Test

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CURRENT ISSUES:
• Replacement issues
• ISSUES WITH NEGATIVES!!!!

QUESTION — should outside brackets have to be

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????

$$\partial_\mu A\Big(Y\partial_\nu h^{\mu\nu} + X\partial^\mu h_\nu^\nu\Big) \tag{1}$$

$$\partial_\mu\Big(YA\partial_\nu h^{\mu\nu} + XA\partial^\mu h_\nu^\nu\Big) \tag{2}$$

Contract:

$$\partial_\mu A\Big(Y\partial_\nu h^{\mu\nu} + X\partial^\mu h_\nu^\nu\Big) \tag{3}$$

1 Representation

Reading in and understanding equations (display initial equation)

Reading in signs between brackets

$$\Big(a\Big) + \Big(b\Big) \to \Big(a\Big) + \Big(b\Big) \tag{4}$$

$$\Big(a\Big) - \Big(b\Big) \to \Big(a\Big) - \Big(b\Big) \tag{5}$$

basic reading in signs inside brackets

$$b_\gamma - g_j \to \Big(b_\gamma - g_j\Big) \tag{6}$$

inside and outside brackets

$$A^\mu + \Big(A^\gamma - B^\zeta\Big) \to A^\mu + \Big(A^\gamma - B^\zeta\Big) \tag{7}$$

$$A^\mu - \Big(A^\gamma - B^\zeta\Big) \to A^\mu - \Big(A^\gamma - B^\zeta\Big) \tag{8}$$

with partial derivatives

$$\partial_\alpha\Big(a + \Big(b_\gamma - g\Big)\Big) \to \partial_\alpha\Big(a + \Big(b_\gamma - g\Big)\Big) \tag{9}$$

multiplied by a tensor

$$A^\mu + C^\epsilon\Big(A^\gamma - B^\zeta\Big) \to A^\mu + C^\epsilon\Big(A^\gamma - B^\zeta\Big) \tag{10}$$

complicated bracket nesting

$$\Big(\Big(a\Big) - \Big(b - \Big(c\Big)\Big)\Big) + \Big(\Big(a - d\Big) - b\Big) \to \Big(\Big(a\Big) - \Big(b - \Big(c\Big)\Big)\Big) + \Big(\Big(a - d\Big) - b\Big) \tag{11}$$

complicated bracket nesting and tensor indices

$$\left(\left(a\right) - \left(b - \left(c\right)\right)\right) + \left(\left(a^{\gamma} - d^{\gamma}\right) - b\right) \rightarrow \left(\left(a\right) - \left(b - \left(c\right)\right)\right) + \left(\left(a^{\gamma} - d^{\gamma}\right) - b\right) \tag{12}$$

complicated bracket nesting and tensor indices, multiplication, and partials

$$\partial_{\zeta}\left(G^{\gamma}\right)\partial^{\zeta}\Box\left(\left(A\right) - \left(B^{\kappa}_{\kappa} - \left(C\right)\right)\right) + \left(\left(A^{\gamma} - D^{\gamma}\right) - B^{\alpha\gamma}_{\alpha}\right) \\ \rightarrow \partial_{\zeta}\left(G^{\gamma}\right)\partial^{\zeta}\Box\left(\left(A\right) - \left(B^{\kappa}_{\kappa} - \left(C\right)\right)\right) + \left(\left(A^{\gamma} - D^{\gamma}\right) - B^{\alpha\gamma}_{\alpha}\right) \tag{13}$$

with equals sign

$$G^{\mu} = A^{\mu} + C^{\mu\epsilon}\left(A_{\epsilon} - B_{\epsilon}\right) \rightarrow G^{\mu} = A^{\mu} + C^{\mu\epsilon}\left(A_{\epsilon} - B_{\epsilon}\right) \tag{14}$$

with begin equation command

```
\begin{equation}
G^{\mu} = A^{\mu} + C^{\mu \epsilon}\(A_{\epsilon} - B_{\epsilon}\)
\end{equation}
->
\begin{equation}
G^{\mu} = A^{\mu} + C^{\mu \epsilon} \( A_{\epsilon} - B_{\epsilon} \)
\end{equation}
```

with begin multline command (but short so it changes to equation)

