Errata for *Conquering the Physics GRE*, edition 2

March 12, 2017

This document contains corrections to *Conquering the Physics GRE*, edition 2. It includes errata that are present in both all printings of edition 2. All errata known at the time of the most recent printing were corrected for that printing, reflecting most of the changes in this list. For errata for edition 1 (printings 1.0, 1.1, and 2.0), and the old stand-alone sample exams, see the other errata file on our website. Note that both page numbers and section numbers may change slightly between each printing of the book, though section numbers should be more stable. The page numbers listed here refer to the page of the error in the *latest version in which the error is still present*.

Feel free to contact us at `physics@physicsgreprep.com` if any of the information here is unclear.

1 Version 1.2 Errata

1.1 Special Relativity

- §6.2.1 p. 222: As a matter of terminology, the wave four-vector stated in eq. (6.15) should be written as $k^\mu = (\omega/c, \mathbf{k})$.

1.2 Exam 1

- Problem 27 solution, p. 370: The perturbing potential should read $V(x) = -qE_0x$, although the answer is unchanged by the omission of the q.

2 Version 1.1 Errata

2.1 Classical Mechanics

- §1.4.1 p. 19: the second-to-last sentence of the first paragraph, both instances of the word “velocity” should read “speed” instead.

2.2 Electricity and Magnetism

- §2.7.3 p. 96: eq. (2.80) should read U_L instead of U_I.
- §2.7.4 p. 97: under "RL circuits," the first sentence should read "resistor and inductor in series with a voltage source," NOT "in parallel."

2.3 Optics and Waves

- §3.2.2 p. 113: eq. (3.18) should specify that $m = 1, 2, ...$ for the interference minimum condition to hold. As described in the text, $m = 0$ corresponds to an interference *maximum*, not minimum.

2.4 Thermodynamics and Statistical Mechanics

- §4.2.6 p. 147: the expression for density is missing a factor of N: $\rho = mN/V$, where m is the mass of a single gas particle. Consequently, eq. (4.42) should not have a factor of N:

$$c = \sqrt{\gamma \frac{k_B T}{m}}.$$

2.5 Quantum Mechanics

- §5.5.4 p. 192: in the last bullet point, all instances of l should read s instead.
- §5.8 p. 213: In the solution to problem 1 in the Approximation Methods section, the equation in the final sentence has a sign error. It should read $\Delta E = K(-2-1) = -3K$.

2.6 Special Relativity

- §6.2.1, p. 221: the sentence below eq. (6.12) should read "The top 2×2 block of the matrix reproduces (6.1)–(6.2)…"

2.7 Laboratory Methods

- §7.2.1 p. 238: the sentence below eq. (7.5) is incorrect as stated, the total variance is the harmonic mean of the variances *divided by the sample size.*
- §7.3.1 p. 241: the last equality in the expression for Z_{LC} is missing a minus sign.

2.8 Specialized Topics

- §8.1.1 p. 256: there is a typo in the fourth sentence of the second paragraph. It should read "the tau [is] about 20 times the mass of the muon," NOT 1000 times the mass of the muon.

2.9 Special Tips and Tricks for the Physics GRE

- §9.4 p. 279: there is a typo in the sixth sentence of the last paragraph. It should read 300K $\approx \frac{1}{40}$eV, NOT 1K $\approx \frac{1}{40}$eV.

2.10 Exam 1

- Problem 62 solution, p. 379: There are some notational errors in this derivation, and the text is not particularly clear. This solution should be replaced by a cleaner version such as this:

  While this is a good fact to memorize, we can get it quickly by recalling Poisson's equation in SI units:

  $$\nabla^2 V = -\rho/\epsilon_0$$

  Since the potential of a point charge at the origin is q is $V = \dfrac{q}{4\pi\epsilon_0}\dfrac{1}{r}$, and its charge density is $\rho = q\delta^3(r)$, we can read off $\nabla^2 V = -4\pi\delta^3(r)$. Even without remembering this shortcut, it's not too bad to derive. To do this, consider what happens when we integrate the Laplacian around a small sphere of radius R about the origin $r = 0$:

  $$\begin{aligned}\int_V \nabla^2 \left(\frac{1}{r}\right) d^3\mathbf{r} &= \int \nabla \cdot \left(\nabla \left(\frac{1}{r}\right)\right) d^3\mathbf{r} \\ &= \int_S \nabla \left(\frac{1}{r}\right) \cdot d\mathbf{S} \\ &= \int_0^{2\pi} \int_0^{\pi} \frac{\partial}{\partial r}\left(\frac{1}{r}\right) R^2 \sin\theta \; d\theta \; d\phi \\ &= -4\pi \frac{R^2}{r^2}.\end{aligned}$$

  Now consider what happens when we vary the integration region defined by R. If $r > 0$ and we take $R \to 0$, we obtain 0. If $r = R$ and we take $R \to 0$, we obtain -4π, even though we are shrinking the volume of integration arbitrarily small. The one function for the Laplacian that is consistent with these two limits is the delta function. In other words, $\nabla^2 \left(\frac{1}{r}\right) = -4\pi\delta^3(r)$.

