

INSTRUCTOR SOLUTIONS MANUAL

SEARS & ZEMANSKY'S

UNIVERSITY PHYSICS

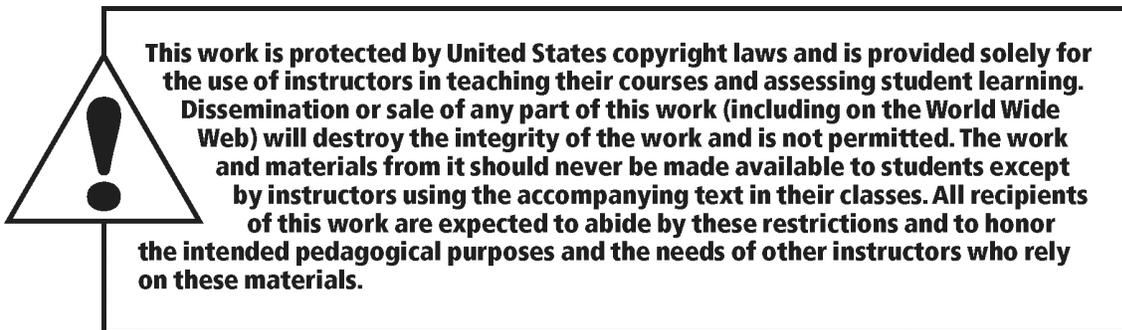
13TH EDITION

**A. LEWIS FORD
WAYNE ANDERSON**

PEARSON

Boston Columbus Indianapolis New York San Francisco Upper Saddle River
Amsterdam Cape Town Dubai London Madrid Milan Munich Paris Montreal Toronto
Delhi Mexico City Sao Paulo Sydney Hong Kong Seoul Singapore Taipei Tokyo

Publisher:	Jim Smith
Executive Editor:	Nancy Whilton
Project Editor:	Chandrika Madhavan
Editorial Manager:	Laura Kenney
Managing Editor:	Corinne Benson
Production Project Manager:	Beth Collins
Production Management and Compositor:	PreMediaGlobal
Executive Marketing Manager:	Kerry Chapman



Copyright © 2012, 2008 Pearson Education, Inc., publishing as Addison-Wesley, 1301 Sansome Street, San Francisco, CA 94111. All rights reserved. Manufactured in the United States of America. This publication is protected by Copyright and permission should be obtained from the publisher prior to any prohibited reproduction, storage in a retrieval system, or transmission in any form or by any means, electronic, mechanical, photocopying, recording, or likewise. To obtain permission(s) to use material from this work, please submit a written request to Pearson Education, Inc., Permissions Department, 1900 E. Lake Ave., Glenview, IL 60025. For information regarding permissions, call (847) 486-2635.

Many of the designations used by manufacturers and sellers to distinguish their products are claimed as trademarks. Where those designations appear in this book, and the publisher was aware of a trademark claim, the designations have been printed in initial caps or all caps.

PEARSON

ISBN 10: 0-321-69706-5
ISBN 13: 978-0-321-69706-6

CONTENTS

	Preface	v
Part I	Mechanics	
	Chapter 1 Units, Physical Quantities, and Vectors	1-1
	Chapter 2 Motion Along a Straight Line.....	2-1
	Chapter 3 Motion in Two or Three Dimensions	3-1
	Chapter 4 Newton's Laws of Motion.....	4-1
	Chapter 5 Applying Newton's Laws.....	5-1
	Chapter 6 Work and Kinetic Energy	6-1
	Chapter 7 Potential Energy and Energy Conservation.....	7-1
	Chapter 8 Momentum, Impulse, and Collisions.....	8-1
	Chapter 9 Rotation of Rigid Bodies	9-1
	Chapter 10 Dynamics of Rotational Motion	10-1
	Chapter 11 Equilibrium and Elasticity	11-1
	Chapter 12 Fluid Mechanics	12-1
	Chapter 13 Gravitation.....	13-1
	Chapter 14 Periodic Motion	14-1
Part II	Waves/Acoustics	
	Chapter 15 Mechanical Waves.....	15-1
	Chapter 16 Sound and Hearing	16-1
Part III	Thermodynamics	
	Chapter 17 Temperature and Heat	17-1
	Chapter 18 Thermal Properties of Matter	18-1
	Chapter 19 The First Law of Thermodynamics	19-1
	Chapter 20 The Second Law of Thermodynamics.....	20-1

