Supplement

to

Studies in Radar Cross-Sections

I - XV

Errata and Addenda

Compiled by

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1 September 1955

WR-27-S

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I. INTRODUCTION

This supplement contains all the errata and addenda to the first fifteen papers in the series "Studies in Radar Cross-Sections" as of 1 September 1955. Inasmuch as several of the papers in the series have been reprinted and some of the corrections listed have been made in the reprinted versions, errata are listed separately for each printing.

The material of this supplement is arranged so that the errata and addenda for each paper can be removed from the supplement and attached to the paper itself.

Much of the unclassified material contained in these reports has also been published in Journal articles and thus the errata and addenda for these related Journal articles is included.
II. STUDIES IN RADAR CROSS-SECTIONS I - XV:

Errata & Addenda


Errata in First Printing

Pg. 27-29 & Appendix B

Pg. 37, Eq. 120

Pg. 39, Eq. 135 & Eq. 136

Pg. 42, Eq. 146

Pg. 46, 5th line above table at bottom of page

Pg. 46

Pg. 50, Eq. A-12

d_{n}^{ml} = 0 whenever (l + n) is odd

Delete the underline from $S_{T_{z}}$

Delete the factor $\frac{\sqrt{k} \frac{2}{r} - \frac{1}{kr}}{2}$

The factor (n-4)! in the fifth term on the right should be replaced by (m-4)!

Delete the ($o_{O}$)

Add the following footnote:
Some of the numerical values appearing on this page are in error. These numbers will be corrected and additional numerical work on the problem will be presented in a forthcoming report, UMM-126.

The Eq. should read

$$s_{\psi} = T \frac{a_{o}}{r} e^{-jkr}$$
The Eq. should read

\[ T = \frac{1}{c_\ell} \sum_{\ell = 0}^{\infty} (j + 1) A_\ell \left[ \frac{d}{d\xi} R_\ell^{(1)}(\xi) \right]_{\xi = \xi_0} A_\ell \left[ \frac{d}{d\xi} R_\ell^{(4)}(\xi) \right]_{\xi = \xi_0} \]

**Errata in Second Printing**

None

**Addenda**

None

Errata in First Printing
None

Errata in Second Printing
None

Addenda
None

Errata in First Printing

Pg. 6
Delete the second sentence of the footnote

Pg. 14, 3rd line from bottom of page
Replace \[ \lim_{\rho \to \infty} (- - -) = w \]
by \[ \lim_{\rho \to \infty} (- - -) = W \]

Pg. 34, line above Eq. A-6
Replace \ldots is not an integer.
by \ldots is not a non-zero integer.

Pg. 35, Eq. A-7
A factor of 4 is missing; the Eq. should read
\[ u = 4 \left( \frac{\pi}{2 \kappa r} \right)^{1/2} \sum_i \]

Pg. 38, line 2
Add an asterisk (*) denoting footnote after the word "non-integral"

Pg. 38, Eq. in line 6
Replace \((\theta_0 < \theta < 0)\)
by \((\theta_0 > \theta > 0)\)

Pg. 38
Add the following footnote:
With the exception of \(n_1 = 0\). In the vector case, the term for \(n_1 = 0\) vanishes, but in the scalar case this term must be taken into account.
Errata in Second Printing

Pg. 14, 3rd line from bottom of page
Same as in 1st printing

Pg. 38, Eq. in line 6
Same as in 1st printing

Addendum

Necessity of Considering Both Tip and Base Contributions for the Shallow Large-Angle Cone

The physical optics monostatic radar cross-section for the finite cone is given by

\[
\sigma = \frac{4\pi}{\lambda^2} \left| g \right|^2,
\]

where

\[
g = \frac{2\pi \tan^2 \theta_1}{(2jk)^2} \left[ -2jk z_o e^{-2jkz_o} - e^{-2jkz_o+1} \right]
\]

For large values of \( kz_o \), \( \sigma \) is dominated by scattering from the base which contributes

\[
\sigma = \pi z_o^2 \tan^4 \theta_1.
\]

(The quantities \( z_o \) and \( \theta_1 \) are defined in the following sketch.)

---

![Diagram](image.png)
As $\theta_1$ approaches $\pi/2$, and $z_o \to 0$, this expression appears to become infinite, while the cone cross-section should actually become that of the circular disc in this limit. When both the tip and the base contributions are considered, however, the cross-section remains finite and approaches that for a circular disc of radius $a$.

