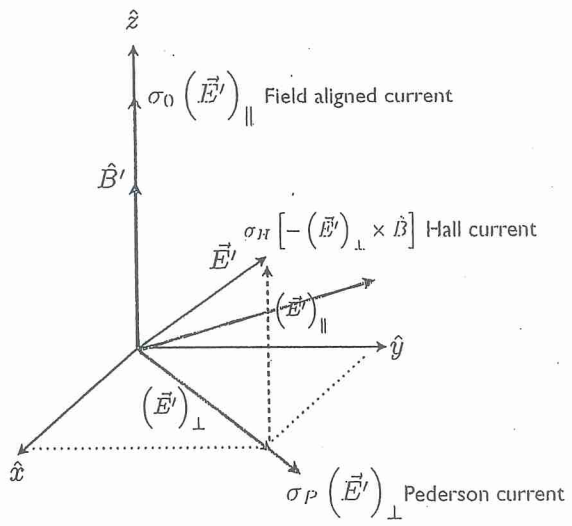
Graduate School Entrance Exam: Space Physics (Ionosphere)
50 points total. **Pick 2 of problems #1, 2, and 3 to complete.** You must complete all parts of your two selected problems for full credit. If you complete all three problems, your score will be computed using the two problems with the highest score.

Useful Hints:



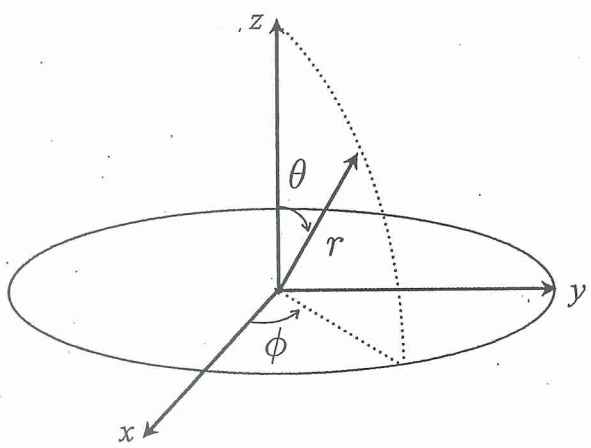
Ionospheric current equation: $\boldsymbol{J} = \boldsymbol{\sigma} \cdot (\boldsymbol{E} + \boldsymbol{U} \times \boldsymbol{B})$

1. (25 points) Shortwave (HF) radio is often used to broadcast over a very wide range through ionospheric reflection. The following is a schedule of shortwave broadcast frequencies towards the East Asia region from Radio Taiwan International:

Time (Taiwan Local Time)	Frequency (MHz)
1100-1200	15.320
1900-2000	7.445

   a) (10 points) Explain the reasoning behind the selection of frequencies.
   b) (15 points) In the event of a solar flare directed at Earth, should broadcast frequencies be adjusted up or down in order to achieve maximum range? Why?

2. (25 points) To solve this problem, use a spherical coordinate system with axes $\hat{r}, \hat{\theta}, \hat{\phi}$, which point in the vertical, southward, and eastward directions respectively, as shown in the diagram to the right.



   Assume the Earth's magnetic field is a pure dipole, with magnetic poles in the same locations as the geographic poles.

   a) (8 points) At the magnetic equator, neutral winds are blowing westward with

注意：背面有試題

magnitude u. The magnitude of the magnetic field is B, while the Hall conductivity is σ_H. What is the magnitude and direction of the Hall current that results? Express your answer in terms of u, B, and σ_H, and the spherical coordinate system. No polarization electric field exists yet at this point.

b) (8 points) Another region of the equatorial ionosphere is dominated by Pederson conductivity with magnitude σ_P. Assuming the same neutral wind direction as in Part a, what is the magnitude and direction of the Pederson current that results, expressed in the spherical coordinate system?

c) (9 points) The Pederson current in Part b produces a polarization electric field, such that the current goes to zero. What is the direction of the $\vec{E}\times\vec{B}$ drift that results for the plasma due to this polarization electric field, expressed in the spherical coordinate system?

3. (25 points) Answer the following questions:

a) (10 points) Explain how the atmospheric pressure and density can be determined mathematically at different altitudes, if the temperature and composition of the atmosphere change with altitude.

b) (15 points) Research suggests that increased carbon dioxide (CO_2) in the Earth's atmosphere acts to warm the lower atmosphere, while resulting in a cooling of the middle and upper atmosphere. The concentration of CO_2 will increase at all altitudes. Discuss what effects these changes in temperature and composition can potentially have for the atmospheric drag encountered by a satellite at some fixed altitude in low Earth orbit. Support your arguments with any applicable equations.

請注意：作答時物理量應為向量者，卻未標示向量符號，將不予計分！應為純量者，卻標示向量符號，也不予計分！試題中，粗體字形表示該物理量為向量。

4. (10 points)

Let $\Phi_B(t) = \int\int_{S(t)} \mathbf{B}(\mathbf{x},t)\cdot d\mathbf{a}$ be the total magnetic flux passing through a surface $S(t)$, where $\mathbf{B}(\mathbf{x},t)$ is the field of magnetic flux density (or simply called the magnetic field). Show that the change of magnetic flux along the fluid trajectory is

$$\frac{d\Phi_B(t)}{dt} = -\oint_{C(S)} d\mathbf{l}\cdot[\mathbf{E}(\mathbf{x},t)+\mathbf{V}(\mathbf{x},t)\times\mathbf{B}(\mathbf{x},t)]$$

where $\mathbf{E}(\mathbf{x},t)$ is the electric field, $\mathbf{V}(\mathbf{x},t)$ is the plasma flow velocity field, $S(t)$ is the surface area covered by the sampled plasma, and $C(S)$ is the loop around of the surface area $S(t)$ in the counterclockwise direction.

5. (30 points)

(a) 請繪圖說明地球磁層以及其鄰近區域結構與各部份的名稱（可以用兩、三個剖面圖來描述此立體結構，請標示座標軸）。

(b) 請繪圖說明安靜期（quiet-time）地球磁層中的大尺度電場（electric field）分布情形。請說明這些電場的形成機制。

(c) 請在圖中標示安靜期地球磁層以及其鄰近區域中電漿密度的分佈，並說明造成磁層中電漿密度分佈不均勻的原因。

(d) 請在圖中標示安靜期地球磁層中電流密度的分佈，並說明這些電流（或電流密度）的形成機制。

(e) 請總結說明導致地球磁層由一個磁偶極場結構變形成為一個有頭有尾的磁層結構之相關物理過程。

6. (10 points)

請說明太陽週期變化情形，包括太陽黑子、太陽磁場、日冕洞的變化情形。並說明太陽表面的各種電漿與電磁場擾動以及太陽風的變化對地球磁層與電離層之太空環境或太空天氣的影響。