```
Quit[]
```

```
SetDirectory[
 "/Users/kazemazizi/Documents/Kazem_Azizi_Mac_Pro_2/IPM_2017/course/B_meson_mass/
   QCD_Side"]
```

```
/Users/kazemazizi/Documents/Kazem_Azizi_Mac_Pro_2/IPM_2017/course/B_meson_mass/
  QCD_Side
```

```
<< tracer
```

```
Remove::rmnsm : There are no symbols matching "Tracer`Private` *". >>
```

```
                              T R A C E R
                             =============

     A MATHEMATICA PACKAGE FOR GAMMA-ALGEBRA IN ARBITRARY DIMENSIONS
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            Version 1.1.1 from Mon Dec 30 15:36:00 MET 1991
                   (based on MATHEMATICA Version 1.2)

The package defines the following commands:

"AntiCommute", "ContractEpsGamma", "Eps", "G",
"GammaTrace", "G5", "H",
"ListCommands", "NoSpur",
"OnShell", "OutputFormat", "RemoveHatMomenta",

"RemoveNCM", "S", "Sigma", "SortLine", "Spur", "T",
"ToDiracBasis",
"ToHatTilde", "ToOtimes", "ToUG5", "U",
"VectorDimension", "Version".

                                   Help on usage as usual per ?Name.

DEFAULT SETTINGS ON STARTUP:

----------------------------

NonCommutativeMultiply will be removed.

Current OutputFormat is set to "texlike".

Package uses a non anticommuting G5 in "d" dimensions.

Package uses the usual anticommuting G5 in "d" dimensions.

WARNING: Use of the Epsilon tensor in d != 4 dimensions with
         anticommuting G5 is algebraically inconsistent.

Dimension set to "4". NOTE: For this setting of the dimension the

Package uses the usual anticommuting G5 in "4" dimensions.

The gamma matrix line(s) "ls" will be traced.
```

```
(*B^0 contains bbar d*)

(* m0sq qbarq part of d quark propagator*)

Sdqbarqsq[a_, b_, l_, x_] := -I * del[a, b] * gs^2 * dbdsq / 7776 * S[x, x] * G[l, x];
```

```
Sdqbarqsq[b, bb, l, x] // Expand
```

$$-\frac{1}{7776}\,\mathrm{i}\,\mathrm{dbdsq}\,\mathrm{gs}^2\,\mathrm{del}[\mathrm{b},\mathrm{bb}]\,\mathrm{x.x}\,\mathrm{G}[\ \mathrm{l},\ \mathrm{x}\ ]$$

```
(* Perturbative part for Heavy b quark *)

(*Remember an integrate over 4-k*)

Sb1[a_, b_, l_, x_] :=
  del[a, b] * Exp[-I * k.x] * I / (2 * Pi) ^ 4 * (G[l, k + mb * U] / (k ^ 2 - mb ^ 2));

Sb1[aa, a, l, x]
```

$$\left(\mathrm{i}\,\mathrm{e}^{-\mathrm{i}\,\mathrm{k.x}}\,\mathrm{del}[\mathrm{aa},\mathrm{a}]\,(\mathrm{mb}\,\mathrm{U}[\ \mathrm{l}\ ]+\mathrm{G}[\ \mathrm{l},\ \mathrm{k}\ ])\right)\Big/\left(16\left(\mathrm{k}^2-\mathrm{mb}^2\right)\pi^4\right)$$

```
(*Perturbative Part*)

(*Remember another intergal over 4-x*)

NonPertqbarqsq = I * Exp[I * p.x]
    (Sb1[aa, a, l, -x] ** G[l, G5] ** Sdqbarqsq[b, bb, l, x] ** G[l, G5]) // Expand
```