Part IV Electromagnetism

Chapter 21	Electric Charge and Electric Field	21-1
Chapter 22	Gauss's Law	22-1
Chapter 23	Electric Potential	23-1
Chapter 24	Capacitance and Dielectrics	24-1
Chapter 25	Current, Resistance, and Electromotive Force	25-1
Chapter 26	Direct-Current Circuits	26-1
Chapter 27	Magnetic Field and Magnetic Forces	27-1
Chapter 28	Sources of Magnetic Field	28-1
Chapter 29	Electromagnetic Induction	29-1
Chapter 30	Inductance	30-1
Chapter 31	Alternating Current	31-1
Chapter 32	Electromagnetic Waves	32-1

Part V Optics

Chapter 33	The Nature and Propagation of Light	33-1
Chapter 34	Geometric Optics	34-1
Chapter 35	Interference	35-1
Chapter 36	Diffraction	36-1

Part VI Modern Physics

Chapter 37	Relativity	37-1
Chapter 38	Photons: Light Waves Behaving as Particles	38-1
Chapter 39	Particles Behaving as Waves	39-1
Chapter 40	Quantum Mechanics	40-1
Chapter 41	Atomic Structure	41-1
Chapter 42	Molecules and Condensed Matter	42-1
Chapter 43	Nuclear Physics	43-1
Chapter 44	Particle Physics and Cosmology	44-1

PREFACE

This Instructor Solutions Manual contains the solutions to all the problems and exercises in University Physics, Thirteenth Edition, by Hugh Young and Roger Freedman.

In preparing this manual, we assumed that its primary users would be college professors; thus the solutions are condensed, and some steps are not shown. Some calculations were carried out to more significant figures than demanded by the input data in order to allow for differences in calculator rounding. In many cases answers were then rounded off. Therefore, you may obtain slightly different results, especially when powers or trig functions are involved.

This edition was constructed from the previous editions authored by Craig Watkins and Mark Hollabaugh, and much of what is here is due to them.

Lewis Ford
Wayne Anderson
Sacramento, CA

UNITS, PHYSICAL QUANTITIES AND VECTORS

- 1.1. IDENTIFY:** Convert units from mi to km and from km to ft.

SET UP: 1 in. = 2.54 cm, 1 km = 1000 m, 12 in. = 1 ft, 1 mi = 5280 ft.

EXECUTE: (a) $1.00 \text{ mi} = (1.00 \text{ mi}) \left(\frac{5280 \text{ ft}}{1 \text{ mi}} \right) \left(\frac{12 \text{ in.}}{1 \text{ ft}} \right) \left(\frac{2.54 \text{ cm}}{1 \text{ in.}} \right) \left(\frac{1 \text{ m}}{10^2 \text{ cm}} \right) \left(\frac{1 \text{ km}}{10^3 \text{ m}} \right) = 1.61 \text{ km}$

(b) $1.00 \text{ km} = (1.00 \text{ km}) \left(\frac{10^3 \text{ m}}{1 \text{ km}} \right) \left(\frac{10^2 \text{ cm}}{1 \text{ m}} \right) \left(\frac{1 \text{ in.}}{2.54 \text{ cm}} \right) \left(\frac{1 \text{ ft}}{12 \text{ in.}} \right) = 3.28 \times 10^3 \text{ ft}$

EVALUATE: A mile is a greater distance than a kilometer. There are 5280 ft in a mile but only 3280 ft in a km.

- 1.2. IDENTIFY:** Convert volume units from L to in.³.

SET UP: 1 L = 1000 cm³. 1 in. = 2.54 cm

EXECUTE: $0.473 \text{ L} \times \left(\frac{1000 \text{ cm}^3}{1 \text{ L}} \right) \times \left(\frac{1 \text{ in.}}{2.54 \text{ cm}} \right)^3 = 28.9 \text{ in.}^3$

EVALUATE: 1 in.³ is greater than 1 cm³, so the volume in in.³ is a smaller number than the volume in cm³, which is 473 cm³.

