Errata for Gravity: An Introduction to Einstein's General Relativity, *Printings 1-7.*

19 ℓ1 after (2.4): If there is space on the page add footnote after 'of the sphere' 'Don't get (2.4) mixed up with (2.1). Eq. (2.1) is for triangles formed by light rays in the four-dimensional curved spacetime that surrounds the Earth according to general relativity. Eq (2.4) is for triangles made up of segments of great circles on the surface of a two-dimensional sphere.'

21, ℓ3 of the first full para.: Replace 'nearby' by 'nearby (infinitesimally separated)' just in its first occurrence. (Clearer).

27, Figure 2.7: Add at the end of the caption if there is space '(You will learn how to construct such surfaces in Section 7.7.)'

29, Problem 9: Replace with the following (if there is not enough space leave out the Comment:)

The surface of the Earth is not a perfect sphere. One quarter of the circumference aound a great circle passing through the poles is $9,985.16$ km. This is slightly less than one quarter the of equatorial circumference, $10,0018.75$ km, meaning the Earth is slightly squashed. Suppose the surface of the Earth is modeled by an axisymmetric surface with a line element of the kind in (2.21) with

$$f(\theta) = \sin\theta(1 + \varepsilon\sin^2\theta)$$

for some small ε. What values of a and ε would best fit reproduce the known polar and equatorial circumferences?

Comment: It is not an accident that one quarter of the polar circumference is almost exactly ten million meters. That was the original definition of the meter.

(This version of the problem should be clearer because it refers entirely to the surface of the Earth, and not to distances in the solid Earth as before. Don't include this paren.)

35, Box 3.1, 2nd col, ℓ1: Replace 'rotated to by' with 'rotated by'.

37, ℓ1 after (3.7): Replace (3.1) by (3.2).

46, Problem 6: Replace 'accuracy' with 'few parts in 10^{13} accuracy'

56, footnote 7: Replace with 'Historically the transformations were derived by Einstein from the assumptions mentioned on p. 49. The idea of space-time was introduced shortly thereafter by H. Minkowski. This historical sequence is followed in may elementary texts today'.

57, caption for Fig 4.8: Delete the next to last sentence 'A hyperbolic angle ... origin.' It's redundant with the last sentence.

64, Box 4.4, 1st par.: Replace 'a fraction $\exp(-t/\tau_p)$ will have decayed' with 'a fraction $\exp(-t/\tau_p)$ will remain undecayed'.

69, ℓ5 from bott.: Replace 'of approximately' with 'approximately'.

72, 5ℓ from bottom of text: Replace 'its 899' with 'it is 899'.

75, Problem 15: Replace three instances of $|(\vec{V})|$ with $|\vec{V}|$. Its simpler and consistent with the other notation in the problem.

79, ℓ1 after (5.5): Replace 'are the same as' with 'coincide with'.

86, ℓ1 after (5.38): Replace 'which from....or' with 'which from (5.36) implies $\mathbf{u} \cdot \mathbf{a} = 0$, and, using (5.37), '

92, 2ℓ after (5.70): Replace 'a a photon' with 'a photon' (repeated word).

93, ℓ1 after (5.75): Replace 'Thus the half of the photons emitted in' with 'Thus the half of the photons that are emitted in' (ie insert 'that are') (clearer).

95, eq(c): In the first line replace $\approx$ by $=$. The second line is ok.

98, 2ℓ before (5.82): Replace 'and, by temporarily suspending the rules for balancing indices, we may write:' with 'with the result:' . Then add to the start of footnote 5. 'This violates temporarily the rules for balancing indices on both sides of an equation that we have been following implicitly and will be describe explicitly in Section 7.3. More pedantically... ' (We don't explain the rules until Sec 7.3).

98, ℓ1 after (5.86): Replace 'according to (5.82)' with 'according to (5.83)'.

99, Example 5.9, ℓ3: Replace 'intertial' with 'inertial' (spelling).

100, Problem 9, ℓ3: Replace 'through through' with 'through' (repeated word).

102, Part b of Problem 17 starting on previous page: Add the following hint at the end of part b if there is space: [Hint: Remember that the time interval between the reception of two photons by a stationary observer is not the same as the time interval between their emission if the source is moving.]

