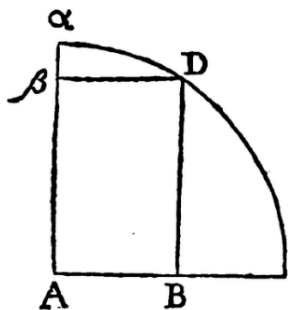


Newton's Power Series For Sine & Cosine (1669/1711)

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Victor Elgersma & Emma Ottenhof



45. If from the Arch αD given the Sine AB was required; I extract the Root of the Equation found above, *viz.* $x = x + \frac{1}{6}x^3 + \frac{1}{40}x^5 + \frac{1}{112}x^7$ (it being supposed that $AB = x$, $\alpha D = z$, and $A\alpha = 1$) by which I find $x = z - \frac{1}{6}z^3 +$

$$\frac{1}{120}z^5 - \frac{1}{5640}z^7 + \frac{1}{362880}z^9 \text{ \&c.}$$

$\sin(z)$

46. And moreover if the Cosine $A\beta$ were required from that Arch given, make $A\beta (=$

$$\sqrt{1 - xx}) = 1 - \frac{1}{2}z^2 + \frac{1}{24}z^4 - \frac{1}{720}z^6 + \frac{1}{40320}z^8 - \frac{1}{3628800}z^{10}, \text{ \&c.}$$

$\cos(z)$

Newton, Isaac, and John Stewart. *Sir Isaac Newton's Two Treatises of the Quadrature of Curves, And Analysis by Equations of an Infinite Number of Terms Explained*. Printed by James Bettenham for J. Nourse, 1745. https://books.google.it/books?id=noQ_AAAAcAAJ (p. 338)

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Finding a Power Series For $z = \sin^{-1}(x)$

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Inverting $z = \sin^{-1}(x)$ to find $x = \sin(z)$

Inverting $z = \ln(1 + x)$

43. Thus if from the Area ABDC of the Hyperbola ($\frac{1}{1+x} = y$) given I wanted to investigate the Base AB, calling the Area z , I extract the Root of this Equation $z(ABCD) = x - \frac{1}{2}x^2 + \frac{1}{3}x^3 - \frac{1}{4}x^4, \&c.$ neglecting those Terms in which x is of more Dimensions than z is desired in the Quotient.

As if I would have a Root of five Dimen-

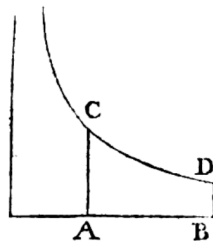
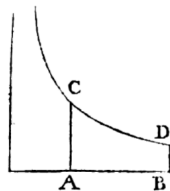


Figure 1: (Newton & Stewart, 1745, p. 337)

Goal:

$$x(z) = \alpha z + \beta z^2 + \gamma z^3 + \delta z^4 + \varepsilon z^5 \dots$$



$$\ln(1+x) \equiv z(x) = x - \frac{1}{2}x^2 + \frac{1}{3}x^3 - \frac{1}{4}x^4 + \frac{1}{5}x^5 + \dots$$

As if \bar{I} would have z to rise to five Dimensions only in the Quotient, I neglect all the Terms $-\frac{1}{8}x^6 + \frac{1}{7}x^7 - \frac{1}{4}x^8$, &c. and extract the Root of this only $\frac{1}{5}x^5 - \frac{1}{4}x^4 + \frac{1}{3}x^3 - \frac{1}{2}x^2 + x - z = 0$.

Figure 2: (Newton & Stewart, 1745, p. 337)

$$-z + x - \frac{1}{2}x^2 + \frac{1}{3}x^3 - \frac{1}{4}x^4 + \frac{1}{5}x^5 = 0$$

$$0 = \begin{cases} +\frac{1}{5}x^5 \\ -\frac{1}{4}x^4 \\ +\frac{1}{3}x^3 \\ -\frac{1}{2}x^2 \\ + x \\ - z \end{cases}$$

$$x = z + p,$$

$$0 = \begin{cases} +\frac{1}{5}x^5 \\ -\frac{1}{4}x^4 \\ +\frac{1}{3}x^3 \\ -\frac{1}{2}x^2 \\ + x \\ - z \end{cases}$$

$$x = z + p,$$

$$0 = \begin{cases} +\frac{1}{5}(z+p)^5 \\ -\frac{1}{4}(z+p)^4 \\ +\frac{1}{3}(z+p)^3 \\ -\frac{1}{2}(z+p)^2 \\ + z + p \\ - z \end{cases}$$

