigenvalues of $\mathcal{M}$.

$$det(\mathcal{M} - \lambda) = (p-\lambda)(-p-\lambda) - \frac{1}{4}(q-J_z)(q+J_z)$$
$$\lambda^2 - \frac{1}{4}(4p^2 + q^2 - J_z^2) = \lambda^2 - \frac{1}{4}(J_{thresh}^2 + q^2 - J_z^2)$$

$$\lambda = \pm\frac{1}{2}\sqrt{J_{thresh}^2 - J_z^2} \tag{2.4}$$

It is apparent that, if $J_z < J_{thresh}$, then $\lambda \in R$, and if $J_z > J_{thresh}$ then $\lambda \in Q$. In the following subsections a general two-dimensional null is studied firstly depending on whether it is potential (Section 2.1) or not (2.2) and then whether the current is greater or less than J_{thresh} (Figure 1).

2.4. **Classifying 2D Null points.**

2.4.1. *Potential Null Points.*

A potential field is current free, i.e. $J = 0 \implies J_z = 0$. It follows that $\mathcal{M}$ is symmetric in the potential case, and from (2.4) the eigenvalues are given by

$$\lambda = \pm J_{thresh}$$

Thus we have two real non-zero eigenvalues. From (2.3) it is apparent that the flux function is simply

$$A = \frac{J_{thresh}}{4}(y^2 - x^2)$$

From the flux function we can quickly discover the geometry of the field lines.

$$B_x = \frac{\partial A}{\partial y} = \frac{J_{thresh}}{4}y, B_y = -\frac{\partial A}{\partial x} = \frac{J_{thresh}}{4}x$$
$$\frac{dy}{dx} = \frac{B_y}{B_x} = \frac{y}{x} \implies ydx = xdy \implies y^2 - x^2 = c$$

Finally, for $c = 0 \implies y = \pm x$, and for $c \neq 0 \implies y = \pm\sqrt{c - x^2}$ The field lines are thus rectangular hyperbola with separatrices that intersect at an angle of $\pi/2$. We call this an -type neutral point, and it is the only possible configuration in 2D for a neutral point in a potential field, as shown in figure 2a.

