UNIVERSITY OF SRI JAYEWARDANEPURA - FACULTY OF APPLIED SCIENCES

B. Sc. Special Degree Fourth Year Second Semester Course Unit Examination March/April 2023

DEPARTMENT OF PHYSICS

PHY 458 2.0 – Space and Atmospheric Physics

Time : Two hours; **No of Questions : 04;** **No of Pages : 03;** **Total Marks : 60**

Answer all questions

---

01. Write short notes on,

(a) Atmosphere of the Venus,

(b) Magnetic field of the Sun and

(c) Millimeter (MM) Waves in radio wave applications.

(15 Marks)

02. **(a)** **(i)** Show that the pressure difference between the top and the bottom surfaces of a vertical air column of height dh of the Earth atmosphere is given by,

$$dP = -N\,mg\,dh\,.$$

Where, N is molecular number density, m is mean molecular mass and g is acceleration due to gravity.

(ii) If the variation of the molecular mass, temperature and acceleration due to gravity with the height is negligible, show that the pressure P changes with the height h is given,

$$P(h) = P_o\, e^{-mgh/kT}\,.$$ (Symbols have their usual meanings)

(b) **(i)** Sketch the atmosphere temperature distribution of the Earth.

(ii) Discuss how the various regions of the Earth's atmosphere have been defined based on the temperature distribution of the atmosphere.

(iii) The temperature of the lowest region of the atmosphere that is in contact with the solid Earth decreases with height. But, the temperature in the stratosphere, increases with height. Explain why?

(iv) The temperature of the atmosphere of the Earth decreases with height at a constant rate of 0.6^oC per $100\ m$ in the lower atmosphere. The temperature at the mean sea level is 27^oC. Estimate the atmospheric temperature at an altitude of 2.8 km.

(15 Marks)

03. **(a)** **(i)** What is **Chapmen Layer Theory?**

(ii) According to the Chapman Layer Theory, the production rate of electrons Q can be written as,

$$Q = Q_o \exp\left[1 - Z - \sec\psi . e^{-Z}\right].$$

Where, $e^{-Z} = \sigma_a NH$ and Q_o is a constant. *Z*, ψ, σ_a, *N* and *H* have their usual meanings.

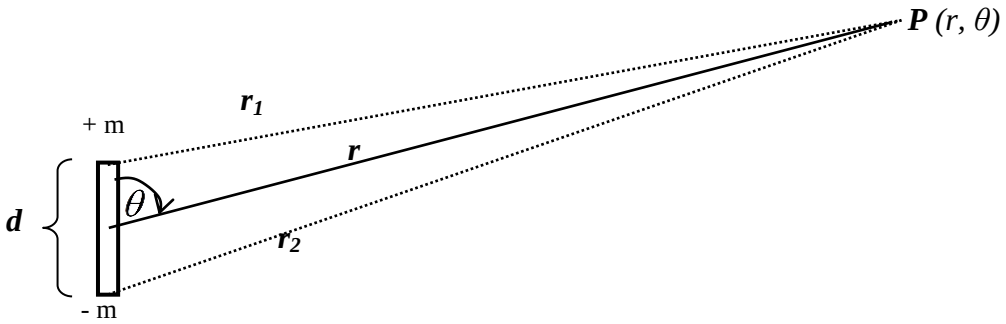
(α) Prove that the electron production rate Q has a maxima at the height, where, $\sigma_a NH = \cos\psi$.

(β) It has been observed that the maximum production rate of electrons in the ionosphere is 2.82×10^9 $m^{-3}s^{-1}$ for $\psi = 45^o$.

Evaluate the maximum production rate of electrons for,

(β_1) $\psi = 0^o$ **(β_2)** $\psi = 30^o$ **(β_3)** $\psi = 60^o$.

(b) The magnetic field of the Earth can be represented to a good approximation by a dipole magnetic field with the intensity of *40 000 nT* at the equator.