$$0 = \left\{ \begin{array}{l} +\frac{1}{5}z^5 + z^4p + \dots \\ -\frac{1}{4}z^4 - z^3p + \frac{3}{2}z^2p^2 + \dots \\ +\frac{1}{3}z^3 + z^2p + zp^2 + \frac{1}{3}zp^3 + \dots \\ -\frac{1}{2}z^2 - zp - \frac{1}{2}p^2 + 0 \\ \cancel{+z^1} + p \\ \cancel{-z^1} \end{array} \right. \quad \begin{array}{l} 5 - 5 = 0 \\ 5 - 4 = 1 \\ 5 - 3 = 2 \\ 5 - 2 = 3 \end{array}$$

5,4,3 ...

5

after the first Term resulting from each Quantity that is collateral to it, I add no more Terms upon the right Hand than the Index of the Dimension of that first Term wants Units of the Index of the greatest Dimension.

$$0 = \begin{cases} +\frac{1}{5}z^5 \\ -\frac{1}{4}z^4 - z^3p \\ +\frac{1}{3}z^3 + z^2p + zp^2 \\ -\frac{1}{2}z^2 - zp - \frac{1}{2}p^2 \\ +z + p \\ -z \end{cases}$$

$$\begin{array}{r}
+ \frac{1}{5}z^5 \text{ \textcircled{C}.} \\
- \frac{1}{4}z^4 - z^3p \text{ \textcircled{C}.} \\
+ \frac{1}{3}z^3 + z^2p + zp^2 \text{ \textcircled{C}.} \\
- \frac{1}{2}z^2 - zp - \frac{1}{2}p^2 \\
+ z + p \\
- z
\end{array}$$

Figure 3: (Newton & Stewart, 1745, p. 337)

$$p = \frac{1}{2}z^2 + O(z^3)$$

$$\begin{aligned}
 &+ \frac{1}{5}z^5 \text{ \Öc.} \\
 &- \frac{1}{4}z^4 - z^3p \text{ \Öc.} \\
 &+ \frac{1}{3}z^3 + z^2p + zp^2 \text{ \Öc.} \\
 &- \frac{1}{2}z^2 - zp - \frac{1}{2}p^2 \\
 &+ z + p \\
 &- z
 \end{aligned}$$

Figure 3: (Newton & Stewart, 1745, p. 337)

$z + p = x$	$ \begin{aligned} &+ \frac{1}{5}x^5 \\ &- \frac{1}{4}x^4 \\ &+ \frac{1}{3}x^3 \\ &- \frac{1}{2}x^2 \\ &+ x \\ &- z \end{aligned} $	$ \begin{aligned} &+ \frac{1}{5}z^5 \text{ etc.} \\ &- \frac{1}{4}z^4 - z^3p \text{ etc.} \\ &+ \frac{1}{3}z^3 + z^2p + zp^2 \text{ etc.} \\ &- \frac{1}{2}z^2 - zp - \frac{1}{2}p^2 \\ &+ z + p \\ &- z \end{aligned} $
$\frac{1}{2}z^2 + q = p$		

$$z + p = x$$

$$+ \frac{1}{5}x^5$$

$$- \frac{1}{4}x^4$$

$$+ \frac{1}{3}x^3$$

$$- \frac{1}{2}x^2$$

$$+ x$$

$$- z$$

$$+ \frac{1}{5}z^5 \text{ \Ô.}$$

$$- \frac{1}{4}z^4 - z^3p \text{ \Ô.}$$

$$+ \frac{1}{3}z^3 + z^2p + zp^2 \text{ \Ô.}$$

$$- \frac{1}{2}z^2 - zp - \frac{1}{2}p^2$$

$$+ z + p$$

$$- z$$

$$\frac{1}{2}z^2 + q = p$$

$$0 = \begin{cases} +\frac{1}{5}z^5 \\ -\frac{1}{4}z^4 - z^3p \\ +\frac{1}{3}z^3 + z^2p + zp^2 \\ -\frac{1}{2}z^2 - zp - \frac{1}{2}p^2 \\ +z + p \\ -z \end{cases}$$



$$0 = \begin{cases} zp^2 \\ -\frac{1}{2}p^2 \\ -z^3p \\ +z^2p \\ -zp \\ +p \\ +\frac{1}{5}z^5 \\ -\frac{1}{4}z^4 \\ +\frac{1}{3}z^3 \\ -\frac{1}{2}z^2 \end{cases}$$

