```
In[144]:= x = .;
B = .;
W1 = .;
W2 = .;
W3 = .;
gw = .;
gb = .;
Z = .;
Bm = .;
B = .;
v = .;
h = .;
fai0 = .;
m = .;

(*Original gamma matrices for fermions*)
y[1] = {{0, 0, 0, -1}, {0, 0, -1, 0}, {0, 1, 0, 0}, {1, 0, 0, 0}};
y[2] = {{0, 0, 0, -I}, {0, 0, I, 0}, {0, I, 0, 0}, {-I, 0, 0, 0}};
y[3] = {{0, 0, 1, 0}, {0, 0, 0, -1}, {-1, 0, 0, 0}, {0, 1, 0, 0}};
y[4] = {{-1, 0, 0, 0}, {0, -1, 0, 0}, {0, 0, 1, 0}, {0, 0, 0, 1}};
e4 = IdentityMatrix[4];

y[1] // MatrixForm
y[2] // MatrixForm
y[3] // MatrixForm
y[4] // MatrixForm

(*Original gamma matrices for fermions-commutation relations*)
Print["Original gamma matrices commutation relations"];

(*Calculation to verify that 4 gamma matrices (4×4) satisfy anti-
 commutation relations*)
yf = 0;

yt = 0;

For[kh = 1, kh <= 4, kh++,
  For[ks1 = 1, ks1 <= 4, ks1++, yf = Det[y[kh].y[ks1] + y[ks1].y[kh]];
   yt = yf + yt;
   If[kh == ks1 && yf == 16, Print["x=", kh, ",y=", ks1, ",OK"]];
   If[kh =!= ks1 && yf == 0, Print["x=", kh, ",y=", ks1, ",OK"]];]];

(*Pauli matrices for bosons*)
t1 = {{0, 0, 0, 0}, {0, 0, 0, 0}, {0, 1, 0, 0}, {1, 0, 0, 0}};
t2 = {{0, 0, 0, 0}, {0, 0, 0, 0}, {0, -I, 0, 0}, {I, 0, 0, 0}};
t3 = {{0, 0, 1, 0}, {0, 0, 0, -1}, {1, 0, 0, 0}, {0, -1, 0, 0}};
(*t3={{0,0,0,0},{0,0,0,0},{1,0,0,0},{0,-1,0,0}};*)

(*Identity matrix for fermions*)
(*t4={{-1,0,0,0},{0,-1,0,0},{0,0,0,0},{0,0,0,0}};
t5={{0,0,0,0},{0,0,0,0},{0,0,1,0},{0,0,0,1}};
t5=0;*)
t4 = {{-1, 0, 0, 0}, {0, -1, 0, 0}, {0, 0, 1, 0}, {0, 0, 0, 1}};

t1 // MatrixForm
```

```
t2 // MatrixForm
t3 // MatrixForm
t4 // MatrixForm

fai1 = {fai0 + h * x / Sqrt[2], fai0 + h * x / Sqrt[2], 0, 0}; (*Left-handed*)
fai2 = {0, 0, fai0 + h * x / Sqrt[2], fai0 + h * x / Sqrt[2]}; (*Right-handed*)

y1 = I * gw / 2 * (t1 * W1 + t2 * W2 + t3 * Z);
y2 = I * gb / 2 * Z * t4;
(*y2=I*gb/2*Z*t50;
y3=(A+m)/2*t5;*)
y3 = 0;
ys = (y1 + y2 + y3);
ys = (y1 + y2);
ys // MatrixForm

Print["-----------------------------------------------------"];

y1d = Conjugate[I] * gw / 2 * (Conjugate[t1] * W1 + Conjugate[t2] * W2 + Conjugate[t3] * Z);
y2d = Conjugate[I] * gb / 2 * (Conjugate[t4] * Z);
(*y2d=Conjugate[I]*gb/2*(Conjugate[t50]*Z);