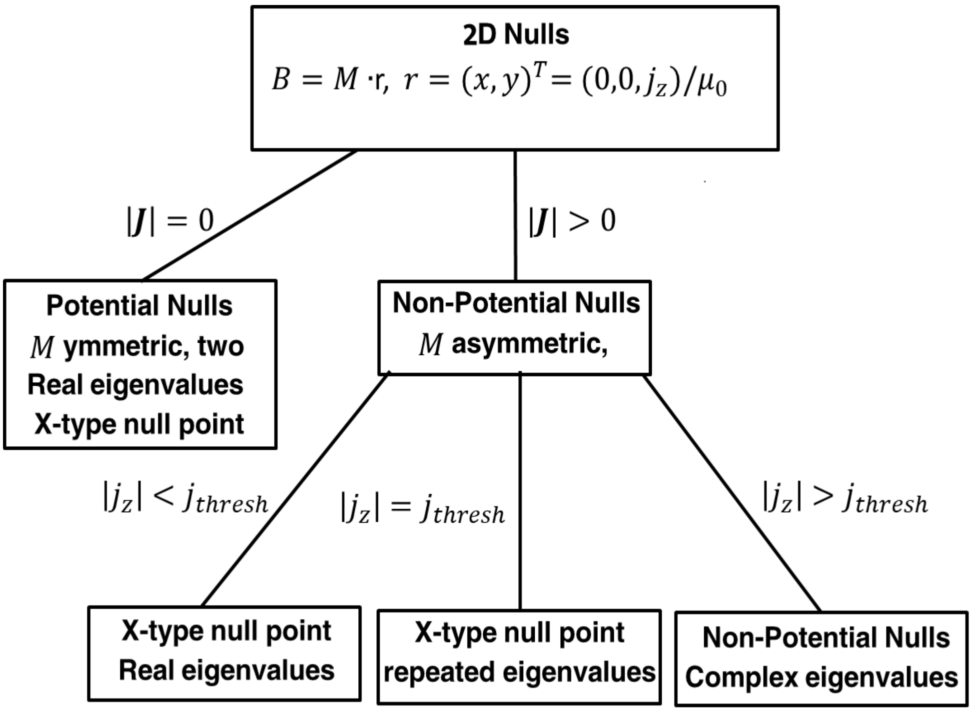

Figure 1: A categorization of the different types of 2D null and the respective limits of J_z (the$z$-component of current) and J_{thresh} (the threshold current) at which they occur.

2.4.2. *Non-Potential Null Points.*
Although we are concerned with a potential field extrapolation in this investigation, we briefly consider here the case of 2D neutral points in a non-potential field. Two dimention neutral points with current are classified by the magnitude of J_z and J_{thresh}.

1. $J_z < J_{thresh}$: Here, 2.4 $\Longrightarrow$ the eigenvalues are real, equal in magnitude, and opposite in sign, and 2.3$\Longrightarrow$ $A = ay^2 - bx^2$ where $a, b > 0$, ie. the field lines are hyperbolae with separatrices that intersect at an angle of

$$\tan^{-1}\left(\frac{J_{thresh}^2 - J_z^2}{J_z}\right)$$

Again, we have an X-type neutral point, as shown in figure 2b ,which reduces to the potential case (rectangular hyperbolae) as $J_z \Longrightarrow 0$.

2. $J_z = J_{thresh}$: Here, 2.4 $\Longrightarrow$ the eigenvalues are both zero, 2.3$\Longrightarrow$

$$A = \left\{ \begin{array}{ll} -\frac{1}{2}J_{thresh}x^2 & J_{thresh} = 1 \\ \frac{1}{2}J_{thresh}y^2 & J_{thresh} = -1 \end{array} \right.$$

Hence

$$B_x = \frac{\partial A}{\partial x} = \left\{ \begin{array}{cc} 0 & J_{thresh} = 1 \\ J_{thresh}y, & J_{thresh} = -1 \end{array} \right.$$