109, last par, ℓ5: Replace 'gradients in the gravitational potential — differences in $\vec{g}$ — across...' with 'gradients in $\vec{g}$ across' (Its the gravitational field not the potential that has the gradients.)

115, caption for Fig 6.6, ℓ6: Replace 'There signals' with 'These signals'.

119, ℓ1: Replace '10^{14}' with '10^{15}'.

119, ℓ1 above the box: Replace 'nonuniformities in Φ' with 'nonuniformities in the gravitational field $\vec{g}$'. (Its the field that matters.)

124, ℓ1 above (6.16): Replace 'determined by' by 'determined by the relation between velocity and period $V_s = (2\pi R_s)/(12\text{hr})$ and ' (There are two relations that determine the velocity.)

130, Box 6.2 ℓ1 of next to last par: Replace 'Define $V_g(t)$ to be the ground speed of the plane carrying the flying clocks' with 'Define $V_g(t)$ to be the speed of the plane with respect to the ground'... (Apparently 'ground speed' is not unambiguous for all readers.)

133, Problem 10: Replace 'element with a decay time of 4 billion years' with 'element like ^{238}U with an exponential decay time of 6.5 billion years'. (Clearer and more relevant.)

133, Problem 12: Replace with the following which is clearer:

[S] In the two-dimensional flat plane, a straight line path of extremal distance is the shortest distance between two points. On a two-dimensional round sphere, extremal paths are segments of great circles. Show that between any two points on the sphere there is an extremal path that provides the shortest distance between them when compared with nearby paths.

Show there is another path between the two points which is extremal, but neither the longest or shortest distance between the points when compared with nearby paths. Show that there is no one path that provides the longest distance between the points.

133, Problem 14: Replace with the following which gives a little more motivation for the problem (two sentences added in middle and d) changed to just a question because its not an orbit):

[C] Consider a particle moving in a circular orbit of radius R about the Earth. Suppose the geometry of spacetime outside the Earth is given by the static weak field metric (6.20) with $\Phi = -GM_\oplus/r$. Let P be the period of the orbit measured in the time t. Consider two events A and B located at the same spatial position on the orbit but separated in t by the period P. The particle's world line is a curve of extremal proper time between A and B. As discussed in Section 3.5, that means the proper time around the orbit is a maximum, minimum, or saddle point with respect to *nearby* paths. But we can also ask whether the proper time is longer and shorter than *any* other world line, nearby or not. Analyze this question for the circular orbit by calculating to first order in $1/c^2$ the proper time along the following world lines connecting points A and B in spacetime.

a. The orbit of the particle itself.

b. The world line of an observer who remains fixed in space between A and B.

c. The world line of a photon that moves radially away from A and reverses direction in time to return to B in a time P.

Can you find another curve of extremal proper time that connects A and B?

137, Box 7.1, $\ell 1$: Replace 'flat space' with 'flat spacetime'.

137, Box7.1, rt. col. $\ell 4$, $\ell 5$ from end: Replace $t' = -\infty$ with $t' = -\pi$ on $\ell 5$ from bottom, and replace $t' = \infty$ with $t' = \pi$ on $\ell 4$ from bottom.

141, (7.17): Delete all the factors of 2 in this equation so it reads:

$$g_{AB}(x,y) = \begin{pmatrix} 1 - y^2/(3a^2) & xy/(3a^2) \\ \\ xy/(3a^2) & 1 - x^2/(3a^2) \end{pmatrix} + \begin{pmatrix} \text{terms of third} \\ \text{and higher} \\ \text{order in } x \text{ and } y \end{pmatrix}$$

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142, ℓ2 after (7.18): Replace 'span' with 'spans' (to agree with 'family'.)

142, ℓ6 after (7.18): Replace 'as it can' with 'as they can' (to agree with 'world lines'.)

143, ℓ1 after (7.22): Replace 'when $t = 0$' with 'when $T = 0$'. ie cap T.

153, ℓ2 of Orthonormal Bases: $\alpha = 0, 1, ...$ should be $\hat{\alpha} = 0, 1, ...$ ie put a hat on the alpha.

156, ℓ1 above (7.59): Replace 'with different lengths, directions, etc' with 'with different lengths and directions.' (So readers don't worry what etc means.)

