The following is an errata for the text *Quantum mechanics and Path Integrals* by R. Feynman edited by A. Hibbs (1965) Mc Graw Hill, New York.

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If you have any additions, questions, comments or corrections please feel free to send them to me: tsh@mathematicuslabs.com

Last update: 21st of March-2002 Tim Hatamian, Mathematicus Laboratories

Chapter-2

2.1)Page-28, Eq (2-9): should read (add parentheses around the terms involving the x-end-points):

$$S_{cl} = \frac{m\omega}{2\sin\omega T}\left[(x_a^2 + x_b^2)\cos\omega T - 2x_a x_b\right]$$

Chapter-3

3.1) Page 63, the text in the parentheses just before Eq3-60 should read "Prob. 3-7".

3.2) Page 64, Eq 3-62 last term should read: $\frac{f^2 T^3}{24m}$

3.3) Page 64, Eq 3-63 the first term in the exponent should omit ω.

3.4) Page 72, Eq 3-88 The right hand side is missing an overall factor of **1/A**. The sum in the exponent is missing a factor of **T/2**.

3.5) Page 73, Eq 3-89 The right hand side is missing a factor of $\mathbf{(2/\epsilon T)^{1/2}}$. On the left hand side the exponent is missing a factor of **T/2**.

3.6) Page 73, Eq 3-94 should be unitless. Computation shows that the l.h.s. should have a denominator of: $\mathbf{(2/\epsilon T)^{N/2}}$.

Chapter-6

6.1) Page121, Eq 6-7 The first occurrence of the V[*x*(*s*)] should read; V[*x*(*s*),*s*].

6.2) Page122: Merely a poor choice of editing and typesetting. The brilliant argument on page 122 leading to Eq(6-11) does not have the full immediate impact on most students that it should, since there is no explicit mention of the fact that the path integral is being reduced to an ordinary integral. Aside from the explicit mention of the action being taken, had the contents of pages 121 and 122 faced each other the presentation would have further improved.

6.3) Page 136, Fig 6-8: The term $R^2 d\sigma$ is incorrect. The solid angle is $d\sigma/R^2$, the area is $d\sigma$. The area at the point is then $(R_a+R_b)^2\, d\sigma$. The ratio of the latter term and $R^2\, d\Omega$ (area at point b) gives Eq 6-43 which is correct.

6.4) Page 137, Eq 6-46 the lhs is a differential cross section i.e. $d\sigma/d\Omega$

6.5) Page 138, Eq 6-53 the lhs is a differential cross section i.e. $d\sigma/d\Omega$.

6.6) Page 151, Eq 6-85: Personally I find the Fermi Golden rule not very useful, but if presented it must at least be qualified that it good only to $O(V^2)$ and then, when $V \neq V(E \text{ or } p)$.

6.7) Page 152, Eq 6-92: Same as above and that it is good for elastic scattering.

6.8) Page 153, Eq 6-96: The denominator term $d\pi$ should be changed to 2π.

6.9) Page 153: The very last sentence on the page should start with the word "By" instead of "In".

6.10) Page 155, Eq 6-101 The first term on the rhs, lower integration bound should be $-\delta T/\hbar$.

6.11) Pages 156&157, the notation has switched from δT to ΔT.

6.12) Page 157, Eq 6-109: The term multiplying $i\pi$ should be $\delta(E_k-E_m)$_.

Chapter-7

7.1) Page 165, Eq 7-2: the argument of the wave function χ^* should be x_2 not x_0.

7.2) Page 169, Eq 7-16: A term V(3) should be inserted between $K_0(4,3)$ and ψ.

7.3) Page 169, Eq 7-18: A symbol χ should be inserted in the “bra”(so to speak!) on the rhs.

7.4) Page 172, Eq 7-27: The leading minus sign MAY be incorrect.

7.5) Page 172, second line of text after Eq. (7-27): The referred equation should be (7-24) instead of Eq. (7-14).