Consider the limit as $z_o \to 0$ and $a$ remains fixed:

$$g \to \frac{2\pi a^2}{(2jk)^2 z_o^2} \left[ -2jkz_o (1-2jkz_o) - 1 + 2jkz_o \cdot \frac{(2jkz_o)^2}{2} + 1 \right],$$

or

$$g \to \frac{2\pi a^2}{(2jk)^2 z_o^2} \left( -2k^2 z_o^2 \right) = \pi a^2,$$

the area of the corresponding circular disc, as is proper.

In investigating the region of validity for the base scattering formula given above, it is immediately obvious that the customary assumption, that base scattering alone is important for $kz_o \to 1$, is correct. For then, any increase to infinity of $\sigma$ can be obtained only by making the base of the cone infinite. The cone then approaches an infinite flat plate. In this case both the complete expression for $\sigma$ and the base scattering expression blow up as $a^4$, but the base contribution is a good approximation to the complete one.

For small $kz_o$, the region in which the base contribution becomes infinite while the total $\sigma$ does not, the base scattering cross-section should not be used to approximate the total $\sigma$.

The condition that the base contribution be a good approximation is

$$\left| -2jkz_o e^{-2jkz_o} \right|^2 \approx \left| -2jkz_o e^{-2jkz_o} e^{-2jkz_o} + 1 \right|^2$$
or

\[ 1 + \left( \frac{\sin(x/2)}{x/2} \right)^2 - 2 \cdot \left( \frac{\sin x}{x} \right) \approx 1 \]

where \( x = 2kz_0 \).

A computation based on the above condition yields the result that for \( x > 20 \), or \( k_z > 10 \), the relative error \( \left| \frac{\sigma_{\text{total}} - \sigma_{\text{base}}}{\sigma_{\text{base}}} \right| \) is less than 10%.

This computation is an indication of the range for which the complete expression may be replaced by that for the base contribution alone.

Errata in First Printing

Pg. 13, 3rd line of Eq. IV-5

Divide the first factor of this term by

\[ 1 - \exp \left[ -\frac{\pi^2 j}{2(\pi - \theta_2)} \right] \]

Pg. 39, in Fig. VI-1

The "experimental point" plotted at \( \theta_1 = 70^\circ \) should be at \( \theta_1 = 65^\circ \)

Errata in Second Printing

Pg. 39, in Fig. VI-1

Same as in first printing

Addenda

None

Errata

Pg. 1, Eq. 1
Replace $R = \ldots$ by $R_{\text{max}} = \ldots$

Pg. 6, Fig. 3
The value of 2 shown on the ordinate scale is misplaced; it should be located at the heavy ordinate line directly below. Since the ordinate scale is logarithmic, reference to the rest of the ordinate scale indicates the proper location of the misplaced 2.

Pg. 13, in legend of Fig. 6
The 2nd line of the legend should read \ldots of Focal Length $F/\sqrt{2}$.

Addenda

For additional comments relative to the finite cone see the Addenda for Studies in Radar Cross-Sections III.

Errata in First Printing

Pg. 11, Eq. 2.4-3
Replace \( \hat{k} + 2(\hat{k}) \quad . . . \) by \( \hat{k} - 2(\hat{k}) \quad . . . \)

Pg. 16,
Caption on the horizontal scale should be \( \gamma \) DEGREES

Pg. 39, Eq. 3.4-6
The last term should be \( (z + b_1)^2 \, d\phi^2 \)

Pg. 41, line below Eq. 3.4-16
Replace "For \( \phi = 0 \) . . . ." by "For \( \phi = 0 \) . . . ."

Errata in Second Printing

Pg. 39, Eq. 3.4-6
Same as in 1st printing

Pg. 41, line below Eq. 3.4-16
Same as in 1st printing

Addenda

None

This paper is replaced by Studies in Radar Cross-Sections XII; all of the data appearing in this paper appear in Studies XII together with much additional data. For additional comments relative to the finite cone see the addenda to Studies in Radar Cross-Sections III.

