UNIVERSITY OF SRI JAYEWARDANEPURA
FACULTY OF APPLIED SCIENCES

B. Sc. Special Degree Fourth Year Second Semester Course Unit Examination

December 2019

DEPARTMENT OF PHYSICS

PHY 458 2.0 – Space and Atmospheric Physics

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

Answer all questions

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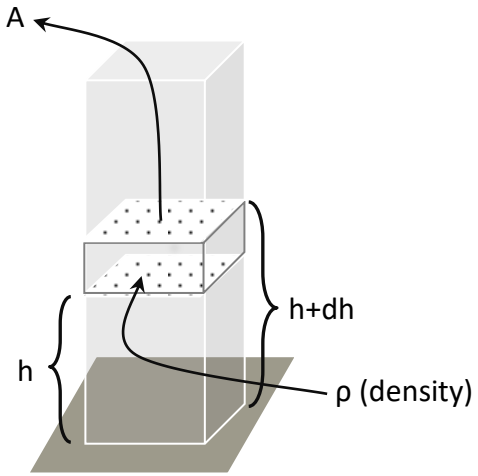
01. (*a*)



Show that the pressure difference dP, between the top and the bottom surfaces of a vertical air column of height dh is given by,

$$dP = -N\bar{m}g\,dh\,.$$

Where, N is the molecular number density, $\bar{m}$ is the mean molecular mass and g is the acceleration due to gravity.

Hence, show that the molecular number density, N of the Earth's atmosphere varies as a function of height h as given below;

$$N(h) = N(0)\cdot e^{-h/H} \;\; ; \;\; H = \frac{k\,T}{\bar{m}\;g}$$

(Symbols have their usual meanings).

P. T. O

(*b*) Define the term "**Scale Height**" and evaluate its numerical value for the Earth.

You may assume that, acceleration due to gravity = 10 ms^{-2} , Boltzmann constant = 1.38×10^{-23} $J\ K^{-1}$ and for the atmosphere of the Earth, mean molecular mass = 5.0×10^{-26} kg and the absolute temperature of the region = 300 *K*.

Using the suitable diagrams, explain how the molecular number density, *N*, changes with the height, *h*, from the surface of the Earth.

(*c*) **Prove that**, the total number of molecules in a vertical air column having a cross section of $1\ m^2$ and a height h from the ground can be written as,

$$N(h)=\frac{N_o kT}{\bar{m}g}\left(1-e^{-\bar{m}gh/kT}\right).$$

Obtain an expression for the height h_{10} of the atmosphere which only 10% of the total number of molecules reside.

Determine the value of h_{10} .

(15 Marks)

02. **(*a*)** Explain briefly, why the production rate of electrons in the ionosphere reduces as the height increases above 500 km and as the height decreases below 50 km.

(*b*) 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.

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

(ii) 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,

(α) $\psi = 0^o$ **(β)** $\psi = 30^o$ **(γ)** $\psi = 60^o$.

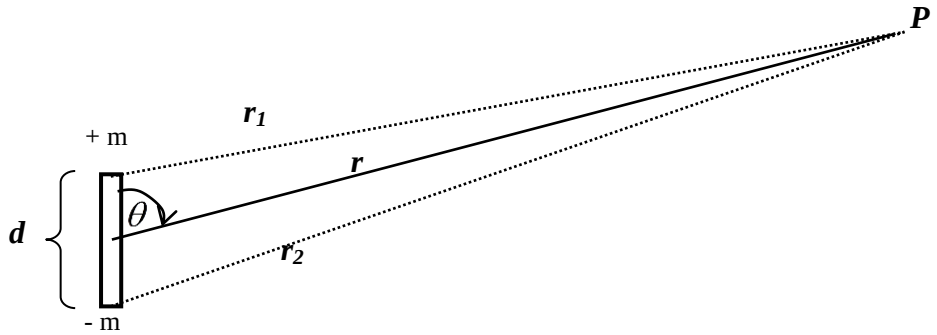
P. T. O

(iii) Hence, briefly explain the Chapmen Layer Theory?

What is the importance of the Chapmen Layer Theory to Radio Transmission?

(15 Marks)

03. **(*a*)** 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.



A short bar magnet of length d is kept vertically as shown in the figure above.

(i) **Show that** the magnetic field intensity at a point ***P*** at a distance r ($r >> d$) making an angle θ with the vertical can be expressed as,

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

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) **Hence,** find the intensity of the magnetic field at the poles of the Earth.

(iii) **Sketch** the shape of the magnetic field of the Earth affected by the solar wind.

(*b*) In 1958, *Explorer 1* and *Explorer 2* satellites confirmed the existence of two huge regions having large quantities of charged particles trapped under James Van Allen. The **region 1** is situated at an altitude of about 1000 km, and has lateral extend of about 5000 km, which contains of mostly high energy **protons**. The **region 2** is situated at an altitude of about 16000 km, and has lateral extend of about 20000 km, which contains of mostly high energy **electrons**. The trapped radiation was mapped out by Explorer *4*, *Pioneer 3* and *Luna 1* satellites which travel along highly elliptical orbits around the Earth.

P. T. O

(i) **Name** the two regions where charged particles are been trapped and **explain** how they are formed.

(ii) With the help of suitable diagrams, describe how the above two regions of charged particles completely encircle the Earth.

(iii) How do you use this phenomenon to explain the "**Aurora Effect**" near the Earth's poles.

(15 Marks)

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

(ii) What is the main role of the **Resonator** (Resonance Circuit) in a radio to tune a radio channel ?

(iii) Show that the **resonance frequency** (f_o) of the Resonator is given by,

$$f_o = \frac{1}{2\pi\sqrt{LC}}.$$

(Where all the symbols have their usual meanings)

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

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

(iii) Write down the relationship between the "**absorption of radio waves**" and the "**frequency of the Radio waves**" in the lower atmosphere.

(*c*) The radio broadcasting station used a SW radio signal with a power of 100 kW. If they used the 10 MHz carrier frequency signal, the power of the received input signal is 15 kW. If they used 20 MHz signal, the received input power is 25 kW.

(i) Find the suitable value for the carrier frequency of the radio waves, if they want to receive the signal with input power of 40 kW.

(ii) Is it possible to broadcast the above frequency signal using ionospheric modes ?

(15 Marks)

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