********MathematicaTutorial: SBU********

(Debug) In[ ]:=
```
Today
```
(Debug) Out[ ]=

Tue 26 Nov 2024

Removing all definitions and Setting Directory

Removing all definitions, values attributes, messages and default options that have been created in the Global` context and that don' t have the Protected attribute (Protected attributes are those qualities, traits or characteristics that, by law, cannot be discriminated against)

(Debug) In[ ]:=
```
(*Quit Kernal*)
Quit[]
```
(Debug) In[ ]:=
```
(*Keep the defined variables but will wash the assigned value*)
ClearAll["Global`*"]
```
```
aa
```
(Debug) In[ ]:=
```
aa = 2
```
(Debug) Out[ ]=
```
2
```
```
aa
```
(Debug) In[ ]:=
```
(*To remove a perticular variable*)
Clear[aa]
```
(Debug) In[ ]:=
```
SetDirectory[NotebookDirectory[]];
```

Differential Equations

Solve

(Debug) In[ ]:=

```
a1 = Solve[3 a^3 - 2 b^2 - c^3 - h == 0, b][[2, 1, 2]]
```

(Debug) Out[ ]=

$$\frac{\sqrt{3 a^3 - c^3 - h}}{\sqrt{2}}$$

(Debug) In[ ]:=

```
N[a1 /. {a → 2, c → 1, h → 2}]
```

(Debug) Out[ ]=

```
3.24037
```

```
a11[a_, c_, h_] := Solve[3 a^3 - 2 b^2 - c^3 - h == 0, b]

N[a11[2, 1, 2]]

Cc
```

Magnetization

(Debug) In[ ]:=

```
Solve[M == Tanh[M * z/T + Bext/T], M]
```

Solve: This system cannot be solved with the methods available to Solve.

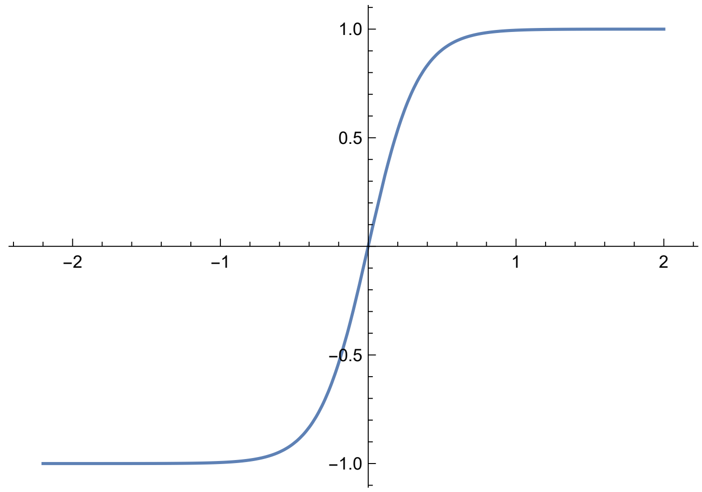
(Debug) Out[ ]=

```
Solve[M == Tanh[Bext/T + M z/T], M]
```

(Debug) In[ ]:=

```
z = 3;
Bext = 0;
T = 1;
aa = ParametricPlot[{M, Tanh[M * z/T + Bext/T]}, {M, -2.2, 2}, AspectRatio → 0.7]
```

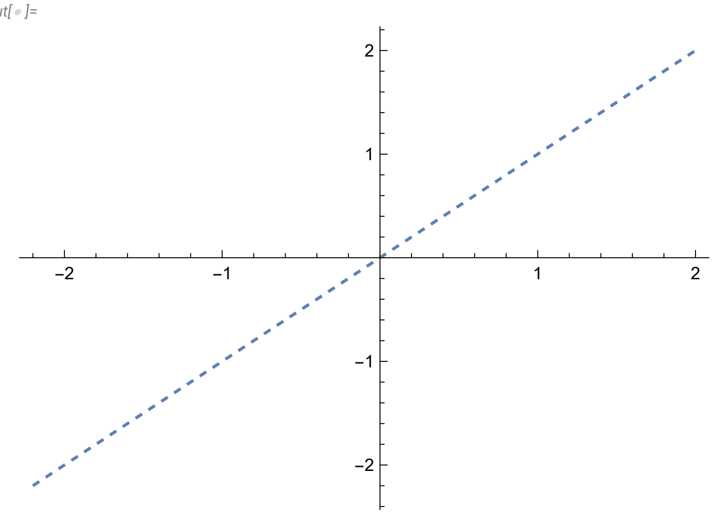
(Debug) Out[ ]=



(Debug) In[ ]:=

```
bb = Plot[M, {M, -2.2, 2}, AspectRatio → 0.7, PlotStyle → Dashed]
```

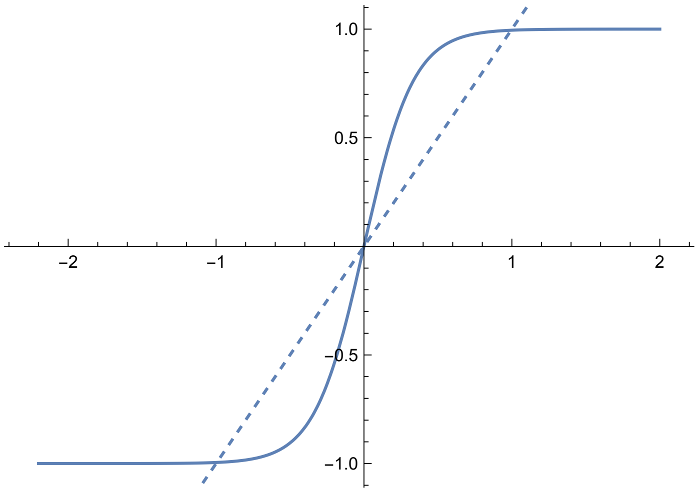
(Debug) Out[ ]=



(Debug) In[ ]:=

```
Show[aa, bb]
```

(Debug) Out[ ]=



Differential Solve

(Debug) In[ ]:=

```
DSolve[b''[x] + b'[x] + b[x] == 0, b[x], x][[1, 1, 2]]
```

(Debug) Out[ ]=

$$e^{-x/2}\, c_2 \,\text{Cos}\left[\frac{\sqrt{3}\; x}{2}\right] + e^{-x/2}\, c_1 \,\text{Sin}\left[\frac{\sqrt{3}\; x}{2}\right]$$

```
D[b[x], {x, 9}]
```