Errata in First Printing

Pg. 4, Fig. 2\(^1\)

The physical optics curve in the region \(0.08 < (R_o/\lambda) < 0.3\) is in error. The correct curve should pass through the following points:

<table>
<thead>
<tr>
<th>(R_o/\lambda)</th>
<th>0.08</th>
<th>0.16</th>
<th>0.24</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\sigma/\pi R_o^2)</td>
<td>0.24</td>
<td>0.80</td>
<td>1.35</td>
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</tbody>
</table>

Pg. 11, Eq. 3.2-4

Replace \(F(\beta)\) by \(\hat{F}\)

""

Pg. 12, Eq. in line 2

Replace \(\sigma(\beta)\) by \(\sigma\)

Pg. 12, Eq. 3.2-5

Replace \(\sigma_e(\beta)\) by \(\sigma_e\)

""

Pg. 12, 2nd line below Eq. 3.2-6

Replace \(\sigma(\beta)\) by \(\sigma\)

Pg. 12, 3rd line below Eq. 3.2-6

The Eq. should read

\[ -b\eta \int d\phi d\eta. \]

Pg. 21, Eq. 4.1-1

The following restriction on \(\alpha\) should appear with the Eq.:

\[ \sqrt{1/b} < \alpha < (\pi/2) - \sqrt{1/b} \]

\(^1\)The vector solution which appears on the figure is intended to be a reproduction of the theoretical sphere curve which appears in "Propagation of Short Radio Waves" by D. E. Kerr. Due to plotting errors the curve appearing on this figure is slightly in error. Reference to Kerr's book will indicate the location and magnitude of the errors.
An exponent of 3/2 is missing; the denominator should be

\[ \pi D^2 \left( (Aa)^2 + (Bb)^2 \right)^{3/2} \]

Pg. 51, line above Eq.

Replace \( \phi_t = \phi_r = 0 \) ....
by \( \phi_t = \phi_r = \phi \) ....

Pg. 51, Eq. 6.1-5

Replace \( \sigma(\theta) \) ....
by \( \sigma(\theta, \phi) \) ....

Pg. 57

In the caption for the horizontal scale: Replace \( \beta_1 + \beta \)
by \( \beta_1 + \beta/2 \)
In the legend attached to the curve itself: Replace \( \beta \beta/2 \)
by \( \beta_1 - \beta/2 \)

Errata in Second Printing

Pg. 4, Fig. 2
Same as in 1st Printing
Pg's. 11 & 12
Same as in 1st Printing
Pg. 28
Same as in 1st Printing
Pg. 57
Same as in 1st Printing

Addenda

(1) For additional comments relative to the finite cone see the addenda for Studies in Radar Cross-Sections III.

(2) The Nose-On Cross-Section of an Ogive of Half-Angle \( \alpha \)

Since an ogive of half-angle \( \alpha \) obtained by rotating an arc of a circle
of radius $R$ about its chord becomes a sphere of radius $R$ when $a$ is set equal to $\pi/2$, the nose-on cross-section of an ogive should approach the cross-section of a sphere as $a \rightarrow \pi/2$. The nose-on cross-section formula for an ogive, given in Studies in Radar Cross-Sections VIII, does not, at first glance, seem to have this property.

The physical optics method employed in Studies VIII to obtain these cross-section formulas involves the assumption, among others, that the wavelength is small with respect to the characteristic dimension of the scatterer. Thus the formulas are only expected to hold for those scatterers for which $\lambda/4\pi R$ is small.

With this in mind, let us examine more closely the nose-on cross-section formula for the ogive, $\sigma(a)$, given in Studies VIII (Eq. 4.3-7)

$$\sigma(a) = \frac{\lambda^2 \tan^4 a}{16 \pi} \frac{1}{a^{1/2}} \left(\frac{\lambda}{4\pi R}\right)^{1/2}$$

and its relation to the geometric optics cross-section for a sphere, $\pi R^2$. To do this consider

$$\frac{\sigma(a)}{\pi R^2} = \left[\sqrt{\frac{\lambda}{4\pi R}} \tan a\right]^4$$