(i) Show that the magnetic field intensity $H(r,\theta)$ at a point *P* (shown in the figure above) due to a vertical short bar magnet of length *d* ($d << r$) is given by,

$$H(\ r,\ \theta\ ) = \frac{\mu_o}{4\ \pi} \cdot \frac{M}{r^3} \cdot \left(\ 1 + 3\ \cos^2\theta\ \right)^{1/2}.$$

Where, the other symbols have their usual meanings. [Hint : If $r >> d$, $r_1 \approx r_2 \approx r$ and $r_2^3 - r_1^3 \approx 3\ r^2\ d\ \cos\theta$]

(ii) Find the magnetic field intensity at your examination hall, **PLT** with coordinates (6.854576^o N, 79.905638^o E).

(You are given $\mu_o = 4\ \pi\ \times\ 10^{-7}\ Hm^{-1}$ and the radius of the Earth $6.4 \times 10^6\ m$)

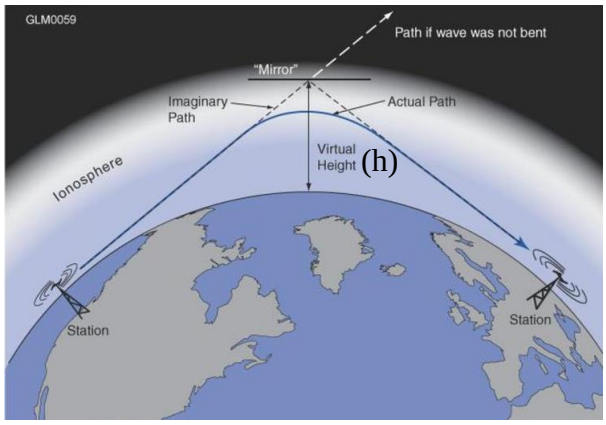
(15 Marks)

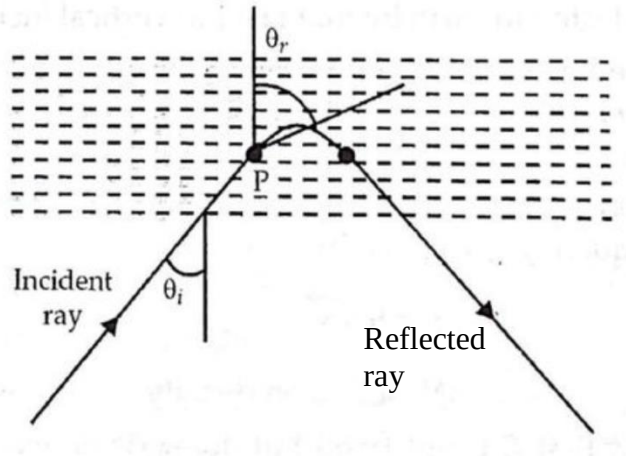
04. **(*a*)** **(i)** Briefly explain how a **Condenser Microphone** and a **Speaker** works.

(ii) Describe the main steps in a **radio communication**.

(iii) What is meant by **absorption of radio waves** by the ionosphere ?

(*b*) A radio wave with frequency f come to the ionosphere from the ground radio station with incident angle θ_i and reflected back with angle θ_r to the another ground radio station as in the following diagram. The virtual height of the radio wave is h.





(i) If the incident angle $\theta_i = 0$, for the normal incident, show that the critical frequency f_c of the ionosphere is,

$$f_c = 9 \times (N_{\max})^{1/2}.$$

Where, N_{max} is the maximum number density of the ionosphere and refractive index n is given by $n = \sqrt{1 - \frac{81\ N}{f^2}}$ and $n^2 = \varepsilon_r$. Where, the other symbols have their usual meanings.

(ii) Then, show that the condition for the wave to be reflected back to the Earth is given by,

$$Sin\theta_i > \sqrt{1 - \left(\frac{f_c}{f}\right)^2}$$

(iii) **(α)** What is **skip distance** and **Maximum usable frequency** (MUF) of the radio waves ?

(β) If the maximum usable frequency is f_{MUF} and the skip distance of the atmosphere is D_{skip}, ($D_{skip} = \frac{2h}{\tan\theta_c}$), show that the following relationships.

(β₁) $f_{MUF} > f_c$

(β₂) $D_{skip} = 2h\sqrt{\left(\frac{f_{MUF}}{f_c}\right)^2 - 1}$

(15 Marks)

****