Numerical Differential Solve

Simple Harmonic Oscillator

(Debug) In[ ]:=

```
α = 0;
ω0 = 1;
f = 0;
ω = 0.666;
ss1 =
 NDSolve[{y''[t] + α * y'[t] + ω0^2 * y[t] == f * Cos[ω * t], y'[0] == 1, y[0] == 0}, y, {t, 0, 40}][[
   1, 1, 2]]
```

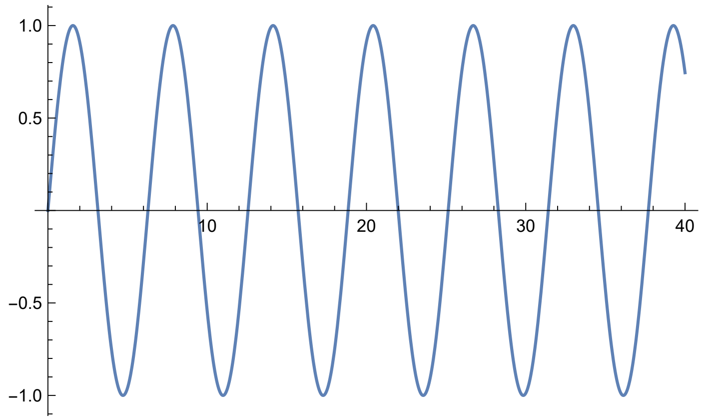
(Debug) Out[ ]=

InterpolatingFunction[Domain: {{0., 40.}} Output: scalar]

(Debug) In[ ]:=

```
Plot[ss1[t], {t, 0, 40}]
```

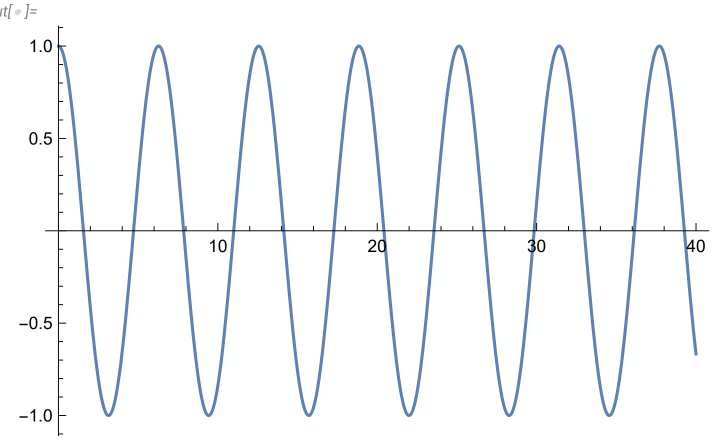
(Debug) Out[ ]=



(Debug) In[ ]:=

```
Plot[ss1'[t], {t, 0, 40}]
```

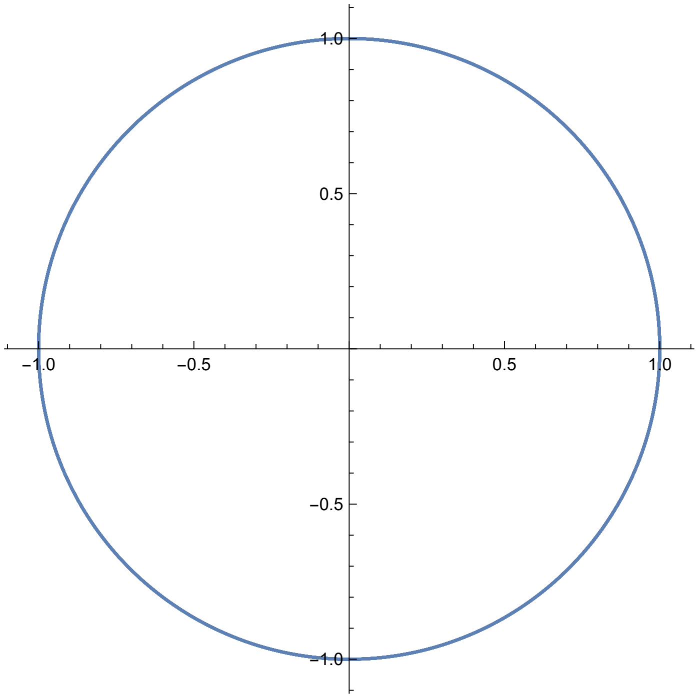
(Debug) Out[ ]=



(Debug) In[ ]:=

```
ParametricPlot[{ss1[t], ss1'[t]}, {t, 0, 40}]
```

(Debug) Out[ ]=



Damped Harmonic Oscillator

(Debug) In[ ]:=

```
α = 0.2;
ω0 = 1;
f = 0.52;
ω = 0.666;
ss = NDSolve[{y''[t] + α * y'[t] + ω0^2 * Sin[y[t]] == f * Cos[ω * t], y'[0] == 1, y[0] == 0},
   y, {t, 0, 100}][[1, 1, 2]]
```

(Debug) Out[ ]=

```
InterpolatingFunction[ Domain: {{0., 100.}} Output: scalar ]
```

→

λ ∧ δ

λ

5 / 6

$\frac{5}{6}\ 1^4$

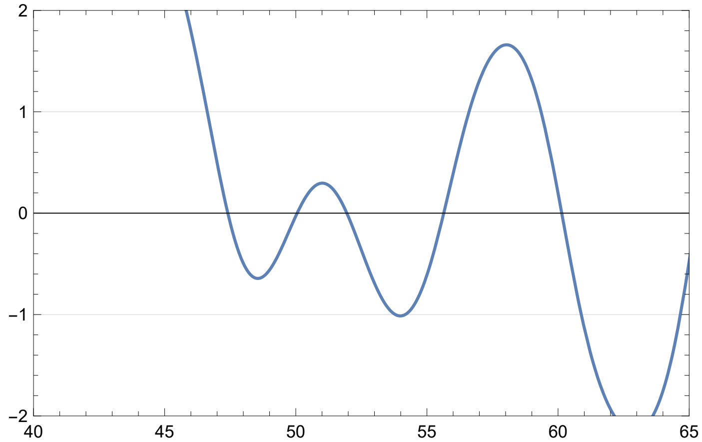
s_3

g = 5 * 6 + 8 − 9

(Debug) In[ ]:=

```
Plot[ss[t], {t, 0, 100}, PlotRange → {{40, 65}, {-2, 2}},
 Frame → True, GridLines → {{-1, 0, 1}, {-1, 0, 1}}]
```

