ERRATA for *A GENERAL RELATIVITY WORKBOOK* (1st Printing)

- Inside front cover, under "Useful Formulae," left side for Riemann tensor in a LIF should be $R_{\alpha\beta\mu\nu}$, not $R^{\alpha}{}_{\beta\mu\nu}$.
- Page xvii, 1st line of text: "stop at after" should be "stop after".
- Page xix-xx, paragraph that spans the pages: Either delete the entire paragraph (which is incorrect) or replace with "Instructors adopting the text for classes should contact University Science Books at deskcopy@uscibooks.com for access to the instructor's manual."
- Page 3, 6th line above the heading "Geodesic Hypothesis": the word "objects" is doubled.
- Page 5, last line of the 2nd paragraph: change "measuring its resistance" to "measuring is its resistance".
- Page 4, figure 1.2, label under point *B*: "$t_B = c(0.02 \text{ s})$" should be "$ct_B = c(0.02 \text{ s})$".
- Page 8, 2nd line above the heading "The Einstein Equation": "spacetime" is badly hyphenated.
- Page 10, P1.5, 3rd line from the bottom: "$(1 + x)^n = 1 + nx$" should be "$(1 + x)^n \approx 1 + nx$".
- Page 26, sentence before exercise 2.6.1: insert "(that is, at $y = z = 0$, with $x > 0$)" between "axis in".
- Page 34, 5th line above the heading "Relativistic Energy and Momentum": change "in IRF" to "in an IRF".
- Page 35, 2nd line: change "simple form) of the" to "simple form of) the".
- Page 35, First line after equation 3.18: change "energy, However," to "energy. However," (comma to period).
- Page 38, second line before equation 3.30: should be "in the $+x$ direction with $\beta = v$." (The "with" was omitted.)
- Page 38, equation 3.32: change $\boldsymbol{p}_{1f}$ to $\boldsymbol{p}_{2f}$.
- Page 40, line immediately following equation 3.37, p^x should be $\boldsymbol{p}_\pi$.
- Page 42, problem P3.3, second line: "(v < = 135 MeV)" should be "($m_\pi = 135$ MeV)".
- Page 46, the two lines above equation 4.15: should be "acting on a particle", not "acting on particle".
- Page 51, line between equations 4.29 and 4.30: "left" should be "right" and vice versa.
- Page 54, second line above equation 5.1: should be "neighboring point Q" not "neighboring point P".
- Page 58, seventh line: "we define a vector ds" should be "we define a vector $\boldsymbol{e}_\theta$".
- Page 58, line following equation 5.20: $g_{r\theta}$ should have an italic r subscript.
- Page 60, figure 5.4, the basis vector $\boldsymbol{e}_\theta$ should be $\boldsymbol{e}_p$.
- Page 62, second line of equation 5.30: $(-\gamma\beta)^2$ should be simply $(\gamma\beta)^2$.
- Page 62, Exercise 5.2.1 should be numbered 5.5.1.
- Page 64, problem P5.4, part b, 2nd line: change "coordinates in the cartesian" to "components in the cartesian".
- Page 64, problem P5.4, part e: ∂x should be $\boldsymbol{e}_q$.
- Page 64, problem P5.6, 5th line from the problem's end: replace θ with r.
- Due to a computer glitch, the page numbers in chapter 6 are out of sequence: they should read 65-76 instead of 81-92. This means that pages having numbers in the range 81-92 appear in chapter 6 and also in chapters 7 and 8. Index entries for items in chapter 6 point you to the correct (misnumbered) page in chapter 6. For example, "Covector" in the index points you to pages 82-86, but it means the pages with those numbers in chapter 6, not the pages with the same numbers in chapter 7.
- First page numbered 84 (actual 68), third line under "Tensor Equations": "exactly the same", not "exactly same".
- Page 78, third line from the bottom: delete one "the" from "the the box's length."
- Page 79, 2nd line from the bottom: change "we did in equation 7.5" to "as we did in equation 7.5".
- Page 79, end of 2nd line from the bottom: replace "left" by "right".
- Page 80, between equations 7.7 and 7.8, $m^2 = -p^\mu p_\mu$, not $p^\mu p_\mu$.
- Pages 88, 354, 360-362, 364, 365, 368, 373, 377, 384, 390, 408, 412, 471, often several times per page: "Lorentz gauge" should be "Lorenz gauge", after Ludwig Lorenz, not Hendrik Lorentz. (This error appears in many books.)
- Page 90, second line above equation 8.5: change "worldine" to "worldline".
- Page 91, line above equation 8.8: replace "But notice that equation 8.1 means that" with "But notice that"
- Page 91, equation 8.8: replace with

