

Student Guide – Scale Height

Background Information

1. Complete the following table with numerical and algebraic values for atmospheric density at various heights above the surface of a terrestrial body.

<i>Height</i>	<i>Algebraic Expression</i>	<i>Density Value</i>
$z=1.00 H$	$\rho = \rho_0 e^{-\frac{1}{H}}$	0.368
$z=2.00 H$		
	$\rho = \rho_0 e^{-\frac{2.5}{H}}$	
		0.183
$z=6.00 H$		
		0.00166

2. Scale Height is defined as $H = \frac{kT}{\mu m_H g}$ where $k = 1.38 \times 10^{-23}$ J/K. Perform dimensional analysis and determine the units of scale height.

Atmospheric Simulators

3. The height $h_{1/2}$ is defined as the altitude where the density (or pressure) is half its value at the surface. Solve algebraically for the value of $h_{1/2}$ (and then check your value in the simulator).

4. The scale height, atmospheric surface density (in terms of Earth's atmospheric surface density), and maximum elevation for Venus, Earth, and Mars are given in the table below. Use scale height to calculate the atmospheric density at the maximum elevation for each body (in terms of Earth's surface density).

Body	Surface Atm Density (ρ_0)	Maximum Altitude (km)	Algebraic Expression and Value
Venus	$93\rho_0$	11	
Earth	ρ_0	8.9	
Mars	$0.0064\rho_0$	22	

5. a) At what altitude (in units of both km and scale height) does Earth's atmospheric density fall to 1/10 its initial value?

b) What is the pressure at the cruising altitude of most airplanes (approximately 10 km)?

c) The summits of Earth's tallest mountains (notably Mount Everest) lie within the "Death Zone"—the elevations at which atmospheric pressure is too low for humans to survive for extended periods. The pressure at the beginning of the "death zone" is 356 millibars, or 35.6 kPa. At what altitude does this occur, in units of km and scale height?

6. Given the scale height H , radius R , acceleration of gravity g , and the density of the atmosphere at sea level ρ_0 for Earth, identify an algebraic expression and calculate its value for the total mass of Earth's atmosphere.
7. a) Find the scale height for the planet Venus if its atmosphere was 100% H_2 .
- b) Find the scale height for the planet Venus if its atmosphere was 100% CH_4 .
- c) Find the scale height for the planet Venus if its atmosphere was 50% H_2 and 50% CH_4 .
- d) How accurate do you believe your answer to part c) to be? Explain. (Hint: You might find some help on the spherical cow page.)
8. Earth's primordial atmosphere is thought to be very similar to the atmosphere of Titan today. Use the second simulator to determine the scale height of the atmosphere on the very early Earth. Give the value and provide a short description of the process. How does Earth's primordial atmosphere differ from the atmosphere on Titan today?

10. a) A spherical stone ($\rho_M=3 \text{ g/cm}^3$) meteorite of radius $R_M = 0.5 \text{ m}$ heads toward Earth at high velocity. What do you think is the likely outcome? Explain why?

b)) An identical stone (with the same kinematics) heads toward Mars. What do you think is the likely outcome? Explain why?

c) An identical stone (with the same kinematics) heads toward Venus. What do you think is the likely outcome? Explain why?

11. Suppose you are part of a group of scientists in year 2100 tasked with finding a suitable planet for human habitation. You are considering an Earthlike planet with mass $2.2 M_E$, radius $1.3 R_E$, and surface temperature 300 K.

a) What is the scale height of the planet's atmosphere if the atmosphere is composed of 50% Ar, 30% O₂, and 20% N₂?

b) The solar system in which the planet resides is full of small cometary bodies and debris, leading some members of your group to be concerned about planetary impacts. You have determined that the debris is no larger than 50 m in radius, and that all of it is rocky (density $\sim 5 \text{ km}$). If the planet's atmosphere has a surface density of 2.8 kg/m^3 , would the planet be safe from impacts?