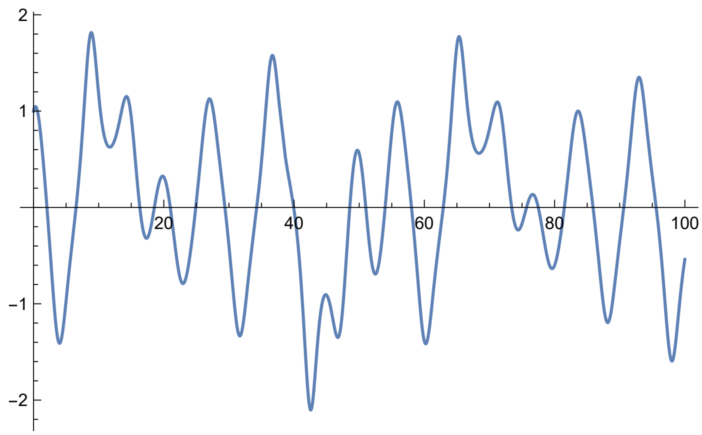
(Debug) Out[ ]=



(Debug) In[ ]:=

```
Plot[ss'[t], {t, 0, 100}, PlotRange → All]
```

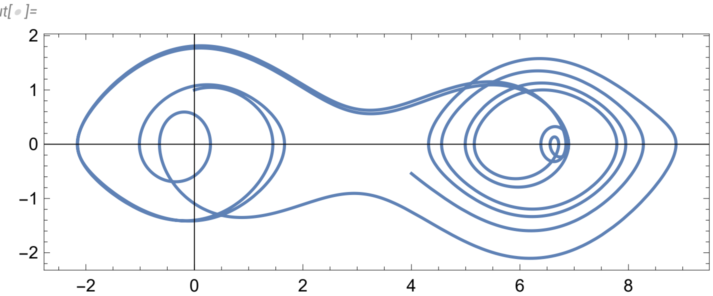
(Debug) Out[ ]=



(Debug) In[ ]:=

```
ParametricPlot[{ss[t], ss'[t]}, {t, 0, 100}, PlotRange → All, Frame → True]
```

(Debug) Out[ ]=



Boundary Value Problems

```
Exp[]
```

(Debug) In[ ]:=

```
DSolve[{y''[x] + y[x] == E^x, y[0] == 1, y[1] == 1 / 2}, y, x]
```

(Debug) Out[ ]=

```
{{y → Function[{x}, 1/2 Sin[1] (Cos[x] Csc[1] + e^x Cos[x]^2 Csc[1] - e Sin[x] -
      e Cot[1]^2 Sin[x] - Cot[1] Csc[1] Sin[x] + Csc[1]^2 Sin[x] + e^x Csc[1] Sin[x]^2)]}}
```

Partial Differential Equation

$$\frac{\partial P\ (x,\ t)}{\partial t} = d * \frac{\partial^2 P\ (x,\ t)}{\partial x^2},\ p\ (x,\ 0) = \text{Sin}[x]$$

∂

$\frac{dt}{dx}$

(Debug) In[ ]:=

```
DSolve[{D[P[x, t], t] == d * D[P[x, t], {x, 2}], P[x, 0] == Sin[x]}, P[x, t], {x, t}]
```

(Debug) Out[ ]=

```
{{P[x, t] → e^(-d t) Sin[x]}}
```

(Debug) In[ ]:=

```
NDSolve[{D[u[x, t], t] == D[u[x, t], x, x], u[x, 0] == Sin[x], u[0, t] == 0, u[π, t] == 0},
  u, {x, 0, π}, {t, 0, 1}]
```

(Debug) Out[ ]=

```
{{u → InterpolatingFunction[ Domain: {{0., 3.14}, {0., 1.}}
                             Output: scalar ]}}
```

Coupled Differential Equations

$$V = \Lambda\left(\left(1-\frac{\psi^2}{M^2}\right)^2 + \frac{\phi-\phi_c}{m_1} - \frac{(\phi-\phi_c)^2}{m_2^2} + \frac{\phi^4\psi^2}{M^2\,\phi_c^4} + \frac{\psi}{b}\right).$$

The Klien-Gordon classical background equations of motion in the number of e-fold times are given by [32],

$$\phi'' + \left(\frac{H'}{H}+3\right)\phi' + \frac{V_\phi}{H^2} = 0, \qquad \psi'' + \left(\frac{H'}{H}+3\right)\psi' + \frac{V_\psi}{H^2} = 0. \qquad (3.1)$$

Here, $V_X = dV/dX$ where, $X = \{\phi, \psi\}$, prime is the derivative with respect to the number of e-folds and the Hubble rate H is defined as $H^2 = 2V/(6 - \phi'^2 - \psi'^2)$. The evolution of the field

