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Electrostatic potential drop with no electric field PAUL BELLAN, Caltech — It is commonly believed that because plasma is a near perfect electrical conductor, one can assume that electron motion will short out any spatial variation in the electrostatic potential V and so the electrostatic electric field $-\nabla V$ can be assumed to be zero. As an example of this sort of argument, see p. 23 of Parker's book, Cosmical Magnetic Fields (Oxford, 1979). However, assuming that a perfectly conducting plasma cannot support an electrostatic potential drop is a serious error, because the property of a perfect conductor is that the net electric field must be zero, not that just the electrostatic component is zero. Since $\mathbf{E} = -\nabla\mathbf{V} - \partial\mathbf{A}/\partial\mathbf{t}$ it is quite possible to have $\mathbf{E}$ vanish while ∇V is finite, provided $\partial\mathbf{A}/\partial\mathbf{t}$ is such as to cancel ∇V. This is of special interest in the classic MHD situation of a straight cylindrical flux tube being twisted up. The axial component of the ideal Ohm's law is $E_z + U_r B_\phi - U_\phi B_r = 0$ and since U_r and B_r are both zero for the twisting of a straight flux tube, the axial component of the ideal MHD Ohm's law reduces to $E_z = -\partial V/\partial z - \partial A_z/\partial t = 0$. Twisting up a flux tube, i.e., increasing B_ϕ, corresponds to increasing A_z since $B_\phi = -\partial A_z/\partial r$. *Thus, twisting up a flux tube requires that a nontrivial electrostatic potential drop* $\partial V/\partial z = -\partial A_z/\partial t$ *develop along the length of the flux tube during the twisting up process.* This electrostatic potential drop is typically neglected in studies of the twisting of solar corona flux tubes, but is known to be essential in laboratory experiments involving the twisting flux tubes.
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