- 1.3. IDENTIFY:** We know the speed of light in m/s. $t = d/v$. Convert 1.00 ft to m and t from s to ns.

SET UP: The speed of light is $v = 3.00 \times 10^8 \text{ m/s}$. 1 ft = 0.3048 m. 1 s = 10⁹ ns.

EXECUTE: $t = \frac{0.3048 \text{ m}}{3.00 \times 10^8 \text{ m/s}} = 1.02 \times 10^{-9} \text{ s} = 1.02 \text{ ns}$

EVALUATE: In 1.00 s light travels $3.00 \times 10^8 \text{ m} = 3.00 \times 10^5 \text{ km} = 1.86 \times 10^5 \text{ mi}$.

- 1.4. IDENTIFY:** Convert the units from g to kg and from cm³ to m³.

SET UP: 1 kg = 1000 g. 1 m = 1000 cm.

EXECUTE: $19.3 \frac{\text{g}}{\text{cm}^3} \times \left(\frac{1 \text{ kg}}{1000 \text{ g}} \right) \times \left(\frac{100 \text{ cm}}{1 \text{ m}} \right)^3 = 1.93 \times 10^4 \frac{\text{kg}}{\text{m}^3}$

EVALUATE: The ratio that converts cm to m is cubed, because we need to convert cm³ to m³.

- 1.5. IDENTIFY:** Convert volume units from in.³ to L.

SET UP: 1 L = 1000 cm³. 1 in. = 2.54 cm.

EXECUTE: $(327 \text{ in.}^3) \times (2.54 \text{ cm/in.})^3 \times (1 \text{ L}/1000 \text{ cm}^3) = 5.36 \text{ L}$

EVALUATE: The volume is 5360 cm³. 1 cm³ is less than 1 in.³, so the volume in cm³ is a larger number than the volume in in.³.

- 1.6. IDENTIFY:** Convert ft² to m² and then to hectares.

SET UP: 1.00 hectare = 1.00 × 10⁴ m². 1 ft = 0.3048 m.

EXECUTE: The area is $(12.0 \text{ acres}) \left(\frac{43,600 \text{ ft}^2}{1 \text{ acre}} \right) \left(\frac{0.3048 \text{ m}}{1.00 \text{ ft}} \right)^2 \left(\frac{1.00 \text{ hectare}}{1.00 \times 10^4 \text{ m}^2} \right) = 4.86 \text{ hectares}$.

EVALUATE: Since $1 \text{ ft} = 0.3048 \text{ m}$, $1 \text{ ft}^2 = (0.3048)^2 \text{ m}^2$.

1.7. IDENTIFY: Convert seconds to years.

SET UP: $1 \text{ billion seconds} = 1 \times 10^9 \text{ s}$. $1 \text{ day} = 24 \text{ h}$. $1 \text{ h} = 3600 \text{ s}$.

EXECUTE: $1.00 \text{ billion seconds} = (1.00 \times 10^9 \text{ s}) \left(\frac{1 \text{ h}}{3600 \text{ s}} \right) \left(\frac{1 \text{ day}}{24 \text{ h}} \right) \left(\frac{1 \text{ y}}{365 \text{ days}} \right) = 31.7 \text{ y}$.

EVALUATE: The conversion $1 \text{ y} = 3.156 \times 10^7 \text{ s}$ assumes $1 \text{ y} = 365.24 \text{ d}$, which is the average for one extra day every four years, in leap years. The problem says instead to assume a 365-day year.

1.8. IDENTIFY: Apply the given conversion factors.

SET UP: $1 \text{ furlong} = 0.1250 \text{ mi}$ and $1 \text{ fortnight} = 14 \text{ days}$. $1 \text{ day} = 24 \text{ h}$.

EXECUTE: $(180,000 \text{ furlongs/fortnight}) \left(\frac{0.125 \text{ mi}}{1 \text{ furlong}} \right) \left(\frac{1 \text{ fortnight}}{14 \text{ days}} \right) \left(\frac{1 \text{ day}}{24 \text{ h}} \right) = 67 \text{ mi/h}$

EVALUATE: A furlong is less than a mile and a fortnight is many hours, so the speed limit in mph is a much smaller number.

