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Proof of Fact 9. For each fixed $r \in (0, 1/2)$ and $y \in (0, 1)$, the maximum value of x is

$$x(y,\sin^{-1}\frac{2r}{1+2r},r) = (1-y)\tan\left(\sin^{-1}\left(\frac{y+2r}{1+2r}\right) - \sin^{-1}\left(\frac{2r}{1+2r}\right)\right).$$

Letting $r \to 0$ in the above gives

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$$(1-y)\frac{y}{\sqrt{1-y^2}},$$

a quantity which is zero when y = 0 and for $y \to 1$, and which is otherwise positive. The derivative of this quantity is $(1 - y)(x^2 + y - 1)$

$$\frac{-(1-y)(y^2+y-1)}{(1-y^2)^{3/2}},$$

which has as its single zero in (0, 1) the number we desire.

Our work here is done. Shoot.