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\begin{multline}
G^{\mu} = A^{\mu} + C^{\mu \epsilon}\(A_{\epsilon} - B_{\epsilon}\)
\end{multline}
->
\begin{equation}
G^{\mu} = A^{\mu} + C^{\mu \epsilon} \( A_{\epsilon} - B_{\epsilon} \)
\end{equation}
```

with begin multline command and long enough to stay multline

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\begin{multline}
G^{\mu} = A^{\mu} + C^{\mu \epsilon}\(A_{\epsilon} - B_{\epsilon}\) + A^{\mu}
+ C^{\mu \epsilon}\(A_{\epsilon} - B_{\epsilon}\)  + A^{\mu}
+ C^{\mu \epsilon}\(A_{\epsilon} - B_{\epsilon}\) + A^{\mu}
+ C^{\mu \epsilon}\(A_{\epsilon} - B_{\epsilon}\)  + A^{\mu}
+\\ C^{\mu \epsilon}\(A_{\epsilon} - B_{\epsilon}\) + A^{\mu}
+ C^{\mu \epsilon}\(A_{\epsilon} - B_{\epsilon}\) + A^{\mu}
+ C^{\mu \epsilon}\(A_{\epsilon} - B_{\epsilon}\) + A^{\mu}
+ C^{\mu \epsilon}\(A_{\epsilon} - B_{\epsilon}\) + A^{\mu}
+\\ C^{\mu \epsilon}\(A_{\epsilon} - B_{\epsilon}\) + A^{\mu}
+ C^{\mu \epsilon}\(A_{\epsilon} - B_{\epsilon}\) + A^{\mu}
+ C^{\mu \epsilon}\(A_{\epsilon} - B_{\epsilon}\)
\end{multline}
->
\begin{multline}
G^{\mu} = A^{\mu} + C^{\mu \epsilon} \( A_{\epsilon} - B_{\epsilon} \)+ A^{\mu}
+ C^{\mu \epsilon} \( A_{\epsilon} - B_{\epsilon} \)+ A^{\mu}
+ C^{\mu \epsilon} \( A_{\epsilon} - B_{\epsilon} \)+ A^{\mu} \\
+ C^{\mu \epsilon} \( A_{\epsilon} - B_{\epsilon} \)+ A^{\mu}
+ C^{\mu \epsilon} \( A_{\epsilon} - B_{\epsilon} \)+ A^{\mu}
+ C^{\mu \epsilon} \( A_{\epsilon} - B_{\epsilon} \)+ A^{\mu} \\
+ C^{\mu \epsilon} \( A_{\epsilon} - B_{\epsilon} \)+ A^{\mu}
+ C^{\mu \epsilon} \( A_{\epsilon} - B_{\epsilon} \)+ A^{\mu}
+ C^{\mu \epsilon} \( A_{\epsilon} - B_{\epsilon} \)+ A^{\mu} \\
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+ C^{\mu \epsilon} \( A_{\epsilon} - B_{\epsilon} \)+ A^{\mu}
+ C^{\mu \epsilon} \( A_{\epsilon} - B_{\epsilon} \)
\end{multline}
```

also print above to test what it looks like visually: output is

$$\begin{multline}G^{\mu} = A^{\mu} + C^{\mu\epsilon}\Big(A_{\epsilon} - B_{\epsilon}\Big) + A^{\mu} + C^{\mu\epsilon}\Big(A_{\epsilon} - B_{\epsilon}\Big) + A^{\mu} + C^{\mu\epsilon}\Big(A_{\epsilon} - B_{\epsilon}\Big) + A^{\mu} \\ + C^{\mu\epsilon}\Big(A_{\epsilon} - B_{\epsilon}\Big) + A^{\mu} + C^{\mu\epsilon}\Big(A_{\epsilon} - B_{\epsilon}\Big) + A^{\mu} + C^{\mu\epsilon}\Big(A_{\epsilon} - B_{\epsilon}\Big) + A^{\mu} \\ + C^{\mu\epsilon}\Big(A_{\epsilon} - B_{\epsilon}\Big) + A^{\mu} + C^{\mu\epsilon}\Big(A_{\epsilon} - B_{\epsilon}\Big) + A^{\mu} + C^{\mu\epsilon}\Big(A_{\epsilon} - B_{\epsilon}\Big) + A^{\mu} \\ + C^{\mu\epsilon}\Big(A_{\epsilon} - B_{\epsilon}\Big) + A^{\mu} + C^{\mu\epsilon}\Big(A_{\epsilon} - B_{\epsilon}\Big) \quad (15)\end{multline}$$

each line could be longer before wrapping but I'm pretty happy with how it looks for now

with etas and deltas and fractions

$$7X\eta_{\mu\nu}\delta^{\gamma}_{\nu}\Box A^{\mu} + \frac{1}{3}\delta^{\gamma}_{\mu}C^{\mu\epsilon}\Big(A_{\epsilon} - B_{\epsilon}\Big) \to 7X\delta^{\gamma}_{\nu}\eta_{\mu\nu}\Box A^{\mu} + \frac{1}{3}\delta^{\gamma}_{\mu}C^{\mu\epsilon}\Big(A_{\epsilon} - B_{\epsilon}\Big) \tag{16}$$

multiple coefficients

$$\Big(XYZ\partial_{\nu}h^{\mu\nu} + 6bX\partial^{\mu}h^{\nu}_{\nu}\Big) \to \Big(XYZ\partial_{\nu}h^{\mu\nu} + 6bX\partial^{\mu}h^{\nu}_{\nu}\Big) \tag{17}$$

multiple coefficients in unusual order

$$\Big(XY\partial_{\nu}h^{\mu\nu}Z + b6X\partial^{\mu}h^{\nu}_{\nu}\Big) \to \Big(XYZ\partial_{\nu}h^{\mu\nu} + 6bX\partial^{\mu}h^{\nu}_{\nu}\Big) \tag{18}$$

breaks (is this good or no??)

$$A^{\alpha}\frac{1}{3}B_{\gamma} \to \text{ Equation: pop from empty list} \tag{19}$$

this one seems to work...

$$A^{\alpha}3B_{\gamma} \to 3A^{\alpha}B_{\gamma} \tag{20}$$

QUESTION: does multiplication always need brackets? If no, when does it need them? Why does the whole number work but the fraction breaks....

