INSTRUCTOR SOLUTIONS MANUAL

SEARS & ZEMANSKY'S

UNIVERSITY PHYSICS

13TH EDITION

A. LEWIS FORD
WAYNE ANDERSON

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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

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UNITS, PHYSICAL QUANTITIES AND VECTORS

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

SET UP: $1\text{ in.} = 2.54\text{ cm}$, $1\text{ km} = 1000\text{ m}$, $12\text{ in.} = 1\text{ ft}$, $1\text{ mi} = 5280\text{ ft}$.

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

(b) $1.00\text{ km} = (1.00\text{ km})\left(\dfrac{10^3\text{ m}}{1\text{ km}}\right)\left(\dfrac{10^2\text{ cm}}{1\text{ m}}\right)\left(\dfrac{1\text{ in.}}{2.54\text{ cm}}\right)\left(\dfrac{1\text{ ft}}{12\text{ in.}}\right) = 3.28\times10^3\text{ ft}$

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: $1\text{ L} = 1000\text{ cm}^3$. $1\text{ in.} = 2.54\text{ cm}$

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

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

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 $v = 3.00\times10^8\text{ m/s}$. $1\text{ ft} = 0.3048\text{ m}$. $1\text{ s} = 10^9\text{ ns}$.

EXECUTE: $t = \dfrac{0.3048\text{ m}}{3.00\times10^8\text{ m/s}} = 1.02\times10^{-9}\text{ s} = 1.02\text{ ns}$

EVALUATE: In 1.00 s light travels $3.00\times10^8\text{ m} = 3.00\times10^5\text{ km} = 1.86\times10^5\text{ mi}$.

1.4. **IDENTIFY:** Convert the units from g to kg and from cm^3 to m^3.

SET UP: $1\text{ kg} = 1000\text{ g}$. $1\text{ m} = 1000\text{ cm}$.

EXECUTE: $19.3\dfrac{\text{g}}{\text{cm}^3}\times\left(\dfrac{1\text{ kg}}{1000\text{ g}}\right)\times\left(\dfrac{100\text{ cm}}{1\text{ m}}\right)^3 = 1.93\times10^4\dfrac{\text{kg}}{\text{m}^3}$

EVALUATE: The ratio that converts cm to m is cubed, because we need to convert cm^3 to m^3.

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

SET UP: $1\text{ L} = 1000\text{ cm}^3$. $1\text{ in.} = 2.54\text{ cm}$.

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 cm^3. 1 cm^3 is less than 1 in.^3, so the volume in cm^3 is a larger number than the volume in in.^3.

1.6. **IDENTIFY:** Convert ft^2 to m^2 and then to hectares.

SET UP: $1.00\text{ hectare} = 1.00\times10^4\text{ m}^2$. $1\text{ ft} = 0.3048\text{ m}$.

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

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

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

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)** $55.0 \text{ miles/gallon} = (55.0 \text{ miles/gallon})\left(\dfrac{1.609 \text{ km}}{1 \text{ mi}}\right)\left(\dfrac{1 \text{ gallon}}{3.788 \text{ L}}\right) = 23.4 \text{ km/L}.$

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

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)** $\left(60\dfrac{\text{mi}}{\text{h}}\right)\left(\dfrac{1 \text{ h}}{3600 \text{ s}}\right)\left(\dfrac{5280 \text{ ft}}{1 \text{ mi}}\right) = 88\dfrac{\text{ft}}{\text{s}}$

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

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

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

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

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 $1 \text{ mg} = 10^{-3} \text{ g}$, $1 \text{ µg } 10^{-6} \text{ g}$, and $1 \text{ kg} = 10^{3} \text{ g}$.

EXECUTE: **(a)** $(410 \text{ mg/day})\left(\frac{10^{-3} \text{ g}}{1 \text{ mg}}\right)\left(\frac{1 \mu\text{g}}{10^{-6} \text{ g}}\right) = 4.10\times10^{5} \mu\text{g/day}.$

(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 $(2.0 \text{ mg})\left(\frac{10^{-3} \text{ g}}{1 \text{ mg}}\right) = 2.0\times10^{-3} \text{ g/day}.$ The number of tablets required each day is the number of grams recommended per day divided by the number of grams per tablet: $\frac{0.0030 \text{ g/day}}{2.0\times10^{-3} \text{ g/tablet}} = 1.5 \text{ tablet/day}.$ 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)** $\frac{10 \text{ m}}{890\times10^{3} \text{ m}} = 1.1\times10^{-3}\%.$

(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 $\pi\times10^{7}$. 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: $(365.24 \text{ days/1 yr})\left(\frac{24 \text{ h}}{1 \text{ day}}\right)\left(\frac{3600 \text{ s}}{1 \text{ h}}\right) = 3.15567\ldots\times10^{7} \text{ s};\ \pi\times10^{7} \text{ s} = 3.14159\ldots\times10^{7} \text{ s}$

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

$$(2\times10^{8} \text{ cars}\times10000 \text{ mi/yr/car}\times1 \text{ yr/365 days})/(20 \text{ mi/gal}) = 3\times10^{8} \text{ gal/day}$$

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) $200 \text{ m} = (2.00\times10^4 \text{ cm})\left(\frac{1 \text{ in.}}{2.54 \text{ cm}}\right) = 7.9\times10^3$ inches. This is much greater than the height of a person.

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

(d) 200 mm = 0.200 m = 7.9 inches. This is much too short.

(e) $200 \text{ months} = (200 \text{ mon})\left(\frac{1 \text{ y}}{12 \text{ mon}}\right) = 17$ 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. ≅ 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 $1 \text{ L} = 1000 \text{ cm}^3$ and $1 \text{ cm} = 10 \text{ mm}$.

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: $V_{\text{bottle}} = (2.0 \text{ L})[(1000 \text{ cm}^3)/(1.0 \text{ L})][(10 \text{ mm})^3/(1.0 \text{ cm})^3] = 2.0\times10^6 \text{ mm}^3$. The number of kernels is then $N_{\text{kernels}} = V_{\text{bottle}}/V_{\text{kernels}} \approx (2.0\times10^6 \text{ mm}^3)/(180 \text{ mm}^3) = 11{,}000$ 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 cm^3 to m^3 to find the volume in m^3 breathed in a year.

SET UP: Assume 10 breaths/min. $1 \text{ y} = (365 \text{ d})\left(\frac{24 \text{ h}}{1 \text{ d}}\right)\left(\frac{60 \text{ min}}{1 \text{ h}}\right) = 5.3\times10^5$ 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 $(4)(10 \text{ breaths/min})(500\times10^{-6} \text{ m}^3)\left(\frac{5.3\times10^5 \text{ min}}{1 \text{ y}}\right) = 1\times10^4 \text{ m}^3/\text{yr}$.

(b) $d = \left(\frac{6V}{\pi}\right)^{1/3} = \left(\frac{6[1\times10^4 \text{ m}^3]}{\pi}\right)^{1/3} = 27 \text{ m}$

EVALUATE: Our estimate assumes that each cm^3 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 y = 365 days. 1 day = 24 h, 1 h = 60 min. Use 80 years for the lifetime.