The range (in $a$) of the validity of the cross-section formula for the ogive given above indicates that,

$$\frac{\sigma(a)}{\pi R^2} < \left[\sqrt{\frac{\lambda}{4\pi R}} \tan \left(\frac{\pi}{2} - \sqrt{\frac{\lambda}{4\pi R}}\right)\right]^4$$

i.e.,

$$\frac{\sigma(a)}{\pi R^2} < \left[\sqrt{\frac{\lambda}{4\pi R}} \cot \sqrt{(\lambda/4\pi R)}\right]^4.$$
Since the function \((x \cot x)\) is always less than one for small positive \(x\), and since the limit of \((x \cot x)\) is one as \(x\) approaches zero, it follows that for a fixed \(\lambda/4\pi R\) the nose-on cross-section of an ogive as defined in Studies VIII never exceeds the geometric optics sphere answer of \(\pi R^2\). In fact, keeping in mind the range of validity for \(\sigma(\alpha)\) for the ogive, it thus appears as though the ogive answer "approaches" the sphere answer as \(\alpha\) approaches \(\pi/2\) if \(\lambda/4\pi R\) is small. This is illustrated in the following figure.

By examination of Equation 4.1-3, which applies for the sphere and Equation 4.3-5, for the ogive (see pg. 21 & 27 of Studies VIII), it is readily seen that if \(\alpha\) is set equal to \(\pi/2\) in the "ogive - integral" one obtains the "sphere - integral"\(^1\). The sphere integral can be evaluated exactly while, with \(\alpha < \pi/2\), the ogive integral must be approximated.

\(^1\)This explains the plotted points at \(\alpha = \pi/2\) on the figure.
\[ \alpha_1 = \left( \frac{\pi}{2} \right) - \left( \frac{\lambda}{4 \pi R} \right)^{\frac{1}{2}} \]
for \( (\lambda/4\pi R) = 10^{-3} \)

\[ \alpha_2 = \left( \frac{\pi}{2} \right) - \left( \frac{\lambda}{4 \pi R} \right)^{\frac{1}{2}} \]
for \( (\lambda/4\pi R) = 10^{-4} \)

THE NOSE-ON CROSS-SECTION, \( \sigma(\alpha) \), OF AN OGIVE WITH LARGE HALF-ANGLE

Errata

None

Addenda

None

Studies in Radar Cross-Sections - X: The Radar Cross-Section of a Sphere by H. Weil, (to be published).

Errata

Pg. 13, 4th line from bottom of page
Replace ....page 79.... by ....page 59....

Pg. 19, Eq. (II-5) & (II-6)
Insert brackets:
\[
\frac{d}{d\xi} \left[ (\xi^2-1) \frac{dU_{mn}}{d\xi} \right] - \ldots\ldots\ldots
\]
\[
\frac{d}{d\eta} \left[ (1-\eta^2) \frac{dV_{mn}}{d\eta} \right] - \ldots\ldots\ldots
\]

Pg. 20, Eq. II-12
Replace \ldots+ \left[ \frac{m^2}{1-\xi^2} \right] \ldots
by \ldots+ \left[ \frac{-m^2}{1-\xi^2} \right] \ldots

Pg. 36, Eq. IV-8
Replace \sigma = \ldots by \sigma' = \ldots

Pg. 37, Eq. IV-10
\( H_n(\xi_o) \) should be replaced by \( H^n_q(\xi_o) \) in second series only.

Pg. 42, Eq. V-14
Replace \(-8c^{m-1} \Gamma (...)\) by \(-8c^{m-2} \Gamma (...)\)

Pg. 43, Eq. V-20
Replace \( P_{-n-1}(\xi) \) and \( Q_n(\xi) \) by \( P_{-k-1}(\xi) \) and \( Q_k(\xi) \)

Pg. 54, 2nd line below Eqs.
Replace Ref. 26 by Ref. 30.
Pg. 55, 7th line from bottom of page
Replace Reference 28 by Reference 15.

Pg. 65, in $I_{1}^{Nn}$
Replace $S_{on}^{(1)}(\eta)$ by $S_{onN}^{(1)}(\eta)$
by $S_{on}^{(1)}(\eta)$ $S_{on}^{(1)}(\eta)$

Pg. 65, in $I_{2}^{Nn}$
Replace $S_{on}^{(1)}(\eta)$ by $S_{on}^{(1)}(\eta)$

Pg. 69, Eq. in middle of page (also in 1st line under Equation)
Replace $P_{m+n+k}^{m}(\cos \theta)$ by $P_{m+k}^{m}(\cos \theta)$

Pg. 69, last Eq. (at bottom of page)
Replace right hand side by 0.