1.9. IDENTIFY: Convert miles/gallon to km/L.

SET UP: $1 \text{ mi} = 1.609 \text{ km}$. $1 \text{ gallon} = 3.788 \text{ L}$.

EXECUTE: (a) $55.0 \text{ miles/gallon} = (55.0 \text{ miles/gallon}) \left(\frac{1.609 \text{ km}}{1 \text{ mi}} \right) \left(\frac{1 \text{ gallon}}{3.788 \text{ L}} \right) = 23.4 \text{ km/L}$.

(b) The volume of gas required is $\frac{1500 \text{ km}}{23.4 \text{ km/L}} = 64.1 \text{ L}$. $\frac{64.1 \text{ L}}{45 \text{ L/tank}} = 1.4 \text{ tanks}$.

EVALUATE: $1 \text{ mi/gal} = 0.425 \text{ km/L}$. A km is very roughly half a mile and there are roughly 4 liters in a gallon, so $1 \text{ mi/gal} \sim \frac{2}{4} \text{ km/L}$, which is roughly our result.

1.10. IDENTIFY: Convert units.

SET UP: Use the unit conversions given in the problem. Also, $100 \text{ cm} = 1 \text{ m}$ and $1000 \text{ g} = 1 \text{ kg}$.

EXECUTE: (a) $\left(60 \frac{\text{mi}}{\text{h}} \right) \left(\frac{1 \text{ h}}{3600 \text{ s}} \right) \left(\frac{5280 \text{ ft}}{1 \text{ mi}} \right) = 88 \frac{\text{ft}}{\text{s}}$

(b) $\left(32 \frac{\text{ft}}{\text{s}^2} \right) \left(\frac{30.48 \text{ cm}}{1 \text{ ft}} \right) \left(\frac{1 \text{ m}}{100 \text{ cm}} \right) = 9.8 \frac{\text{m}}{\text{s}^2}$

(c) $\left(1.0 \frac{\text{g}}{\text{cm}^3} \right) \left(\frac{100 \text{ cm}}{1 \text{ m}} \right)^3 \left(\frac{1 \text{ kg}}{1000 \text{ g}} \right) = 10^3 \frac{\text{kg}}{\text{m}^3}$

EVALUATE: The relations $60 \text{ mi/h} = 88 \text{ ft/s}$ and $1 \text{ g/cm}^3 = 10^3 \text{ kg/m}^3$ are exact. The relation $32 \text{ ft/s}^2 = 9.8 \text{ m/s}^2$ is accurate to only two significant figures.

1.11. IDENTIFY: We know the density and mass; thus we can find the volume using the relation $\text{density} = \text{mass}/\text{volume} = m/V$. The radius is then found from the volume equation for a sphere and the result for the volume.

SET UP: $\text{Density} = 19.5 \text{ g/cm}^3$ and $m_{\text{critical}} = 60.0 \text{ kg}$. For a sphere $V = \frac{4}{3} \pi r^3$.

EXECUTE: $V = m_{\text{critical}}/\text{density} = \left(\frac{60.0 \text{ kg}}{19.5 \text{ g/cm}^3} \right) \left(\frac{1000 \text{ g}}{1.0 \text{ kg}} \right) = 3080 \text{ cm}^3$.

$r = \sqrt[3]{\frac{3V}{4\pi}} = \sqrt[3]{\frac{3}{4\pi}(3080 \text{ cm}^3)} = 9.0 \text{ cm}$.

EVALUATE: The density is very large, so the 130-pound sphere is small in size.

1.12. IDENTIFY: Convert units.

SET UP: We know the equalities $1 \text{ mg} = 10^{-3} \text{ g}$, $1 \text{ }\mu\text{g} = 10^{-6} \text{ g}$, and $1 \text{ kg} = 10^3 \text{ g}$.

EXECUTE: (a) $(410 \text{ mg/day}) \left(\frac{10^{-3} \text{ g}}{1 \text{ mg}} \right) \left(\frac{1 \text{ }\mu\text{g}}{10^{-6} \text{ g}} \right) = 4.10 \times 10^5 \text{ }\mu\text{g/day}$.

(b) $(12 \text{ mg/kg})(75 \text{ kg}) = (900 \text{ mg}) \left(\frac{10^{-3} \text{ g}}{1 \text{ mg}} \right) = 0.900 \text{ g}$.