$x + p = x$	$+$ $\frac{1}{2}x^5$ $-$ $\frac{1}{4}x^4$ $+$ $\frac{1}{6}x^3$ $-$ $\frac{1}{8}x^2$ $+$ x $-$ x	$+$ $\frac{1}{2}x^5$ Et c. $-$ $\frac{1}{4}x^4 - x^3p$ Et c. $+$ $\frac{1}{6}x^3 + x^2p + xp^2$ Et c. $-$ $\frac{1}{8}x^2 - xp - \frac{1}{2}p^2$ $+$ $x + p$ $-$ x
$\frac{1}{2}x^2 + q = p$	$+$ xp^2 $-$ $\frac{1}{2}p^3$ $-$ x^3p $+$ x^2p $-$ xp $+$ p $+$ $\frac{1}{5}x^5$ $-$ $\frac{1}{4}x^4$ $+$ $\frac{1}{3}x^3$ $-$ $\frac{1}{2}x^2$	

Figure 4: (Newton & Stewart, 1745, p. 337)

$$0 = \begin{cases} +z\left(\frac{1}{2}z^2 + q\right)^2 \\ -\frac{1}{2}\left(\frac{1}{2}z^2 + q\right)^2 \\ -z^3\left(\frac{1}{2}z^2 + q\right) \\ +z^2\left(\frac{1}{2}z^2 + q\right) \\ -z\left(\frac{1}{2}z^2 + q\right) \\ +\left(\frac{1}{2}z^2 + q\right) \\ +\frac{1}{5}z^5 \\ -\frac{1}{4}z^4 \\ +\frac{1}{3}z^3 \\ -\frac{1}{2}z^2 \end{cases} = \begin{cases} \frac{1}{4}z^5 + z^3q \\ -\frac{1}{8}z^4 - \frac{1}{2}z^2q \\ -\frac{1}{2}z^5 - z^3q \\ +\frac{1}{2}z^4 + z^2q \\ -\frac{1}{2}z^3 - qz \\ +\frac{1}{2}z^2 + q \\ +\frac{1}{5}z^5 \\ -\frac{1}{4}z^4 \\ +\frac{1}{3}z^3 \\ -\frac{1}{2}z^2 \end{cases} \quad \begin{matrix} 5 - 5 = 0 \\ 5 - 4 = 1 \\ 5 - 5 = 0 \\ 5 - 4 = 1 \\ 5 - 3 = 2 \end{matrix}$$

$$0 = \begin{cases} +z\left(\frac{1}{2}z^2 + q\right)^2 \\ -\frac{1}{2}\left(\frac{1}{2}z^2 + q\right)^2 \\ -z^3\left(\frac{1}{2}z^2 + q\right) \\ +z^2\left(\frac{1}{2}z^2 + q\right) \\ -z\left(\frac{1}{2}z^2 + q\right) \\ +\left(\frac{1}{2}z^2 + q\right) \\ +\frac{1}{5}z^5 \\ -\frac{1}{4}z^4 \\ +\frac{1}{3}z^3 \\ -\frac{1}{2}z^2 \end{cases} = \begin{cases} \frac{1}{4}z^5 + z^3q \\ -\frac{1}{8}z^4 - \frac{1}{2}z^2q \\ -\frac{1}{2}z^5 - z^3q \\ +\frac{1}{2}z^4 + z^2q \\ -\frac{1}{2}z^3 - qz \\ +\frac{1}{2}z^2 + q \\ +\frac{1}{5}z^5 \\ -\frac{1}{4}z^4 \\ +\frac{1}{3}z^3 \\ -\frac{1}{2}z^2 \end{cases} \begin{array}{l} 5 - 5 = 0 \\ 5 - 4 = 1 \\ 5 - 5 = 0 \\ 5 - 4 = 1 \\ 5 - 3 = 2 \end{array}$$

LINEAR in q

$$q = \frac{\frac{1}{6}z^3 - \frac{1}{8}z^4 + \frac{1}{20}z^5}{1 - z + \frac{1}{2}z^2}$$

2. When I see that p , q , or r , &c. in the last resulting Equation, is found of one Dimension only, I seek it's Value, that is to say the remaining Terms, which are still to be added to the Quotient, by means of Division; as you see done here.

