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In[ ]:= (*  $\sigma_1^k b_2$  for  $k=0,1,2,3$  *)
B0 =  $b_2$ ;
B1 =  $s^{-1} b_1$ ;
B2 =  $s^{-n} t w_{1,2} + (1 - s^{-2}) s^{-1} b_1 + s^{-2} b_2$ ;
B3 =  $s^{-n} t (1 - s^{-2} + s^{-4} q^2) w_{1,2} +$ 
       $s^{-1} (1 - s^{-2} + s^{-4}) b_1 + s^{-2} (1 - s^{-2}) b_2$ ;
(* Solutions for the equation *)
x =  $-1 + s^{-2} - s^{-4} q^2$ ;
y =  $-s^{-2} + s^{-4} q^2 - s^{-6} q^2$ ;
z =  $s^{-6} q^2$ ;

(* Verification *)
B3 + x B2 + y B1 + z b2 // Simplify

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Out[]:= 0