- Solution 64, p. 380: There are a couple typos in the formulas in the last sentence of the first paragraph. It should read: "From $\gamma = (1 - v^2)^{-1/2}$, this corresponds to a velocity $v_{Lab} = (1 - m_K^2/E^2)^{1/2}$." The rest of the solution is correct as written.

- Problem 73 and solution, p. 303 and 382: The first equation in the solution is missing a factor of R in the last equality. It should read $F = -kR\omega = mR\dot{\omega}$. This error is propagated through the rest of the solution and the answer choices for the problem, resulting in inconsistent units. To correct this, all factors of $e^{-kRt/m}$ should be replaced by $e^{-kt/m}$, *including in each of the answer choices in the problem.* With this modification the correct answer choice remains unchanged.

- Solution 83, p. 385: the solution is ambiguous about the roles of the kinetic and potential energy in the Hamiltonian H. Between the sentences "After a sudden expansion" and "The expectation value of energy after the expansion," add the following:

  The potential V also stays constant on the interval $[0, a]$, but changes from ∞ to 0 on the interval $[a, 2a]$. Since ψ vanishes on $[a, 2a]$, the kinetic energy operator $T = -\frac{\hbar^2}{2m}\frac{d^2}{dx^2}$ gives zero when acting on ψ. (If you're worried about the fact that the derivative of ψ is discontinuous at $x = a$, meaning that the second derivative is a delta function, note that $\psi(a) = 0$, and zero times a delta function is still zero.)

- Solution 84, p. 385: the solution did not specify how choice C could be eliminated. The revised solution reads:

  D - This looks long and complicated, but it's really just a matter of limiting cases. A and B are eliminated by dimensional analysis, since the reflection coefficient must be dimensionless. To eliminate E, note that as $\alpha \to 0$, the coefficient of reflection must go to zero because the barrier disappears, and the particle continues to propagate to $x > 0$ with probability 1. Choice C looks reasonable at first, but the reflection coefficient must always take a value between 0 and 1, by definition, for all values of parameters in the problem. If α is chosen sufficiently large, then the reflection coefficient of choice C is greater than 1, which is unphysical. This leaves only D.

2.11 Exam 2

- Problem 2, p. 312: the directions of the particle velocity and $\mathbf{B}$ should be swapped. The first sentence of the problem should read: "A charged particle moving in the direction $\hat{\mathbf{n}} = \frac{1}{\sqrt{2}}(\hat{\mathbf{x}} + \hat{\mathbf{y}})$ enters a region of uniform magnetic field $\mathbf{B} = B_0\hat{\mathbf{x}}$." The solution remains unchanged.

2.12 Exam 3

- Problem 20, p. 343: Answer choice D should have T^3 in the numerator, NOT T^2. The solution is correct as written.

- Solution 8, p. 412: The correct answer should be B NOT A. The component of the centrifugal force perpendicular to the string is obtained by multiplying by $\cos(45° - \theta)$ NOT $\cos(45° + \theta)$. This change of sign introduces a minus sign into the denominator of the final answer, causing the correct answer to change from A to B.

3 Version 1.0 Errata

3.1 Classical Mechanics

- §1.2.1 p. 8: first sentence below eq. (1.4) should read "the tangential acceleration is zero" instead of "the radial acceleration is zero."

- §1.2.2 p. 10: problem 2 should specify that the satellite's orbit has the same period as the Earth's *rotation*.

- §1.3.1 p. 12: we should clarify that $\hat{\mathbf{r}}$ is the vector between the two masses, and that the sign depends on which force (1 on 2, or 2 on 1) is being considered

- §1.3.3 p. 14: third paragraph should reference Section 1.3.2 rather than Section 1.3.1.

- §1.4.5 p. 23: problem 5 should specify that the puck is a point mass and that the string is massless.

