Significant Errata for Matter & Interactions I: Modern Mechanics

Errors in first printing, ISBN 0-471-35491-0, *and* in second printing, ISBN 0-471-66328-X

P. 74: answer to Ex. 2.5 should be 65 km.

P. 101: 5th line from bottom should be $\frac{dp_x}{dt} = \omega p_z$

P. 118: At the end of the paragraph after the first "stop and think", $-Fr$ should be $-F\Delta r$.

P. 164: answer to Ex. 4.27: Should solve for the final height, $y_f = y_i + (v_i^2 - v_f^2)/(2g)$

P. 189: The URL has changed to http://www.chemistry.usna.edu/jah/ResearchStuff/Friction_page.html

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P. 8: Neutron decay is $n \to p^+ + e^- + \bar{\nu}$, where $\bar{\nu}$ means "antineutrino".

P. 26: Example solution has wrong sign. Should be $\Delta\vec{p} = \vec{p}_f - \vec{p}_i = \langle -15000, 3000, 0 \rangle \text{ kg} \cdot \text{m/s}$

P. 56: First paragraph should end like this: In the general case it is useful to think of the rate of change of a vector in terms of two components, radial (perpendicular to the vector, representing a rate of change of direction as we have calculated here) and tangential (parallel to the vector, representing a rate of change of magnitude, as in the case where the speed is changing).

P. 104: Omissions from summary page:
Macroscopic spring: $|\vec{F}| = k_s|s|$, where $s = L - L_{\text{relaxed}}$
Speed of sound in a solid: $v = d\sqrt{k_s/m}$, where d is distance between nuclei, m is atomic mass

P. 105: Last equation should be $\frac{T}{2} = 0.056$ s

P. 106: Last equation should be $\omega^2 \geq \frac{g}{\mu R}$

P. 152: Should say explicitly: Kinetic energy $K = \frac{mc^2}{\sqrt{1 - v^2/c^2}} - mc^2$; $K \approx \frac{1}{2}mv^2 = \frac{p^2}{2m}$ if $v << c$

P. 154-155: Throughout the calculations, the carbon nucleus charge should be +6*e*, not +8*e*. This affects many of the results. See corrected solution at the end of this document.

P. 159, Prob. 4.5: The problem is stated incorrectly. The initial value of $K+U$ is greater than zero, which indicates that this is not a bound state: the comet will escape to infinitely far away and never return. Here is the correct problem statement: A comet is in an elliptical orbit around the Sun. Its closest approach to the Sun is a distance of 4×10^{10} m (inside the orbit of Mercury), at which point its speed is 8.17×10^4 m/s . Its farthest distance from the Sun is far beyond the orbit of Pluto. What is its speed when it is 6×10^{12} m from the Sun? (This is the approximate distance of Pluto from the Sun.)

P. 162: The end of Problem 4.16 (c) should say, "Sufficently high temperatures are found in the interior of the Sun, where fusion reactions take place." The actual temperature inside the Sun is lower than calculated due to a quantum-mechanical effect called "tunneling".

P. 197: Air resistance force should be $\vec{F}_{\text{air}} = -\frac{1}{2}C\rho A v^2 \hat{v}$, and add this:

Heat capacity = energy per gram required to raise temperature 1K

$$\Delta E_{\text{thermal}} = mC\Delta T;\ C = \frac{\Delta E_{\text{thermal}}}{m\Delta T} \quad (C \text{ in J/K per gram, } m \text{ in grams})$$

P. 218: In the middle of the page the list of quantized energy levels should include $0+E_0$.

P. 227: The reference level at the bottom of Figure 6.26 should be deleted. The four energy levels should be labeled E_0 (the ground state, inside the potential energy well), E_0+1.9 eV, E_0+2.5 eV, andE_0 +3.0 eV.