160, Example 7.11, 3ℓ from bottom: Replace 'These are' with 'There are'.

162, ℓ2 above (7.75): Replace 'found by substituting (7.75)...is' with 'is the spatial part of the line element found by substituting (7.75) into (7.4). Explicitly, '

162, ℓ1 after (7.79): Delete 'independent'. (Orthogonal is enough.)

165-6, b) of Problem 10: The vectors should have hats on the indices, viz, $\mathbf{e}_{\hat{0}}, \mathbf{e}_{\hat{1}}$.

166, Problem 14a: Replace 'along a radial line' with 'along a radial line at constant t' . (Clearer.)

167, Problem 21, part c: Replace $x-$axis with x^1-axis.

170, ℓ1: Replace 'applies the motion' with 'applies to the motion'.

184, Problem 5: Replace 'from variational principle' with 'from the variational principle'.

184, Problem 12, ℓ3: Replace 'classic example of a two....' with 'classic example of a curved two...' ie insert 'curved' (Clearer?)

194, ℓ2 of last par.: Replace 'replacing t ... by GM/c^2. with 'replacing τ by $c\tau$ and M by GM/c^2. (There are no t's to replace.)

195, eq (9.32) to end of paragraph: This should read:

$$E_{\text{Newt}} \left(1 + \frac{E_{\text{Newt}}}{2mc^2} \right) = \frac{m}{2} \left(\frac{dr}{d\tau} \right)^2 + \frac{L^2}{2mr^2} - \frac{GMm}{r} - \frac{GML^2}{c^2 mr^3}$$

where $L = m\ell$. This has the same form as the energy integral in Newtonian gravity with additional relativistic corrections to the potential on the right proportional to $1/r^3$ and to the energy on the left. The Newtonian limit is recovered when these relativistic corrections are dropped and the $\tau-$ derivative replaced by a $t-$ derivative.

197, caption for Fig 9.4, 5ℓ from bottom: Insert a comma so it reads 'the outer one is stable, the inner one is unstable.'

198, caption for Fig 9.4 cont, 2nd to last sentence: Some commas would help, namely '... comes in from infinity, moves part way around the central mass, and then plunges into the center.'

199, 3ℓ above example: Replace 'flawed near $r = 2M$' with 'flawed at $r = 2M$'. (They are ok for any $r > 2M$.)

199, Example 9.1, ℓ9: Replace (9.35) with (9.36).

201, Eq(9.49): The denominator should be $[(\mathcal{E} - V_{\text{eff}}(r))]^{1/2}$ rather than $[(\mathcal{E} - V_{\text{eff}}(r)]^{1/2}$. (Parenthesis missing after $V_{\text{eff}}(r)$).

202, Figure 9.5, ℓ4 of caption: Replace 'curve of ℓ vs e' with curve of ℓ vs $\mathcal{E}$, ie replace e by $\mathcal{E}$.

206, 4ℓ below (9.69): Add to last sentence so it reads 'Thus in $c \neq 1$ units $b \equiv |\ell/(ce)|$ if ℓ has the units of angular momentum per unit rest mass.'

207, Figure 9.8: Replace W_{eff} with $M^2 W_{\text{eff}}$ on the three vertical axes, ie add M^2.

208, Figure 9.9: Replace V_{eff} on vertical axis of the first figure with $M^2 W_{\text{eff}}$.

209, 2ℓ above (9.72): Replace 'by (9.22) and (9.29)' with 'by solving (9.59) and (9.63) for $u^r = dr/d\lambda$ and $u^\phi = d\phi/d\lambda$. (Clearer and correct eqn references.)

209, 2ℓ above (9.73): Replace '(9.63) and (9.72)' with '(9.72) and solving (9.63) for $dr/d\lambda$. (Clearer.)

214, 2ℓ above (9.89): Replace 'defection' with 'deflection' (spelling).

215, Problem 9.2: Replace 'Assume ... annihilate' with 'Assume that both electron and positron are nearly at rest with respect to the star when they annihilate.'

216, Problem 11: Replace 'Show that ... will grow as' with "Show that a small radial displacement δr from the unstable circular orbit at the maximum of the effective potential V_{eff} will grow as". (Clearer).

216, Problem 12: Replace 'Schwarzschild radius' with 'Schwarzschild coordinate radius'.