y3d=(A+m)/2*t5;*)
y3d = 0;
ysd = (y1d + y2d + y3d);
ysd = (y1d + y2d);
ysd // MatrixForm

Print["-----------------------------------------------------"];

ya1 =
  FullSimplify[(y1 + y2 + y3)] /. W1 - I W2 -> Wp /. W1 + I W2 -> Wm /. -W1 + I W2 -> -Wp /.
       -W1 - I W2 -> -Wm /. I W1 + W2 -> I Wp /.
     I W1 - W2 -> I Wm /. -I W1 - W2 -> -I * Wp /. -I W1 + W2 -> -I * Wm;
ya2 = FullSimplify[(y1d + y2d + y3d)] /. W1 - I W2 -> Wp /. W1 + I W2 -> Wm /.
        -W1 + I W2 -> -Wp /. -W1 - I W2 -> -Wm /. I W1 + W2 -> I Wp /.
     I W1 - W2 -> I Wm /. -I W1 - W2 -> -I * Wp /. -I W1 + W2 -> -I * Wm;
FullSimplify[(y1 + y2 + y3).(y1d + y2d + y3d)] /. W1 - I W2 -> Wp /. W1 + I W2 -> Wm /.
       -W1 + I W2 -> -Wp /. -W1 - I W2 -> -Wm /. I W1 + W2 -> I Wp /.
    I W1 - W2 -> I Wm /. -I W1 - W2 -> -I * Wp /. -I W1 + W2 -> -I * Wm;

ya1 // MatrixForm
ya2 // MatrixForm

FullSimplify[ExpandAll[ya1.ya2]] // MatrixForm

Print["-----------------------------------------------------"];
Print["-----------------------------------------------------"];

(*Left-handed*)
Print["Left-handed"];
(y1 + y2 + y3).fai1 /. W1 - I W2 -> Wp /. W1 + I W2 -> Wm /. -W1 + I W2 -> -Wp /.
      -W1 - I W2 -> -Wm /. I W1 + W2 -> I Wp /. I W1 - W2 -> I Wm /.
   -I W1 - W2 -> -I * Wp /. -I W1 + W2 -> -I * Wm // MatrixForm
```

```
(y1d + y2d + y3d).fai1 /. W1 - I W2 -> Wp /. W1 + I W2 -> Wm /. -W1 + I W2 -> -Wp /.
       -W1 - I W2 -> -Wm /. I W1 + W2 -> I Wp /. I W1 - W2 -> I Wm /.
    -I W1 - W2 -> -I * Wp /. -I W1 + W2 -> -I * Wm // MatrixForm
y4 = Coefficient[((y1 + y2 + y3).fai1).((y1d + y2d + y3d).fai1) / 2 /. W1 - I W2 -> Wp /.
           W1 + I W2 -> Wm /. -W1 + I W2 -> -Wp /. -W1 - I W2 -> -Wm /.
        I W1 + W2 -> I Wp /. I W1 - W2 -> I Wm /. -I W1 - W2 -> -I * Wp /.
     -I W1 + W2 -> -I * Wm, fai0 + h x / Sqrt[2], 2];

FullSimplify[ExpandAll[y4]]

Print["----------------------------------------------------"];

Zm = Simplify[Coefficient[y4, Z, 2]];
Wmp = Simplify[Coefficient[y4, Wm Wp, 1]];
Am = Simplify[Coefficient[y4, A, 2]];
ms = Simplify[Coefficient[y4, m, 2]];

Print["Z coefficient=", Zm];