Pg. 74, add Ref. 30

Addendum
Recent computations on the scalar cross-section of the prolate spheroid (nose-on back-scattering) indicate that the broken portion of the scalar curve shown in UMM-126 is misleading. The available values indicate that the second and third maxima, instead of becoming successively larger, actually decrease slightly from the ordinate of the first. Ordinates of both second and third maxima are slightly greater than 1.0 and less than the ordinate of the first, and that of the third is less than that of the second. Abscissas of both are approximately the same as those shown in UMM-126. No accurate values are yet available for the regions of the minima, but it appears likely that the first minimum shown is nearly correct and that the ordinate of the second should be slightly greater than that of the first. The results of these recent computations are shown in the following figure.
ACOUSTICAL BACK-SCATTERING FROM A PROLATE SPHEROID ($a/b=10$)

Errata
Pg. 47, 1st col., 6th row Replace 4" sq. 1/8" thick)
by 4" sq., 0.8" thick)
Pg. 53, Ref. A.10 Replace 308-23 by 302-23
Pg. 89, 4th col., 2nd row Replace .12 by .02

Addenda
None

**Errata**

Pg. 60, line below exp \[-E/kT\]  
E is the magnitude of the electric vector, should be replaced by:
E is the ionization potential of the atoms or molecules making up the smoke (measured in units of energy),

Pg. 143, 4th line  
\[1 - (\hat{A} \cdot \hat{B})^2\] should be replaced by  
\[1 - (\hat{A} \cdot \hat{B})^2\]

**Addenda**

None
Errata
Opposite Page i

ii, 3rd line of (1) under Intermediate objectives

Pg. 12, last line

Pg. 14, 1st line

Pg. 35, Fig. 5.2-16

Pg. 42, legend of Fig. 5.3-3

Pg. 46, 1st line of footnote

Pg. 133, legend of Fig. 6-13

Pg. 147

Pg. 148, 4th line from bottom

Pg. 149, Title of Fig. 7.1-3

Report 2260-1-T should be Studies in Radar Cross-Sections XV, not XIV; and the authors are C.E. Schensted, J.W.Crispin, and K. M. Siegel.

The words...vector wave equation should be replaced by...theory.

Replace...minute...by...half-minute...

Replace...are...by...is...

The horizontal scale of the graph should read from 0° to 100° instead of from 0° to 10° as shown.1

Replace...Envelopes...by...

Limits...

Replace...at...by...by...

Replace...Means...by...Mean

Replace...S-band...by...L-band...

The theoretical curve and the formula for it which appear in Fig. 7.1-2 are in error; see the following figure for the appropriate changes.

Replace k₂<<k₁.) by k₁ were too large.).

Insert a double asterisk at end of title and add this footnote:** K₃ is independent of λ.

1This is also the case in Fig. 5.2-18 on page 37.
\[ \sigma(\theta) = \frac{\pi}{4} \left( \frac{B}{2} \right)^2 \left\{ \left[ \tan(\alpha + \theta)U(\alpha + \theta) + \tan(\alpha - \theta)U(\alpha - \theta) \right]^2 J_0^2(kB\sin\theta) \\
+ \left[ \tan(\alpha + \theta)U(\alpha + \theta) - \tan(\alpha - \theta)U(\alpha - \theta) \right]^2 J_1^2(kB\sin\theta) \right\} \]

where \( U(x) = 0 \) if \( x \leq 0 \) and \( U(x) = 1 \) if \( x > 0 \) and \( \alpha < \frac{\pi}{2} \)

\[ \text{AZIMUTH ANGLE (\( \theta \)) IN DEGREES} \]

CROSS-SECTION OF A FINITE CONE FOR OFF-NOSE ASPECTS
Replace... \tan(\alpha+\theta) e^{\sqrt{\lambda}} \ldots by... 
\tan(\alpha+\theta) \sqrt{T_o} e... 

The limits on the integral should be z's instead of Z's

All z's in the integral should be primed

Replace... \exp \left[ (4\pi i R \sin \theta'/\pi) - 1 \right] 
by... \exp (4\pi i R \sin \theta'/\lambda) - 1 

Replace... \exp i2kR \sin \theta' ... by... 
\exp i2k z' ...