$$\tau(\sigma) = \int_0^{\tau(\sigma)} d\tau = \int_0^\sigma \sqrt{-g_{\mu\nu} \frac{dx^\mu}{d\sigma} \frac{dx^\nu}{d\sigma}}\, d\sigma \quad \Rightarrow \quad \frac{d\tau}{d\sigma} = \sqrt{-g_{\mu\nu} \frac{dx^\mu}{d\sigma} \frac{dx^\nu}{d\sigma}} = L$$

- Page 91: equation 8.11 got all screwed up somehow. The correct equation should look like this

$$0 = \frac{d}{d\sigma}\left[-g_{\alpha\mu} \frac{dx^\mu}{d\tau} \right] + \frac{1}{2} \frac{\partial g_{\mu\nu}}{\partial x^\alpha} \frac{dx^\mu}{d\tau} \frac{dx^\nu}{d\sigma}$$

- Page 92, fifth line from the bottom should have a closing parenthesis between the 1 and the period.
- Page 93, Figure 8.2: points *A* and *B* and the worldline of the free particle should all lie on the *t* axis.
- Page 94, equation 8.22 should read

$$\tau_{AB} \equiv \int_0^1 L(\sigma)\, d\sigma \quad \text{where} \quad L = \sqrt{-g_{\mu\nu} \dot{x}^\mu \dot{x}^\nu}$$

(continued)

- Page 102, equation 8.55: delete the brackets around the right side.
- Page 107, four lines above equation 9.9 (end of the previous paragraph): h should be r_s.
- Page 113, 10th line: "$t \infty h$" should be "$t \approx h$".
- Page 114, problem P9.1, second line: delete extra "and".
- Page 127, problem P10.2, second line: delete close parenthesis after M.
- Page 132, line following "Spatial Curvature": change $g_{tt} = 1 - 2GM/r$ to $g_{tt} = -(1 - 2GM/r)$.
- Page 141, problem P11.4, 6th line above equation 11.33: "Darmour" should be "Damour".
- Page 144, equation 12.5 and the line above: change "flat space" to "flat spacetime".
- Page 149, box 12.4, title and 2nd line of exercise: change "flat space" to "flat spacetime".
- Page 155, footnote: the link is broken: use http://adsabs.harvard.edu/full/2001ASPC..252...21C
- Page 157, 2nd line above equation 13.16: change "energy per time I_s," to "energy per unit time I_s,".

- Page 165, equation 13.27: change $\sqrt{1 + \dfrac{2GM}{r_0 u(u+1)}}$ to $\sqrt{1 - \dfrac{2GM}{r_0 u(u+1)}}$