(more on next page)

P. 286: Last equation should be $E + M_d c^2 = \sqrt{(p_p c)^2 + (M_p c^2)^2} + \sqrt{(p_n c)^2 + (M_n c^2)^2}$

P. 291, Prob. 8.11: Here is a modified version of a problem from Chapter 4 (not from Chapter 6).

P. 298, Fig. 9.10: “torque” should be “angular momentum”.

P. 303: In Ex. 9.12 and 9.13 “angular frequency ω_1” should read “angular speed ω_1“.

P. 327: Should also state the differential form of the angular momentum principle: $\Delta \vec{L}_{tot,A} = \vec{\tau}_{net,ext,A} \Delta t$
There are missing moments of inertia:

Uniform thin rod of length L about axis perpendicular to rod, through center of rod: $I = \frac{1}{12}ML^2$

Uniform solid cylinder of length L, radius R, about axis perpendicular to cylinder, through center of cylinder: $I = \frac{1}{12}ML^2 + \frac{1}{4}MR^2$

P. 331: The impact parameter in Figure 9.62 should be smaller, so that the asteroids will collide.

P. 339, answer to Ex. 9.25 (which is on p. 316): 8.33 N

P. 355: After the second centered equation, dS_2/dq_2 (not dS_2/dQ_2) is the slope moving from right to left.

P. 359 and P. 375: It would be clearer to say $C = \Delta E_{atom}/\Delta T$, where $\Delta E_{atom} = \Delta E_{system}/N_{atoms}$.

P. 366: Last sentence should say “An average mass of 29 grams per mole...”

P. 376, first equation: The value of h was incorrectly used for $\hbar$. Also, it would be appropriate to use $k_s = 4(5\ \text{N/m})$. Making these corrections, the temperatures are 62.5 K, 58.9 K, 66.6 K; heat capacity $3.4 \times 10^{-23}\ \text{J/K}$.

P. 405, Fig. 11.29: The symbols y and z should be switched in the square roots.

P. 423, second equation: $\frac{Q_L}{W} = \frac{1}{T_H/T_L - 1} > 1$

P. A-3 (Vector Appendix): In Figure A.4, the symbols y and z should be switched in the square roots.

P. A-7 (Vector Appendix): Answer for A.9 (page 5) should be $\hat{a} = 4.0\hat{\imath} - 2.4\hat{\jmath} + 6.2\hat{k}$.

Inside back cover: Add these:

Height of atmosphere ≈ 50 km   Radius of Moon = 1.75×10^6 m $T_{Kelvin} = T_{Celsius} + 273$

Improvements to problem statements

Problem 4.16, p. 161 (Nuclear fusion): It makes more sense to do part (b) first, then part (a).

Problem 5.10, p. 205 (Bungee jumping): In parts (e), (f), and (g), give numerical results for your design.

Problem 6.1, p. 227 (Determining energy levels): Part (b) Explain how to use an absorption measurement to distinguish between the two proposed schemes.

Problem 7.1, p. 254 (Jumping straight up—experiment): Part (c) Use your height measurements and physics principles to determine approximately the amount of time during the jump when your feet are in contact with the floor.

Problem 10.8, p. 379 (Experiment: measurement of the heat capacity of water): The information printed on a microwave may give the current in amperes (A) rather than the power. The power can be calculated by multiplying the current rating times the voltage. If the rating is 6 A, and the voltage is 120 V, the power is (6 A)(120 V) = 720 watts.

(corrected pages 154-155 follow)

Figure 4.48 Initial state (part a).

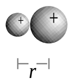

Figure 4.49 Final state (part a).

Solution

(a) *System:* alpha particle and carbon nucleus. No external forces.
Initial state: Very far apart, particles moving toward each other (Figure 4.48).
Final state: Particles at rest, touching each other (Figure 4.49).

Energy principle: $\Delta K + \Delta U_e + \Delta(mc^2) + \Delta(Mc^2) = 0$

$$U_i = 0 \text{ (particles very far apart) and } K_f = 0 \text{ (particles at rest)}$$

$$\text{no change of identity, so } \Delta(mc^2) + \Delta(Mc^2) = 0$$

$$\text{so } \left[0 - \left(\frac{p_1^2}{2m} + \frac{p_1^2}{2M}\right)\right] + \left(\frac{1}{4\pi\varepsilon_0}\frac{(2e)(6e)}{r} - 0\right) = 0$$

where m is the mass of the alpha particle and M is the mass of the carbon nucleus.