Replace = \theta by = \cos \theta; Replace z by z'

Replace 2R^2 \sin \theta' by 2R^2 \sin^2 \theta'
[is incomplete in front of J_1,]

Replace... 2R \tan(\pi-\theta) by... 
2R \tan(\pi-\theta') ...

All the \theta' should be \theta'' and the \lambda should be \lambda^2.

Add the following sentence to the end of the second paragraph. 
(Similarly, the possibility of two or more successive ionizing collisions by the same particle may be neglected.)

The quantities are in MKS units.

Replace \theta_2 < y by |\theta_2| < y.

Delete the word...and...

Replace... impossible... by... unreasonable...
Pg. 214, footnote Replace...appendix...by...section...
Pg. 226, second paragraph Replace...this appendix...by...
Section 5.3...
Pg. 246, 2nd line from bottom The element ds has been omitted from the integral.
Pg. 257, 6th line The word plan should be plane.
Pg. 263, Ref. 18 Replace...Exhaust Stream of the
Jet...by...Exhaust Stream of Jet...
Pg. 263, Ref. 13 Replace the name Wilhams by Williams.

Addenda
None

Errata

Pg. 12, Fig. 2.3-1

Pg. 73, 3rd line of Eq. from bottom of page

Pg. 79, 2nd line below Eq.

Pg. 101, Eq. in 3rd line of Section A.2.4

Pg. 103, 2nd line under Eq. A.2-19

Pg. 109, after Eq. in 3rd line below figure

Pg. 117, 2nd line above Eq. A.3-7

Pg. 119, line above Eq. A.3-15

Pg. 119, Eq.A.3-16

Pg. 119, in (A.3-17)

Pg. 124, in (A.3-34)

Pg. 133, Eq. A.3-51

The peak for vertical polarization at \( \gamma = 150^\circ \) should be approximately 1.5 m²

\[ \sigma^2 \text{ term should be added to } \]

the right hand member

Replace \( \rho = a \) by \( \rho = -a \)

Eq. can be simplified to read

\[ z = z_0 = \frac{(b - a) \sin \alpha}{1 - \cos \alpha} \]

Replace \( \hat{\beta}_1 \sin \hat{\beta}_1 \) by \( \hat{\beta}_1 \sin \beta_1 \)

add the phrase - where the principal value of the arctangent is used

Replace...Equations (A.3-1) and... by...Equations (A.3-4) and...

Replace...can replace Equation... by...can replace terms in Equation...

Replace \( \eta_2 \) by \( \eta^2 \)

Replace \( 8\pi \eta \) by \( 8\pi \eta \)

A factor of \( \cos^2 \theta \) is missing

The right hand member of the equation should be multiplied by the factor

\[ \left[ 3 \tan^{-1}(1/3) \right]^2 \]
Pg. 136, "elliptical" part of Eq. A.3-54

The right hand member of the equation should be multiplied by the factor \[ 3 \tan^{-1}(1/3)^2 \]

Pg. 153, Copy 89

This address should read:
Dr. A.D. Wheelon, Ramo-....

Addenda
None. For additional comments on the tapered wedge the reader is referred to Studies in Radar Cross-Sections XVII.
III - JOURNAL ARTICLES

Errata & Addenda


(1) Throughout this article the superscript 1 on the Legendre functions appears as a prime. That is, $P_{n_1}^1(x)$ should read $P_{n_1}^1(x)$ throughout the article.

(2) On page 172 in the line directly above Equation (2.4) the quantity $\sqrt{1-x_0}$ should read $\sqrt{1-x_0}$.


(1) The two equations which appear in the second footnote of the left column on page 308 are not clear. They may be made clear by the appropriate insertion of grouping symbols and should read as follows:

$$\left[ \frac{f^{(1)}}{f^{(2)}} \right] \left[ \frac{f^{(1)} - \rho f^{(2)}}{\left( f^{(1)} + 1 \right)} \right] = 0$$

and

$$\frac{f^{(1)}}{f^{(2)}} + \rho = 0.$$


(1) Page 46, Equation (26) - the left hand member should read

$$P_{21}^0(0) =$$

(i.e., the 2 is part of the subscript).

(2) Page 48, Equation (35) - the first factor in the second term of the left hand member should read

$$Q_{n_1}(x)$$

(i.e., the $n_1$ is a subscript).