(Debug) In[ ]:=

```
ClearAll["Global`*"]
mp = 2.435515 * 10^18; RM = Sqrt[2.137 * 10^-9];
kc = (6.394970897 * 10^-39) / mp; k0 = 0.05 * kc;
M = 0.1;
ϕc = M;
m1 = 3 * 10^5;
m2 = 11;
Λ = (2.21 * 10^-9)/(3.429508708250553`) * (12 π^2)/(m1^2);
ψ0 = Sqrt[(Λ Sqrt[2 ϕc m1] M)/(96 π^(3/2))];
b = -8 * 10^9;
V[n_] = Λ ((1 - ψ[n]^2/M^2)^2 + (ϕ[n] - ϕc)/m1 - (ϕ[n] - ϕc)^2/m2^2 + (2 ϕ[n]^4 ψ[n]^2)/(M^4 ϕc^2) + ψ[n]/b);
SV[n_] = V[n] /. {ψ[n] → sψi[n], ϕ[n] → sϕi[n]};
ϕi = ϕc (1 + 0.0011);
ψi = ψ0;
dψi = (-D[V[n], ψ[n]]) / V[n] /. {ψ[n] → ψi, ϕ[n] → ϕi};
dϕi = (-D[V[n], ϕ[n]]) / V[n] /. {ψ[n] → ψi, ϕ[n] → ϕi};
ni = Log[(k0 / (Hi * 1 * 10^6))];
nf = -54;

Hi = √(V[n] / (3 (1 - dψi^2 / 6 - dϕi^2 / 6))) /. {ψ[n] → ψi, ϕ[n] → ϕi};

HPH[n_] = (1 / (2 V[n])) (6 - ϕ'[n]^2 - ψ'[n]^2) (V'[n] / (6 - ϕ'[n]^2 - ψ'[n]^2) -
    (V[n] (-2 ϕ'[n] × ϕ''[n] - 2 ψ'[n] × ψ''[n])) / (6 - ϕ'[n]^2 - ψ'[n]^2)^2);

sHPH[n_] := HPH[n] /. {ϕ → sϕi, ψ → sψi};

H[n_] = √((2 * V[n]) / (6 - ((ϕ'[n])^2 + (ψ'[n])^2)));

sH1[n_] := H[n] /. {ϕ → sϕi, ψ → sψi};

varsI = {ϕ[n], ψ[n]};
initsI = {ϕ[ni] == ϕi, ψ[ni] == ψi, ϕ'[ni] == dϕi, ψ'[ni] == dψi};
eqnsI = {ϕ''[n] + (HPH[n] + 3) * ϕ'[n] + D[V[n], ϕ[n]] / (H[n])^2 == 0,
   ψ''[n] + (HPH[n] + 3) * ψ'[n] + D[V[n], ψ[n]] / (H[n])^2 == 0};

{sϕi[n_], sψi[n_]} =
 varsI /. NDSolve[Join[eqnsI, initsI], varsI, {n, ni, nf}, MaxSteps → Infinity,
    MaxStepSize → 0.001, Method → {"ExplicitRungeKutta"}][[1]]
```

(Debug) Out[ ]=

```
{InterpolatingFunction[ Domain: {{-126., -54.}} Output: scalar ][n],
 Data not in notebook. Store now

 InterpolatingFunction[ Domain: {{-126., -54.}} Output: scalar ][n]}
 Data not in notebook. Store now
```

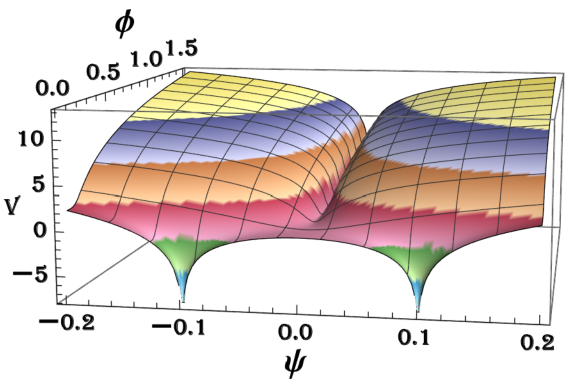
```
a[h_, c_] = h + c

a[h, c]
```

(Debug) In[ ]:=

```
Plot3D[Log[V[n]/Λ], {ψ[n], -0.2, 0.2}, {ϕ[n], 0, 1.5}, Boxed → True, PlotPoints → 100,
 Mesh → 10, ColorFunction → "DarkBands", Axes → True, AxesLabel → {"ψ", "ϕ", "V"},
 AxesStyle → Directive[Black, 12, FontFamily → "Algerian", Bold], ImageSize → 490]
```

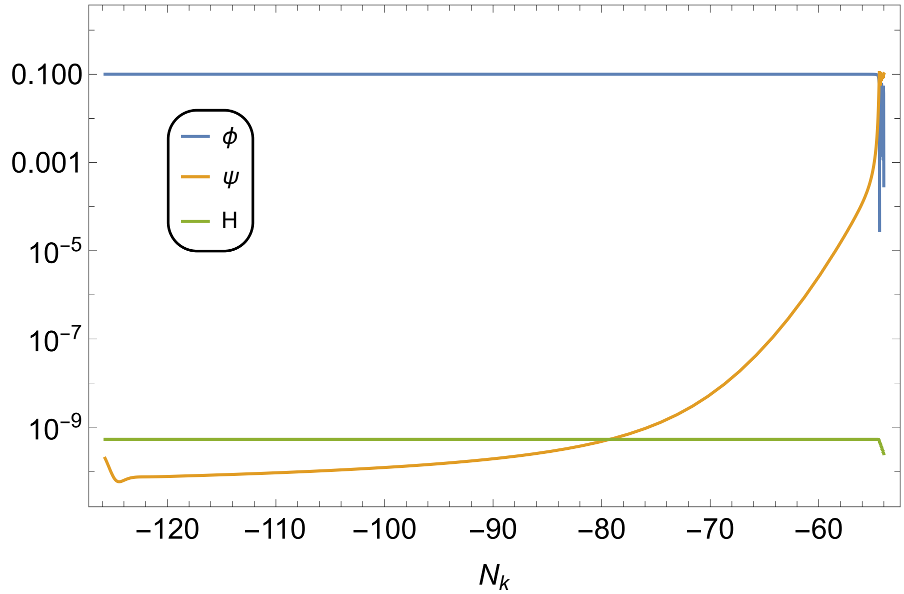
(Debug) Out[ ]=



(Debug) In[ ]:=

```
LogPlot[{sϕi[n], Abs[sψi[n]], sH1[n]}, {n, ni, nf},
 Frame → True, FrameLabel → {"N_k", ""}, FrameStyle → Directive[Black, 15],
 PlotLegends → Placed[LineLegend[{"ϕ", "ψ", "H"}, LabelStyle → 12,
    LegendMarkerSize → {{15, 10}}, LegendFunction → (Framed[#, RoundingRadius → 15] &),
    LegendMargins → 2], {0.15, 0.65}], ImageSize → 490]
```