216, Problem 13: Replace $\ell = 4.6$ with $\ell/M = 4.6$. (So the units are correct.)

218, Problem 21 (beginning on prev. page), 4ℓ: Replace 'from the line the extension of sight' with 'from the extension of the line of sight'. (This change applies only to printings 4-7.).

229, $\ell 5$: Replace 'both at S and X' with 'both S and X' (ie delete 'at'.)

242, eq(11.12): Delete the factor of 2 so the first part of the equation reads:

$$\Delta D \approx \beta \theta_E D_S$$

Leave the inequalities alone.

243, Figure 11.6, $\ell 4$: Replace 'how close and lensing object to line of sight' with 'how close the lensing object comes to the line of sight'. (Two words changed.)

245, Box 11.1, 2ℓ from end of 3rd para.: Replace 'from few percent' with 'from a few percent'.

245, Box 11.1 1ℓ below d.: Replace 'Stephen' with 'Stefan'.

246, $\ell 8$ of first complete para.: Replace 'by an amount that depends on their velocity .... from the observer' with 'by an amount that depends on the velocity of the emitting matter and whether it is moving toward or away from the observer.' (its the matter that has the relevant velocity not the photons).

247, $\ell 2$ above (11.16): Replace 'Schwarzschild radius' with 'Schwarzschild coordinate radius'.

247, $\ell 2$ from bottom: Replace 'for matter emitted at' with 'for photons emitted at'.

248, ℓ2: Replace "(2) when the photon .... $-\pi/2$." with "(2) at angles $\pm\phi_t$ where a photon emitted tangentially to the disk reaches the observer. (The angles $\pm\phi_t$ will be close to $\pm\pi/2$ but slightly different because of the bending of light.)"

248, 1ℓ below (11.21): Replace "At the points .... heading to the observer vanishes." with "The radial component $p^r(r,\pm\phi_t)$ vanishes because $\pm\phi_t$ are angles where photons emitted tangentially to the disk reach the observer."

248, eq (11.22): Replace $\pm\pi/2$ with $\pm\phi_t$ in two places.

249, ℓ5 from bott. of text: Replace 'for disk' with 'for the disk'.

258, ℓ3 of 1st full para.: Replace 'defined for by' with 'defined by'.

261, box 12.2, ℓ2 from end: Replace M/R^2 with mM/R^2 ie add a m.

263, ℓ2, Figure 12.3: Replace 'Schwarzschild radius with Schwarzschild coordinate radius'.

263, eq 12.7b: The exponent in the second term on the right should be 3/2 not 2/3 and the equation would look better if the first two terms on the right were interchanged, viz:

$$\frac{v(r)}{2M} = -\frac{2}{3}\left(\frac{r}{2M}\right)^{3/2} + \frac{r}{2M} - 2\left(\frac{r}{2M}\right)^{1/2} + 2\log\left[1 + \left(\frac{r}{2M}\right)^{1/2}\right]$$

264, ℓ1 of text: Replace 'hits in the singularity' with 'hits the singularity'.

266, ℓ2 from bottom on 2nd para. in Box 12.3: Replace 'Schwarzschild radii' with 'Schwarzschile coordinate radii'.

266, 2ℓ above (12.8): Replace $v \approx t_R - r_R$ with $v_R \approx t_R + r_R$.

271, ℓ4 from end of 1st para: Replace 'world line of the collapsing star' with 'world line of the collapsing star's surface'

*272, ℓ2:* Replace 'increasing r is spacelike' with 'increasing r is a spacelike'.

273, ℓ4: Replace 'Example 12.3' with 'Example 12.1'.

274, ℓ4 from bottom of text: Replace 'leading the increasing' with 'leading to the increasing'.

276, Problem 1, ℓ1: Replace 'make one He nuclei' with 'make He nuclei'.

276, Problem 2, part b: Replace period by ? at end.

277, Problem 9, ℓ4: Replace 'directions' by 'direction'.

278, Problem 16, ℓ4: Replace 'for graviational redshift' with 'for the gravitational redshift'. Replace 'for the redshift' with 'an expression for the redshift'.

281, 2nd bullet, ℓ2: Replace 'center of' with 'centers of'.