(c) The mass of each tablet is $(2.0 \text{ mg}) \left(\frac{10^{-3} \text{ g}}{1 \text{ mg}} \right) = 2.0 \times 10^{-3} \text{ g/day}$. The number of tablets required each

day is the number of grams recommended per day divided by the number of grams per tablet:

$$\frac{0.0030 \text{ g/day}}{2.0 \times 10^{-3} \text{ g/tablet}} = 1.5 \text{ tablet/day. Take 2 tablets each day.}$$

(d) $(0.000070 \text{ g/day}) \left(\frac{1 \text{ mg}}{10^{-3} \text{ g}} \right) = 0.070 \text{ mg/day}$.

EVALUATE: Quantities in medicine and nutrition are frequently expressed in a wide variety of units.

1.13. IDENTIFY: The percent error is the error divided by the quantity.

SET UP: The distance from Berlin to Paris is given to the nearest 10 km.

EXECUTE: (a) $\frac{10 \text{ m}}{890 \times 10^3 \text{ m}} = 1.1 \times 10^{-3} \%$.

(b) Since the distance was given as 890 km, the total distance should be 890,000 meters. We know the total distance to only three significant figures.

EVALUATE: In this case a very small percentage error has disastrous consequences.

1.14. IDENTIFY: When numbers are multiplied or divided, the number of significant figures in the result can be no greater than in the factor with the fewest significant figures. When we add or subtract numbers it is the location of the decimal that matters.

SET UP: 12 mm has two significant figures and 5.98 mm has three significant figures.

EXECUTE: (a) $(12 \text{ mm}) \times (5.98 \text{ mm}) = 72 \text{ mm}^2$ (two significant figures)

(b) $\frac{5.98 \text{ mm}}{12 \text{ mm}} = 0.50$ (also two significant figures)

(c) 36 mm (to the nearest millimeter)

(d) 6 mm

(e) 2.0 (two significant figures)

EVALUATE: The length of the rectangle is known only to the nearest mm, so the answers in parts (c) and (d) are known only to the nearest mm.

1.15. IDENTIFY: Use your calculator to display $\pi \times 10^7$. Compare that number to the number of seconds in a year.

SET UP: $1 \text{ yr} = 365.24 \text{ days}$, $1 \text{ day} = 24 \text{ h}$, and $1 \text{ h} = 3600 \text{ s}$.

EXECUTE: $(365.24 \text{ days/yr}) \left(\frac{24 \text{ h}}{1 \text{ day}} \right) \left(\frac{3600 \text{ s}}{1 \text{ h}} \right) = 3.15567 \dots \times 10^7 \text{ s}$; $\pi \times 10^7 \text{ s} = 3.14159 \dots \times 10^7 \text{ s}$

The approximate expression is accurate to two significant figures. The percent error is 0.45%.

EVALUATE: The close agreement is a numerical accident.

1.16. IDENTIFY: Estimate the number of people and then use the estimates given in the problem to calculate the number of gallons.

SET UP: Estimate 3×10^8 people, so 2×10^8 cars.

EXECUTE: $(\text{Number of cars} \times \text{miles/car day}) / (\text{mi/gal}) = \text{gallons/day}$

$$(2 \times 10^8 \text{ cars} \times 10000 \text{ mi/yr/car} \times 1 \text{ yr}/365 \text{ days}) / (20 \text{ mi/gal}) = 3 \times 10^8 \text{ gal/day}$$

EVALUATE: The number of gallons of gas used each day approximately equals the population of the U.S.

1.17. IDENTIFY: Express 200 kg in pounds. Express each of 200 m, 200 cm and 200 mm in inches. Express 200 months in years.

SET UP: A mass of 1 kg is equivalent to a weight of about 2.2 lbs. 1 in. = 2.54 cm. 1 y = 12 months.

EXECUTE: (a) 200 kg is a weight of 440 lb. This is much larger than the typical weight of a man.

(b) $200 \text{ m} = (2.00 \times 10^4 \text{ cm}) \left(\frac{1 \text{ in.}}{2.54 \text{ cm}} \right) = 7.9 \times 10^3 \text{ inches}$. This is much greater than the height of a person.