Figure 5: (Newton & Stewart, 1745, p. 338)

$$1 - x + \frac{1}{2}x^2 - \frac{1}{6}x^3 + \frac{1}{24}x^4 - \frac{1}{120}x^5 \left(\frac{1}{6}x^3 + \frac{1}{24}x^4 + \frac{1}{120}x^5 \right)$$

Figure 6: (Newton & Stewart, 1745, p. 337)

$$q = \frac{\frac{1}{6}z^3 - \frac{1}{8}z^4 + \frac{1}{20}z^5}{1 - z + \frac{1}{2}z^2}$$

$$\begin{array}{r} \textcircled{1} - z + \frac{1}{2}z^2 \overline{) \textcircled{\frac{1}{6}z^3} - \frac{1}{8}z^4 + \frac{1}{20}z^5} \\ \hline \end{array}$$

$$\begin{array}{r}
 \left(1 - z + \frac{1}{2}z^2\right) \left(\frac{1}{6}z^3 - \frac{1}{8}z^4 + \frac{1}{20}z^5\right) \\
 \hline
 \left(-\frac{1}{6}z^3 + \frac{1}{6}z^4 - \frac{1}{12}z^5\right) \\
 \hline
 0 + \frac{1}{24}z^4 + \frac{1}{30}z^5
 \end{array}$$

The diagram shows a multiplication of two power series. The first series, $1 - z + \frac{1}{2}z^2$, is circled in blue. The second series, $\frac{1}{6}z^3$, is also circled in blue. A blue 'X' is placed above the multiplication. The resulting series, $-\frac{1}{6}z^3 + \frac{1}{6}z^4 - \frac{1}{12}z^5$, is circled in blue. A horizontal line is drawn below this result, and the final result, $0 + \frac{1}{24}z^4 + \frac{1}{30}z^5$, is shown below the line. Blue arrows point from the circled terms to the corresponding terms in the result.

$$\begin{array}{r}
 \textcircled{1} - z + \frac{1}{2}z^2 \quad / \quad \frac{1}{6}z^3 - \frac{1}{8}z^4 + \frac{1}{20}z^5 \quad \backslash \quad \frac{1}{6}z^3 + \textcircled{\frac{1}{24}z^4} \\
 - \frac{1}{6}z^3 + \frac{1}{6}z^4 - \frac{1}{12}z^5 \\
 \hline
 0 \quad \textcircled{+\frac{1}{24}z^4} - \frac{1}{30}z^5
 \end{array}$$

A blue arrow with a '%' symbol points from the circled $\frac{1}{24}z^4$ term in the remainder to the circled '1' in the dividend.

$$\begin{array}{r}
 \left(1 - z + \frac{1}{2}z^2\right) \times \left(\frac{1}{6}z^3 - \frac{1}{8}z^4 + \frac{1}{20}z^5\right) \\
 \hline
 \frac{1}{6}z^3 - \frac{1}{8}z^4 + \frac{1}{20}z^5 \\
 - \frac{1}{6}z^3 + \frac{1}{6}z^4 - \frac{1}{12}z^5 \\
 \hline
 0 + \frac{1}{24}z^4 - \frac{1}{30}z^5 \\
 \hline
 -\frac{1}{24}z^4 + \frac{1}{24}z^5 \\
 \hline
 0 + \frac{1}{120}z^5
 \end{array}$$

The diagram shows a long division process. The dividend is $\frac{1}{6}z^3 - \frac{1}{8}z^4 + \frac{1}{20}z^5$ and the divisor is $1 - z + \frac{1}{2}z^2$. The quotient is $\frac{1}{6}z^3 - \frac{1}{8}z^4 + \frac{1}{20}z^5$. The remainder is $-\frac{1}{24}z^4 + \frac{1}{24}z^5$. The final result is $0 + \frac{1}{120}z^5$. Blue circles highlight the divisor, the dividend, the quotient, and the remainder. Blue arrows indicate the flow of the calculation.

$$\begin{array}{r}
 \textcircled{1} - z + \frac{1}{2}z^2 \quad \Bigg/ \quad \frac{1}{6}z^3 - \frac{1}{8}z^4 + \frac{1}{20}z^5 \quad \Bigg/ \quad \frac{1}{6}z^3 + \frac{1}{24}z^4 + \textcircled{\frac{1}{120}z^5} \\
 \hline
 - \frac{1}{6}z^3 + \frac{1}{6}z^4 - \frac{1}{12}z^5 \\
 \hline
 0 + \frac{1}{24}z^4 - \frac{1}{30}z^5 \\
 - \frac{1}{24}z^4 + \frac{1}{24}z^5 \\
 \hline
 0 + \textcircled{\frac{1}{120}z^5}
 \end{array}$$

$$q = \frac{\frac{1}{6}z^3 - \frac{1}{8}z^4 + \frac{1}{20}z^5}{1 - z + \frac{1}{2}z^2}$$