(Debug) Out[ ]=



(Numerical) Integration

Definite

(Debug) In[ ]:=

```
aa[x_] = Integrate[1/(x^3 + 1), x]
```

(Debug) Out[ ]=

$$\frac{\text{ArcTan}\left[\frac{-1+2x}{\sqrt{3}}\right]}{\sqrt{3}} + \frac{1}{3}\text{Log}[1+x] - \frac{1}{6}\text{Log}\left[1-x+x^2\right]$$

(Debug) In[ ]:=

```
N[aa[2] - aa[1]]
```

(Debug) Out[ ]=

0.254353

(Debug) In[ ]:=

```
NIntegrate[1/(x^3 + 1), {x, 1, 2}]
```

(Debug) Out[ ]=

0.254353

Code for nested integrals

$$\Omega^r_{\rm gw}(f) = \frac{16\pi}{3}\left(\frac{G\mu}{H_0}\right)^2 \frac{\Gamma}{f a_0}\int_{a_{min}}^{a_{\rm eq}}\left(\frac{a(t)}{a_0}\right)^4 \frac{da}{H(a)} n_r(l,t)\,,$$

$$\Omega_{\rm gw}(f,q,n_*) = \sum_j^{n_*} \frac{j^{-q}}{\mathcal{E}}\Omega^j_{\rm gw}(f)\,, \qquad (12)$$

(Debug) In[ ]:=

```
ClearAll["Global`*"]
Gμ = 1 * 10^-10;
a0 = 1;
h = 0.6736;
H0 = ((100 * 10^3 * h) / (3.08568 * 10^22));
ξr = Sqrt[(1 - Y)] * Sqrt[k (k + ct)];
ct = 0.23;
k = (2 Sqrt[2])/π ((1 - 8 * vr^6)/(1 + 8 * vr^6)) (1 - vr^2) (1 + 2 Sqrt[2] vr^3);
Y = 0.8;
vr = 0.662 * Sqrt[1 - Y];
Γ0 = 50;
Γ = Γ0 * (1 - Fppm)^BcΓ;
Fppm = Sqrt[Y];
(*For Chiral Current*)
BcΓ = BsΓ/Sqrt[2];
(*1.5 for kinks, (2 for cusps)*)
BsΓ = 2.6;
α = 0.3688566917981026;
Ωr = 9.2188 * 10^-5;
Ωm = 0.308;
ct = 0.23;
(*G1=Import[
  "C:\\Users\\adeel\\OneDrive\\Desktop\\Current_Carrying_CSs\\Data_points\\Gvsa.DAT"];
G=Interpolation[G1,InterpolationOrder→1];*)
G[a_] = 1;
F = 0.1;
er = (α * ξr)/(Γ * Gμ);
tpl = 5.39 * 10^-44;
```

$$aminr = \frac{a0 * \sqrt{2 * H0\ \sqrt{\Omega r}\ (\epsilon r + 1)\ tpl}}{G\mu};$$

$$aeq = a0 * \frac{\Omega r}{\Omega m};$$

$$l = \frac{2\ * a * j}{f * a0};$$

$$Ar = \mathcal{F} * \frac{ct * \nu r}{\sqrt{2}\ * \xi r^3};$$

$$Cr = \frac{Ar}{\alpha * \xi r}\ (\alpha * \xi r + \Gamma * G\mu)^{3/2};$$

$$Hr = H0 * \sqrt{\mathcal{G}[a] * \Omega r}\ \left(\frac{a0}{a}\right)^2;$$

$$tr = \frac{a^2}{2\ a0^2\ H0\ \sqrt{\mathcal{G}[a] * \Omega r}};$$

$$nr[f\_] = \frac{Cr}{tr^{3/2}\ (l + \Gamma * G\mu * tr)^{5/2}};$$

$$q = \frac{5}{3}\ (*Kinks*);$$

$$Pj = \frac{\Gamma * j^{-q}}{Zeta\left[\frac{4}{3}\right]};$$

```
ss = 100;
ss1 = 101;
```

$$NRs[f\_?NumericQ] := Sum\left[NIntegrate\left[\left(\frac{a}{a0}\right)^4 j * Pj * \frac{nr[f]}{Hr},\ \{a, aminr, aeq\}, MaxRecursion \to 20, WorkingPrecision \to 16\right], \{j, 1, ss\}\right];$$

$$NRi[f\_?NumericQ] := NIntegrate\left[\left(\frac{a}{a0}\right)^4 j * Pj * \frac{nr[f]}{Hr},\ \{a, aminr, aeq\}, \left\{j, ss1, 10^5\right\}, MaxRecursion \to 20, WorkingPrecision \to 16\right];$$

```
NR[f_] = NRs[f] + NRi[f];
```

$$\Omega rGW[f\_] = h^2 * ((16 * \pi) / 3)\ (G\mu / H0)^2\ (1 / (a0 * f))\ (NR[f]);$$

(Debug) In[ ]:=

```
f = 10^f1; kk = 0;
Do[
 Clear[ΩGWTotSum];
 ΩGWTotSum[f_] = ΩrGW[f];
 kk = kk + 1;
 ddf[kk] = {f, ΩGWTotSum[f]};
 Print[ddf[kk]];
 ddd = Table[ddf[jj], {jj, 1, kk}];
 , {f1, Log10[0.31622776601683794`], Log10[10^3], 0.2}]
```

{0.316228, 2.82403×10^{-10}}

{0.501187, 2.8248×10^{-10}}

{0.794328, 2.82534×10^{-10}}

NIntegrate: Numerical integration converging too slowly; suspect one of the following: singularity, value of the integration is 0, highly oscillatory integrand, or WorkingPrecision too small.

{1.25893, 2.82571×10^{-10}}

NIntegrate: Numerical integration converging too slowly; suspect one of the following: singularity, value of the integration is 0, highly oscillatory integrand, or WorkingPrecision too small.