Therefore,

$$J = -J_z \Longrightarrow \frac{dx}{dy} = 0 \Longrightarrow y = const.$$

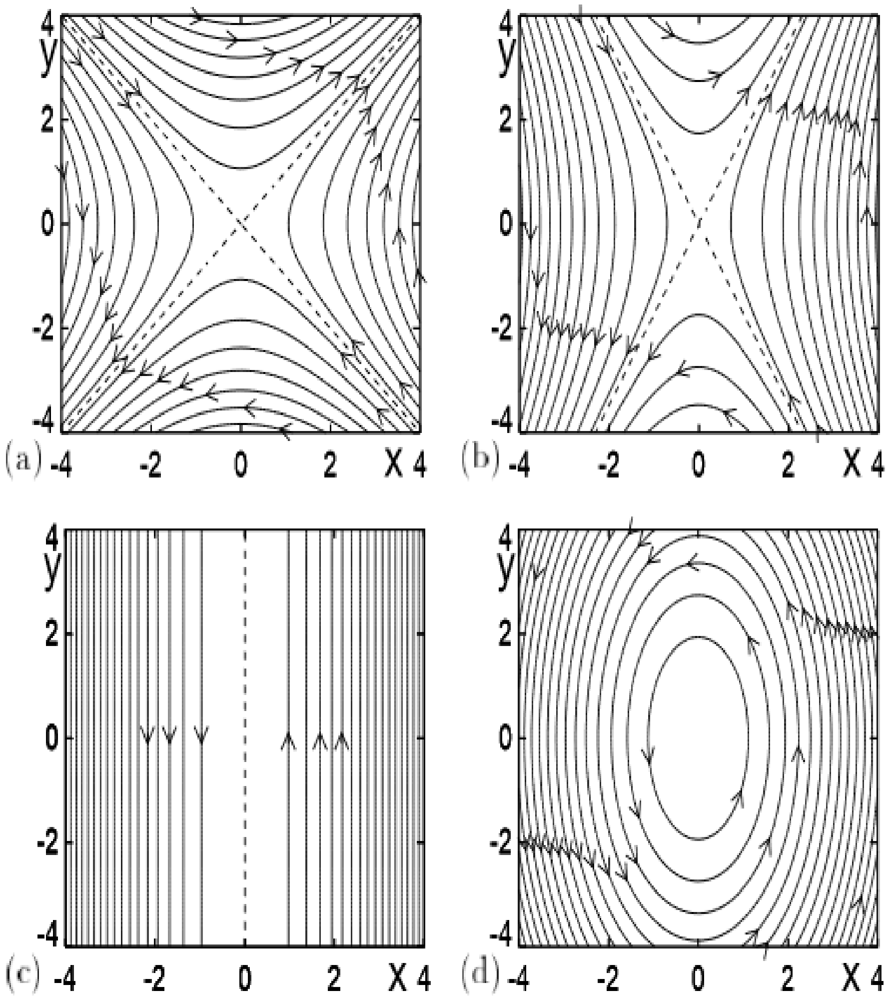

Figure 2: A categorization of the different types of two-dimensional null and the respective limits of z (the z-component of current) and J_{thresh} (the threshold current) at which they occur.

$$J = J_z \Longrightarrow \frac{dy}{dx} = 0 \Longrightarrow x = const.$$

Thus this configuration produces anti-parallel field lines with a null either along the x-axis or the y-axis respectively (3 c).

3. $J_z > J_{thresh}$:Here, 2.4 $\Longrightarrow$ the eigenvalues are complex conjugates.
For the case $J_{thresh} = 0$, 2.3$\Longrightarrow$

$$A = -\frac{1}{4}(y^2 + x^2)$$

ie. the field lines are circular and centred around the origin.
For the case $J_{thresh} \neq 0$ 2.3$\Longrightarrow$

$$A = -\frac{1}{4}(ay^2 + bx^2)$$

(where a, b are constants, both greater than zero), ie. the field lines are concentric ellipses (figure2)

3. BASIC EQUATIONS

The usual MHD equations for an ideal, are used. Hence,

$$\mathbf{E} + \mathbf{v} \times \mathbf{B} = \eta \mathbf{J}, \tag{3.1}$$

$$\nabla \times \mathbf{E} = 0, \tag{3.2}$$

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J}, \tag{3.3}$$

$$\nabla \cdot \mathbf{B} = 0. \tag{3.4}$$

Where $\mathbf{v}$, is the plasma velocity, $\mathbf{B}$, the magnetic field and J is the current. In this part, the fundamental structure of reconnection in 2D is talked about. It comes to pass that the manner by which the magnetic flux is rebuilt amid the procedures. We settle just Maxwell's equations (3.1, 3.2, 3.3, 3.4) Moreover, an enduring arrangement is accepted, with the goal that the Faraday's equation (6) suggests that in 2D, where is some scalar capacity. One further necessity which is forced that the non-ideal region, for example the region where the term on the right hand side of (3.1) is non-zero, must be restricted. We consider a limited non-ideal region (D) as the nonexclusive circumstance for astrophysical plasmas, since these plasma shave very high magnetic Reynolds numbers, and scattering is upgraded just in all around localized region, for instance when the nearness of solid electric flows may drive miniaturized scale insecurities.

4. TWO DIMENSION KINEMATIC SOLUTION

In this section two-dimensional solution is solved. In order to obtain a physically acceptable solution, with all physical quantities continuous and smooth, the magnetic field and resistivity are first prescribed. The magnetic fields chosen to be a simple linear 2D X-point,

$$\mathbf{B} = \frac{B_0}{L_0}(y, kx, 0) \tag{4.1}$$

where is k a constant, so that $j = (k-1)/\mu\hat{z}$. The resistivity is defined as

$$\eta = \eta_0 \begin{cases} ((k^2x^2 + y^2) - 1)^2 & (k^2x^2 + y^2) < 1 \\ 0 & \text{otherwise} \end{cases} \tag{4.2}$$

Where η_0 is constant. The profile of η is shown in figure 3(a).