Please email jbrucero@uwo.ca for if you think this is a bug

*****things that shouldn't work
*** uneven brackets

$$\Big(A{+}B \to WORKING(thoughthemessagecouldbegreatlyimproved)"Equation : Pleaseemailjbrucero@uwo.caforifyouthinkth \tag{21}$$

*** uneven index brackets

$$A^{\{}\gamma \to Workinginthatitshoulderrorbutagaintheissuecouldprobablybecaughtearlierandabettermessagegiven)"Equation : strin \tag{22}$$

$$A^{\gamma} + B^{\{} \to thisonereadstheequationfine - isthisanissue???\Big(A^{\gamma} + B\Big) \tag{23}$$

2 Multiply

2.1 FOIL out terms, distributing derivatives when necessary (recommended)

Basic case:

$$\Big(A\Big)\partial_{\mu}\Big(Y\partial_{\nu}h^{\mu\nu} + X\partial^{\mu}h^{\nu}_{\nu}\Big) \to \Big(YA\partial_{\nu}\partial_{\mu}h^{\mu\nu} + XA\partial^{\mu}\partial_{\mu}h^{\nu}_{\nu}\Big) \tag{24}$$

Also need to test adding summations, with and without partials, and subtracting summations, with and without partials

2.2 distribute partial derivatives

Basic case:

$$\partial_\mu\Big(Y\partial_\nu h^{\mu\nu} + X\partial^\mu h^\nu_\nu\Big) \to \Big(Y\partial_\nu\partial_\mu h^{\mu\nu} + X\partial^\mu\partial_\mu h^\nu_\nu\Big) \tag{25}$$

** number coefficients

$$\partial_\mu\Big(5\partial_\nu h^{\mu\nu} + 3\partial^\mu h^\nu_\nu\Big) \to \Big(5\partial_\nu\partial_\mu h^{\mu\nu} + 3\partial^\mu\partial_\mu h^\nu_\nu\Big) \tag{26}$$

** mixed coefficients

$$\partial_\mu\Big(5\partial_\nu h^{\mu\nu} + V\partial^\mu h^\nu_\nu\Big) \to \Big(5\partial_\nu\partial_\mu h^{\mu\nu} + V\partial^\mu\partial_\mu h^\nu_\nu\Big) \tag{27}$$

** product rule

$$\partial_\mu\Big(A^\gamma B^\zeta\Big) \to \Big(\partial_\mu A^\gamma B^\zeta + \partial_\mu B^\zeta A^\gamma\Big) \tag{28}$$

** three term product rule

$$\partial_\mu\Big(A^\gamma B^\zeta G^\alpha\Big) \to \Big(\partial_\mu A^\gamma B^\zeta G^\alpha + \partial_\mu B^\zeta G^\alpha A^\gamma + \partial_\mu G^\alpha B^\zeta A^\gamma\Big) \tag{29}$$

*** Distribute through multiple terms

$$\partial_\mu\Big(A^\gamma B^\zeta\Big)\partial_\alpha\Big(A_\gamma\Big) + \partial_\alpha\Big(G_{\mu\zeta}\Big) \to \Big(\partial_\mu A^\gamma B^\zeta + \partial_\mu B^\zeta A^\gamma\Big)\Big(\partial_\alpha A_\gamma\Big) + \Big(\partial_\alpha G_{\mu\zeta}\Big) \tag{30}$$

** multiple partials product rule

$$\partial_\alpha\partial_\gamma\Big(A^\alpha B^\gamma\Big) \to \Big(\partial_\alpha\partial_\gamma A^\alpha B^\gamma + \partial_\gamma B^\gamma\partial_\alpha A^\alpha + \partial_\alpha\partial_\gamma B^\gamma A^\alpha + \partial_\gamma A^\alpha\partial_\alpha B^\gamma\Big) \tag{31}$$

** what about squares

ISSUE

$$\Box\Big(A^\alpha B_\alpha\Big) - > NOTWORKING\Big(\Box A^\alpha B_\alpha + \Box B_\alpha A^\alpha + \Box B_\alpha A^\alpha + \Box A^\alpha B_\alpha\Big) \tag{32}$$

******** also check with equals signssssss
It appears that numbers are working but symbolic coefficients are not
** non-tensor terms
** only partial terms

ALSO test product rule with multiple tensors!!!!

QUESTION: why num co, symco, AND tensorCos?? What happens with multiple coefficients???

2.3 FOIL out terms without distributing derivatives

Basic case:

$$\Big(A\Big)\Big(Y\partial_\nu h^{\mu\nu} + X\partial^\mu h^\nu_\nu\Big) \to \Big(YA\partial_\nu h^{\mu\nu} + XA\partial^\mu h^\nu_\nu\Big) \tag{33}$$

Alternate cases:
*** constants that can move through the derivatives

$$\partial_\mu A\Big(Y\partial_\nu h^{\mu\nu} + X\partial^\mu h^\nu_\nu\Big) \to \partial_\mu\Big(YA\partial_\nu h^{\mu\nu} + XA\partial^\mu h^\nu_\nu\Big) \tag{34}$$

$$A\partial_\mu\Big(Y\partial_\nu h^{\mu\nu} + X\partial^\mu h^\nu_\nu\Big) - > (NOTworking)FIXED\partial_\mu\Big(YA\partial_\nu h^{\mu\nu} + XA\partial^\mu h^\nu_\nu\Big) \tag{35}$$

$$4\partial_\mu\Big(Y\partial_\nu h^{\mu\nu} + X\partial^\mu h^\nu_\nu\Big) \to \partial_\mu\Big(4Y\partial_\nu h^{\mu\nu} + 4X\partial^\mu h^\nu_\nu\Big) \tag{36}$$