Print["Wmp coefficient=", Wmp];
Print["A coefficient=", Am];
(*gw=0.63;*)
gw = 0.653;(*changed*)

cos = (1 - 0.2276) ^ (1 / 2);
cos^2 + 0.2276;
g = gw / cos;
gb = (g^2 - gw^2) ^ (1 / 2);
v = 246;

Print["Z=", v * (Zm^ (0.5))]
Print["Wmp=", v * (Wmp^ (0.5))]
Print["A=", v * (Am^ (0.5))]
(*Print["Higgs particle mass"];
Print["m=",v*(ms^(0.5))]*)

Print["----------------------------------------------------"];

x = .;
B = .;
W1 = .;
W2 = .;
W3 = .;
gw = .;
gb = .;
Z = .;
Bm = .;
B = .;
v = .;
h = .;
fai0 = .;
m = .;

(*Right-handed*)
Print["Right-handed"];
```

```
(y1 + y2 + y3).fai2 /. W1 - I W2 -> Wp /. W1 + I W2 -> Wm /. -W1 + I W2 -> -Wp /.
      -W1 - I W2 -> -Wm /. I W1 + W2 -> I Wp /. I W1 - W2 -> I Wm /.
   -I W1 - W2 -> -I * Wp /. -I W1 + W2 -> -I * Wm // MatrixForm
(y1d + y2d + y3d).fai2 /. W1 - I W2 -> Wp /. W1 + I W2 -> Wm /. -W1 + I W2 -> -Wp /.
      -W1 - I W2 -> -Wm /. I W1 + W2 -> I Wp /. I W1 - W2 -> I Wm /.
   -I W1 - W2 -> -I * Wp /. -I W1 + W2 -> -I * Wm // MatrixForm

y4 = Coefficient[
   (((y1 + y2 + y3).fai2).(((y1d + y2d + y3d).fai2) / 2 /. W1 - I W2 -> Wp /. W1 + I W2 -> Wm /.
        -W1 + I W2 -> -Wp /. -W1 - I W2 -> -Wm /. I W1 + W2 -> I Wp /. I W1 - W2 -> I Wm /.
     -I W1 - W2 -> -I * Wp /. -I W1 + W2 -> -I * Wm, fai0 + h x / Sqrt[2], 2];

FullSimplify[ExpandAll[y4]]
(*Zm=Simplify[
  Coefficient[y4,Z,2]/.Cos[th]→gw/Sqrt[gb^2+gw^2]/.Sin[th]→gb/Sqrt[gb^2+gw^2]];
Wmp=Simplify[Coefficient[y4,Wm Wp,1]/.Cos[th]→gw/Sqrt[gb^2+gw^2]/.
   Sin[th]→gb/Sqrt[gb^2+gw^2]];
Bm=Simplify[Coefficient[y4,B,2]/.Cos[th]→gw/Sqrt[gb^2+gw^2]/.
   Sin[th]→gb/Sqrt[gb^2+gw^2]];*)

Zm = Simplify[Coefficient[y4, Z, 2]];
Wmp = Simplify[Coefficient[y4, Wm Wp, 1]];
Am = Simplify[Coefficient[y4, A, 2]];
ms = Simplify[Coefficient[y4, m, 2]];

Print["Z coefficient=", Zm];
Print["Wmp coefficient=", Wmp];
Print["A coefficient=", Am];
(*gw=0.63;*)
gw = 0.653; (*changed*)

cos = (1 - 0.2276) ^ (1 / 2);
cos ^ 2 + 0.2276;
g = gw / cos;
gb = (g^2 - gw^2) ^ (1 / 2);
v = 246;

Print["Z=", v * (Zm^ (0.5))]
Print["Wmp=", v * (Wmp^ (0.5))]
Print["A=", v * (Am^ (0.5))]
(*Print["Higgs particle mass"];
Print["m=",v*(ms^(0.5))]*)
```