In order to calculate the corresponding plasma velocity, or at least the component $\mathbf{v}_\perp$ perpendicular to, take the vector product of Equation 3.1with $\mathbf{B}$ to give

$$\mathbf{v}_\perp = \frac{(\mathbf{E} - \boldsymbol{\eta}\mathbf{J}) \times \mathbf{B}}{B^2} \tag{4.3}$$

$$= \frac{1}{R_1^2} \begin{cases} \left(E - \frac{\eta_0(k-1)}{\mu}(R_1^2 - 1)^2\right)(-kx, 1) & R_1^2 < 1 \\ E(-kx, 1) & \text{otherwise} \end{cases} \tag{4.4}$$

where $R_1^2 = k^2x^2 + y^2$ Notice that it is vital that the estimation of E be picked to keep the plasma velocity non-singular at the origin. To $|\mathbf{v}| = \mathbf{0}$ have at the starting point requires.

$$\frac{\eta_0(k-1)}{\mu} \tag{4.5}$$

With this decision of E, the velocity have the form of a smooth stagnation flow, appeared in Figure 3 (b-d). So as to explore the advancement of magnetic flux it is valuable to characterize a flux transporting velocity $\mathbf{w}$ ([4]; [5]) which fulfills

$$\mathbf{E} + \mathbf{w} \times \mathbf{B} = \mathbf{0} \tag{4.6}$$

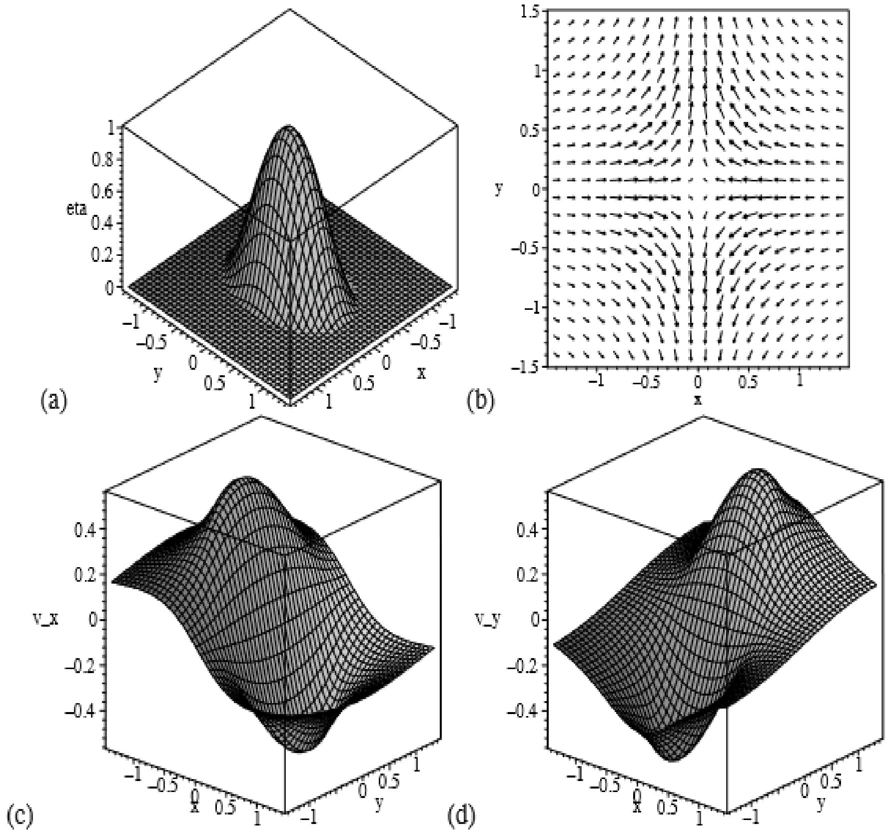

Figure 3: . (a) Plot of η for parameters $\eta_0 = 1, k = 1.5$, .(b), (c) and (d) show the plasma velocity for the same parameters.

