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A Heuristic Argument for Hua's Identity Using Geometric Series

In a ring, Hua observed the identity

$$x - xyx = (x^{-1} + (y^{-1} - x)^{-1})^{-1}$$

when the inverses above exist. He used this to deduce that an additive homomorphism θ of a division ring which satisfies $\theta(1) = 1, \theta(x^{-1}) = \theta(x)^{-1}$, is either a ring homomorphism or an anti-homomorphism. A folklore trick is to use an analogy with geometric series to deduce in a ring that if a, b are such that $1 - ba$ is a unit, then so is $1 - ab$ and

$$(1 - ab)^{-1} = 1 + a(1 - ba)^{-1}b.$$

Indeed, the way to discover this is to write informally

$$\begin{aligned}(1 - ab)^{-1} &= 1 + ab + abab + \cdots \\ &= 1 + a(1 + ba + baba + \cdots)b \\ &= 1 + a(1 - ba)^{-1}b.\end{aligned}$$

This heuristic argument enables us to *discover* the equality of the expressions $(1 - ab)^{-1}$ and $1 + a(1 - ba)^{-1}b$. A formal proof is seen by simple verification! Hua's identity follows using this as:

$$\begin{aligned}(x - xyx)^{-1} &= ((1 - xy)x)^{-1} = x^{-1}(1 - xy)^{-1} \\ &= x^{-1}(1 + x(1 - yx)^{-1}y) = x^{-1} + (1 - yx)^{-1}y \\ &= x^{-1} + (y^{-1}(1 - yx))^{-1} = x^{-1} + (y^{-1} - x)^{-1}.\end{aligned}$$

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http://dx.doi.org/10.4169/amer.math.monthly.121.06.522
MSC: Primary 16R40