(c) $200 \text{ cm} = 2.00 \text{ m} = 79 \text{ inches} = 6.6 \text{ ft}$. Some people are this tall, but not an ordinary man.

(d) $200 \text{ mm} = 0.200 \text{ m} = 7.9 \text{ inches}$. This is much too short.

(e) $200 \text{ months} = (200 \text{ mon}) \left(\frac{1 \text{ y}}{12 \text{ mon}} \right) = 17 \text{ y}$. This is the age of a teenager; a middle-aged man is much older than this.

EVALUATE: None are plausible. When specifying the value of a measured quantity it is essential to give the units in which it is being expressed.

1.18. IDENTIFY: The number of kernels can be calculated as $N = V_{\text{bottle}}/V_{\text{kernel}}$.

SET UP: Based on an Internet search, Iowa corn farmers use a sieve having a hole size of 0.3125 in. \cong 8 mm to remove kernel fragments. Therefore estimate the average kernel length as 10 mm, the width as 6 mm and the depth as 3 mm. We must also apply the conversion factors 1 L = 1000 cm³ and 1 cm = 10 mm.

EXECUTE: The volume of the kernel is: $V_{\text{kernel}} = (10 \text{ mm})(6 \text{ mm})(3 \text{ mm}) = 180 \text{ mm}^3$. The bottle's volume is: $V_{\text{bottle}} = (2.0 \text{ L})[(1000 \text{ cm}^3)/(1.0 \text{ L})][(10 \text{ mm})^3/(1.0 \text{ cm})^3] = 2.0 \times 10^6 \text{ mm}^3$. The number of kernels is then $N_{\text{kernels}} = V_{\text{bottle}}/V_{\text{kernels}} \approx (2.0 \times 10^6 \text{ mm}^3)/(180 \text{ mm}^3) = 11,000 \text{ kernels}$.

EVALUATE: This estimate is highly dependent upon your estimate of the kernel dimensions. And since these dimensions vary amongst the different available types of corn, acceptable answers could range from 6,500 to 20,000.

1.19. IDENTIFY: Estimate the number of pages and the number of words per page.

SET UP: Assuming the two-volume edition, there are approximately a thousand pages, and each page has between 500 and a thousand words (counting captions and the smaller print, such as the end-of-chapter exercises and problems).

EXECUTE: An estimate for the number of words is about 10^6 .

EVALUATE: We can expect that this estimate is accurate to within a factor of 10.

1.20. IDENTIFY: Approximate the number of breaths per minute. Convert minutes to years and cm³ to m³ to find the volume in m³ breathed in a year.

SET UP: Assume 10 breaths/min. $1 \text{ y} = (365 \text{ d}) \left(\frac{24 \text{ h}}{1 \text{ d}} \right) \left(\frac{60 \text{ min}}{1 \text{ h}} \right) = 5.3 \times 10^5 \text{ min}$. $10^2 \text{ cm} = 1 \text{ m}$ so

$10^6 \text{ cm}^3 = 1 \text{ m}^3$. The volume of a sphere is $V = \frac{4}{3}\pi r^3 = \frac{1}{6}\pi d^3$, where r is the radius and d is the diameter.

Don't forget to account for four astronauts.

EXECUTE: (a) The volume is $(4)(10 \text{ breaths/min})(500 \times 10^{-6} \text{ m}^3) \left(\frac{5.3 \times 10^5 \text{ min}}{1 \text{ y}} \right) = 1 \times 10^4 \text{ m}^3/\text{yr}$.

$$(b) d = \left(\frac{6V}{\pi} \right)^{1/3} = \left(\frac{6[1 \times 10^4 \text{ m}^3]}{\pi} \right)^{1/3} = 27 \text{ m}$$

EVALUATE: Our estimate assumes that each cm³ of air is breathed in only once, where in reality not all the oxygen is absorbed from the air in each breath. Therefore, a somewhat smaller volume would actually be required.

1.21. IDENTIFY: Estimate the number of blinks per minute. Convert minutes to years. Estimate the typical lifetime in years.

SET UP: Estimate that we blink 10 times per minute. $1 \text{ y} = 365 \text{ days}$. $1 \text{ day} = 24 \text{ h}$, $1 \text{ h} = 60 \text{ min}$. Use 80 years for the lifetime.