Out[163]//MatrixForm=

$$\begin{pmatrix} 0 & 0 & 0 & -1 \\ 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{pmatrix}$$

Out[164]//MatrixForm=

$$\begin{pmatrix} 0 & 0 & 0 & -i \\ 0 & 0 & i & 0 \\ 0 & i & 0 & 0 \\ -i & 0 & 0 & 0 \end{pmatrix}$$

Out[165]//MatrixForm=

$$\begin{pmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 \\ -1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix}$$

Out[166]//MatrixForm=

$$\begin{pmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Original gamma matrices commutation relations

x=1,y=1,OK

x=1,y=2,OK

x=1,y=3,OK

x=1,y=4,OK

x=2,y=1,OK

x=2,y=2,OK

x=2,y=3,OK

x=2,y=4,OK

x=3,y=1,OK

x=3,y=2,OK

x=3,y=3,OK

x=3,y=4,OK

x=4,y=1,OK

x=4,y=2,OK

x=4,y=3,OK

x=4,y=4,OK

Out[175]//MatrixForm=

$$\begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{pmatrix}$$

Out[176]//MatrixForm=

$$\begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & -i & 0 & 0 \\ i & 0 & 0 & 0 \end{pmatrix}$$

Out[177]//MatrixForm=

$$\begin{pmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 \\ 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \end{pmatrix}$$

Out[178]//MatrixForm=

$$\begin{pmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Out[186]//MatrixForm=

$$\begin{pmatrix} -\frac{1}{2}\, i\, gb\, Z & 0 & \frac{i\, gw\, Z}{2} & 0 \\ 0 & -\frac{1}{2}\, i\, gb\, Z & 0 & -\frac{1}{2}\, i\, gw\, Z \\ \frac{i\, gw\, Z}{2} & \frac{1}{2}\, i\, gw\, (W1 - i\, W2) & \frac{i\, gb\, Z}{2} & 0 \\ \frac{1}{2}\, i\, gw\, (W1 + i\, W2) & -\frac{1}{2}\, i\, gw\, Z & 0 & \frac{i\, gb\, Z}{2} \end{pmatrix}$$

\-

Out[193]//MatrixForm=

$$\begin{pmatrix} \frac{i\, gb\, Z}{2} & 0 & -\frac{1}{2}\, i\, gw\, Z & 0 \\ 0 & \frac{i\, gb\, Z}{2} & 0 & \frac{i\, gw\, Z}{2} \\ -\frac{1}{2}\, i\, gw\, Z & -\frac{1}{2}\, i\, gw\, (W1 + i\, W2) & -\frac{1}{2}\, i\, gb\, Z & 0 \\ -\frac{1}{2}\, i\, gw\, (W1 - i\, W2) & \frac{i\, gw\, Z}{2} & 0 & -\frac{1}{2}\, i\, gb\, Z \end{pmatrix}$$

\-

Out[198]//MatrixForm=

$$\begin{pmatrix} -\frac{1}{2}\, i\, gb\, Z & 0 & \frac{i\, gw\, Z}{2} & 0 \\ 0 & -\frac{1}{2}\, i\, gb\, Z & 0 & -\frac{1}{2}\, i\, gw\, Z \\ \frac{i\, gw\, Z}{2} & \frac{i\, gw\, Wp}{2} & \frac{i\, gb\, Z}{2} & 0 \\ \frac{i\, gw\, Wm}{2} & -\frac{1}{2}\, i\, gw\, Z & 0 & \frac{i\, gb\, Z}{2} \end{pmatrix}$$

Out[199]//MatrixForm=

$$\begin{pmatrix} \frac{i\, gb\, Z}{2} & 0 & -\frac{1}{2}\, i\, gw\, Z & 0 \\ 0 & \frac{i\, gb\, Z}{2} & 0 & \frac{i\, gw\, Z}{2} \\ -\frac{1}{2}\, i\, gw\, Z & -\frac{1}{2}\, i\, gw\, Wm & -\frac{1}{2}\, i\, gb\, Z & 0 \\ -\frac{1}{2}\, i\, gw\, Wp & \frac{i\, gw\, Z}{2} & 0 & -\frac{1}{2}\, i\, gb\, Z \end{pmatrix}$$

Out[200]//MatrixForm=

$$\begin{pmatrix} \frac{1}{4}\, (gb^2 + gw^2)\, Z^2 & \frac{1}{4}\, gw^2\, Wm\, Z & 0 & 0 \\ -\frac{1}{4}\, gw^2\, Wp\, Z & \frac{1}{4}\, (gb^2 + gw^2)\, Z^2 & 0 & 0 \\ 0 & \frac{1}{4}\, gb\, gw\, (Wm - Wp)\, Z & \frac{1}{4}\, (gb^2 + gw^2)\, Z^2 & -\frac{1}{4}\, gw^2\, Wp\, Z \\ \frac{1}{4}\, gb\, gw\, (-Wm + Wp)\, Z & 0 & \frac{1}{4}\, gw^2\, Wm\, Z & \frac{1}{4}\, (gb^2 + gw^2)\, Z^2 \end{pmatrix}$$

