

```

SWxy[U_, kk_] :=
SWxy[U, kk] = Block[{ $U = U, $k = kk, $p = kk },
Module[{ G, F, fs, f, bs, e, b, es },
G = Simp[Table[ξk/k!, {k, 0, $k + 1}].
NestList[Simp[B[xU, #]] &, yU, $k + 1];
fs = Flatten@Table[f1,i,j,k[η], {1, 0, $k}, {i, 0, 1},
{j, 0, 1}, {k, 0, 1}];
F = fs.(bs = fs /. fl,i,j,k[η] => el U@{yi, aj, xk});
es = Flatten[Table[Coefficient[e, b] == 0,
{e, {F - 1U / η → 0, F ** G - yU ** F - ∂ηF}},
{b, bs}]];
F = F /. DSolve[es, fs, η][[1]];
IE[0,
F x + η y + (U /. {CU → -t η ξ, QU → η ξ (1 - T) / ħ}),
F + 0$k /. {e → 1, U → Times}
] /. (v : η | ξ | t | T | y | a | x) → v1
]];
tSWxyi,j :=
SWxy[$U, $k] /. {ξ1 → ξi, η1 → ηj, (v : t | T | y | a | x)1 → vk};
tSWxa := IE[αj ak, e-Y αj ξi xk, 1];
tSWya := IE[αi ak, e-Y αi ηj yk, 1];

```

Exponentials as needed.

Task. Define $\text{Exp}_{U_i,k}[\xi, P]$ which computes $e^{\xi Q(P)}$ to e^k in the algebra U_i , where ξ is a scalar, X is x_i or y_i , and P is an ϵ -dependent near-ocile element, giving the answer in \mathbb{E} -form. Should satisfy $U@ \text{Exp}_{U_i,k}[\xi, P] == \mathbb{S}_U[e^{\xi X}, x \rightarrow Q(P)]$.

Methodology. If $P_0 := P_{\epsilon=0}$ and $e^{\xi Q(P)} = \mathcal{O}(e^{\xi P_0} F(\xi))$, then $F(\xi=0) = 1$ and we have:

$$\mathcal{O}(e^{\xi P_0} (P_0 F(\xi) + \partial_\xi F)) = \mathcal{O}(\partial_\xi e^{\xi P_0} F(\xi)) = \partial_\xi \mathcal{O}(e^{\xi P_0} F(\xi)) = e^{\xi P_0} \mathcal{O}(P) = \mathcal{O}(e^{\xi P_0} F(\xi)) \mathcal{O}(P)$$

This is an ODE for F . Setting inductively $F_k = F_{k-1} + e^k \varphi$ we find that $F_0 = 1$ and solve for φ .

```

(* Bug: The first line is valid only if 0(eP0) == e0(P0). *)
(* Bug: ξ must be a symbol. *)
ExpUi[0, {ξ, P}] := Module[{LQ = Normal@P /. e → 0},
IE[ξ LQ /. (x | y)i → 0, ξ LQ /. (t | a)i → 0, 1]];
ExpUi[k, {ξ, P}] := Block[{ $U = U, $k = k },
Module[{ P0, φ, φs, F, j, rhs, at0, atξ },
P0 = Normal@P /. e → 0;
φs = Flatten@Table[φj1,j2,j3[ξ], {j2, 0, k},
{j1, 0, 2k + 1 - j2}, {j3, 0, 2k + 1 - j2 - j1}];
F = Normal@Last@ExpUi[k-1, {ξ, P}] +
ek φs.(φs /. φjs[ξ] => Times@@{yi, ai, xi}{js});
rhs =
Normal@
Last@
mi,j → i [IE[ξ P0 /. (x | y)i → 0, ξ P0 /. (t | a)i → 0, F + 0k]
mi,j → j [IE[0, 0, P + 0k]];
at0 = (# == 0) & /@
Flatten@CoefficientList[F - 1 /. ξ → 0, {yi, ai, xi});
atξ = (# == 0) & /@
Flatten@CoefficientList[(∂ξF) + P0 F - rhs,
{yi, ai, xi});
IE[ξ P0 /. (x | y)i → 0, ξ P0 /. (t | a)i → 0, F + 0k] /.
DSolve[And@@(at0 ∪ atξ), φs, ξ][[1]]];