282, Sect. 13.1, ℓ6: Insert dash — between 'black hole' and 'and a normal star' ie so it reads 'black hole — and a normal star'.

287, Figure 13.4, 5ℓ from bott.: Replace 'The projection' with 'The projections'. Also Change 3×10^6 to $3.7 \pm 0.2 \times 10^6$. (That's a more accurate current number.)

287, Figure 13.4, bottom line: Replace 'location of radio' with 'location of the radio'.

291, Figure 13.6: Append the following sentence to the end of the caption if there is space: 'The directed line segments in this figure are only schematic representations of the directions of the vectors at the two points [cf. Section 7.8].'

291, Figure 13.6: Replace the figure with one where the vector $\bar{\mathbf{p}}$ is reoriented as in the following figure:

,
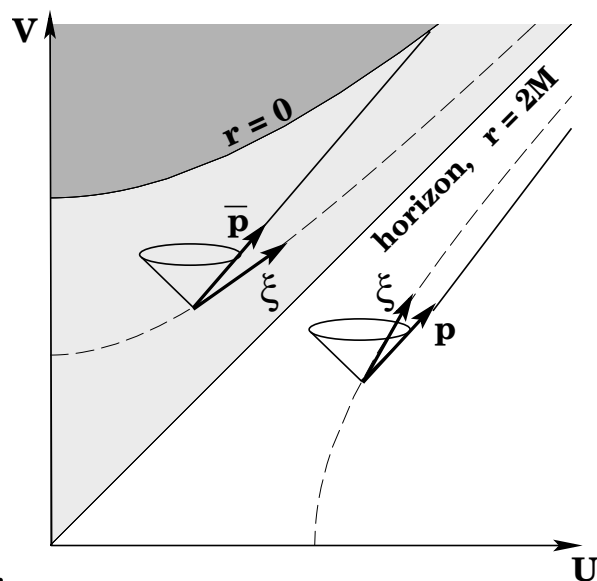
Explanation: (not for inclusion in the text.) Suppose $-\mathbf{p}\cdot\xi > 0$ so that the energy of the outgoing particle is positive when it reaches infinity. Since ξ is *timelike* outside the black hole this means that $p^t > 0$ as shown. Conservation of energy implies $\bar{\mathbf{p}}\cdot\xi = -\mathbf{p}\cdot\xi > 0$. Since ξ is *spacelike* inside the black hole this means that $\bar{p}^t$ is also positive as shown in the new figure but not in the old.

292 $\ell2$ from end of first complete para: Delete 'spherical' so it's 'A black hole ...' (Its true in general although the analysis is only for the spherical case.)

293, $\ell2$ below 13.13: Replace 'Stephan' by 'Stefan'.

299, Figure 14.1: Replace sentence 'The scale .... on the page'. with 'Vertical (time) distances have been compressed by a factor of five with respect to the horizontal (space) distances to get the diagram to fit on the page.'

300, $\ell2$, Figure 14.2: Replace 'Schwarzschile radius' by 'Schwarzschild coordinate radius'.

305, Box 14.1, $\ell1$ of text: Replace 'In late 2002, NASA expects to launch' (printings 1-2) or 'In the near future, NASA expects to launch' (printing 3 and 4) with 'On April 20, 2004 NASA launched'. (Its been launched finally!)

306, eq. (14.28): Reverse the bottom pairs of indices on the Christoffel symbols so they read:

$$(\Gamma^x_{yt})_{z-axis} = \cdots , (\Gamma^y_{xt})_{z-axis} = \cdots ,$$

(The Christoffel symbols are symmetric so it doesn't make any difference, but this way the statement above 'non-vaniching Christoffel symbols that occur in the gyroscope equation (14.6)' is literaly true.)

308, 3ℓ above the end of the text: Replace 'along gyro' with 'along the gyro'.

309, Problem 4: (a) Replace 'an observer ..... respectively.' with 'an observer who is moving with the spin and keeps the spatial parts of the two spacelike basis vectors $\mathbf{e}_{\hat{1}}$ and $\mathbf{e}_{\hat{3}}$ pointing along the r and ϕ directions respectively.'

(b) The equations should be replaced by:

$$s^{\hat{1}} = s_* \cos(\Omega' t), \qquad s^{\hat{3}} = -s_* \sin(\Omega' t) \, .$$

(A minor matter is that on the preceding page the second line of the problem doesn't need to be indented.)