$$-\left(\left(\mathrm{i}\,\mathrm{dbdsq}\,\mathrm{e}^{-\mathrm{i}\,\mathrm{k.}(-\mathrm{x})+\mathrm{i}\,\mathrm{p.x}}\,\mathrm{gs}^2\,\mathrm{mb}\,\mathrm{del}[\mathrm{aa},\mathrm{a}]\,\mathrm{del}[\mathrm{b},\mathrm{bb}]\,\mathrm{x.x}\,\mathrm{G}[\ \mathrm{l},\ \mathrm{x}\ ]\right)\Big/\left(124\,416\left(\mathrm{k}^2-\mathrm{mb}^2\right)\pi^4\right)\right)-\left(\mathrm{i}\,\mathrm{dbdsq}\,\mathrm{e}^{-\mathrm{i}\,\mathrm{k.}(-\mathrm{x})+\mathrm{i}\,\mathrm{p.x}}\,\mathrm{gs}^2\,\mathrm{del}[\mathrm{aa},\mathrm{a}]\,\mathrm{del}[\mathrm{b},\mathrm{bb}]\,\mathrm{x.x}\,\mathrm{G}[\ \mathrm{l},\ \mathrm{k},\ \mathrm{x}\ ]\right)\Big/\left(124\,416\left(\mathrm{k}^2-\mathrm{mb}^2\right)\pi^4\right)$$

```
(*Perform trace of Gamma matrices*)

NonPertqbarqsq = NonPertqbarqsq /. l → ls // Expand
```

$$-\left(\left(\mathrm{i}\,\mathrm{dbdsq}\,\mathrm{e}^{-\mathrm{i}\,\mathrm{k.}(-\mathrm{x})+\mathrm{i}\,\mathrm{p.x}}\,\mathrm{gs}^2\,\mathrm{del}[\mathrm{aa},\mathrm{a}]\,\mathrm{del}[\mathrm{b},\mathrm{bb}]\,\mathrm{k.x}\,\mathrm{x.x}\right)\Big/\left(31\,104\left(\mathrm{k}^2-\mathrm{mb}^2\right)\pi^4\right)\right)$$

```
(*a→b,aa→bb*)

NonPertqbarqsq = NonPertqbarqsq /. del[aa, a] del[b, bb] :→ 3 // Expand
```

$$-\left(\left(\mathrm{i}\,\mathrm{dbdsq}\,\mathrm{e}^{-\mathrm{i}\,\mathrm{k.}(-\mathrm{x})+\mathrm{i}\,\mathrm{p.x}}\,\mathrm{gs}^2\,\mathrm{k.x}\,\mathrm{x.x}\right)\Big/\left(10\,368\left(\mathrm{k}^2-\mathrm{mb}^2\right)\pi^4\right)\right)$$

```
NonPertqbarqsq = NonPertqbarqsq /. k.(-x) :→ -S[k, x] // Expand
```

$$-\left(\left(\mathrm{i}\,\mathrm{dbdsq}\,\mathrm{e}^{\mathrm{i}\,\mathrm{k.x}+\mathrm{i}\,\mathrm{p.x}}\,\mathrm{gs}^2\,\mathrm{k.x}\,\mathrm{x.x}\right)\Big/\left(10\,368\left(\mathrm{k}^2-\mathrm{mb}^2\right)\pi^4\right)\right)$$

```
(*Perform integral over x*)

NonPertqbarqsq = NonPertqbarqsq /. Exp[i k.x + i p.x] :→ (2 Pi) ^ D DiracD[p + k] // Expand
```

$$-\left(\left(\mathrm{i}\,2^{-7+\mathrm{D}}\,\mathrm{dbdsq}\,\mathrm{gs}^2\,\pi^{-4+\mathrm{D}}\,\mathrm{DiracD}[\mathrm{k}+\mathrm{p}]\,\mathrm{k.x}\,\mathrm{x.x}\right)\Big/\left(81\left(\mathrm{k}^2-\mathrm{mb}^2\right)\right)\right)$$

```
(*Separate the k.x to k.{mu} x.{mu}. We will write x.{mu} as a four-
 derivative with respect to the initial momentum p*)
```

```
NonPertqbarqsq =
 NonPertqbarqsq /. S[k, x] :> Module[{dummy}, k.{dummy} Hold[x.{dummy}]] /.
  S[x, x] :> Module[{dummy}, x.{dummy} Hold[x.{dummy}]]
```

