



UNIVERSITY OF SRI JAYEWARDANEPURA - FACULTY OF APPLIED SCIENCES
B. Sc. Special Degree Fourth Year Second Semester Course Unit Examination April/May 2022
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.** If the average temperature of the Sun, $T_s = 6000$ K, Radius of the Sun, $R_s = 7 \times 10^5$ km, Radius of the Earth, $R_E = 6400$ km and mean orbital distance of the Earth around the Sun, $d = 149598000$ km.

- (a)** Show that the Solar Flux at the Earth's Orbit, S_o is given by the following equation.

$$S_o = \sigma T_s^4 \left(\frac{R_s}{d} \right)^2$$

Where, $\sigma = 5.67 \times 10^{-8} \text{ Js}^{-1} \text{ m}^{-2} \text{ K}^{-4}$ is the plank constant.

- (b)** If the albedo of the Earth, $A = 0.4$, Derive the expression for the effective temperature of the Earth, T_e as given below,

$$T_e = \left(\frac{R_s}{d} \right)^{1/2} \left(\frac{1-A}{4} \right)^{1/4} T_s.$$

Hence, find the effective temperature of the Earth.

- (c)** Using Eddington Approximation the ground temperature of the Earth, T_g is given as of the following equation,

$$T_g = T_e \left(1 + \frac{3\tau_o}{4} \right)^{1/4}$$

Where, $\tau_o = 1.9$ is the opacity of the infra-red in the terrestrial atmosphere.

- (i)** Find the ground temperature of the Earth, using the above equation.
(ii) It is a little bit higher value of the average temperature of the Earth (290 K), Why ?
(iii) Explain how you find the accurate average temperature value of the Earth.

(15 Marks)

- 02. (a)** What are the Escape Velocity and the Most Probable Speed of the Earth?

Obtain the equations for the Escape Velocity and the Most Probable Speed of the Earth atmosphere.

[You are given the Maxwellian Distribution of the gasses are,

$$f(V) = 4\pi \left(\frac{M}{2\pi RT} \right)^{3/2} V^2 \cdot \exp \left(-MV^2 / 2RT \right),$$

where, the symbols have their usual meanings.]

Hence, show that particles in the Earth atmosphere cannot escape to the interplanetary space!

- (b) In the Earth's atmosphere, the mean free path of the gas molecules, d (in meters) increases with height, h (in meters) as of the following equation,

$$d(h) = \alpha h^6 + \beta,$$

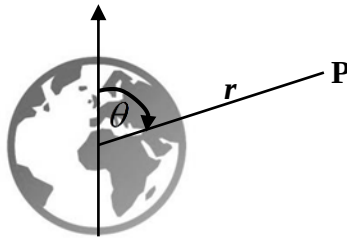
Where α and β are unknown constants.

The mean free path of the gas molecules at the mean sea level is $5.0 \times 10^{-8} m$ and the mean free path of the gas molecules at the 1 km height is $1.0 \times 10^{-5} m$.

- Determine the values of α and β of the above equation.
- What is the mean free path of the gas molecules of the atmosphere at the height of 600 km?
- Determine the height from the mean sea level where the mean free path of the gas molecules becomes 250 m.

(15 Marks)

03. The magnetic field of the Earth can be represented to a good approximation by a dipole magnetic field with the intensity of $40\,000\text{ nT}$ at the equator.



Magnetic field intensities H_r and H_θ at a point P (on the plane of the magnet, as shown in the figure above) due to a short bar magnet of length d ($d \ll r$) is given by,

$$H_r = \frac{\mu_o}{4\pi} \cdot \frac{2M}{r^3} \cos \theta \quad \text{and} \quad H_\theta = \frac{\mu_o}{4\pi} \cdot \frac{M}{r^3} \sin \theta.$$

Where, the other symbols have their usual meanings.

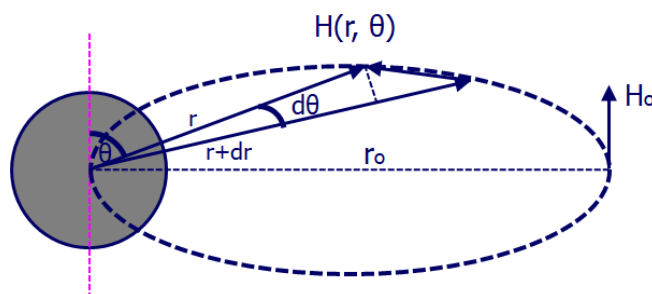
- (a) **Show that** the total magnetic field due to a short bar magnet can be given as,

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

- (b) Also **Show that** the inclination angle, ω of the field is,

$$\omega = \tan^{-1}(2 \cot \theta)$$

- (c)



Hence, using above diagram of the field line, **show that r** can be represented by the following equation,

$$r = r_o \sin^2 \theta$$

Where, r_o is the radial distance of the field line at the equator.

- (d) Using above results in (a), (b) and (c), **get a Mathematical description for the dipole magnetic field** as,

$$H(r, \theta) = H_o \frac{[1 + 3 \cos^2 \theta]^{\frac{1}{2}}}{\sin^6 \theta} \text{ where, } H_o = \frac{\mu_o M}{4\pi r_o^3}.$$

- (e) Using the above equations,

- i. Find the intensity of the magnetic field at the poles of the Earth.
- ii. Describe how you would calculate the magnetic field intensity at your current location. Assume the Latitude and Longitude the of the your location of the examination center is (6.8545° N, 79.9056° E).
- iii. Sketch the shape of the magnetic field of the Earth under the influence of the solar wind.

(15 Marks)

04. (a) The equation of **radiative transfer** of the Sun, given by the **Eddington approximation** is expressed as;

$$I(\theta, 0) = \frac{\sigma T_e^4}{2\pi} \left(1 + \frac{3}{2} \cos \theta \right).$$

Where $I(\theta, 0)$ is the intensity of the solar radiation emitted from the top of the photosphere (opacity $\tau = 0$) at an angle θ to the vertical. T_e is the effective temperature of the Sun.

- (i) Show that the above equation indicates that $I(\theta, 0)$ will decrease as θ is increasing from 0° to 90°.
- (ii) Using part (i), explain what is “**limb darkening**” of the Sun ?

- (b) Last five solar cycles (Sunspots Maxima) displayed in the following table based on the NASA observation charts.

Solar Cycle	Year
20	1968
21	1979
22	1989
23	2002
24	2014

- (i) According to the Rudolf Wolf’s idea, when will be the next sunspots maxima (25th solar cycle) ?
- (ii) According to the George Ellery Hale’s idea, when will be the next sunspots maxima (25th solar cycle) ?
- (iii) How the solar cycle (Sunspots Maxima) effects on Earth for the following ?
Human Health, Ozone Layer, Global Warming & Radio Communication

(15 Marks)