*** multiple terms

$$\Big(A{+}5B{+}CD\Big)\partial_\mu\Big(Y\partial_\nu h^{\mu\nu}{+}X\partial^\mu h^\nu_\nu\Big) \rightarrow \partial_\mu\Big(YA\partial_\nu h^{\mu\nu}{+}5YB\partial_\nu h^{\mu\nu}{+}YCD\partial_\nu h^{\mu\nu}{+}XA\partial^\mu h^\nu_\nu{+}5XB\partial^\mu h^\nu_\nu{+}XCD\partial^\mu h^\nu_\nu\Big) \tag{37}$$

*** etas and deltas

$$\delta^\gamma_\zeta\eta^{\nu\alpha}\partial_\mu\Big(Y\partial_\nu h^{\mu\zeta}+X\partial^\mu h^\zeta_\nu\Big)\rightarrow\partial_\mu\Big(Y\delta^\gamma_\zeta\eta^{\nu\alpha}\partial_\nu h^{\mu\zeta}+X\delta^\gamma_\zeta\eta^{\nu\alpha}\partial^\mu h^\zeta_\nu\Big) \tag{38}$$

*** sum of mixed constants

$$\Big(A\eta^{\gamma\epsilon}{+}A5B{+}56\delta^\phi_\xi\Big)\partial_\mu\Big(Y\partial_\nu h^{\mu\nu}{+}X\partial^\mu h^\nu_\nu\Big)\rightarrow\partial_\mu\Big(YA\eta^{\gamma\epsilon}\partial_\nu h^{\mu\nu}{+}5YAB\partial_\nu h^{\mu\nu}{+}56Y\delta^\phi_\xi\partial_\nu h^{\mu\nu}{+}XA\eta^{\gamma\epsilon}\partial^\mu h^\nu_\nu{+}5XAB\partial^\mu h^\nu_\nu{+}56X\delta^\phi_\xi\partial \tag{39}$$

TODO: decide on how partials behave then implement test cases for them
Question: do all nodes have summation objects or do some have multgroup objects?? – they appear to all be summation objects
*** derivative is attached to a multgroup and doesn't need to be distributed

$$\partial_\gamma A^\gamma\Big(Y\partial_\mu\partial_\nu h^{\mu\nu}+X\partial_\mu\partial^\mu h^\nu_\nu\Big)\rightarrow\Big(Y\partial_\gamma A^\gamma\partial_\mu\partial_\nu h^{\mu\nu}+X\partial_\gamma A^\gamma\partial_\mu\partial^\mu h^\nu_\nu\Big) \tag{40}$$

** with added term at the end

$$\partial_\mu A^\epsilon\Big(Y\partial_\nu h^{\mu\nu}+X\partial^\mu h^\nu_\nu\Big)+B^\epsilon\rightarrow\Big(Y\partial_\mu A^\epsilon\partial_\nu h^{\mu\nu}+X\partial_\mu A^\epsilon\partial^\mu h^\nu_\nu+B^\epsilon\Big) \tag{41}$$

***with subtracted term at the end

$$\partial_\mu A^\epsilon\Big(Y\partial_\nu h^{\mu\nu}+X\partial^\mu h^\nu_\nu\Big)-B^\epsilon\rightarrow\Big(Y\partial_\mu A^\epsilon\partial_\nu h^{\mu\nu}+X\partial_\mu A^\epsilon\partial^\mu h^\nu_\nu-B^\epsilon\Big) \tag{42}$$

*** test FOIL ability ** 2 terms

$$\Big(A^\epsilon+B^\gamma\Big)\Big(\partial_\mu X^\mu+M^{\nu\zeta}_\gamma\Big)\rightarrow\Big(A^\epsilon\partial_\mu X^\mu+A^\epsilon M^{\nu\zeta}_\gamma+B^\gamma\partial_\mu X^\mu+B^\gamma M^{\nu\zeta}_\gamma\Big) \tag{43}$$

** 3 terms

$$H\Big(A^\epsilon{+}B^\gamma\Big)\Big(\partial_\mu X^\mu{+}M^{\nu\zeta}_\gamma\Big)\Big(X{+}Y\Big)\rightarrow\Big(HXA^\epsilon\partial_\mu X^\mu{+}HYA^\epsilon\partial_\mu X^\mu{+}HXA^\epsilon M^{\nu\zeta}_\gamma{+}HYA^\epsilon M^{\nu\zeta}_\gamma{+}HXB^\gamma\partial_\mu X^\mu{+}HYB^\gamma\partial_\mu X^\mu{+}HX \tag{44}$$

TODO figure out the part with switching and write test cases for it
ALSO etas and deltas
** multgroup also has constant factor

$$B\partial_\gamma A^\gamma\Big(Y\partial_\mu\partial_\nu h^{\mu\nu}+X\partial_\mu\partial^\mu h^\nu_\nu\Big)\rightarrow\Big(BY\partial_\gamma A^\gamma\partial_\mu\partial_\nu h^{\mu\nu}+BX\partial_\gamma A^\gamma\partial_\mu\partial^\mu h^\nu_\nu\Big) \tag{45}$$

**** Shouldn't be distributed

$$A^\zeta\partial_\mu\Big(Y\partial_\nu h^{\mu\nu}+X\partial^\mu h^\nu_\nu\Big)\rightarrow A^\zeta\partial_\mu\Big(Y\partial_\nu h^{\mu\nu}+X\partial^\mu h^\nu_\nu\Big) \tag{46}$$

$$\partial_\mu\Big(Y\partial_\nu h^{\mu\nu}+X\partial^\mu h^\nu_\nu\Big)+T^\gamma\Big(A_\gamma+B_\gamma\Big)\rightarrow\partial_\mu\Big(Y\partial_\nu h^{\mu\nu}+X\partial^\mu h^\nu_\nu\Big)+\Big(T^\gamma A_\gamma+T^\gamma B_\gamma\Big) \tag{47}$$