309, Problem 10: Replace 'geodetic and frame dragging' with 'geodetic precession and frame dragging effects'.

312, ℓ7 from bottom: Replace 'when ρ vanishes and when Δ vanishes' with 'when ρ or Δ vanishes.'

316, ℓ2 : Replace 'as the horizon' with 'as a $t =$const. slice of the horizon'.

316, Figure 15.2: Replace '...embeddable in flat space.' by '...embeddable in flat space as an axisymmetric surface.'

316, ℓ2 from bott.: Period after '193'.

319, Example 15.2, 3rd para., ℓ3: Replace 'analogous to scattering' with 'analogous to a scattering'.

319, Example 15.2 2nd para, ℓ3 from bottom: The equation should be $\delta J = m\ell$, ie replace l with ℓ.

319, eq(15.23): The factor
$$\left(1 - \frac{a^2}{r^2}\right)$$

should be
$$\left(1 + \frac{a^2}{r^2}\right)$$

ie one change in sign.

321, ℓ3 above bott.: Replace '$e - 1$' with '$1 - e$'.

327, Box 15.1, 2nd to last para.: Remove comma after 'electric' in 'electric, and magnetic'.

329, Problem 11: Add an [A] label at the start.

329, Problem 13, ℓ3: 'that' repeated.

330, Problem 16: Replace 'how long' with 'the maximum time'. (Clearer).

335, Figure 16.1: In the left hand figure change x_A to 0 (zero) and x_B to L_*. (More consistent with caption.) In the right hand figure locate 'L_*' *midway* between the maximum left-right excursions of the wiggly line.

335, Figure 16.1 capt. If there is space, replace 'initially at' with 'initially at coordinates' and 'frequency of the wave' with 'frequency of the wave as the right hand figure shows.' (clearer what the difference between the diagrams is.)

337, Figure 16.2: In the first figure insert a ∘ at the center like in the other figures. (It represents the fiducial mass.)

337, Figure 16.2, capt. ℓ5: Replace 'are shown' with 'is shown' (to agree with 'behavior'.)

337, Figure 16.2, capt, ℓ7: no comma after 'X-direction'.

338, 2nd para., ℓ3: Replace (3.5) with (3.4).

338, eq.(16.14): The signs should be reversed in the second of these two equations so it reads:
$$y = \frac{1}{\sqrt{2}}(-x' + y').$$

339, 3ℓ above (16.18a): Replace 'the length of ' with 'twice the lengths of'. (The optical path length is twice the lengths of the arms.)

339, eq(16.18a) and b: in *both* equations replace $L_{(x)} - L_{(y)}$ with $2(L_{(x)} - L_{(y)})$ so that for example (16.18a) reads:

$$\Delta L \equiv 2(L_{(x)} - L_{(y)}) = n\lambda, \quad n = 0, 1, 2, \cdots \quad \text{constructive interference}$$

(The optical path is twice the lengths of the arms.)

345, Problem 10: Replace 'electric field' with 'electric fields'.

345, Problem 11: Replace 'in potential' with 'in the potential'. Replace 'and that corresponding' with 'and that the corresponding' .

345, Problem 12: The factors of c are wrong. It should be '...momentum density multiplied by c^2.' and '... energy density divided by c.'

350, Figure 17.3, capt. ℓ3: Replace 'energy per unit time per ... frequency.' with 'energy per unit time, per unit area, per unit solid angle, per unit frequency'.

350, Figure 17.3, capt, ℓ5: Replace 'predicted the Planck' with 'predicted by the Planck.

351, Figure 17,4 capt. ℓ5: Delete comma between r and 'as'.

351, Figure 17.4, 2 ℓ from bottom: Replace 'massive the' with 'massive as the'

353, Box 17.1, ℓ6: Replace 'its' with 'it is'.

354, para 3, ℓ4: Replace 'large the' with 'the large'.

354, bott. para., ℓ2: Replace 'of *standard*' with 'of a *standard*'.

358, last para., ℓ3: Replace 'discussion in Section 12.1' with 'discussion at the beginning of Chapter 12'.

359, 1st full para., ℓ2 from bottom: Replace 'that range' with 'the range'.