- §1.7.4 p. 43: the last sentence of problem 2 should read "What horizontal distance x does the ball travel before returning to its height at launch?"

- §1.7.4 p. 45: below eq. (1.52), the sentence should read "pushing up" instead of "pushing down."

- §1.9 p. 51: In the solution to problem 2, the italicized text should read "in the sphere" instead of "on the sphere."

3.2 Electricity and Magnetism

- §2.1.2 p. 59: the last sentence before section 2.1.3 should read $\rho(\mathbf{r}) \propto \delta^3(\mathbf{r})$ NOT $\rho(\mathbf{r}) = \delta^3(\mathbf{r})$.

- §2.1.3 p. 60: item 2 should specify that the field is either constant and perpendicular to S *or* parallel to S, and item 3 should say that $|\mathbf{E}|$ is constant whenever $\mathbf{E} \cdot d\mathbf{S}$ is nonzero, not that the field itself is constant.

- §2.2.2 p. 74: the LHS of the first equation below (2.27) should read $|\mathbf{B}| \int_C dl$ instead of $|\mathbf{B}| \int_C d\mathbf{l}$.

- §2.3.3 p. 82: the discussion of mutual inductance is garbled and the first paragraph should read as follows: "When two current loops are positioned close to each other, a changing current in one produces a time-varying magnetic field that can influence the other and vice-versa. The flux Φ_{21} through loop 2 is proportional to the current I_1 in loop 1 via

  $$\Phi_{21} = M_{12} I_1,$$

  where M_{12} is a constant entirely dependent on geometry and known as the mutual inductance. It turns out that $M_{12} = M_{21}$, so this relationship is symmetric: $\Phi_{12} = M_{21} I_2 = M_{12} I_2$.

- §2.8 p. 100: in the solution to problem electrodynamics to problem 3, the pairs A and B and C and D are swapped in the last two sentences, which should read "A and B can be eliminated by dimensional analysis. Its a tough call between C and D…"

3.3 Optics and Waves

- §3.2.4 p. 113: in the middle of the last paragraph before section 3.2.5, the sentence should read "odd or even multiple of π as appropriate," NOT "odd or even multiple of 2π."

- §3.6 p. 127: in the solution to problem 13, the second sentence should read "$m < 0$" rather than "$m < 1$."

3.4 Thermodynamics and Statistical Mechanics

- §4.1.4 p. 133: the Hamiltonian we wrote for a diatomic gas is an unholy combination of Hamiltonian and Lagrangian variables. It should read

$$H = \frac{p_x^2}{2m} + \frac{p_y^2}{2m} + \frac{p_z^2}{2m} + \frac{L_1^2}{2I_1} + \frac{L_2^2}{2I_2} + \frac{p_s^2}{m} + \frac{1}{2}ks^2,$$

  where L_1 and L_2 are the momenta conjugate to rotations about the two rotational axes, and p_s is the momentum conjugate to s.

- §4.1.4 p. 134: in the second paragraph, all occurrences of "heat capacity" should read "internal energy."

- §4.1.4 p. 134: in the third paragraph, the first sentence should read "still applies to translational and *rotational* degrees of freedom" (NOT vibrational)

- §4.2.6 p. 145: eqs. (4.41) and (4.42) apply to ALL ideal gases, not just monotonic ones.

- §4.3 p. 146: the LHS of eqs. (4.45) and (4.46) should read $\langle N \rangle$ instead of N, because they represent average particle number.

- §4.5 p. 152: in the solution to problem 11, the equation after "The internal energy still depends on a" was missing a minus sign and should read $U = -\partial \ln Z_N / \partial \beta = -Na + \cdots$. The solution to the problem is unaffected.

- §4.5 p. 152: in the solution to problem 13, the LHS of the last equation on the page should be $\langle N \rangle$ instead of N.

3.5 Quantum Mechanics and Atomic Physics

- §5.4.3 p. 180: Due to a copy-and-paste error, equation (5.43) is incorrect and should read

$$H = -\frac{\hbar^2}{2\mu}\nabla^2 - \frac{e^2}{4\pi\epsilon_0}\frac{1}{r}$$

3.6 Special Relativity

- §6.4.1, p. 225: the right-hand side of the last formula before sec. 6.4.2 should have f_{emit} not ν_{emit} on the RHS.

3.7 Laboratory Methods

- §7.4.2, p. 243: in "Pair production", the first sentence was missing a factor of c^2 and should read $E_\gamma > 2m_ec^2$.