{1.99526, 2.82595×10^{-10}}

NIntegrate: Numerical integration converging too slowly; suspect one of the following: singularity, value of the integration is 0, highly oscillatory integrand, or WorkingPrecision too small.

General: Further output of NIntegrate::slwcon will be suppressed during this calculation.

{3.16228, 2.82612×10^{-10}}

{5.01187, 2.82622×10^{-10}}

{7.94328, 2.82629×10^{-10}}

{12.5893, 2.82633×10^{-10}}

{19.9526, 2.82636×10^{-10}}

{31.6228, 2.82638×10^{-10}}

{50.1187, 2.82639×10^{-10}}

{79.4328, 2.8264×10^{-10}}

{125.893, 2.8264×10^{-10}}

{199.526, 2.8264×10^{-10}}

{316.228, 2.82641×10^{-10}}

{501.187, 2.82641×10^{-10}}

{794.328, 2.82641×10^{-10}}

(Debug) In[ ]:=

```
ddd
```

(Debug) In[ ]:=

```
cc = {{1.`*^-12, 2.387992815460308`*^-20},
   {3.1622776601683794`*^-12, 1.3428659051720894`*^-19},
   {1.`*^-11, 7.551469668241913`*^-19}, {3.1622776601683794`*^-11,
    4.246467435574246`*^-18}, {1.`*^-10, 2.3879000649252278`*^-17},
   {3.1622776601683795`*^-10, 1.3427009812130997`*^-16},
   {1.`*^-9, 7.548537556973553`*^-16}, {3.1622776601683795`*^-9, 4.24125724135352`*^-15},
   {1.`*^-8, 2.3786568563816526`*^-14},
   {3.162277660168379`*^-8, 1.3263863917068893`*^-13},
   {1.`*^-7, 7.265105498643671`*^-13}, {3.162277660168379`*^-7, 3.771645611509287`*^-12},
   {1.`*^-6, 1.693651380688711`*^-11}, {3.162277660168379`*^-6, 5.596343752145578`*^-11},
   {0.00001`, 1.2143170387412448`*^-10}, {0.000031622776601683795`,
    1.8545473320185802`*^-10}, {0.0001`, 2.2990103790072095`*^-10},
   {0.00031622776601683794`, 2.5572136241355057`*^-10},
   {0.001`, 2.6940085293627206`*^-10}, {0.0031622776601683794`, 2.7629192262618254`*^-10},
   {0.01`, 2.796631122065546`*^-10}, {0.0316227766016838379`, 2.812823078810208`*^-10},
   {0.1`, 2.8204891564907916`*^-10}, {0.31622776601683794`, 2.824025096002165`*^-10},
   {0.5011872336272722`, 2.824798743528717`*^-10},
   {0.7943282347242815`, 2.82533884505459`*^-10},
   {1.2589254117941675`, 2.8257078900715945`*^-10},
   {1.9952623149688797`, 2.825954968534554`*^-10},
   {3.1622776601683795`, 2.826117568128351`*^-10},
   {5.011872336272725`, 2.826223150019687`*^-10}, {7.943282347242818`,
    2.826291056068594`*^-10}, {12.589254117941675`, 2.826334429579627`*^-10},
   {19.952623149688797`, 2.826362064886411`*^-10}, {31.622776601683793`,
    2.826379570299117`*^-10}, {50.11872336272725`, 2.82639065229726`*^-10},
   {79.43282347242821`, 2.8263976582007043`*^-10}, {125.89254117941675`,
    2.8264020817557667`*^-10}, {199.52623149688807`, 2.826404871483842`*^-10},
   {316.22776601683796`, 2.826406623222553`*^-10}, {501.18723362727246`,
    2.826407707412721`*^-10}, {794.3282347242822`, 2.826408361580744`*^-10}};
cc1 = {{1.`*^-12, 2.387992815460308`*^-20},
   {3.1622776601683794`*^-12, 1.3428659051720894`*^-19},
   {1.`*^-11, 7.551469668241913`*^-19}, {3.1622776601683794`*^-11,
    4.246467435574246`*^-18}, {1.`*^-10, 2.3879000649252278`*^-17},
   {3.1622776601683795`*^-10, 1.3427009812130997`*^-16},
   {1.`*^-9, 7.548537556973553`*^-16}, {3.1622776601683795`*^-9, 4.24125724135352`*^-15},
   {1.`*^-8, 2.3786568563816526`*^-14},
   {3.162277660168379`*^-8, 1.3263863917068893`*^-13},
   {1.`*^-7, 7.265105498643671`*^-13}, {3.162277660168379`*^-7, 3.771645611509287`*^-12},
   {1.`*^-6, 1.693651380688711`*^-11}, {3.162277660168379`*^-6, 5.596343752145578`*^-11},
   {0.00001`, 1.2143170387412448`*^-10}, {0.000031622776601683795`,
    1.8545473320185802`*^-10}, {0.0001`, 2.2990103790072095`*^-10},
   {0.00031622776601683794`, 2.5572136241355057`*^-10},
   {0.001`, 2.6940085293627206`*^-10}, {0.0031622776601683794`, 2.7629192262618254`*^-10},
   {0.01`, 2.796631122065546`*^-10}, {0.0316227766016838379`, 2.812823078810208`*^-10},
```

```
{0.1`, 2.8204891564907916`*^-10}, {0.31622776601683794`, 2.824025096002165`*^-10},
{0.5011872336272722`, 2.824798743528717`*^-10},
{0.7943282347242815`, 2.82533884505459`*^-10},
{1.2589254117941675`, 2.8257078900715945`*^-10},
{1.9952623149688797`, 2.825954968534554`*^-10},
{3.1622776601683795`, 2.826117568128351`*^-10},
{5.011872336272725`, 2.826223150019687`*^-10}, {7.943282347242818`,
 2.826291056068594`*^-10}, {12.589254117941675`, 2.826334429579627`*^-10},
{19.952623149688797`, 2.826362064886411`*^-10}, {31.622776601683793`,
 2.826379570299117`*^-10}, {50.11872336272725`, 2.82639065229726`*^-10},
{79.43282347242821`, 2.8263976582007043`*^-10}, {125.89254117941675`,
 2.8264020817557667`*^-10}, {199.52623149688807`, 2.826404871483842`*^-10},
{316.22776601683796`, 2.826406623222553`*^-10}, {501.18723362727246`,
 2.826407707412721`*^-10}, {794.3282347242822`, 2.826408361580744`*^-10}};
```