7.6) Page 172, Eq 7-29: The last term before the ellipsis in the square brackets should contain the variation of S not s.

7.7) Page 172, Eq 7-30: The rhs term in the brackets should contain the variation of S not s.

7.8) Page 180, Eq 7-59: The term involving $\delta(t-s)$ should multiply <1>.

7.9) Page 190, Eq 7-107: The last two terms are functions of the *vector* $\mathbf{r}_k$.

Chapter-8

8.1) Page 199, Eq 8-7: The prefactor should be $(2^n n!)^{-1/2}$.

8.2) Page 200, Eq 8-10: The exponent of **exp** should be entire remainder of the lhs. Apply brackets. Also, since the x variable is complex, its squares should read $|x|^2$ and the cross terms must read $x_1{}^* x_2$. Note that this observation applies to ALL further occurrences of x throughout chapter-8 if they are intended as complex.

8.3) Page 200, Eq 8-12: All three occurrences of the exponent **2iωT** have the wrong sign, they should read: $e^{-2i\omega T}$.

8.4) Page 201, Eq 8-15: The first occurrence of the factor $(1+ \frac{1}{2} e^{-2i\omega T}+\ldots)$ is missing the indicated ellipsis.

8.5) Page 201, Eq 8-18: The scale factor is missing a square root, it should read: $(m\omega/\pi\hbar)^{1/2}$.

8.6) Page 201, Eq 8-19: The scale factor is missing a square root, it should read: $(2m\omega/\hbar)^{1/2}$.

8.7) Page 213, first line of text after Eq 8-68: The reference to the index n is incorrect; it should read $j=N$.

8.8) Page 216, Eq 8-78: There is much ambiguity regarding the number of terms in the sums over the normal coordinates Q_α on this and the next page. First if they are complex then the number of modes is half of the N original real coordinates.

8.9) Page 217, Eqs. 8-83 and 8-84: As in item 8.8, N may need to be redefined to be consistent with that defined on page 214. Furthermore, If α starts at 0 then upper limit of the sum must be N-1. In all it appears that a consistent range for the index α is $[1,N/2]$.

8.10)Page 222, Eq 8-109: The rhs should read: $c^2\, (d^2 a \,/\, dx^2)$.

8.11)Page 229, Eq 8-132: The exponent is missing a density factor ρ.

8.12)Page 231, Eq 8-133: The third terms in the square brackets should be proportional to ϕ^2.

8.13)Page 233, Eq 8-137: The exponent has the wrong sign. Also the first wave function in the integral should be conjugated: $\phi_m{}^*$.

Chapter-9

9.1)Page 238, Eq 9-12: The integration over all k-modes $(\int \ldots d^3k \,/\, 8\pi^3)$ is missing on the rhs.

9.2)Page 239 prob 9-3: The potential is given by: $\phi = \Sigma_i \; e/|r-q_i|$.

9.3)Page 240 Eq 9-21: The index of j on the rhs should be 1k.

9.4) Page 240 Eq 9-25: Both sums on the rhs have the wrong sign.

9.5) Page 241 Eq 9-27: The term first term on the second line must be an absolute square: $|\phi_k|^2$.

9.6) Page 241 Eq 9-28: A minus sign must apply to the whole of the rhs.

9.10) Page 246 in the paragraph above Eq 9-43: The expression in this paragarph should *multiply* the prefactor with the operators.

9.11) Page 247 Prob 9-8: The expression for ϕ_1 should contain a factor $\sqrt{2}$ on the rhs.

9.12)Page 249 Eq 9-52: replace h with $\hbar$.

9.13)Page 249 Eq 9-56: The last occurrence of the index **b** is a subscript.

9.14) Page 250 Eq 9-60: The symbol $\mathcal{D}q_i$ is to be understood as $\Pi_i \, \mathcal{D}q_i$.