which is conceivable in two dimension since the electric field $(\mathbf{E})$ is constantly opposite to $(\mathbf{B})$. By examination with a perfect Ohm's law, can be viewed as a stream inside which the magnetic flux is frozen. The component of $(\mathbf{w})$ perpendicular to $(\mathbf{B})$ can be found from 4.6 to be

(4.7) $$\mathbf{w}_\perp = \frac{\mathbf{E} \times \mathbf{B}}{B^2}$$

The part of $(\mathbf{w})$ parallel to $(\mathbf{B})$ is typically thought to be zero, with the goal that the above gives an articulation for w itself. Note that for reconnection to take place, the flux transporting velocity $(\mathbf{w})$ must be come particular at the null point, which is a mark of the breaking of the field lines ([6]). Here, $(\mathbf{w})$ takes the structure

(4.8) $$\mathbf{w} = \frac{\eta_0(k-1)}{(y^2 + k^2x^2)\mu}\,(-kx, y, 0)$$

The development of the magnetic flux in this procedure is pictured as pursues. Two transition tubes are selected which at first lie in the in stream areas on inverse sides of the dispersion locale. Each flux tube is then followed out at each time by coordinating the field lines from two cross-sections, one at either end of each cylinder. These cross-sections are permitted to develop in the perfect stream, and are picked to such an extent that they never go into the non-ideal region (see Figure 4). The cross-section are picked along these lines in order to guarantee that a similar field lines are constantly followed at each time, because in the perfect area the field is solidified

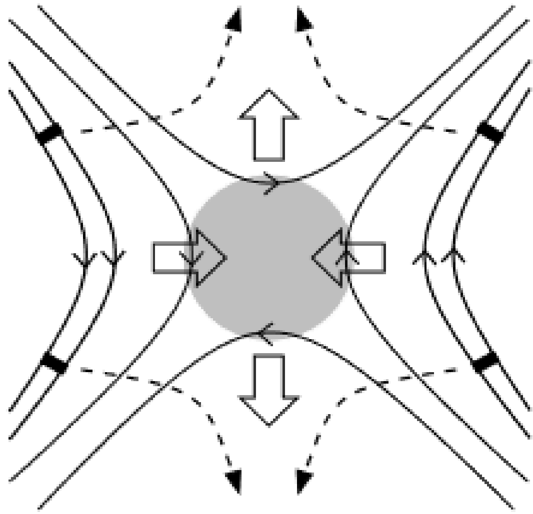

Figure 4: The choice of cross-sections (thick black bars) from which the flux tubes are traced ensures that the paths they follow (dashed lines), as they move in the ideal flow, never take them into the non-ideal region (shaded).

to the stream, so field lines might be distinguished by plasma elements there. The way that each cylinder is followed from a perfect cross area at each end will become significant in later precedents, which are depicted with the assistance of comparable liveliness. Additionally, the transition tubes are picked at first to be symmetric about $x = 0$.

The manner by which the flux tubes develop in the reconnection procedure is appeared in Figure 5, which indicates outlines from the film contained on the going with CD. Note that, in spite of the fact that the non-ideal region (D) is of critical size with in the container appeared, the transition tubes followed from either end stay associated until they achieve the X-point at $(0, 0)$. At the X-point the field lines which structure the transition tubes are cut and rejoined, lastly two interesting reconnected flux tubes move far from the X-point in inverse quadrants. By and by, while going through the diffusion region and moving far from the X-point, the transition tubes sneak past the plasma, yet stay associated. At long last they leave and are diverted in the perfect stream