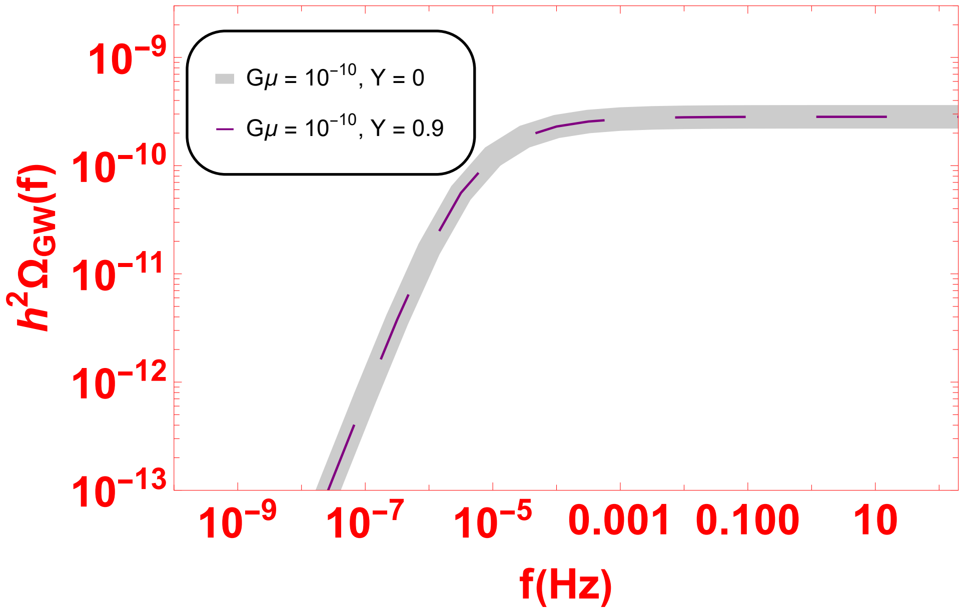
Stop

Part-2

(Debug) In[ ]:=

```
V1 = ListLogLogPlot[{cc, cc1}, Joined → True,
  Frame → True, FrameLabel → {{"h²Ω_GW(f)", None}, {"f(Hz)", None}},
  PlotRange → {{10^-10, 2 * 10^2}, {1 * 10^-13, 3 * 10^-9}}, FrameStyle → Directive[Red, 22, Bold],
  ImageSize → 500, PlotStyle → {{Black, Thickness[0.03], Opacity[0.2]},
    {Purple, Thickness[0.003], Dashing[0.09]}, {Orange, Thickness[0.003]},
    {Darker[Green], Thickness[0.003], Dashing[0.006]}, {Darker[Red], Thickness[0.003]}},
  LabelStyle → Directive[Black, 15], PlotLegends →
   Placed[LineLegend[{"Gμ = 10^-10, Y = 0", "Gμ = 10^-10, Y = 0.9"},
     LabelStyle → {12, Background → White}, LegendMarkerSize → {{10, 10}},
     LegendFunction → (Framed[#, RoundingRadius → 20] &), LegendMargins → 10], {0.2, 0.8}]]
```

(Debug) Out[ ]=



Some unanswered Questions

Use Wolfram Cloud : If you are using Wolfram Cloud, you can share a notebook with multiple users . While users can edit their copies, real - time collaboration is still limited . Coordination between users is required .

Loop, Data Import, Export, Table Formation

Nested loop

(Debug) In[ ]:=

```
function[x_, y_] = x^3 + y^4 + 4 y^3 + x^2 + y^2 + y;
```

(Debug) In[ ]:=

```
x = x1;
kk = 0;
xmin = -4;
xmax = 4;
ymin = -4;
ymax = 4;
y = y1;
Do[
 Clear[function];
 Do[function[x_, y_] = x^3 + y^4 + 4 y + x^2;
  kk = kk + 1;
  ddf[kk] = {x, y, function[x, y]};
  Print[ddf[kk]];
  ddd = Table[ddf[jj], {jj, 1, kk}];, {y1, ymin, ymax, 1}];, {x1, xmin, xmax, 1}]
```

```
{-4, -4, 192}
{-4, -3, 21}
{-4, -2, -40}
{-4, -1, -51}
{-4, 0, -48}
{-4, 1, -43}
{-4, 2, -24}
{-4, 3, 45}
{-4, 4, 224}
{-3, -4, 222}
{-3, -3, 51}
{-3, -2, -10}
{-3, -1, -21}
{-3, 0, -18}
{-3, 1, -13}
{-3, 2, 6}
{-3, 3, 75}
{-3, 4, 254}
{-2, -4, 236}
{-2, -3, 65}
{-2, -2, 4}
{-2, -1, -7}
{-2, 0, -4}
{-2, 1, 1}
```

{-2, 2, 20}

{-2, 3, 89}

{-2, 4, 268}

{-1, -4, 240}

{-1, -3, 69}

{-1, -2, 8}

{-1, -1, -3}

{-1, 0, 0}

{-1, 1, 5}

{-1, 2, 24}

{-1, 3, 93}

{-1, 4, 272}

{0, -4, 240}

{0, -3, 69}

{0, -2, 8}

{0, -1, -3}

{0, 0, 0}

{0, 1, 5}

{0, 2, 24}

{0, 3, 93}

{0, 4, 272}

{1, -4, 242}

{1, -3, 71}

{1, -2, 10}

{1, -1, -1}

{1, 0, 2}

{1, 1, 7}

{1, 2, 26}

{1, 3, 95}

{1, 4, 274}

{2, -4, 252}

{2, -3, 81}

{2, -2, 20}

{2, -1, 9}

{2, 0, 12}

{2, 1, 17}

```
{2, 2, 36}
{2, 3, 105}
{2, 4, 284}
{3, -4, 276}
{3, -3, 105}
{3, -2, 44}
{3, -1, 33}
{3, 0, 36}
{3, 1, 41}
{3, 2, 60}
{3, 3, 129}
{3, 4, 308}
{4, -4, 320}
{4, -3, 149}
{4, -2, 88}
{4, -1, 77}
{4, 0, 80}
{4, 1, 85}
{4, 2, 104}
{4, 3, 173}
{4, 4, 352}
```

