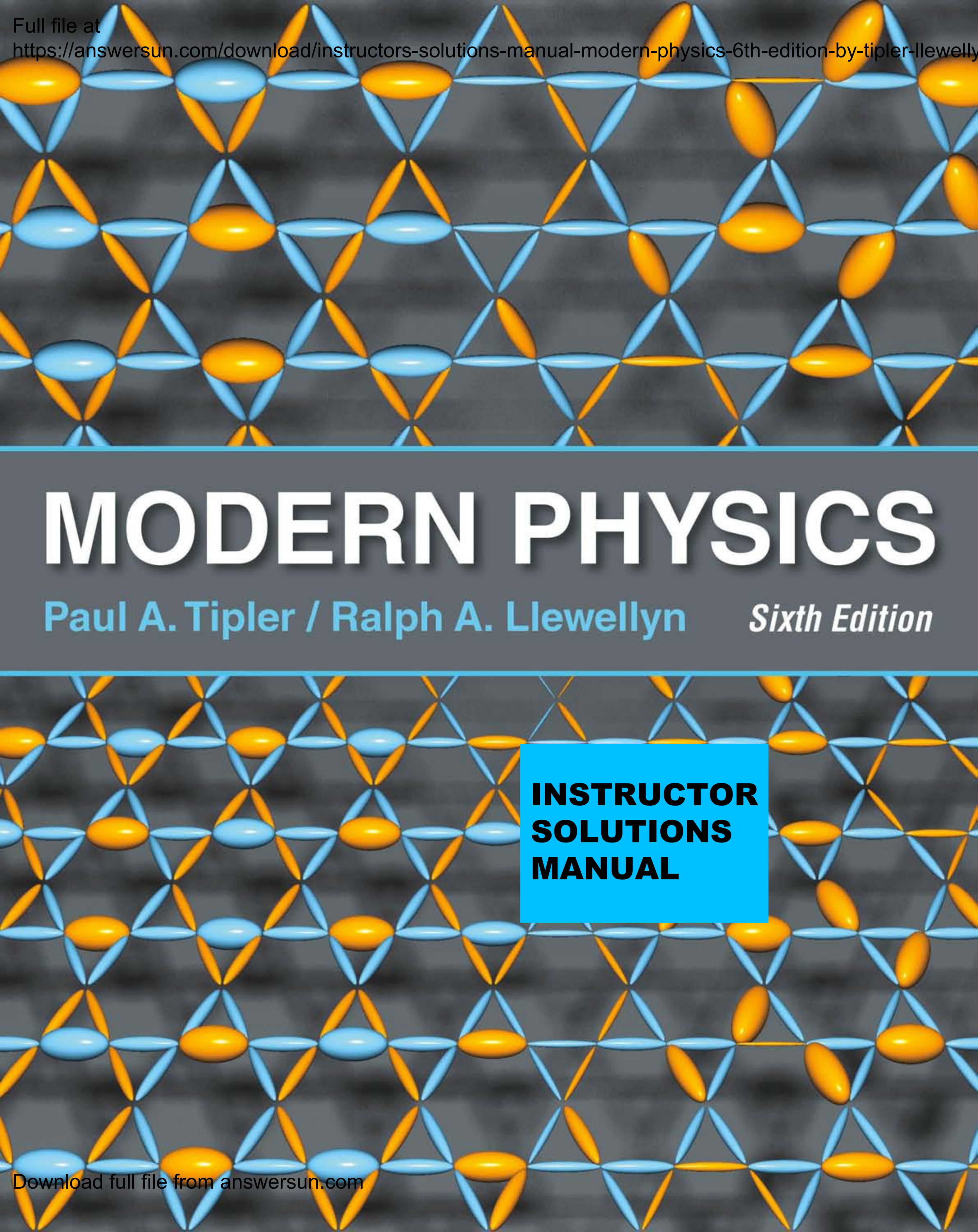

MODERN PHYSICS

Paul A. Tipler / Ralph A. Llewellyn

Sixth Edition

INSTRUCTOR SOLUTIONS MANUAL

Instructor Solutions Manual

for

Modern Physics

Sixth Edition

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W. H. Freeman and Company
New York

