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In[78]:= degree = 8;
series = 1 + Plus @@ Table[ai xi, {i, 2, degree}] + 0[x]degree+1

Out[79]= 1 + a2 x2 + a3 x3 + a4 x4 + a5 x5 + a6 x6 + a7 x7 + a8 x8 + 0[x]9

In[80]:= unknowns = Table[ai, {i, 2, degree}];
expression = 
$$\frac{-2 z[x] - x (y[x])^3}{x} - z'[x] /. \{y[x] \rightarrow \text{series}, z[x] \rightarrow D[\text{series}, x], z'[x] \rightarrow D[\text{series}, \{x, 2\}]\};$$

coefflist = CoefficientList[Normal[expression], x];
solution = Solve[Thread[coefflist == 0], unknowns];
(series /. solution)[[1]]

Out[84]=  $1 - \frac{x^2}{6} + \frac{x^4}{40} - \frac{19 x^6}{5040} + \frac{619 x^8}{1088640} + 0[x]^9$ 

In[35]:= D[ $1 - \frac{x^2}{6} + \frac{x^4}{40} - \frac{19 x^6}{5040} + \frac{619 x^8}{1088640} + 0[x]^9$ , x]

Out[35]=  $-\frac{x}{3} + \frac{x^3}{10} - \frac{19 x^5}{840} + \frac{619 x^7}{136080} + 0[x]^8$ 

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