*** with added term at the end

$$A^\epsilon\partial_\mu\Big(Y\partial_\nu h^{\mu\nu}+X\partial^\mu h^\nu_\nu\Big)+B^\epsilon\rightarrow A^\epsilon\partial_\mu\Big(Y\partial_\nu h^{\mu\nu}+X\partial^\mu h^\nu_\nu\Big)+B^\epsilon \tag{48}$$

*** with subtracted term at the end

$$A^\epsilon\partial_\mu\Big(Y\partial_\nu h^{\mu\nu}+X\partial^\mu h^\nu_\nu\Big)-B^\epsilon\rightarrow A^\epsilon\partial_\mu\Big(Y\partial_\nu h^{\mu\nu}+X\partial^\mu h^\nu_\nu\Big)-B^\epsilon \tag{49}$$

Is this sensical or non-sensical???

$$\Big(\partial_{alpha}\Big)\Big(A^\gamma B_\gamma\Big)->LEADSTO\partial_{alpha}\Big(A^\gamma B_\gamma\Big) \tag{50}$$

What about...

$$\Big(\partial_\alpha\Big)\partial^\alpha\Big(A^\gamma B_\gamma\Big) - > LEADSTO \partial_\alpha\partial^\alpha\Big(A^\gamma B_\gamma\Big) \tag{51}$$

Also need to test adding summations, with and without partials, and subtracting summations, with and without partials

3 Contract

3.1 contract etas and deltas

$$\delta^\gamma_\beta \eta^{\nu\alpha}\partial_\mu h^\mu_\alpha \partial_\nu h^\beta_\gamma \to \partial_\mu h^{\mu\nu}\partial_\nu h^\gamma_\gamma \tag{52}$$

3.2 contract only deltas

Basic case:

$$\delta^\nu_\alpha \partial_\mu h^\mu_\alpha \partial_\nu h^\gamma_\gamma \to \partial_\mu h^\mu_\alpha \partial_\alpha h^\gamma_\gamma \tag{53}$$

3.3 contract only etas

Basic case:

$$\eta^{\nu\alpha}\partial_\mu h^\mu_\alpha \partial_\nu h^\gamma_\gamma \to \partial_\mu h^{\mu\nu}\partial_\nu h^\gamma_\gamma \tag{54}$$

Alternative cases:

4 Factor

4.1 factor out GCF

Basic case:

$$\Big(3Y\partial_\nu h^{\mu\nu} + Y\partial^\mu h^\nu_\nu\Big) \to Y\Big(3\partial_\nu h^{\mu\nu} + \partial^\mu h^\nu_\nu\Big) \tag{55}$$

Alternative cases:

$$\Big(X\partial_\nu h^{\mu\nu} + Y\partial_\nu h^{\mu\nu}\Big) \to \partial_\nu h^{\mu\nu}\Big(X+Y\Big) \tag{56}$$

*** sum

$$\Big(XA^\alpha_\alpha + YA^\alpha_\alpha\Big) \to A^\alpha_\alpha\Big(X+Y\Big) \tag{57}$$

*** no outer brackets...

$$XA^\alpha_\alpha + YA^\alpha_\alpha \to A^\alpha_\alpha\Big(X+Y\Big) \tag{58}$$

$$\Big(X\partial_\gamma h^{\mu\gamma} + Y\partial_\nu h^{\mu\nu}\Big) \to \partial_\gamma h^{\mu\gamma}\Big(X+Y\Big) \tag{59}$$

$$\Big(X\partial_\gamma h^{\mu\gamma}A^\alpha_\alpha + Y\partial_\nu h^{\mu\nu}\Big) \to \partial_\gamma h^{\mu\gamma}\Big(XA^\alpha_\alpha + Y\Big) \tag{60}$$

$$\Big(X\partial_\gamma h^{\mu\gamma} + Yh^{\gamma\nu}\Big) \to \Big(X\partial_\gamma h^{\mu\gamma} + Yh^{\gamma\nu}\Big) \tag{61}$$

$$\Big(\frac{1}{2}\partial_\gamma h^{\mu\gamma} + \frac{1}{4}h^{\gamma\nu}\Big) \to \frac{1}{4}\Big(2\partial_\gamma h^{\mu\gamma} + h^{\gamma\nu}\Big) \tag{62}$$

*** factor of 1 (implied)

$$\Big(X\partial_\nu h^{\mu\nu} + \partial_\nu h^{\mu\nu}\Big) \to \partial_\nu h^{\mu\nu}\Big(X+1\Big) \tag{63}$$

4.2 factor out user specified term

*** smaller numerical

$$\Big(\frac{1}{2}\partial_\gamma h^{\mu\gamma}+\frac{1}{4}h^{\gamma\nu}\Big),\frac{1}{8}\rightarrow\frac{1}{8}\Big(4\partial_\gamma h^{\mu\gamma}+2h^{\gamma\nu}\Big) \tag{64}$$

*** bigger numerical

$$\Big(\frac{1}{2}\partial_\gamma h^{\mu\gamma}+\frac{1}{4}h^{\gamma\nu}\Big),8\rightarrow 8\Big(\frac{1}{16}\partial_\gamma h^{\mu\gamma}+\frac{1}{32}h^{\gamma\nu}\Big) \tag{65}$$