Instructor Solutions Manual to Accompany Tipler & Llewellyn Modern Physics, Sixth Edition

Published under license, in the United States by
W. H. Freeman and Company
41 Madison Avenue
New York, NY 10010

www.whfreeman.com

Preface

This book is an Instructor Solutions Manual for the problems which appear in *Modern Physics, Sixth Edition* by Paul A. Tipler and Ralph A. Llewellyn. This book contains solutions to every problem in the text and is not intended for class distribution to students. A separate Student Solutions Manual for *Modern Physics, Sixth Edition* is available from W. H. Freeman and Company. The Student Solutions Manual contains solutions to selected problems from each chapter, approximately one-fourth of the problems in the book.

Figure numbers, equations, and table numbers refer to those in the text. Figures in this solutions manual are not numbered and correspond only to the problem in which they appear. Notation and units parallel those in the text.

Please visit W. H. Freeman and Company's website for *Modern Physics, Sixth Edition* at www.whfreeman.com/tiplermodernphysics6e. There you will find 30 More sections that expand on high interest topics covered in the textbook, the Classical Concept Reviews that provide refreshers for many classical physics topics that are background for modern physics topics in the text, and an image gallery for Chapter 13. Some problems in the text are drawn from the More sections.

Every effort has been made to ensure that the solutions in this manual are accurate and free from errors. If you have found an error or a better solution to any of these problems, please feel free to contact me at the address below with a specific citation. I appreciate any correspondence from users of this manual who have ideas and suggestions for improving it.

Sincerely,

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Chapter 1 – Relativity I

1-1. (a) Speed of the droid relative to Hoth, according to Galilean relativity, u_{Hoth} , is

$$\begin{aligned} u_{Hoth} &= u_{spaceship} + u_{droid} \\ &= 2.3\times10^{8}\, m/s + 2.1\times10^{8}\, m/s \\ &= 4.4\times10^{8}\ m/s \end{aligned}$$

(b) No, since the droid is moving faster than light speed relative to Hoth.

1-2. (a) $t = \dfrac{2L}{c} = \dfrac{2\left(2.74\times10^{4}\, m\right)}{3.00\times10^{8}\, m/s} = 1.83\times10^{-4}\, s$

(b) From Equation 1-6 the correction $\delta t = \dfrac{2L}{c}\times\dfrac{v^{2}}{c^{2}}$

$$\delta t = \left(1.83\times10^{-4}\, s\right)\left(10^{-4}\right)^{2} = 1.83\times10^{-12}\, s$$

(c) From experimental measurements $\dfrac{\delta c}{c} = \dfrac{4\, km/s}{299,796\, km/s} = 1.3\times10^{-5}$

No, the relativistic correction of order 10^{-8} is three orders of magnitude smaller than the experimental uncertainty.

1-3. $\dfrac{0.4 \text{ fringe}}{\left(29.8 km/s\right)^{2}} = \dfrac{1.0 \text{ fringe}}{\left(v\ km/s\right)^{2}} \rightarrow v^{2} = \dfrac{1.0}{0.4}\left(29.9\ km/s\right)^{2} = 2.22\times10^{3} \rightarrow v = 47.1\, km/s$

1-4. (a) This is an exact analog of Example 1-1 with L = 12.5 *m*, c = 130 *mph*, and v = 20 *mph*. Calling the plane flying perpendicular to the wind plane #1 and the one flying parallel to the wind plane #2, plane #1 win will by Δt where

$$\Delta t = \frac{Lv^{2}}{c^{3}} = \frac{\left(12.5mi\right)\left(20mi/h\right)^{2}}{\left(130mi/h\right)^{3}} = 0.0023h = 8.2s$$

(b) Pilot #1 must use a heading $\theta = \sin^{-1}\left(20/130\right) = 8.8^{\circ}$ relative to his course on both legs. Pilot #2 must use a heading of 0° relative to the course on both legs.

