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# CS571 Programming language structure II

## Lambda Calculus

Using the  $\beta$ -rule, simplify the following expressions to a final (*normal*) form, if one exists. If one does not exist, explain why.

1.  $(\lambda x.(x y))(\lambda z.z)$
2.  $((\lambda x.((\lambda y.(x y)) x))(\lambda z.w))$
3.  $((((\lambda f.(\lambda g.(\lambda x.((f x)(g x)))))(\lambda m.(\lambda n.(n m)))))(\lambda n.z)) p)$
4.  $((\lambda x.(x x))(\lambda x.(x x)))$
5.  $((\lambda f.((\lambda g.((f f) g)))(\lambda h.(k h))))(\lambda x.(\lambda y.y))$
6.  $(\lambda g.((\lambda f.((\lambda x.(f (x x)))(\lambda x.(f (x x)))))) g)$