*** smaller tensor

$$\Big(X\partial_\gamma h^{\mu\gamma}A^\gamma+Y\partial_\nu h^{\mu\nu}A^\gamma\Big),A^\gamma\rightarrow A^\gamma\Big(X\partial_\gamma h^{\mu\gamma}+Y\partial_\nu h^{\mu\nu}\Big) \tag{66}$$

*** not included tensor

$$X\partial_\mu\partial_\nu h^{\mu\nu}+Y\partial_\nu h^{\mu\nu},A^{alpha}\rightarrow\Big(X\partial_\mu\partial_\nu h^{\mu\nu}+Y\partial_\nu h^{\mu\nu}\Big) \tag{67}$$

*** different index

(***decide if this should be the expected behaviour (tensor logic question))

$$\Big(X\partial_\gamma h^{\mu\gamma}A^\gamma+Y\partial_\nu h^{\mu\nu}A^\gamma\Big),A^\alpha\rightarrow\Big(X\partial_\gamma h^{\mu\gamma}A^\gamma+Y\partial_\nu h^{\mu\nu}A^\gamma\Big) \tag{68}$$

*** make sure it's recognizing not to factor out tensors under partials

$$\Big(X\partial_\mu\partial_\nu h^{\mu\nu}+Y\partial_\nu h^{\mu\nu}A^\gamma\Big),\partial_\nu h^{\mu\nu}\rightarrow\partial_\nu h^{\mu\nu}\Big(YA^\gamma\Big)+\Big(X\partial_\mu\partial_\nu h^{\mu\nu}\Big) \tag{69}$$

*** what about if there's a different index with the same sum pattern, and what about coefficient of 1

$$\Big(XA^\alpha_\alpha+A^\alpha_\alpha\Big),A^\beta_\beta\rightarrow A^\beta_\beta\Big(X+1\Big) \tag{70}$$

— variation, no brackets…

$$XA^\alpha_\alpha+A^\alpha_\alpha,A^\beta_\beta\rightarrow A^\beta_\beta\Big(X+1\Big) \tag{71}$$

5 Replace

5.1 replace indices

Basic case:

*** single replacement

$$4X\partial_\mu\partial_\nu h^{\mu\nu}+Y\partial_\nu h^{\mu\nu}A^\gamma,\mu\rightarrow\alpha\rightarrow\Big(4X\partial_\alpha\partial_\nu h^{\alpha\nu}+Y\partial_\nu h^{\alpha\nu}A^\gamma\Big) \tag{72}$$

*** list replacement

$$4X\partial_\mu\partial_\nu h^{\mu\nu}+Y\partial_\nu h^{\mu\nu}A^\gamma,\mu,\nu,\gamma\rightarrow\alpha,\beta,\xi\rightarrow\Big(4X\partial_\alpha\partial_\beta h^{\alpha\beta}+Y\partial_\beta h^{\alpha\beta}A^\xi\Big) \tag{73}$$

*** replace index that doesn't exist

$$4X\partial_\mu\partial_\nu h^{\mu\nu}+Y\partial_\nu h^{\mu\nu}A^\gamma,\mu,\nu,\xi\rightarrow\alpha,\beta,\chi\rightarrow\Big(4X\partial_\alpha\partial_\beta h^{\alpha\beta}+Y\partial_\beta h^{\alpha\beta}A^\gamma\Big) \tag{74}$$

*** what if it's not there but it's one of the replacement indices

$$4X\partial_\mu\partial_\nu h^{\mu\nu}+Y\partial_\nu h^{\mu\nu}A^\gamma,\mu,\nu,\alpha\rightarrow\alpha,\beta,\xi\rightarrow\Big(4X\partial_\alpha\partial_\beta h^{\alpha\beta}+Y\partial_\beta h^{\alpha\beta}A^\gamma\Big) \tag{75}$$

*** long number of indices (mismatched list lengths)

5.2 replace terms

Basic case:

*** direct replacement

$$4X\partial_\mu\partial_\nu h^{\mu\nu} + Y\partial_\nu h^{\mu\nu}A^\gamma, A^\gamma \to B^\gamma \to \Big(4X\partial_\mu\partial_\nu h^{\mu\nu} + Y\partial_\nu h^{\mu\nu}B^\gamma\Big) \tag{76}$$

*** more complicated replacement term

$$4X\partial_\mu\partial_\nu h^{\mu\nu}+Y\partial_\nu h^{\mu\nu}A^\gamma, \partial_\nu h^{\mu\nu} \to \partial_\gamma V^{\mu\gamma} ISSUE: "Equation: indicestoreplacedonotmatchinlength!Pleaseemailjbrucero@uwc \tag{77}$$

$$4X\partial_\mu\partial_\nu h^{\mu\nu}+Y\partial_\nu h^{\mu\nu}A^\gamma, \partial_\nu h^{\mu\nu} \to V^\mu \to ISSUE: "Equation: indicestoreplacedonotmatchinlength!Pleaseemailjbrucero@uwc \tag{78}$$

— ***probably one of the most complicated algorithms, need to look over in detail then finish cases***