359, 2nd full para., ℓ1: Insert 'in' between 'shown' and 'Figure'.

362, Figure 17.12, ℓ4: Replace 'temperature resolution of resolution' with 'temperature resolution' (ie delete 'of resolution.').

362, Figure 17.12, ℓ6: Replace 'of millikelvin' with 'of a millikelvin'.

365, Problem 3, last line: Replace $\omega/2\pi$ with $\omega/2\pi c$.

368, ℓ7: Replace 'predications' with 'predictions' (spelling).

370, 3ℓabove (18.11): Replace 'frequency of the photon' with 'frequency of a photon'.

370, bottom line: Remove the squares from the equation so that it reads '... approximately $\Delta t = a(t_0)R + (\text{terms of order} R^2)$. '

374, ℓ1: Replace 'and the ρ_r is an energy density' with 'and ρ_r is'.

374, 3ℓ above end of section: Replace '...(18.25) this happened when... ' with '... (18.25), radiation dominated the matter now visible when ...'

376, ℓ1 after (18.30): Replace 'total matter energy density' with 'energy density in matter, radiation, and vacuum'. If this won't fit just delete 'matter' instead.

383, Figure 18.5 capt, ℓ2 from end: Replace (18.48) with (18.46).

383, ℓ2 of text: Replace 'observations' with 'observation'.

383, ℓ5 of text: Replace 'observations' with 'observation'.

386, ℓ3: Replace 'analog' with 'analogs' (to agree with coordinates).

389, ℓ4 above end of first full para.: Replace 'impossible determine' with 'impossible to determine'.

390, last line in Example 18.2: Replace $t \sim 180$ s, or the first three minutes.' with $t \sim 130$ s, or the first few minutes.'. (Multiplication now correct.)

396, Problem 18.3: Add at the end of last sentence 'and discuss the conditions under which it is finite.'

397, Problem 14: Replace 'Calculate these the angle subtended by an object a size' with 'Calculate the angle subtended by an object of size'

398: Problem 25: Replace 'Estimate the value of Ω_v that would' with '[C] Is there a value of Ω_v that would '. Replace period at end with ?.

399, Problem 27, last line: Replace 'has even negative pressure' with 'has negative pressure *or* energy density'

399, Problem 29: Replace 'every FRW model' with 'every FRW model which contains some matter or radiation' (It's not true if the matter and radiation are both zero.)

408, 2ℓ above (19.12): Replace 'follows from (19.11)' with 'follows from (19.11), (19.10) and (19.7)' (more explicit).

410, last lines of footnote: Delete the sentence 'An expansion in Legendre ... of the line.' (turns out to be confusing to some.)

411, ℓ2 after (19.15): Replace 'approximately 2°' with 'a few degrees'. (The estimate is not that accurate.)

412, Box 19.2, 6ℓ from end: Replace 'may' by 'can'.

414, Problem 4: Add a leading '[A]'.

435, ℓ2 after (20.61): Replace 'particle' by 'observer'.

436, ℓ2 of footnote: The superscripts on the Γ's in the first relation should be ϕ's not θ's so it reads:
$$\Gamma^{\phi}_{\phi\theta} = \Gamma^{\phi}_{\theta\phi} = \cot\theta$$

438, Box 20.1, eqn(n): The first partial derivative should be with respect to x^3 not x^2 so it reads:
$$\left[\frac{\partial}{\partial x^3}\left(g^{1/2}_{22}V^{\hat{2}}\right)...\right]$$

442, Problem 9: Replace 'in a another' with 'in another' (delete 'a').

444, Problem 19: Add classification [C]. Beginnng with 'these normal....'' replace as follows: 'these normal vectors satisfy $\nabla_\ell \ell = \kappa\ell$ where κ is some function of the x^α. Show that the equation for null geodesics (8.42) can be put in this form by using a parameter that is not an affine parameter, thus showing that ℓ is a tangent to a null geodesic.'

444, Problem 20c: Replace 'linear combination' with 'linear combination with constant coeffecients'.

444, Problem 26: Replace 'Schwarzschild radius' with 'Schwarzschild coordinate radius'.

453, 1ℓ below (21.26): Should be 'when calculated with (21.25)' (insert 'with').