5. NATURE OF TWO DIMENSION RECONNECTION

A field line velocity $(\mathbf{w})$ in two dimension, dependably exists, fulfilling

$$\frac{\partial \mathbf{B}}{\partial t} = \nabla \times (\mathbf{w} \times \mathbf{B}), \tag{5.1}$$

$(\mathbf{w})$ is equivalent to the plasma velocity $((\mathbf{v}))$ in ideal-region, and is the velocity with which the field lines sneak past the plasma in non-ideal region. Likewise, $(\mathbf{w})$ is smooth and differentiable wherever aside from at null point, where it has a hyperbolic peculiarity, connoting the breaking of magnetic field lines there. For a model see section 4. While with in a non-ideal region, field lines hold their associations until they achieve the X-point. In other words, field line protection holds wherever aside from at the separatrices of the null point. When the field lines lie on the separatrices of the null point, they break and are rejoined at the invalid point, changing the availability.The mapping between field line footpoints is spasmodic. Consider the schematic X-point appeared in Figure 6 (a). For instance, as the field line secured at footpoint A_1 moves

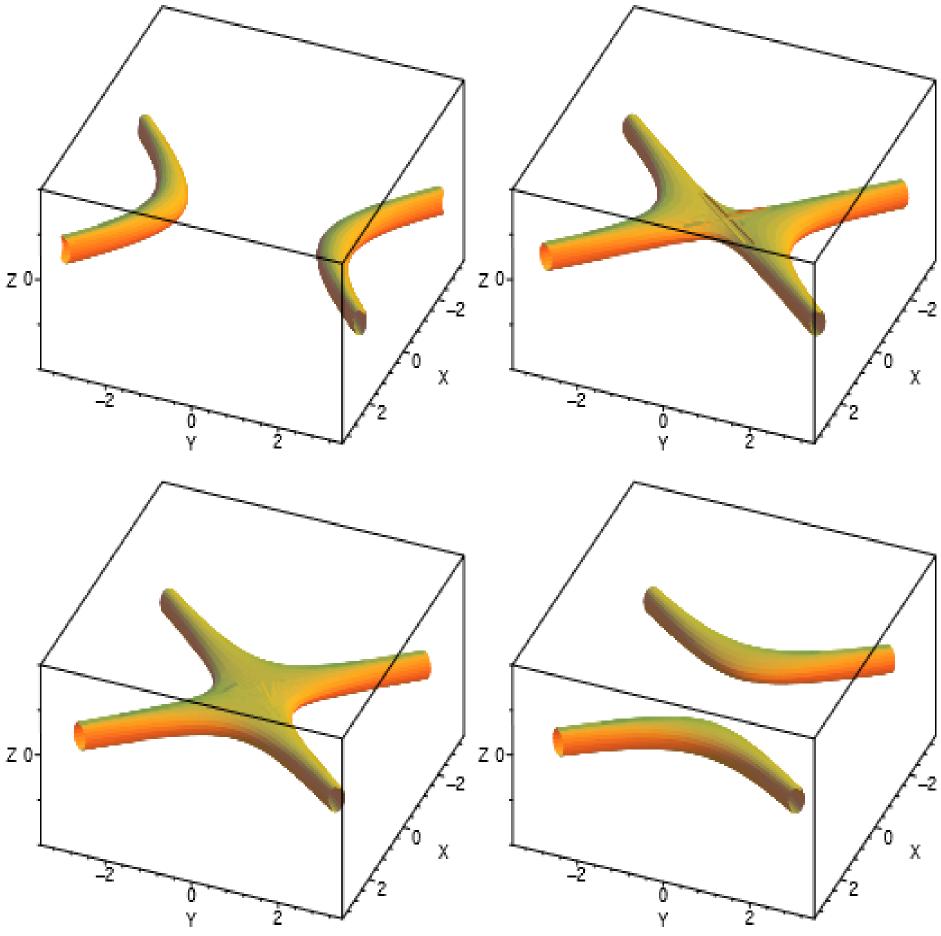

Figure 5: The global behavior of the reconnecting flux tubes for a localized 3D region within the non-ideal region.

towards the separatrix, it is associated with B_2 on the contrary limit. In any case, as A_1 moves over the separatrix (to A_2) it abruptly ends up associated with a point D on a similar limit as itself. This discontinuous mapping is an outcome of the reality the field lines break just at a single point.