6 Sort

6.1 combine like terms differing only by a numerical factor

Basic case:

$$3A^\gamma + \frac{5}{7}A^\gamma \to \Big(\frac{26}{7}A^\gamma\Big) \tag{79}$$

*** fraction simplification

$$3A^\gamma + \frac{4}{2}A^\gamma \to \Big(5A^\gamma\Big) \tag{80}$$

*** coefficient of 1 (implied)

$$A^\gamma + A^\gamma \to \Big(2A^\gamma\Big) \tag{81}$$

*** more complicated term

$$3\partial_\gamma A^\gamma + \frac{5}{7}\partial_\beta A^\beta \to \Big(\frac{26}{7}\partial_\gamma A^\gamma\Big) \tag{82}$$

$$3\partial_\gamma\partial^\mu A^\gamma_{\nu\mu} + 7\partial_\beta\partial^\zeta A^\beta_{\nu\zeta} \to \Big(10\partial_\gamma\partial^\mu A^\gamma_{\nu\mu}\Big) \tag{83}$$

*** not all terms combine

$$3\partial_\gamma A^\gamma + 4A^\chi + \frac{5}{7}\partial_\beta A^\beta \to \Big(\frac{26}{7}\partial_\gamma A^\gamma + 4A^\chi\Big) \tag{84}$$

*** things that shouldn't combine

*** different tensors

$$3A^\gamma + \frac{5}{7}B^\gamma \to \Big(3A^\gamma + \frac{5}{7}B^\gamma\Big) \tag{85}$$

*** not differing only by numerical factor

$$3XA^\gamma + 7A^\gamma \to \Big(3XA^\gamma + 7A^\gamma\Big) \tag{86}$$

***different free indices

$$A^\beta + A^\alpha \to \Big(A^\beta + A^\alpha\Big) \tag{87}$$

***different number of partials

$$3\partial_\gamma A^\gamma_\nu + 7\partial_\beta\partial^\zeta A^\beta_{\nu\zeta} \to \Big(3\partial_\gamma A^\gamma_\nu + 7\partial_\beta\partial^\zeta A^\beta_{\nu\zeta}\Big) \tag{88}$$

*** different position of free index

$$3\partial_\gamma\partial^\mu A^\gamma_{\nu\mu} + 7\partial_\beta\partial^\zeta A^\beta_{\zeta\nu} \to \Big(3\partial_\gamma\partial^\mu A^\gamma_{\nu\mu} + 7\partial_\beta\partial^\zeta A^\beta_{\zeta\nu}\Big) \tag{89}$$

***(Unless A is a symmetric tensor, in which case):

$$3\partial_\gamma\partial^\mu A^\gamma_{\nu\mu} + 7\partial_\beta\partial^\zeta A^\beta_{\zeta\nu} \to \Big(10\partial_\gamma\partial^\mu A^\gamma_{\nu\mu}\Big) \tag{90}$$

6.2 combine like terms differing by any (numerical or symbolic) coefficient

*** basic case

$$3XA^\gamma + 7A^\gamma \to \Big(\Big(3X+7\Big)A^\gamma\Big) \tag{91}$$

*** more complicated term

$$3B\partial_\gamma A^\gamma + \frac{5}{7}V\partial_\beta A^\beta \to \Big(\Big(3B+\frac{5}{7}V\Big)\partial_\gamma A^\gamma\Big) \tag{92}$$

$$3B\partial_\gamma A^\gamma + \frac{5}{7}B\partial_\beta A^\beta \to \Big(\frac{26}{7}B\partial_\gamma A^\gamma\Big) \tag{93}$$

$$3M\partial_\gamma\partial^\mu A^\gamma_{\nu\mu} + 7X\partial_\beta\partial^\zeta A^\beta_{\nu\zeta} \to \Big(\Big(3M+7X\Big)\partial_\gamma\partial^\mu A^\gamma_{\nu\mu}\Big) \tag{94}$$

*** not all terms combine

$$3V\partial_\gamma A^\gamma + 4ZA^\chi + \frac{5}{7}N\partial_\beta A^\beta \to \Big(\Big(3V+\frac{5}{7}N\Big)\partial_\gamma A^\gamma + 4ZA^\chi\Big) \tag{95}$$

***shouldn't combine

$$3B\partial_\gamma A^\gamma + \frac{5}{7}V^\alpha_\alpha\partial_\beta A^\beta \to (I think this is what I want but should double check/see if an improvement combine these too \to would this behe \tag{96}$$

*** different tensors

$$3CA^\gamma + \frac{5}{7}DB^\gamma \to \Big(3CA^\gamma + \frac{5}{7}DB^\gamma\Big) \tag{97}$$

***different free indices

$$XA^\beta + A^\alpha \to \Big(XA^\beta + A^\alpha\Big) \tag{98}$$

***different number of partials

$$3\partial_\gamma A^\gamma_\nu + 7M\partial_\beta\partial^\zeta A^\beta_{\nu\zeta} \to \Big(3\partial_\gamma A^\gamma_\nu + 7M\partial_\beta\partial^\zeta A^\beta_{\nu\zeta}\Big) \tag{99}$$

*** different position of free index

$$3V\partial_\gamma\partial^\mu A^\gamma_{\nu\mu} + 7L\partial_\beta\partial^\zeta A^\beta_{\zeta\nu} \to \Big(3V\partial_\gamma\partial^\mu A^\gamma_{\nu\mu} + 7L\partial_\beta\partial^\zeta A^\beta_{\zeta\nu}\Big) \tag{100}$$

***(Unless A is a symmetric tensor, in which case):

$$3V\partial_\gamma\partial^\mu A^\gamma_{\nu\mu} + 7L\partial_\beta\partial^\zeta A^\beta_{\zeta\nu} \to \Big(\Big(3V+7L\Big)\partial_\gamma\partial^\mu A^\gamma_{\nu\mu}\Big) \tag{101}$$