461, 1ℓafter (21.50): Replace 'functions of the same small..' with 'functions whose derivatives are of the same small...'

462, ℓ3 from bottom: Add '=0' to the end of the equation so it reads:

$$\ldots h'_{\alpha\beta} = 0$$

464, eq(21.60): Add an '=0' to the end so it reads

$$\cdots = -\mathbf{k} \cdot \mathbf{k} f = 0$$

468, Problem18: (a) Delete '(for some redefined r)'. (b) Replace '$f(t)$' by '$h(t)$' in two places. (So as not to get confused with the previous $f(t)$.)

469, Problem 19: (a) Replace (a) with the following 'For a time independent *static* source (no velocities) argue that it is possible to choose coordinates so the metric perturbations $h_{\alpha\beta}$ are unchanged by $t \to -t$ and that this means $h_{it} = h_{ti} = 0$.

471, ℓ5: Replace 'on the left' with 'on the right'.

475, 2ℓ below (22.5): Replace 'A flux of energy .... example of a box... ' with 'A flux of energy is the same thing as a momentum density so that generally $T^{tx} = T^{xt}$,' A simple example is a box ...'. Replace the last line in this para. 'Thus ... (22.17)' with 'The symmetry $T^{tx} = T^{xt}$ is explicit in (22.17).'

480, 3ℓ above (22.39): Replace the sentence 'There is some .... to curved spacetime.' with 'A straightforward but not unique way of generalizing a flat spacetime stress-energy tensor to curved spacetime is to replace the flat metric by $g_{\alpha\beta}$. (The previous sentence was correct, but probably intelligible only to experts. Let me know if this doesn't fit and I'll rewrite.)

484, 2ℓ above (22.7): delete the comma between 'vectors' and 'as'.

494, ℓ2 from end of 1st para.: Replace 'emitted' by 'received' so it reads 'The retarded wave is received *after* the event that is it's source.

496, 2ℓ above (23.23): Insert 'the' between 'obtain' and 'following'.

509, Figure 23.3: Replace the last sentence 'The effects ... Earth' with 'The effects of gravitational waves have thus been detected in the universe, although gravitational waves have not yet been directly received at Earth.'

512, Problem 11: Add after '... the positive z-axis.' as follows: '... the positive z-axis in the Lorentz gauge used in (23.21). Find the same perturbation in the TT-gauge appropriate for the z-axis and evaluate the power in gravitational waves emitted along the positive x-axis.'

513, Problem 14: Replace 'Suppose velocity' with 'Suppose the velocity' (insert 'the'.)

513, Problem 18: Replace 'Using' with 'Use'.

514, Problem 19b: Replace 'out to edge' with 'out to the edge' (insert 'the').

516, ℓ3 in 24.1: Replace 'particles' with 'identical particles'.

516, ℓ5 in 24.1: Replace 'any two fermions' with 'any two identical fermions'.

516, ℓ2, 2nd para. in 24.1: Replace 'fermions' with 'identical fermions'.

518, ℓ2 above (24.5): Replace 'for a gas of $\mathcal{N}$ fermions' with 'for a gas of $\mathcal{N}$ identical fermions'.

519, 2ℓbelow (24.7): Replace 'box to small' with 'box to a small' (insert 'a').

527, Figure 24.6, capt. ℓ2: Replace 'The' with 'the'.

527, ℓ2 of text: Replace 'result' with 'results' (to agree with 'family'.)

534, ℓ5 from end of box: Replace 'Chapter 5.5' with 'Section 5.5'.

535, 2nd bullet, ℓ2: 'have' repeated.

541, para. 1, ℓ3: Replace 'that mass' with 'that the mass'.

541, para 1, ℓ5: Replace 'that mass' with 'that the mass'.

541, para. 2, ℓ5 from end: Replace 'prespective' with 'perspective' (spelling).

542, ℓ3: Replace 'intertial' with 'inertial' (spelling).

542, first full para. ℓ8 from end: Replace 'intertial' with 'inertial' (spelling).

547, Riemann Curvature: The equation for $R_{\hat\theta\hat\phi\hat\theta\hat\phi}$ has the wrong overall sign. It should read:

$$R_{\hat\theta\hat\phi\hat\theta\hat\phi} = (1 - e^{-\lambda})/r^2.$$