A field line (or flux tube) which lies incompletely inside the non-ideal region moves with the plasma velocity $(\mathbf{v})$ wherever outside the non-ideal region (see Figure 6 (b)). Within the non-ideal region it sneaks past the plasma at the velocity w. For each flux tube which is going to reconnect (in an in stream district of $(\mathbf{v})$, there exists a relating flux tube on the contrary side of the X-point with which it will become consummately rejoined after reconnection, to such an extent that two one of a kind however contrastingly associated flux tubes are created (see Figure 6 (c)). This will from this time forward be alluded to as 'impeccable reconnection' of flux tubes.

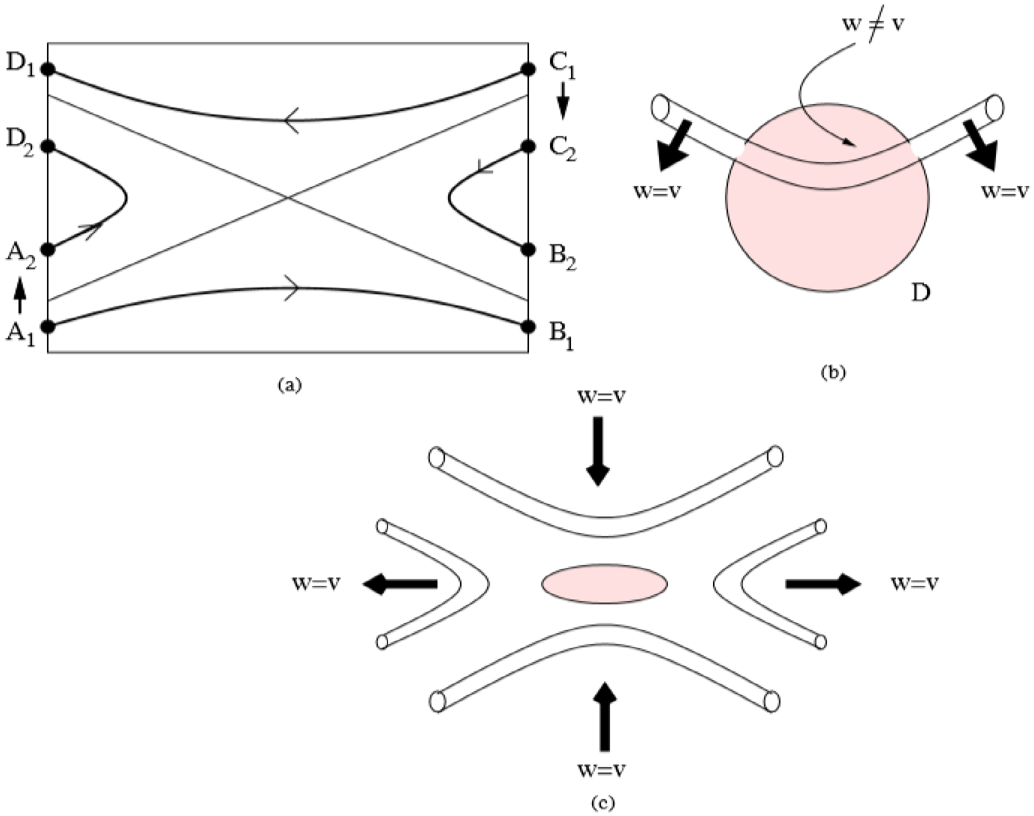

Figure 6: In two dimensional reconnection: (a) the mapping of field line footpoints, (b) motion of a flux tube passing through the non-ideal region, and (c) the breaking and rejoining of flux tubes.

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