6.3 sort the tensors in each term by number of derivatives (least to greatest)

$$\partial_\gamma\Box G^{\nu\gamma}\partial_\beta\partial^\xi M^\beta_\xi\Box\Box\partial_\chi X^{\kappa\zeta}_\nu\partial_\mu T^\mu \to \partial_\mu T^\mu\partial_\beta\partial^\xi M^\beta_\xi\partial_\gamma\Box G^{\nu\gamma}\partial_\chi\Box\Box X^{\kappa\zeta}_\nu \tag{102}$$

***What about with coefficients

$$4A\partial_\gamma\Box G^{\nu\gamma}\partial_\beta\partial^\xi M^\beta_\xi\Box\Box\partial_\chi X^{\kappa\zeta}_\nu\partial_\mu T^\mu \to WORKING 4A\partial_\mu T^\mu\partial_\beta\partial^\xi M^\beta_\xi\partial_\gamma\Box G^{\nu\gamma}\partial_\chi\Box\Box X^{\kappa\zeta}_\nu \tag{103}$$

***What about multiple terms and coefficients

$$4A\partial_\gamma\Box G^{\nu\gamma}\partial_\beta\partial^\xi M^\beta_\xi + \frac{7}{8}C\Box\Box\partial_\chi X^{\kappa\zeta}_\nu\partial_\mu T^\mu \to \Big(4A\partial_\beta\partial^\xi M^\beta_\xi\partial_\gamma\Box G^{\nu\gamma} + \frac{7}{8}C\partial_\mu T^\mu\partial_\chi\Box\Box X^{\kappa\zeta}_\nu\Big) \tag{104}$$

***And with brackets

$$\Big(4A\partial_\gamma\Box G^{\nu\gamma}\partial_\beta\partial^\xi M^\beta_\xi\Big)\Big(\frac{7}{8}C\Box\Box\partial_\chi X^{\kappa\zeta}_\nu\partial_\mu T^\mu\Big) \to \Big(4A\partial_\beta\partial^\xi M^\beta_\xi\partial_\gamma\Box G^{\nu\gamma}\Big)\Big(\frac{7}{8}C\partial_\mu T^\mu\partial_\chi\Box\Box X^{\kappa\zeta}_\nu\Big) \tag{105}$$

6.4 sort terms by number of derivatives (least to greatest)

$$\partial_\gamma\partial_\kappa A^\gamma + \partial^\chi B_\chi + C \to \Big(C + \partial^\chi B_\chi + \partial_\gamma\partial_\kappa A^\gamma\Big) \tag{106}$$

***with brackets

$$\Big(\partial_\gamma\partial_\kappa A^\gamma + \partial^\chi B_\chi + C\Big) \to \Big(C + \partial^\chi B_\chi + \partial_\gamma\partial_\kappa A^\gamma\Big) \tag{107}$$

***with coefficients

$$\Big(9\partial^\chi B_\chi + \frac{1}{2}T\partial_\gamma\partial_\kappa A^\gamma + MC\Big) \to \Big(MC + 9\partial^\chi B_\chi + \frac{1}{2}T\partial_\gamma\partial_\kappa A^\gamma\Big) \tag{108}$$

*** with multiplied terms

$$\Big(\partial_\gamma\partial_\kappa A^\gamma + \partial_\omega G\Big)\Big(\partial^\chi B_\chi + C\Big) \to \Big(\partial_\omega G + \partial_\gamma\partial_\kappa A^\gamma\Big)\Big(C + \partial^\chi B_\chi\Big) \tag{109}$$

** with multiple tensors per term (I think it goes by either least or greatest...)

$$\Big(\partial_\gamma\partial_\kappa\Box A^\gamma\partial_\omega G + \Box\partial^\chi B_\chi + \Box X_\xi + \Box VC\Big) \to \Big(\Box X_\xi + \Box VC + \partial^\chi\Box B_\chi + \partial_\gamma\partial_\kappa\Box A^\gamma\partial_\omega G\Big) \tag{110}$$

(must sort by total)

$$\partial_\xi H\partial_\omega G\partial^\xi M + \Box A \to \Big(\Box A + \partial_\xi H\partial_\omega G\partial^\xi M\Big) \tag{111}$$

*** interesting thing with brackets - should look into at some point
-¿ At the very least it should be a warning and not make it look like it worked...

*** same idea but with summation -¿ INTERESTING BRACKET STUFF - is it important??

$$(XA^\alpha_\alpha + YA^\alpha_\alpha) \to NOTWORKING(X+Y)A^\alpha_\alpha A^\alpha_\alpha \tag{112}$$

— variations on above:

$$(X\partial_\mu A^\alpha_\alpha + Y\partial_\mu A^\alpha_\alpha) \to sameissue(X+Y)\partial_\mu A^\alpha_\alpha\partial_\mu A^\alpha_\alpha \tag{113}$$

$$(X\partial_\alpha A^\alpha + Y\partial_\alpha A^\alpha) \to ISSUE(X+Y)\partial_\alpha A^\alpha\partial_\alpha A^\alpha \tag{114}$$

$$(X\partial_\alpha h^\alpha + Y\partial_\alpha h^\alpha) \to (X+Y)\partial_\alpha h^\alpha\partial_\alpha h^\alpha \tag{115}$$

$$(X\partial_\alpha h^{\alpha\beta} + Y\partial_\alpha h^{\alpha\beta}) \to (X+Y)\partial_\alpha h^{\alpha\beta}\partial_\alpha h^{\alpha\beta} \tag{116}$$