Model Solvay Conference 2023

Prelims

1 Back to the Year of Jocelyn Bell Burnell

Pulsars (magnetised rotating neutron stars) were discovered by Jocelyn Bell Burnell in 1967. After this one moment many properties of Pulsars have been unravelled and one of them and the most fundamental one is the charge density around these dense objects. Imagine yourself as a scientist working on Pulsars trying to explain and quantify the charge density around a Pulsar.

You may assume that :

- The neutron star's interior is uniformly magnetised, it has a rotational axis aligned with the magnetic axis and is of infinite conductivity.
- The neutron star is a rigid body made up entirely of co-rotating charged particles.
- The charged particles experience a 'force-free' condition inside the neutron star.
- There is initially no charge density outside the neutron star.
- There is a star-centred dipole magnetic field in the exterior.

i Using the above, arrive at mathematical expressions for the electric field inside and outside the neutron star. Now argue that a rotating magnetised neutron star cannot exist in a vacuum.

ii Thus, find an expression for the charge density outside the neutron star at a general point (you may employ the force-free condition yet again).

iii Also, find the regions around the star where $\rho = 0$ and $\rho \to \infty$ where ρ represents the charge density around the star.

iv Also suggest methods by which you could observe and measure charge density, magnetic and electric fields from great distances to put your theoretical results to test.

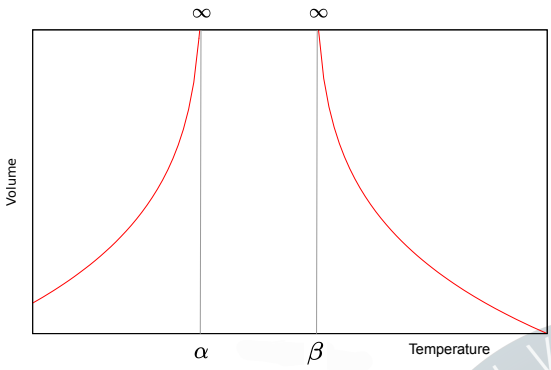
Feel free to explore relavent literature, you can take the help from [1] [2]

[1] Griffiths, D. (2017). Introduction to Electrodynamics (4th ed.). Cambridge: Cambridge University Press. doi:10.1017/9781108333511

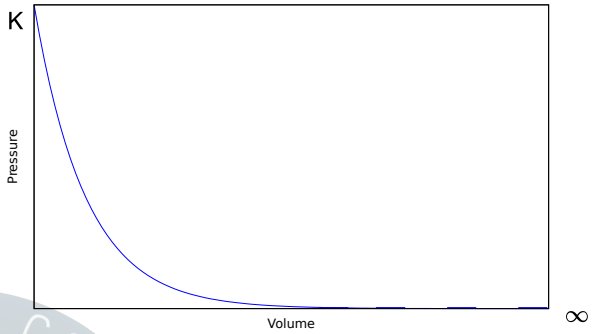
[2] Riley, K., Hobson, M., & Bence, S. (2002). Mathematical Methods for Physics and Engineering: A Comprehensive Guide (2nd ed.). Cambridge: Cambridge University Press. doi:10.1017/CBO9781139164979

2 New Universe , New Thermodynamics

Imagine yourself as a multiversal explorer in a distant future. Your Multiversal drive goes haywire and you're teleported to a parallel universe where the laws of physics are alien to you. Fortunately you are provided with 2 graphs between thermodynamic quantities followed by the matter in that universe; find the underlying equation of state followed by the matter based on that.



V vs T



P vs V

Also, explain the physics and observed phenomena you are expected to see based on your equation of state and compare it with the observations on Earth.
You can also draw graphs between other thermodynamic quantities as an additional task.