```

Zip and Bind

```

E /: IE[L1_, Q1_, P1_] == IE[L2_, Q2_, P2_] :=
CF[L1 == L2] ∧ CF[Q1 == Q2] ∧ CF[Normal[P1 - P2] == 0];
E /: IE[L1_, Q1_, P1_] IE[L2_, Q2_, P2_] :=
IE[L1 + L2, Q1 + Q2, P1 * P2];
{t*, y*, a*, x*, z*} = {t, η, α, ξ, ζ};
{τ*, η*, α*, ξ*, ζ*} = {t, y, a, x, z};
(u-i)* := (u*)i;
Zip{}[P_] := P;
Zip{ξ, ζ}[P_] :=
(Expand[P // Zip{ξ}] /. f-. ξd => ∂{ξ*, d}f) /. ζ* → 0

```

QZip implements the “Q-level zips” on $\mathbb{E}(L, Q, P) = \text{Pe}^{L+Q}$. Such zips regard the L variables as scalars.

```

QZipξs_List, simp@E[L_, Q_, P_] :=
Module[{ {ξ, z, zs, c, ys, ηs, qt, zrule, Q1, Q2},
zs = Table[ξ*, {ξ, ζs}];
c = Q /. Alternatives@@(ξs ∪ zs) → 0;
ys = Table[∂ξ(Q /. Alternatives@@zs → 0), {ξ, ζs}];
ηs = Table[∂z(Q /. Alternatives@@ξs → 0), {z, zs}];
qt = Inverse@Table[Kδz,ξ* - ∂z,ξQ, {ξ, ζs}, {z, zs}];
zrule = Thread[zs → qt.(zs + ys)];
Q2 = (Q1 = c + ηs.zs /. zrule) /. Alternatives@@zs → 0;
simp /@ IE[L, Q2, Det[qt] e-Q2 Zipξs[eQ1(P /. zrule)]];];

```

$\text{QZip}_{\xi s_List} := \text{QZip}_{\xi s, CF}$;

LZip implements the “L-level zips” on $\mathbb{E}(L, Q, P) = \text{Pe}^{L+Q}$. Such zips regard all of Pe^Q as a single “P”. Here the z’s are t and α and the ζ ’s are τ and a .

```

LZipξs_List, simp@E[L_, Q_, P_] :=
Module[{ {ξ, z, zs, c, ys, ηs, lt, zrule, L1, L2, Q1, Q2},
zs = Table[ξ*, {ξ, ζs}];
c = L /. Alternatives@@(ξs ∪ zs) → 0;
ys = Table[∂ξ(L /. Alternatives@@zs → 0), {ξ, ζs}];
ηs = Table[∂z(L /. Alternatives@@ξs → 0), {z, zs}];
lt = Inverse@Table[Kδz,ξ* - ∂z,ξL, {ξ, ζs}, {z, zs}];
zrule = Thread[zs → lt.(zs + ys)];
L2 = (L1 = c + ηs.zs /. zrule) /. Alternatives@@zs → 0;
Q2 = (Q1 = Q /. T2t /. zrule) /. Alternatives@@zs → 0;
simp /@
IE[L2, Q2, Det[lt] e-L2-Q2
Zipξs[eL1+Q1(P /. T2t /. zrule)]] // t2T];

```

$\text{LZip}_{\xi s_List} := \text{LZip}_{\xi s, CF}$;

```

Bind{}[L_, R_] := LR;
Bind{is}[LE, RE] := Module[{n},
Times[
L /. Table[(v : T | t | a | x | y)i → vnei, {i, {is}}],
R /. Table[(v : τ | α | ξ | η)i → vnei, {i, {is}}]
] // LZipFlatten@Table[{τnei, anei}, {i, {is}}] //
QZipFlatten@Table[{ξnei, ynei}, {i, {is}}];];
BL_List := BindL; Bis := Bind{is};
Bind{ξE} := ξ;
Bind{Ls, ξs_List, R} := Bindξs[Bind{Ls}, R];

```

Tensorial Representations

```

tη = t1 = IE[0, 0, 1 + 0$k];
tmi,j → k := Module[{tk},
IE[(τi + τj) tk + αi ak + αj ak, ηi yk + ξj xk, 1]
(tSWxyi,j → tk /. {ttk → tk, Ttk → Tk, ytk → e-Y αi yk,
atk → ak, xtk → e-Y αj xk});];
mj → k [ξE] := ξ ~ Bj,k ~ tmj,k → k;
tm1,2 → 3

```