$$p_1 = \sqrt{\frac{\frac{1}{4\pi\varepsilon_0}\frac{12e^2}{r}}{\frac{1}{2}\left(\frac{1}{m} + \frac{1}{M}\right)}}$$

$$\text{final separation } r = (1.3\times10^{-15}\text{ m})(4^{1/3} + 12^{1/3}) = 5.04\times10^{-15}\text{ m, so}$$

$$p_1 = \sqrt{\frac{\left(9\times10^9\,\frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\frac{12(1.6\times10^{-19}\text{ C})^2}{(5.04\times10^{-15}\text{ m})}}{\frac{1}{2}\left(\frac{1}{4} + \frac{1}{12}\right)\left(\frac{1}{1.66\times10^{-27}\text{ kg}}\right)}} = 7.39\times10^{-20}\text{ kg}\cdot\text{m/s}$$

$$\text{(b) } K_\alpha = \frac{p_1^2}{2m} = \frac{(7.39\times10^{-20}\text{ kg}\cdot\text{m/s})^2}{2(4\times1.66\times10^{-27}\text{ kg})}\left(\frac{10^{-6}\text{ MeV}}{1.6\times10^{-19}\text{ J}}\right) = 2.57\text{ MeV}$$

Figure 4.50 Initial state (part c).

Figure 4.51 Final state (part c).

(c) *System:* alpha particle and carbon nucleus. No external forces.
Initial state: Very far apart, particles moving toward each other (Figure 4.50).
Final state: Oxygen nucleus and photon (Figure 4.51).
Energy principle: $E_{\text{initial}} = E_{\text{final}}$

$$\text{since } K_{\text{oxygen}} \approx 0,$$

$$\left(mc^2 + \frac{p_2^2}{2m}\right) + \left(Mc^2 + \frac{p_2^2}{2M}\right) = M_{\text{oxygen}}c^2 + E_\gamma$$

$$p_2 = \sqrt{\frac{(M_{\text{oxygen}} - m - M)c^2 + E_\gamma}{\frac{1}{2}\left(\frac{1}{m} + \frac{1}{M}\right)}}$$

To calculate accurately the quantity $(M_{\text{oxygen}} - m - M)$ we must use very accurate values of the nuclear masses, because the differences in the rest masses are very slight:

$$M_{\text{oxygen}} - m - M = (15.99052636 - 4.00040868 - 11.99670852)u$$

$$M_{\text{oxygen}} - m - M = -0.00659084\ \text{u}$$

$$(-0.00659084\ \text{u})\left(1.66\times10^{-27}\frac{\text{kg}}{\text{u}}\right)\left(3\times10^{8}\frac{\text{m}^2}{\text{s}^2}\right) = -9.85\times10^{-13}\ \text{J}$$

$$E_\gamma = (10.352\ \text{MeV})\left(\frac{1.6\times10^{-19}\ \text{J}}{10^{-6}\ \text{MeV}}\right) = 16.56\times10^{-13}\ \text{J}$$

We don't have to be so careful in calculating the sum $\left(\frac{1}{m}+\frac{1}{M}\right)$:

$$p_2 = \sqrt{\frac{(16.56\times10^{-13} - 9.85\times10^{-13})\ \text{J}}{\frac{1}{2}\left(\frac{1}{4}+\frac{1}{12}\right)\left(\frac{1}{1.66\times10^{-27}\ \text{kg}}\right)}} = 8.18\times10^{-20}\ \text{kg}\cdot\text{m/s}$$

We find that the incoming momentum p_2 required to create the excited oxygen nucleus is greater than the momentum p_1 required just to overcome the electric potential energy barrier and bring the alpha particle and carbon nucleus in contact (Figure 4.52 shows the energies involved). It is necessary to bring nuclei into contact for a reaction to proceed, since the nuclear force has a very short range. However, in this reaction just making contact is insufficient. A bit more energy is needed in order to produce the larger-mass oxygen nucleus.

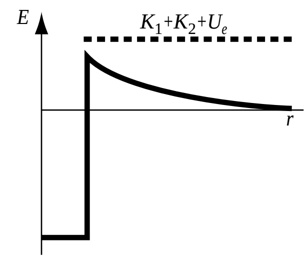

Figure 4.52 The initial kinetic energies are a bit greater than what is needed to overcome the electric potential energy barrier.

(d) See Figure 4.53. The sum of the kinetic and potential energies doesn't change, since no work is done on the two-particle system. The smallest separation is associated with the kinetic energy going to zero.

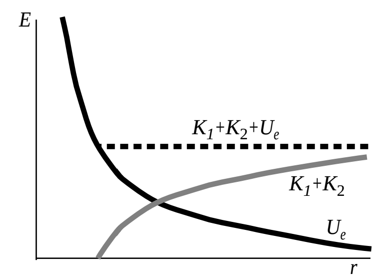

Figure 4.53 Energies as a function of separation between alpha particle and carbon nucleus.