- Page 178, problem P14.8, 7th line from bottom: $2GM$ for a solar-mass black hole is about 10 μs, not 40 ms.
- Page 184, equation number for equation 15.13: replace box character with left parenthesis character.
- Page 202, 12th line from the bottom: change "coordinate differences" to "component differences".
- Page 203, 3rd full paragraph, 3rd line from bottom: again "coordinate" should be "component".
- Page 203, last line of the 4th full paragraph: change "point P" to "event P".
- Page 204, equation 17.16: the expression on the far right should have a dx^σ outside the square brackets.
- Page 205, in the first line of equation 17.22, the lower indices of the Christoffel symbols on the far left and the far right are inconsistent with the definition in equation 17.3. (This does not matter, though, because of box 17.3.)
- Page 207, line below equation 17.31: change $\partial_\mu g_{\mu\nu}$ to $\partial_\alpha g_{\mu\nu}$.
- Page 209, equation 17.38: change $\partial'_\gamma \partial'_\sigma \partial g'_{\mu\nu}$ to $\partial'_\gamma \partial'_\sigma g'_{\mu\nu}$.
- Page 214, first line below equation 18.8: "and its derivative is" should be "and its derivative are".
- Page 215, line below equation 18.16: bad break: hyphenate "spacetime" as "space-time" not "spa-cetime."
- Page 223, 2nd line below equation 19.5: change "local LIF" to just "LIF".
- Page 226, first line of box 19.3: "and $R_{\alpha\beta\nu\mu} = - R_{\alpha\beta\mu\nu}$" should be "and $R_{\beta\alpha\mu\nu} = - R_{\alpha\beta\mu\nu}$".
- Page 227, header at top of page: change "coninued" to "continued".
- Page 227, equation 19.17, second term in parentheses: superscript α should be σ: that is, $- \partial_\nu \Gamma^\alpha_{\beta\mu}$ should be $- \partial_\nu \Gamma^\sigma_{\beta\mu}$.
- Page 230, problem P19.8, 4th line below equation 19.28: change "metric component" to "tensor component".
- Page 230, problem P19.8, 4th line before equation 19.29: change $\mathbf{o}_\mu \cdot A$ to $\mathbf{o}_\mu \cdot \mathbf{A}$.
- Page 233, line after equation 20.7: supply period at the end of the sentence.
- Page 233, 2nd line below equation 20.8: change "itme" to "time".
- Page 241, problem P20.5a, 4th line from end of part a: delete ")" before "You".'
- Page 241, problem P20.1, last line: k_B is 1.536×10^{-40} kg/K, not 1.536×10^{-49} kg/K.
- Page 242, problem P20.8a, 4th line before equation 20.34: change $\mathbf{o}_\mu \cdot A$ to $\mathbf{o}_\mu \cdot \mathbf{A}$.
- Page 246, 2nd paragraph under "The Cosmological Constant," 2nd line: change "stars and galaxies" to "stars and other cosmic objects" (at the time Einstein proposed the constant, galaxies were not really yet discovered).
- Page 251, problem 21.5, 4th line: bad break -- change "spacet-ime" to "space-time".
- Page 251, problem 21.8a, 2nd line from end of part: $d^2x/d\tau$ should be $d^2x/d\tau^2$.
- Page 251, problem 21.8f, 2nd line from end of part: $-g^2/8\pi G$ should be $g^2/8\pi G$. There are also some sign errors in the solutions manual (from forgetting that g_{tt} is negative).
- Page 257, first line on page: change "spatial indices." to "spatial indices)."
- Page 257, 7th line below equation 22.14: change $-G\rho_g(\vec{r})dV/|\vec{r} - \vec{r}_s|$ to $-G\rho_g(\vec{r}_s)dV/|\vec{r} - \vec{r}_s|$ (add s subscript).
- Page 257, first line below equation 22.17: delete extra "and".
- Page 263, problem P22.6, part b, 1st line: Change F_{ij} to F_{kj} (for consistency).
- Page 271, 5th line: change $ds^2 = A(dx^0)^2 +$ to $ds^2 = -A(dx^0)^2 +$
- Page 278, 3rd line below equation 23.51: R_{tt} should be R_{rr}.
- Page 278, equation 23.52: right side should be $-8\pi G f\sigma$, not $-8\pi G C\sigma$.
- Page 278, equation 23.54: maybe put parentheses around "for $r > r_s$".
- Page 283, paragraph with heading "Dark Matter" 5th line: change "quarks and leptons" to "protons and neutrons".
- Page 287, last line: change "$\approx$" to "$=$"
- Page 288, equation 24.6: replace $r^{-1/2}$ by $\vec{v}_G = H_0 \vec{r}_G$.
- Page 289, 12th line from the end: change "average galactic separation" to "average inverse galactic separation".
- Page 290, 2nd line: change "quarks and … of particle physics" to simply "protons and neutrons".
- Page 291, problem 24.7, 5th line: change "halos" to "halo".
- Page 295, line below equation 25.3: change $2g_{rt} dt\, d\bar{r}$ to $2g_{\bar{r}t} dt\, d\bar{r}$.
- Page 297, caption of figure 25.1, 5th line: change "$q(\bar{r}) = R$" to "$\chi \equiv \bar{r}/R$.".

