

Physics

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(Chapter 7) (Gravitation) (Exercises)
(Class 11)

Question 7.16:

Assuming the earth to be a sphere of uniform mass density, how much would a body weigh half way down to the centre of the earth if it weighed 250 N on the surface?

Answer 7.16:

Weight of a body of mass m at the Earth's surface, $W = mg = 250 \text{ N}$

Body of mass m is located at depth, $d = \frac{1}{2} R_e$

Where, R_e = Radius of the Earth

Acceleration due to gravity at depth g (d) is given by the relation: $g' = \left(1 - \frac{d}{R_e}\right)g = \left(1 - \frac{R_e}{2 \times R_e}\right)g = \frac{1}{2}g$

Weight of the body at depth d ,

$$W' = mg' = m \times \frac{1}{2}g = \frac{1}{2}mg = \frac{1}{2}W = \frac{1}{2} \times 250 = 125 \text{ N}$$

Question 7.17:

A rocket is fired vertically with a speed of 5 km s^{-1} from the earth's surface. How far from the earth does the rocket go before returning to the earth? Mass of the earth = $6.0 \times 10^{24} \text{ kg}$; mean radius of the earth = $6.4 \times 10^6 \text{ m}$; $G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$.

Answer 7.17:

Velocity of the rocket, $v = 5 \text{ km/s} = 5 \times 10^3 \text{ m/s}$

Mass of the Earth, $M_e = 6.0 \times 10^{24} \text{ kg}$ and radius of the Earth, $R_e = 6.4 \times 10^6 \text{ m}$

Height reached by rocket mass, $m = h$

At the surface of the Earth,

$$\text{Total energy of the rocket} = \text{Kinetic energy} + \text{Potential energy} = \frac{1}{2}mv^2 + \left(\frac{-GM_em}{R_e}\right)$$

$$\text{At highest point } h, v = 0 \text{ and, Potential energy} = -\frac{GM_em}{R_e + h}$$

$$\text{Total energy of the rocket} = 0 + \left(\frac{-GM_em}{R_e + h}\right) = -\frac{GM_em}{R_e + h}$$

From the law of conservation of energy, we have,

Total energy of the rocket at the Earth's surface = Total energy at height h

$$\begin{aligned} \frac{1}{2}mv^2 + \left(\frac{-GM_em}{R_e}\right) &= -\frac{GM_em}{R_e + h} \Rightarrow \frac{1}{2}v^2 = GM_e \left(\frac{1}{R_e} - \frac{1}{R_e + h}\right) \\ -GM_e \left(\frac{R_e + h - R_e}{R_e(R_e + h)}\right) &\Rightarrow \frac{1}{2}v^2 = \frac{GM_e h}{R_e(R_e + h)} \times \frac{R_e}{R_e} \Rightarrow \frac{1}{2}v^2 = \frac{gR_e h}{R_e + h} \end{aligned}$$

$$\text{Where } g = \frac{GM}{R_e^2} = 9.8 \text{ m/s}^2 \text{ (Acceleration due to gravity on the Earth's surface)}$$

$$\therefore v^2(R_e + h) = 2gR_e h \Rightarrow v^2 R_e = h(2gR_e - v^2)$$

$$h = \frac{R_e v^2}{2gR_e - v^2} = \frac{6.4 \times 10^6 \times (5 \times 10^3)^2}{2 \times 9.8 \times 6.4 \times 10^6 - (5 \times 10^3)^2} = \frac{6.4 \times 25 \times 10^{12}}{100.44 \times 10^6} = 1.6 \times 10^6 \text{ m}$$

Height achieved by the rocket with respect to the centre of the Earth

$$= R_e + h = 6.4 \times 10^6 + 1.6 \times 10^6 = 8.0 \times 10^6$$

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Table of Contents Chapter 7 Physics Answers

1. Understanding the eBook Chapter 7 Physics Answers
 - The Rise of Digital Reading Chapter 7 Physics Answers
 - Advantages of eBooks Over Traditional Books
2. Identifying Chapter 7 Physics Answers
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Chapter 7 Physics Answers
 - User-Friendly Interface
4. Exploring eBook Recommendations from Chapter 7 Physics Answers
 - Personalized Recommendations
 - Chapter 7 Physics Answers User Reviews and Ratings
 - Chapter 7 Physics Answers and Bestseller Lists
5. Accessing Chapter 7 Physics Answers Free and Paid eBooks
 - Chapter 7 Physics Answers Public Domain eBooks
 - Chapter 7 Physics Answers eBook Subscription Services
 - Chapter 7 Physics Answers Budget-Friendly Options
6. Navigating Chapter 7 Physics Answers eBook Formats

- ePub, PDF, MOBI, and More
- Chapter 7 Physics Answers Compatibility with Devices
- Chapter 7 Physics Answers Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Chapter 7 Physics Answers
 - Highlighting and Note-Taking Chapter 7 Physics Answers
 - Interactive Elements Chapter 7 Physics Answers
- 8. Staying Engaged with Chapter 7 Physics Answers
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Chapter 7 Physics Answers
- 9. Balancing eBooks and Physical Books Chapter 7 Physics Answers
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Chapter 7 Physics Answers
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Chapter 7 Physics Answers
 - Setting Reading Goals Chapter 7 Physics Answers
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Chapter 7 Physics Answers
 - Fact-Checking eBook Content of Chapter 7 Physics Answers
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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