Long Division

$$q = \frac{1}{6}z^3 + \frac{1}{24}z^4 + \frac{1}{120}z^5 + O(z^7)$$

Long division:

$$q = \frac{1}{6}z^3 + \frac{1}{24}z^4 + \frac{1}{120}z^5 + O(z^7)$$

$$x = z + \frac{1}{2}z^2 + q$$

$$e^z - 1 \equiv x = z + \frac{1}{2}z^2 + \frac{1}{6}z^3 + \frac{1}{24}z^4 + \frac{1}{120}z^5 + \dots$$

$x = x + \frac{1}{2}x^2 + \frac{1}{6}x^3 + \frac{1}{24}x^4 + \frac{1}{120}x^5 \text{ \&c.}$		
$x + p = x$	$+$ $\frac{1}{2}x^5$ $-$ $\frac{1}{4}x^4$ $+$ $\frac{1}{2}x^3$ $-$ $\frac{1}{2}x^2$ $+$ x $-$ x	$+$ $\frac{1}{2}x^5 \text{ \&c.}$ $-$ $\frac{1}{4}x^4 - x^3p \text{ \&c.}$ $+$ $\frac{1}{2}x^3 + x^2p + xp^2 \text{ \&c.}$ $-$ $\frac{1}{2}x^2 - xp - \frac{1}{2}p^2$ $+$ $x + p$ $-$ x
$\frac{1}{2}x^2 + q = p$	$+$ xp^2 $-$ $\frac{1}{2}p^3$ $-$ x^3p $+$ x^2p $-$ xp $+$ p $+$ $\frac{1}{2}x^5$ $-$ $\frac{1}{4}x^4$ $+$ $\frac{1}{2}x^3$ $-$ $\frac{1}{2}x^2$	$+$ $\frac{1}{2}x^5 \text{ \&c.}$ $-$ $\frac{1}{4}x^4 - \frac{1}{2}x^2q$ $-$ $\frac{1}{2}x^5 \text{ \&c.}$ $+$ $\frac{1}{2}x^4 + x^2q$ $-$ $\frac{1}{2}x^3 - xq$ $+$ $\frac{1}{2}x^2 + q$ $+$ $\frac{1}{2}x^5$ $-$ $\frac{1}{4}x^4$ $+$ $\frac{1}{2}x^3$ $-$ $\frac{1}{2}x^2$
$1 - x + \frac{1}{2}x^2 - \frac{1}{6}x^3 + \frac{1}{24}x^4 - \frac{1}{120}x^5 (\frac{1}{6}x^3 + \frac{1}{24}x^4 + \frac{1}{120}x^5$		

Figure 19: (Newton & Stewart, 1745, p. 337)

Inverting $z = \sin^{-1}(x)$.

infinite

$$\sin^{-1}(x) \equiv z(x) = x + \frac{1}{6}x^3 + \frac{3}{40}x^5 + \frac{5}{112}x^7 + \frac{35}{1152}x^9 + \dots$$

finite

$$z = x + \frac{1}{6}x^3 + \frac{3}{40}x^5 + \frac{5}{112}x^7 + \frac{35}{1152}x^9$$

$$z = x + \frac{1}{6}x^3 + \frac{3}{40}x^5 + \frac{5}{112}x^7 + \frac{35}{1152}x^9$$

rearrange:

$$x = z + p$$

$$0 = \left\{ \begin{array}{l} + \frac{35}{1152}x^9 \\ + \frac{5}{112}x^7 \\ + \frac{3}{40}x^5 \\ + \frac{1}{6}x^3 \\ + x \\ - z \end{array} \right.$$

substitute

$$x = z + p$$

$$0 = \begin{cases} +\frac{35}{1152}(z+p)^9 \\ +\frac{5}{112}(z+p)^7 \\ +\frac{3}{40}(z+p)^5 \\ +\frac{1}{6}(z+p)^3 \\ +x \\ -z \end{cases}$$

$$0 = \begin{cases} +\frac{35}{1152}(z^9 + 9z^8p) + \dots & \frac{9-9}{2} = 0 \\ +\frac{5}{112}(z^7 + 7z^6p + 28z^5p^2) + \dots & \frac{9-7}{2} = 1 \\ +\frac{3}{40}(z^5 + 5z^4p + 10z^3p^2 + 10z^2p^3) + \dots & \frac{9-5}{2} = 2 \\ +\frac{1}{6}(z^3 + 3z^2p + 3zp^2 + p^3) + \dots & \frac{9-3}{2} = 3 \\ +z + p \\ -z \end{cases}$$

9, 7, 5, 3...