- Page 300, last entry in fourth line for R22: should be $\frac{1}{4AD}C_0D_0$ not $\frac{1}{4AC}D_0C_0$.
- Page 303, problem 25.6, 8th line after equation 25.26: delete the extra "the".
- Page 310, 1st line after equation 26.23: delete the extra "that".
- Page 315, after equation 26.25: insert "where t_0 is the current value of t."
- Page 316, problem P26.9, part d: change "scale factor R" to "curvature scale R".
- Page 316, problem P26.10, just before part a: change "Hubble constant" to "Hubble parameter".
- Page 320, 4th line above equation 27.16: change "How its it related" to "How is it related".
- Page 320, section on "The Universe is Flat": needs to be updated to reflect this year's Planck results.
- Page 325, problem 27.7, part e, 2nd line: delete the redundant "T".
- Page 328, line below equation 28.1: change $4\pi G\rho_{0(m,r,v)}/3H_0^2$ to $8\pi G\rho_{0(m,r,v)}/3H_0^2$.
- Page 341, 9th line before the end: change 10^{-5} to 10^5.
- Page 343, third paragraph, fifth line: Change "$\rho \approx$" to "$\rho_r \approx$".
- Page 343, 3rd paragraph, 6th line: change "box 29.51" to "box 29.5".
- Page 344, section on Eternal inflation, last line: change "No one yet knows yet how to construct a plausible of" to "No one knows yet how to construct a plausible model of
- Page 349, problem 29.4, 1st line: change "13.7 Gy" to "13.75 Gy" for consistency.
- Page 352, 3rd line after equation 30.3: need a period after the close parenthesis (before "We").
- Page 354, 3rd line below equation 30.15: "the" occurs twice.
- Page 360, 3rd line from the end: "$af + bf_0$, where a and b are constants" should be "$f + bf_0$, where b is a constant".
- Page 365, 3rd line above equation 31.13: "$(-g_{tt})^{1/2}$" should be "$(-g_{tt})^{-1/2}$".
- Page 367, 2nd line of last paragraph: change "New Gravitational Wave Observatory" to "New Gravitational-wave Observatory".
- Page 377, 2nd line below equation 32.2: "space is flat" should be "spacetime is flat".
- Page 378, equation 32.7a: "$h_+(t, z) =$" should be "$h_+(t, z) \equiv$".
- Page 378, equation 32.8a: "$A = -1$" should be "$A = 1$".
- Page 378, equation 32.8b: change all "1" subscripts to "0" and all "4" subscripts to "3".
- Page 385, equation 33.6: "$I^{jk} =$" should be $I^{jk} \equiv$".
- Page 386, second line above equation 33.11: change "subtracting the trace from each nonzero element to make" to "subtracting symmetric fractions of the trace from each remaining nonzero diagonal element (to make".
- Page 387, equation 33.15: delete the extra factor of 2 in the second term on the right.
- Page 390, exercise 33.3.2, first line: delete the extra "that".
- Page 391, exercise 33.4.1: "by raising" should be "by raising or lowering".
- Page 398, 2nd line above equation 34.1: "xy plane" not "xz plane".
- Page 399, line before equation 34.8: reference should be to equation 33.12, not 33.4.
- Page 400, 2nd line: delete close parenthesis.
- Page 400, equation 34.16a: $A_+ = 7.7 \times 10^{-21}$, not 8.7×10^{-21}.