(Problem 4-33 continued)

$$\text{slope} = \frac{58-10}{(30-4.8)\times 10^{8}} = 1.90\times 10^{-8}\,Hz^{-1/2}$$

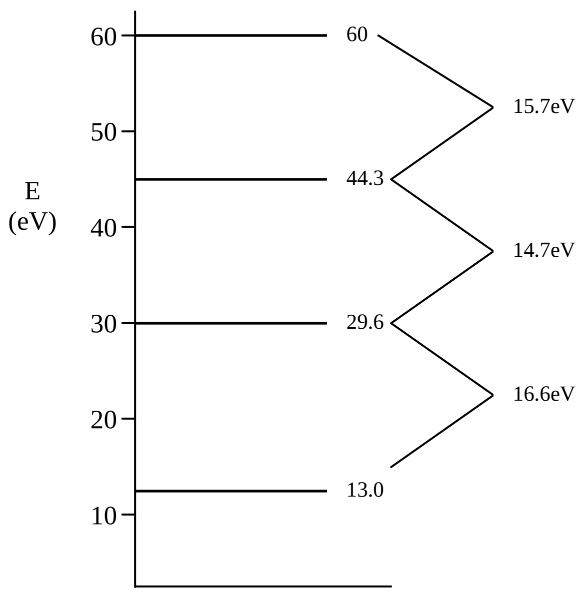
$$\text{slope (Figure 4-19)} = \frac{30-13}{(5-7)\times 10^{8}} = 2.13\times 10^{-8}\,Hz^{-1/2}$$

The two values are in good agreement.

4-34. (a) The available energy is not sufficient to raise ground state electrons to the n =5 level which requires $13.6 - 0.54 = 13.1eV$. The shortest wavelength (i.e., highest energy) spectral line that will be emitted is the 3rd line of the Lyman series, the $n = 4 \rightarrow n = 1$ transition. (See Figure 4-16.)

(b) The emitted lines will be for those transitions that begin on the n = 4, n = 3, or n = 2 levels. These are the first three lines of the Lyman series, the first two lines of the Balmer series, and the first line of the Paschen series.

4-35.



Average transition energy = 15.7 eV

(Problem 8-18 continued)

$$\Delta E = \frac{e\hbar B}{2m_e} = 2.315\times 10^{-4}\,eV$$

(a) The fraction of atoms in each m-state relative to the ground state is: (Example 8-2)

$$\frac{n_{+1}}{n} = e^{-1.8511/0.02586} = e^{-71.58} = 10^{-31.09} = 8.18\times 10^{-32}$$

$$\frac{n_0}{n} = 2\times e^{-1.8509/0.02586} = 2e^{-71.57} = 2\times 10^{-31.08} = 1.64\times 10^{-31}$$

$$\frac{n_0}{n_{-1}} = e^{-1.8507/0.02586} = e^{-71.56} = 10^{-31.08} = 8.30\times 10^{-32}$$

(b) The brightest line with the B-field "on" will be the transition from the m = 0 level, the center line of the Zeeman spectrum. With that as the "standard", the relative intensities will be: $8.30/16.4/8.18 \quad \rightarrow \quad 0.51/1.00/0.50$

8-19. (a) $e^{-\alpha} = \dfrac{N}{V}\dfrac{h^3}{2\;\;2\pi m_e kT^{\;\;3/2}}$ (Equation 8-44)

$$\frac{N}{V} = e^{-\alpha}\frac{2\;\;2\pi m_e kT^{\;\;3/2}}{h^3} = e^{-\alpha}\frac{2\;\;2\pi m_e c^2 kT^{\;\;3/2}}{hc^{\;\;3}}$$

$$= 1\times 2\frac{\left[2\pi\;\;5.11\times 10^5 eV\;\;\;2.585\times 10^{-2} eV\;\;\right]^{1/2}}{1240 eV\bullet nm^{\;\;3}}\left(\frac{10^7\,nm}{1cm}\right)^3 = 2.51\times 10^{19}/cm^3$$