9

9/2

after the first Term, resulting from each Quantity which is collateral to it, you add no more Terms towards the Right Hand, than what the Index of the Dimension of that first Term, wants Pairs of Units of the Index of the highest Dimension;

$$0 = \left\{ \begin{array}{l} + \frac{35}{1152} z^9 \\ + \frac{5}{112} (z^7 + 7z^6 p) \\ + \frac{3}{40} (z^5 + 5z^4 p + 10z^3 p^2) \\ + \frac{1}{6} (z^3 + 3z^2 p + 3z p^2 + p^3) \\ + z \quad + p \\ - z \end{array} \right.$$

$$p = -\frac{1}{6}z^3 + O(z^5)$$

$$0 = \begin{cases} +\frac{35}{1152}z^9 \\ +\frac{5}{112}(z^7 + 7z^6p) \\ +\frac{3}{40}(z^5 + 5z^4p + 10z^3p^2) \\ +\frac{1}{6}(z^3 + 3z^2p + 3zp^2 + p^3) \\ +z \quad +p \\ -z \end{cases}$$

rearrange

$$0 = \begin{cases} +\frac{35}{1152}z^9 \\ +\frac{5}{112}(z^7 + 7z^6p) \\ +\frac{3}{40}(z^5 + 5z^4p + 10z^3p^2) \\ +\frac{1}{6}(z^3 + 3z^2p + 3zp^2 + p^3) \\ +z + p \\ -z \end{cases}$$



$$0 = \begin{cases} +\frac{1}{6}p^3 \\ +\frac{3}{4}z^3p^2 \\ +\frac{1}{2}zp^2 \\ +\frac{35}{112}z^6p \\ +\frac{15}{40}z^4p \\ +\frac{1}{2}z^2p \\ p \\ +\frac{35}{1152}z^9 \\ +\frac{5}{112}z^7 \\ +\frac{3}{40}z^5 \\ +\frac{1}{6}z^3 \\ \cancel{+z} \\ \cancel{-z} \end{cases}$$

substitute

$$0 = \begin{cases} +\frac{1}{6}p^3 \\ +\frac{3}{4}z^3p^2 \\ +\frac{1}{2}zp^2 \\ +\frac{35}{112}z^6p \\ +\frac{15}{40}z^4p \\ +\frac{1}{2}z^2p \\ p \\ +\frac{35}{1152}z^9 \\ +\frac{5}{112}z^7 \\ +\frac{3}{40}z^5 \\ +\frac{1}{6}z^3 \\ \cancel{z} \\ \cancel{z} \end{cases}$$

$p = -\frac{1}{6}z^3 + q$

$$0 = \begin{cases} +\frac{1}{6}\left(-\frac{1}{6^3}z^9\right) + \dots & \frac{9-9}{2} = 0 \\ +\frac{3}{4}z^3\left(\frac{1}{36}z^6\right) + \dots & \frac{9-9}{2} = 0 \\ +\frac{1}{2}z\left(\frac{1}{36}z^6 - \frac{1}{3}qz^3 + \dots\right) & \frac{9-7}{2} = 1 \\ +\frac{35}{112}z^6\left(-\frac{1}{6}z^3\right) + \dots & \frac{9-9}{2} = 0 \\ +\frac{15}{40}z^4\left(-\frac{1}{6}z^3 + q\right) & \frac{9-7}{2} = 1 \\ +\frac{1}{2}z^2\left(-\frac{1}{6}z^3 + q\right) & \frac{9-5}{2} = 2 \\ -\frac{1}{6}z^3 + q \\ +\frac{35}{1152}z^9 \\ +\frac{5}{112}z^7 \\ +\frac{3}{40}z^5 \\ +\frac{1}{6}z^3 \\ +z \\ -z \end{cases}$$

add like terms...

$$0 = \left\{ \begin{array}{l} \left(-\frac{1}{1296} + \frac{1}{48} - \frac{35}{672} + \frac{35}{1152}\right)z^9 \\ \left(+\frac{1}{72} - \frac{15}{240} + \frac{5}{112}\right)z^7 \\ \left(+\frac{15}{40} - \frac{1}{6}\right)qz^4 \\ \left(-\frac{1}{12} + \frac{3}{40}\right)z^5 \\ +\frac{1}{2}z^2q \\ \cancel{-\frac{1}{6}z^3} + q \\ \cancel{+\frac{1}{6}z^3} \end{array} \right.$$

$$0 = \left\{ \begin{array}{l} \left(-\frac{1}{1296} + \frac{1}{48} - \frac{35}{672} + \frac{35}{1152}\right)z^9 \\ \left(+\frac{1}{72} - \frac{15}{240} + \frac{5}{112}\right)z^7 \\ \left(+\frac{15}{40} - \frac{1}{6}\right)qz^4 \\ \left(-\frac{1}{12} + \frac{3}{40}\right)z^5 \\ +\frac{1}{2}z^2q \\ \cancel{-\frac{1}{6}z^3} + q \\ \cancel{+\frac{1}{6}z^3} \end{array} \right.$$