\-

\-

Left-handed

Out[204]//MatrixForm=

$$\begin{pmatrix} -\frac{1}{2}\, i\, gb \left(fai0 + \frac{h\, x}{\sqrt{2}}\right) Z \\ -\frac{1}{2}\, i\, gb \left(fai0 + \frac{h\, x}{\sqrt{2}}\right) Z \\ \frac{1}{2}\, i\, gw\, Wp \left(fai0 + \frac{h\, x}{\sqrt{2}}\right) + \frac{1}{2}\, i\, gw \left(fai0 + \frac{h\, x}{\sqrt{2}}\right) Z \\ \frac{1}{2}\, i\, gw\, Wm \left(fai0 + \frac{h\, x}{\sqrt{2}}\right) - \frac{1}{2}\, i\, gw \left(fai0 + \frac{h\, x}{\sqrt{2}}\right) Z \end{pmatrix}$$

Out[205]//MatrixForm=

$$\begin{pmatrix} \frac{1}{2}\, i\, gb \left(fai0 + \frac{h x}{\sqrt{2}}\right) Z \\ \frac{1}{2}\, i\, gb \left(fai0 + \frac{h x}{\sqrt{2}}\right) Z \\ -\frac{1}{2}\, i\, gw\, Wm \left(fai0 + \frac{h x}{\sqrt{2}}\right) - \frac{1}{2}\, i\, gw \left(fai0 + \frac{h x}{\sqrt{2}}\right) Z \\ -\frac{1}{2}\, i\, gw\, Wp \left(fai0 + \frac{h x}{\sqrt{2}}\right) + \frac{1}{2}\, i\, gw \left(fai0 + \frac{h x}{\sqrt{2}}\right) Z \end{pmatrix}$$

Out[207]= $$\frac{1}{4} \left(gw^2\, Wm\, Wp + \left(gb^2 + gw^2\right) Z^2\right)$$

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Z coefficient $= \frac{1}{4} \left(gb^2 + gw^2\right)$

Wmp coefficient $= \frac{gw^2}{4}$

A coefficient=0

Z=91.3897

Wmp=80.319

A=0.

```
--------------------------------------------------------
```

Right-handed

Out[241]//MatrixForm=

$$\begin{pmatrix} \frac{1}{2}\, i\, gw \left(fai0 + \frac{h x}{\sqrt{2}}\right) Z \\ -\frac{1}{2}\, i\, gw \left(fai0 + \frac{h x}{\sqrt{2}}\right) Z \\ \frac{1}{2}\, i\, gb \left(fai0 + \frac{h x}{\sqrt{2}}\right) Z \\ \frac{1}{2}\, i\, gb \left(fai0 + \frac{h x}{\sqrt{2}}\right) Z \end{pmatrix}$$

Out[242]//MatrixForm=

$$\begin{pmatrix} -\frac{1}{2}\, i\, gw \left(fai0 + \frac{h x}{\sqrt{2}}\right) Z \\ \frac{1}{2}\, i\, gw \left(fai0 + \frac{h x}{\sqrt{2}}\right) Z \\ -\frac{1}{2}\, i\, gb \left(fai0 + \frac{h x}{\sqrt{2}}\right) Z \\ -\frac{1}{2}\, i\, gb \left(fai0 + \frac{h x}{\sqrt{2}}\right) Z \end{pmatrix}$$

Out[244]= $$\frac{1}{4} \left(gb^2 + gw^2\right) Z^2$$

Z coefficient $= \frac{1}{4} \left(gb^2 + gw^2\right)$

Wmp coefficient=0

A coefficient=0

Z=91.3897

Wmp=0.

A=0.