8-20. (a) $e^{-\alpha}\;\;O_2\;\; = \dfrac{N}{V}\dfrac{h^3}{2\pi MkT^{\;\;3/2}}$ (Equation 8-44)

$$= \frac{N_A}{V_M}\frac{hc^{\;\;3}}{2\pi Mc^2 kT^{\;\;3/2}}$$

$$= \frac{6.022\times 10^{23}/mole}{22.4\times 10^3 cm^3/mole}\frac{1.24\times 10^{-4} eV\bullet cm^{\;\;3}}{\left[2\pi\;\;32uc^2\;\;\;931.5\times 10^6 eV/u\;\;\;8.617\times 10^{-5} eV/K\;\;\;273K\;\;\right]}$$

$$= 1.75\times 10^{-7}$$

(Problem 11-88 continued)

$$\left[2\ \ 222.1\ \ moles\right]\ 6.02\times10^{23}\,atoms/mol\quad 1.5\times10^{-4}\ \ = 4.01\times10^{22}$$

Total energy release = $\ 4.01\times10^{22}\ \ 5MeV = 2.01\times10^{23}MeV = 3.22\times10^{10}J$

Because the U.S. consumes about $1.0\times10^{20}J/y$, the complete fusion of the ^2H in 4ℓ of water would supply the nation for about $1.01\times10^{-2}s = 10.1ms$

11-89. (a) $\Delta\lambda \le 2hc/Mc^2$

$$\Delta E \approx \frac{hc\Delta\lambda}{\lambda^2} = \frac{hc}{\lambda^2}^{2}\frac{\Delta\lambda}{hc} = \frac{E^2\Delta\lambda}{hc}$$

$$E_p = \Delta E \le \frac{E^2}{hc}\frac{2hc}{Mc^2} = \frac{2E^2}{Mc^2}$$

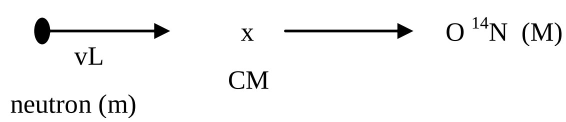
$$E^2 \ge Mc^2E_p/2 \quad\rightarrow\quad E \ge\ Mc^2E_p/2^{\ 1/2}$$

$$\Delta E = E_f - E_i = E_i\left(1 - \frac{4mM}{M+m^{\ 2}}\right) - E_i = -E_i\left(\frac{4mM}{M+m^{\ 2}}\right)$$

$$\frac{-\Delta E}{E_i} = \frac{4mM}{M+m^{\ 2}} = \frac{4m/M}{1+m/M^{\ 2}}$$ which is Equation 11-82 in More section.

(b) $E = \left[\ 5.7MeV\quad 938.28MeV\ \ /2\right]^{1/2} = 51.7MeV$

(c)



The neutron moves at v_L in the lab, so the *CM* moves at $v = v_Lm_N/\ m_N + M$ toward the right and the ^{14}N velocity in the *CM* system is *v* to the left before collision and *v* to the right after collision for an elastic collision. Thus, the energy of the nitrogen nucleus in the lab after the collision is:

$$E\ \ ^{14}N\ \ = \frac{1}{2}M\ \ 2v^{\ 2} = 2Mv^2 = 2M\left(\frac{mv_L}{m+M}\right)^2$$

13-36. (a) Equation 8-12: $v_{rms} = \sqrt{3RT/M}$ is used to compute v_{rms} vs T for each gas ® = gas constant.

Gas	M ($\times 10^{-3} kg$)	$\sqrt{3R/M}$	v_{rms} (m/s) at T = :				
			50K	200K	500K	750K	1000K
H_2O	18	37.2	263	526	832	1020	1180
CO_2	44	23.8	168	337	532	652	753
O_2	32	27.9	197	395	624	764	883
CH_4	16	39.5	279	558	883	1080	1250
H_2	2	111.6	789	1580	2500	3060	3530
He	4	78.9	558	1770	1770	2160	2500

The escape velocities $v_{sc} = \sqrt{2gR} = \sqrt{2GM/R}$, where the planet masses M and radii R, are given in table below.

Planet	Earth	Venus	Mercury	Jupiter	Neptune	Mars
v_{esc} (*km/s*)	11.2	10.3	4.5	60.2	23.4	5.1
$v_{esc}/6$ (*m/s*)	1870	1720	750	10,000	3900	850

On the graph of v_{rms} vs T the $v_{esc}/6$ points are shown for each planet.