- Page 400, 2nd line after heading "The Evidence for Gravitational Waves": change "PSR 1913+16" to "PSR B1913+16".
- Page 401, caption of figure 34.1, 1st line: change "PSR B1913-16" to "PSR B1913+16".
- Page 408, first line after equation 35.1: change "Lorentz" to "Lorenz".
- Page 409, second line after equation 35.9: delete "*except* that the sign of the $\partial\vec{A}_G/\partial t$ term is reversed."
- Page 411, equation 35.20: change "365.25 day" to "365 day" to be more consistent about significant figures.
- Page 411, equation 35.21: change R in the denominator to r to be consistent with previous usage.
- Page 413, equation 35.24a: change $\vec{\nabla} \times \vec{\nabla} \times \vec{F}$ to $\vec{\nabla} \times (\vec{\nabla} \times \vec{F})$.
- Page 415, equation 35.27: put absolute-value bars around $\sin\theta$.
- Page 415, equation 35.28: put absolute-value bars around $d\phi/d\tau$.
- Page 415, caption of figure 35.2b: change "projection of $\vec{s}$ on the circle" to "projection of $\vec{s}$ on the plane of the circle" for the sake of clarity.
- Page 416, equation 35.29, 2nd line, left side: change $+\Gamma^\alpha_{\mu\nu}u^\mu s^\alpha$ to $+\Gamma^\alpha_{\mu\nu}u^\mu s^\nu$.
- Page 418, 2nd line below equation 36.2: change "simplify things, Let's" to "simplify things, let's".
- Page 418, equation 36.5: change R^5 to $2R^5$ in the denominator of the last term.
- Page 424, equation 36.8r, 2nd line: add "dt" following the close parenthesis (making it agree with eqn. 36.8).
- Page 425, exercise 36.5, 7th line from the bottom: reference should be to problem P22.1, not P22.2.
- Page 425, exercise 36.5, 6th line from the bottom: $r \equiv (1 + 2GM/R)^{1/2}R$, not $r \equiv (1 - 2GM/R)^{1/2}R$.
- Page 429, line above equation 37.9: $2dr/d\tau$ should be just $dr/d\tau$.
- Page 430, second line below equation 37.14: "Ω is smaller" should be "$|\Omega|$ is smaller".
- Page 441, 5th line below the "Cosmic Censorship" heading: change "$r^2 + a^2\cos^2\theta = 0$" to simply "$r = 0$".
- Page 443, first line: change "equation 37.5" to "equations 37.5".
- Page 443, problem P38.1: Note: Requires numerical integration.
- Page 447, problem P38.5, equation 38.28: change $\phi(r) = 2\sqrt{GM}\,a...$ to $\phi(r) = \sqrt{2GM}\,a...$

- Page 448, problem P38.10, last line of part b: change "$u \cdot w$" to "$\boldsymbol{u} \cdot \boldsymbol{w}$".
- Page 444, box 38.4, first line: add "at a a given instant of time" after "The outer Kerr event horizon".
- Page 456, the line before equation 39.16: change the period after $dt/d\tau$ to a comma.
- Page 460, equation 39.31: change $4\pi k_B G$ in the numerator of the first factor to $4\pi k_B$.
- Page 461, problem P39.8, part a, 2nd line: change "angular speed in" to "angular speed Ω in".
- Page 461, equation 39.33: delete "(in SI units)" (the equation is the same in both SI and GR units).
- Pages 468-476: delete the running headers, which are left over from the last chapter.
- Page 471, last line of first column: change "Lorentz gauge" to "Lorenz gauge".