Linear in q !

$$\frac{1}{120}z^5 + \frac{1}{252}z^7 + \frac{17}{10368}z^9 = q\left(1 + \frac{1}{2}z^2 + \frac{5}{24}z^4\right)$$

$$\frac{\frac{1}{120}z^5 + \frac{1}{252}z^7 + \frac{17}{10368}z^9}{1 + \frac{1}{2}z^2 + \frac{5}{24}z^4} = q$$

Long Division!

$$\begin{array}{r}
 \left(1 + \frac{1}{2}z^2 + \frac{5}{24}z^4 \right) \left(\frac{1}{120}z^5 + \frac{1}{252}z^7 + \frac{17}{10368}z^9 \right) - \frac{1}{120}z^5 \\
 \hline
 \frac{1}{120}z^5 - \frac{1}{240}z^7 - \frac{5}{2880}z^9 \\
 \hline
 0 - \frac{1}{5040}z^7 - \frac{1}{10368}z^9
 \end{array}$$

X

$$\begin{array}{r}
 \textcircled{1} + \frac{1}{2}z^2 + \frac{5}{24}z^4 \quad / \quad \frac{1}{120}z^5 + \frac{1}{252}z^7 + \frac{17}{10368}z^9 \quad / \quad \frac{1}{120}z^5 - \textcircled{\frac{1}{5040}z^7} \\
 - \frac{1}{120}z^5 - \frac{1}{240}z^7 - \frac{5}{2880}z^9 + \\
 \hline
 0 \quad \textcircled{-\frac{1}{5040}z^7} - \frac{1}{10368}z^9
 \end{array}$$

An arrow points from the circled $\frac{1}{5040}z^7$ term in the bottom row to the circled 1 term in the top row, with a percentage symbol (%) next to the arrow.

$$\begin{array}{r}
 \left(1 + \frac{1}{2}z^2 + \frac{5}{24}z^4 \right) \left(\frac{1}{120}z^5 + \frac{1}{252}z^7 + \frac{17}{10368}z^9 \right) - \frac{1}{120}z^5 - \frac{1}{5040}z^7 \\
 - \frac{1}{120}z^5 - \frac{1}{240}z^7 - \frac{5}{2880}z^9 + \\
 \hline
 0 - \frac{1}{5040}z^7 - \frac{1}{10368}z^9 \\
 + \frac{1}{5040}z^7 + \frac{1}{10080}z^9 \\
 \hline
 0 \quad \frac{1}{362880}z^9
 \end{array}$$

A blue 'X' is drawn above the first two terms of the first line. A blue arrow points from the 'X' to the first term of the first line. Another blue arrow points from the first term of the first line to the first term of the second line. A blue oval encircles the terms $-\frac{1}{5040}z^7 - \frac{1}{10368}z^9$ in the second line.

$$\begin{array}{r}
 \textcircled{1} + \frac{1}{2}z^2 + \frac{5}{24}z^4 \quad / \quad \frac{1}{120}z^5 + \frac{1}{252}z^7 + \frac{17}{10368}z^9 \quad \backslash \quad \frac{1}{120}z^5 - \frac{1}{5040}z^7 + \textcircled{\frac{1}{362880}z^9} \\
 \hline
 - \frac{1}{120}z^5 - \frac{1}{240}z^7 - \frac{5}{2880}z^9 + \\
 \hline
 0 \quad - \frac{1}{5040}z^7 - \frac{1}{10368}z^9 \\
 \hline
 + \frac{1}{5040}z^7 + \frac{1}{10080}z^9 \\
 \hline
 0 \quad \textcircled{\frac{1}{362880}z^9}
 \end{array}$$

A blue arrow points from the circled '1' to the circled $\frac{1}{362880}z^9$ term. A blue arrow points from the circled $\frac{1}{362880}z^9$ term to the circled '1' with a '%' symbol next to it.