$$-\frac{1}{81\left(k^2-mb^2\right)}\,i\,2^{-7+D}\,dbdsq\,gs^2\,\pi^{-4+D}\,DiracD[k+p]$$
$$Hold[x.\{dummy\$622\}]\,Hold[x.\{dummy\$623\}]\,k\_\{dummy\$622\}\,x\_\{dummy\$623\}$$

```
(*Perform integration over k using Dirac delta*)

NonPertqbarqsq = NonPertqbarqsq /. DiracD[k + p] :> 1 /. k :> -p // Expand
```

$$\left(i\,2^{-7+D}\,dbdsq\,gs^2\,\pi^{-4+D}\,Hold[x.\{dummy\$622\}]\right.$$
$$\left.Hold[x.\{dummy\$623\}]\,p\_\{dummy\$622\}\,x\_\{dummy\$623\}\right)\Big/\left(81\left(-mb^2+p^2\right)\right)$$

```
NonPertqbarqsq = NonPertqbarqsq /. D → 4
```

$$\left(i\,dbdsq\,gs^2\,Hold[x.\{dummy\$622\}]\,Hold[x.\{dummy\$623\}]\,p\_\{dummy\$622\}\,x\_\{dummy\$623\}\right)\Big/$$
$$\left(648\left(-mb^2+p^2\right)\right)$$

```
(*In this step apply the derivative x_mu-->-I del/del p_mu in Minkovski space*)

rule1 = {1 / (-mb^2 + p^2) Hold[x.{mu_}] Hold[x.{nu_}] x.{teta_} p.{eta_} :>
     (-I) ^3 (-2 {mu}.{nu} {eta}.{teta} / (p^2 - mb^2) ^2 +
        4 p.{mu} p.{nu} {eta}.{teta} / (p^2 - mb^2) ^3 -
        (2 {teta}.{nu} {eta}.{mu} + 2 {eta}.{nu} {teta}.{mu}) / (p^2 - mb^2) ^2 +
        4 ({teta}.{nu} p.{mu} p.{eta} + {eta}.{nu} p.{mu} p.{teta}) / (p^2 - mb^2) ^3 +
        8 ({nu}.{mu} p.{teta} p.{eta} + {mu}.{teta} p.{nu} p.{eta} +
             {mu}.{eta} p.{nu} p.{teta}) / (p^2 - mb^2) ^3 -
        48 p.{mu} p.{nu} p.{teta} p.{eta} / (p^2 - mb^2) ^4),
   1 / (-mb^2 + p^2) Hold[x.{mu_}] x.{nu_} :> (-I) ^2
     (-2 {mu}.{nu} / (p^2 - mb^2) ^2 + 4 p.{mu} p.{nu}) / (p^2 - mb^2) ^3,
   1 / (-mb^2 + p^2) Hold[x.{mu_}] p.{nu_} :> -I * 2 (p^2 - 2 mb^2) / (p^2 - mb^2) ^2};

NonPertqbarqsq = NonPertqbarqsq //. rule1 // Expand
```

$$\frac{2\,dbdsq\,gs^2}{27\left(-mb^2+p^2\right)^2}-\frac{dbdsq\,gs^2\,p.p}{9\left(-mb^2+p^2\right)^3}+\frac{2\,dbdsq\,gs^2\,p.p^2}{27\left(-mb^2+p^2\right)^4}$$

```
NonPertqbarqsq = NonPertqbarqsq /. p.p → p^2 // Expand
```

$$\frac{2\,dbdsq\,gs^2\,p^4}{27\left(-mb^2+p^2\right)^4}-\frac{dbdsq\,gs^2\,p^2}{9\left(-mb^2+p^2\right)^3}+\frac{2\,dbdsq\,gs^2}{27\left(-mb^2+p^2\right)^2}$$

```
NonPertqbarqsq >> qbarqsq.out
```