3.8 Specialized Topics

3.9 Special Tips and Tricks for the Physics GRE

3.10 Exam 1

- Problem 74 solution, p. 380-381: The expressions for the moment of inertia and the mass of the cylinder should include extra factors of z, the length of the cylinder. These factors cancel in the solution, so the answer remains unchanged. The corrected calculation of the cylinder moment of inertia should read:

$$\begin{aligned} I &= \int r^2 dm \\ &= \int_0^R \rho(r) r^2 (2\pi r z\, dr) \\ &= 2\pi z \int_0^R A r^4 dr \\ &= \frac{2\pi z A}{5} R^5. \end{aligned}$$

  And the corrected calculation of the cylinder mass should read:

$$M = \int dm = \int_0^R \rho(r)(2\pi r z\, dr) = 2\pi z \int_0^R A r^2\, dr = \frac{2\pi z A}{3} R^3,$$

3.11 Exam 2

- Problem 22, p. 315: In order to match the revised solution of this problem, the charge on the outer sphere should be changed from $+2Q$ to $+3Q$.

- Solution 22, p. 390: As stated the correct answer is E, but the discussion on how to decide between answers D and E was unclear. With the change of the charge to $+3Q$, the correct answer remains D. Replace the second half of the solution that begins "To decide between D and E..." with the following explanation:

To decide between D and E, we need to do a quick calculation. Depending on the amount of charge on each shell either D or E could be valid. Call the potential inside the inner shell $V_1(r)$, the potential in between the two shells $V_2(r)$, and the potential outside the outer shell $V_3(r)$. Since the electric field is the *derivative* of the potential, we can add arbitrary constant offsets C_1 and C_2 to the standard Coulomb potentials for the enclosed charge in these regions so that they match on the boundaries according to the conditions $V_1(R) = V_2(R)$ and $V_2(2R) = V_3(2R)$. When we rewrite the boundary conditions in terms of the Coulomb potentials with the constant offsets, we get the following system of equations

$$V_1(R) = V_2(R) \Longleftrightarrow C_1 = -\frac{q}{4\pi\epsilon_0 R} + C_2$$
$$V_2(2R) = V_3(2R) \Longleftrightarrow -\frac{q}{8\pi\epsilon_0 R} + C_2 = +\frac{2q}{8\pi\epsilon_0 R}.$$

The offset C_1 is clearly positive, so $V_1(r) = C_1 > 0$ and D is the correct answer.

- Problem 52, p. 322: The wording of answers in this problem is quite confusing. Replace them with the following choices:

  (A) It implies that the entropy of a perfect crystal of a pure substance must approach zero at absolute zero

  (B) It implies that the entropy of an isolated system can sometimes decrease

  (C) It is a consequence of the fact that the ground state degeneracy of a system determines its entropy

  (D) It implies that absolute zero can never be reached in experiments

  (E) It permits the entropy of a system to be nonzero at absolute zero

- Problem 52 solution, p. 396: The correct answer remains unchanged, but change the explanation to:

  B - Choice B is false because it is forbidden by the second law of thermodynamics. The third law comes in various forms, but all of them require that the entropy approaches a constant at absolute zero. A, C, and E are all true by the Boltzmann definition of entropy $S = k_B \ln \Omega$, where Ω is the degeneracy of the system. A perfect crystal of a pure substance has a degenerate ground state, so $\Omega = 1$ and $S = 0$. But if the ground state were non-degenerate, then S could conceivably nonzero at absolute zero when the system is in the ground state. Since a system at absolute zero is in its ground state, the Boltzmann definition of entropy implies that the entropy of a system approaches a constant at absolute zero. The fact that D follows from the third law is somewhat less obvious, but also true and proven in many textbooks.

3.12 Exam 3

- Problem 20, p. 341 and Solution 20, p. 414: None of the answer choices are correct as written. The solution erroneously computes the flux by multiplying the magnetic field evaluated at the position of the bar by the area. The correct flux is

$$\Phi = \int \mathbf{B} \cdot d\mathbf{A} = \int_0^{vt} dx \int_0^d dy\,(Cx) = \frac{1}{2} C d v^2 t^2.$$

  The correct final answer should be $\dfrac{C^2 v^4 d^2 T^3}{3R}$.

- Solution 62, p. 425: there should be absolute value signs, $\Delta\omega = |\omega' - \omega|$ instead of $\Delta\omega = \omega' - \omega$.

- Solution 69, p. 427: the last two expressions for L should not have an I on the RHS.