Long division:

$$q = \frac{1}{120}z^5 - \frac{1}{5040}z^7 + \frac{1}{362880}z^9$$

$$x = z - \frac{1}{6}z^3 + q$$

$$x = z - \frac{1}{6}z^3 + \frac{1}{120}z^5 - \frac{1}{5040}z^7 + \frac{1}{362880}z^9 + O(z^{11})$$

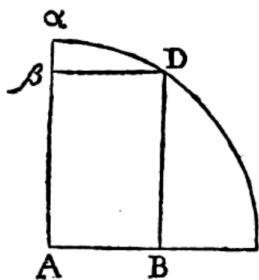
Long division:

$$q = \frac{1}{120}z^5 - \frac{1}{5040}z^7 + \frac{1}{362880}z^9$$

$$x = z - \frac{1}{6}z^3 + q$$

$$x = z - \frac{1}{6}z^3 + \frac{1}{120}z^5 - \frac{1}{5040}z^7 + \frac{1}{362880}z^9 + O(z^{11})$$

$x = z - \frac{1}{6}z^3 + \frac{1}{120}z^5 - \frac{1}{5040}z^7 + \frac{1}{362880}z^9$		
$x = z + p$	$+ \frac{35}{1152}x^9$ $+ \frac{5}{112}x^7$ $+ \frac{3}{40}x^5$ $+ \frac{1}{6}x^3$ $+x$ $-z$	$+ \frac{35}{1152}z^9 + \dots$ $+ \frac{5}{112}(z^7 + 7z^6p) + \dots$ $+ \frac{3}{40}(z^5 + 5z^4p + 10z^3p^2) + \dots$ $+ \frac{1}{6}(z^3 + 3z^2p + 3zp^2 + p^3)$ $+z + p$ $-z$
$p = -\frac{1}{6}z^3 + q$	$+ \frac{1}{6}p^3$ $+ \frac{3}{4}z^3p^2$ $+ \frac{1}{2}zp^2$ $+ \frac{35}{112}z^6p$ $+ \frac{15}{40}z^4p$ $+ \frac{1}{2}z^2p$ p $+ \frac{35}{1152}z^9$ $+ \frac{5}{112}z^7$ $+ \frac{3}{40}z^5$ $+ \frac{1}{6}z^3$ $+z$ $-z$	$-\frac{1}{1296}z^9 + \dots$ $+ \frac{1}{48}z^9 + \dots$ $+ \frac{1}{72}z^7 - \frac{1}{6}qz^4 + \dots$ $-\frac{35}{672}z^9 + \dots$ $-\frac{15}{240}z^7 + \frac{15}{40}qz^4 + \dots$ $-\frac{1}{12}z^5 + \frac{1}{2}z^2q$ $-\frac{1}{6}z^3 + q$ $+ \frac{35}{1152}z^9$ $+ \frac{5}{112}z^7$ $+ \frac{3}{40}z^5$ $+ \frac{1}{6}z^3$ $+z$ $-z$
$1 + \frac{1}{2}z^2 + \frac{5}{24}z^4 \quad \bigg/ \quad \frac{1}{120}z^5 + \frac{1}{252}z^7 + \frac{17}{10368}z^9 \quad \bigg/ \quad \frac{1}{120}z^5 - \frac{1}{5040}z^7 + \frac{1}{362880}z^9$		



45. If from the Arch αD given the Sine AB was required; I extract the Root of the Equation found above, *viz.* $z = x + \frac{1}{6}x^3 + \frac{1}{40}x^5 + \frac{1}{112}x^7$ (it being supposed that $AB = x$, $\alpha D = z$, and $A\alpha = 1$) by which I find $x = z - \frac{1}{6}z^3 + \frac{1}{120}z^5 - \frac{1}{5040}z^7 + \frac{1}{362880}z^9$ &c. (1711)

$$x = \sum_{n=0}^{\infty} \frac{(-1)^n}{(2n+1)!} z^{2n+1} \quad (2026)$$

**Finding $\cos(z)$ By Applying the
Binomial Series To $\sqrt{1 - \sin^2(z)}$**

Contents

1. Finding a Power Series For $z = \sin^{-1}(x)$
2. Inverting $z = \sin^{-1}(x)$ to find $x = \sin(z)$
3. Finding $\cos(z)$ By Applying the Binomial Series To $\sqrt{1 - \sin^2(z)}$

Questions?

Newton, Isaac, and John Stewart. *Sir Isaac Newton's Two Treatises of the Quadrature of Curves, And Analysis by Equations of an Infinite Number of Terms Explained*. Printed by James Bettenham for J. Nourse, 1745. https://books.google.it/books?id=noQ_AAAAcAAJ.