9.15)Page 9-61 Eq 9-61: Both differentials on the normal modes must read as path differentials $\mathcal{D}$.

9.16)Page 252 Eq 9-67: add an ***i*** multiplier to both rhs's.

9.17)Page 253 Last paragraph: **j** is intended as $\mathbf{j}_k$.

9.18) Page 254 Eq 9-71: The sum over N should exclude N=M.

9.19) Page 257 Text just below Eq 9-78: The first symbol should read δE".

9.20) Page 258 Eq 9-81: The exponent ***iωt*** should have a + sign.

9.21) Page 258 Eq 9-82: The exponent ***i*ω*(t-s)*** should have a **-** sign.

9.22) Page 258 Eq 9-83: The exponent **(k.R-ω*t*)** should have an ***i*** multiplier.

Chapter-10

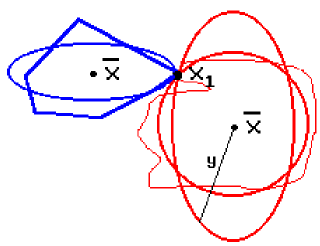
10.1) Page 271, Eq 10-20: The lhs should be dQ/dV.

10.2) Page 272, Eq 10-25 should read: $U = F + T\mathrm{S}$

10.3) Page 276, Eq 10-44: The term *Sinh*(ωβħ) in the exponent should NOT be squared.

10.4) Page 281, Eq 10-55: The last term (*iky*) in the Hamiltonian has the incorrect units. It must be replaced by (*iky*)/β. This ostensibly due to some sloppiness in dropping the divisor correctly shown in Eq(10-50) but later dropped in two unnumbered Eqs immediately following Eq(10-53)as well as the delta function in the paragraph starting with "We now...".

10.5) Pages 280-281: The presentation of this very important treatment is to some extent botched in an apparent attempt to save a page of explanations. Firstly, It would be terribly helpful for the reader to see a graphical exposition of the method being applied:



The caption might read: "*The closed paths at each x are separated into groups based on their centroid. All path of a group have the same centroid $\bar{x}$. We sum over the paths in each group, then sum over the groups*".

As such, several important equations in the treatment are simply incorrect if only (manifestly) by their discrepant units: Eq's(10-51) and (10-53): The expression for Z must contain the sum over initial states (in this case over the x_1 variable).

Once the integration over the initial points is added, Z acquires a new unit of length(or volume) which is ostensibly incorrect. The latter error would be corrected if the method outlined in the drawing were implemented carefully (Fortunately these two wrong are related but in the end fail to cancel each other as we shall show).

If we implement the grouping idea we need to make a double sum but the two variables x_1 and $\bar{x}$ are not entirely independent. Therefore a constraint is clearly needed. We also see that if the constraint were to have the units [$1/x^d$], we will be ok on units. This is jointly achieved by the delta function. Therefore at the very beginning (Eq10-51) we must replace

$$\int dx_0 \rightarrow \int dx_1 \int d\bar{x}\, \delta\left(\frac{1}{\beta\hbar}\int_0^{\beta\hbar} (x(t) - \bar{x})dt\right)$$

Once the *y* shorthand is introduced the correct form of Eq(10-55) will emerge as follows:

$$Z = \int dx \int dY \int \frac{dk}{2\pi}\int_Y^Y Dy(u)\left\{\mathbf{exp}\left[-\frac{1}{\hbar}\int_0^{\beta\hbar}\left(\frac{m}{2}\dot{y}^2 + \frac{1}{2}V''y^2 + \frac{iky}{\beta}\right)du\right]\right\}$$

$Y = y(0) = y(\beta\hbar) = x_1 - \bar{X}$.

10.6) Page 281, prob.(10-5): If the correct form of Eq(10-55) is used no extra comment to the effect of summing over *y* is needed. Also it is useful to note that throughout page 281 $V''(0)=V''(y=0)=V''(\bar{X})$_ which is a constant when summing over *y*.

10.7) Page 282, and page *xiii*: Insert a heading for the topic, "The effective potential method" starting on page 282.

10.8) Page 283, Eq(10-59): A minus sign must multiply the exponent involving *m*.

10.9) Page 283, Eq(10-62): The normalization of $1/\lambda = (2\pi\beta\hbar/m)^{1/2}$.

10.10) Page 285, First expression is unnumbered. It must contain $\dot{y}^2$ instead of y^2.

10.11) Page 285, Eq(10-66): leaving a free particle path integral in the equation is a bit silly. Also (for sticklers to detail), the font on the ħ is different than the rest of the book.

10.12) Page 286, Eq(10-70): The term ħ must be squared.

10.13) Page 286, Eq(10-74): The first integral in the exponent (the kinetic energy term) must contain:

(i) A discrete sum over *i* and,

(ii) the term $\dot{R}^2$ must be labeled with *i*.

10.14) Page 289, Eq(10-77): The integral sign for $d^N\boldsymbol{R}(0)$ is missing.

Chapter-11

11.1) Page 303: six lines above the start of section 11-2. The symbol for density matrix should be ρ not β

11.2) Page 303: four lines above the start of section 11-2. Change the verbiage "*enters into a*" to "*enters as a* ".

11.3)On the lhs of equations 11-25, 11-26, 11-28, 11-30, and 11-32, change all references to E'_0 to F'.

11.4)Page 308 Eq 11-36: The minus sign in the exponent must apply to the *both* integrals. Apply brackets.

11.5)Page 313 Eq 11-60: The sign of the first term on the rhs should be minus.

11.6)Page 314 Paragraph above Eq 11-62: The reference to Chap-2 should changed be to Chapter-3. Similarly, in the first paragraph of Page-315.

11.7)Page 316 Paragraph above Eq 11-78: The reference to (11-6) should changed be to Eq (11-61).

Chapter-12

12.1)Page 326 Eq 12-14: The symbol $\mathcal{D}k$ is to be understood as $\Pi_i dk_i/2\pi$.

12.2)Page 331 Eq 12-39: The scale factor must contain σ^2.

12.3)Page 335 Paragraph above Eq 12-57: The reference to (12-26) should changed be to Eq (12-56).

12.4)Page 335 the exponent in both Eqs (12-56) and (12-57) should have a single integral.

12.5)Page 336 Eq 12-61: The denominator in the exponent must contain $\boldsymbol{P}$ instead of Φ.

12.6)Page 338 Paragraph above Eq 12-68: Replace $\boldsymbol{G}$ with $\boldsymbol{W}$.

12.7)Page 340 Eq 12-77: This result can only be obtained by integrating θ over $-\infty$ to $+\infty$. But these are not the correct range of θ , but that of $tg\theta$. This poses no problem since $dx/dt = tg\theta$ in the first place and we must correct the formulas at the end of the first paragraph on pg 338. The discussion should have retained $tg\theta$ throughout instead of θ . This change simply propagates through the ensuing computation, and does not affect the structure of either 12-76 or any part of 12-77.

12.8)Page 346 Eq 12-96: The differential on Q_f should be the simple type: dQ_f.

12.9)Page 349 Eq 12-108: The lhs is missing the matrix element: $|\boldsymbol{q}_{nm}|^2$.

12.10)Page 350 Eq 12-110: The symbol $(\boldsymbol{E}_m\text{-}\boldsymbol{E}_n)$ is the independent variable of the function $\boldsymbol{a}_R$.

12.11)Page 350 Eq Paragraph above Eq 12-112: The reference to (12-32) should changed be to Equation (11-45).

Appendix

A.1) The denominator on the r.h.s of form-4 is NOT part of the exponent; it applies to the whole expression.

A.2) the argument of the Gamma-function has a denominator of m not n.