(Debug) In[ ]:=

```
ddd
```

(Debug) Out[ ]=

```
{{-4, -4, 192}, {-4, -3, 21}, {-4, -2, -40}, {-4, -1, -51}, {-4, 0, -48}, {-4, 1, -43},
 {-4, 2, -24}, {-4, 3, 45}, {-4, 4, 224}, {-3, -4, 222}, {-3, -3, 51}, {-3, -2, -10},
 {-3, -1, -21}, {-3, 0, -18}, {-3, 1, -13}, {-3, 2, 6}, {-3, 3, 75}, {-3, 4, 254},
 {-2, -4, 236}, {-2, -3, 65}, {-2, -2, 4}, {-2, -1, -7}, {-2, 0, -4}, {-2, 1, 1},
 {-2, 2, 20}, {-2, 3, 89}, {-2, 4, 268}, {-1, -4, 240}, {-1, -3, 69}, {-1, -2, 8},
 {-1, -1, -3}, {-1, 0, 0}, {-1, 1, 5}, {-1, 2, 24}, {-1, 3, 93}, {-1, 4, 272},
 {0, -4, 240}, {0, -3, 69}, {0, -2, 8}, {0, -1, -3}, {0, 0, 0}, {0, 1, 5}, {0, 2, 24},
 {0, 3, 93}, {0, 4, 272}, {1, -4, 242}, {1, -3, 71}, {1, -2, 10}, {1, -1, -1},
 {1, 0, 2}, {1, 1, 7}, {1, 2, 26}, {1, 3, 95}, {1, 4, 274}, {2, -4, 252}, {2, -3, 81},
 {2, -2, 20}, {2, -1, 9}, {2, 0, 12}, {2, 1, 17}, {2, 2, 36}, {2, 3, 105}, {2, 4, 284},
 {3, -4, 276}, {3, -3, 105}, {3, -2, 44}, {3, -1, 33}, {3, 0, 36}, {3, 1, 41},
 {3, 2, 60}, {3, 3, 129}, {3, 4, 308}, {4, -4, 320}, {4, -3, 149}, {4, -2, 88},
 {4, -1, 77}, {4, 0, 80}, {4, 1, 85}, {4, 2, 104}, {4, 3, 173}, {4, 4, 352}}
```

```
(*Table helps in: Multiplying a pre-factor, shuffle the axis, Log,*)
```

(Debug) In[ ]:=

```
ddd⟦All, 3⟧
```

(Debug) Out[ ]=

```
{192, 21, -40, -51, -48, -43, -24, 45, 224, 222, 51, -10, -21, -18, -13, 6, 75, 254,
 236, 65, 4, -7, -4, 1, 20, 89, 268, 240, 69, 8, -3, 0, 5, 24, 93, 272, 240, 69, 8, -3,
 0, 5, 24, 93, 272, 242, 71, 10, -1, 2, 7, 26, 95, 274, 252, 81, 20, 9, 12, 17, 36, 105,
 284, 276, 105, 44, 33, 36, 41, 60, 129, 308, 320, 149, 88, 77, 80, 85, 104, 173, 352}
```

(Debug) In[ ]:=

```
Length[ddd]
```

(Debug) Out[ ]=

```
81
```

(Debug) In[ ]:=

```
gg = Table[{ddd⟦jj, 1⟧, ddd⟦jj, 2⟧, ddd⟦jj, 3⟧}, {jj, 1, Length[ddd]}]
```

(Debug) Out[ ]=

```
{{-4, -4, 192}, {-4, -3, 21}, {-4, -2, -40}, {-4, -1, -51}, {-4, 0, -48}, {-4, 1, -43},
 {-4, 2, -24}, {-4, 3, 45}, {-4, 4, 224}, {-3, -4, 222}, {-3, -3, 51}, {-3, -2, -10},
 {-3, -1, -21}, {-3, 0, -18}, {-3, 1, -13}, {-3, 2, 6}, {-3, 3, 75}, {-3, 4, 254},
 {-2, -4, 236}, {-2, -3, 65}, {-2, -2, 4}, {-2, -1, -7}, {-2, 0, -4}, {-2, 1, 1},
 {-2, 2, 20}, {-2, 3, 89}, {-2, 4, 268}, {-1, -4, 240}, {-1, -3, 69}, {-1, -2, 8},
 {-1, -1, -3}, {-1, 0, 0}, {-1, 1, 5}, {-1, 2, 24}, {-1, 3, 93}, {-1, 4, 272},
 {0, -4, 240}, {0, -3, 69}, {0, -2, 8}, {0, -1, -3}, {0, 0, 0}, {0, 1, 5}, {0, 2, 24},
 {0, 3, 93}, {0, 4, 272}, {1, -4, 242}, {1, -3, 71}, {1, -2, 10}, {1, -1, -1},
 {1, 0, 2}, {1, 1, 7}, {1, 2, 26}, {1, 3, 95}, {1, 4, 274}, {2, -4, 252}, {2, -3, 81},
 {2, -2, 20}, {2, -1, 9}, {2, 0, 12}, {2, 1, 17}, {2, 2, 36}, {2, 3, 105}, {2, 4, 284},
 {3, -4, 276}, {3, -3, 105}, {3, -2, 44}, {3, -1, 33}, {3, 0, 36}, {3, 1, 41},
 {3, 2, 60}, {3, 3, 129}, {3, 4, 308}, {4, -4, 320}, {4, -3, 149}, {4, -2, 88},
 {4, -1, 77}, {4, 0, 80}, {4, 1, 85}, {4, 2, 104}, {4, 3, 173}, {4, 4, 352}}
```

(Debug) In[ ]:=

```
gg⟦All, 3⟧
```

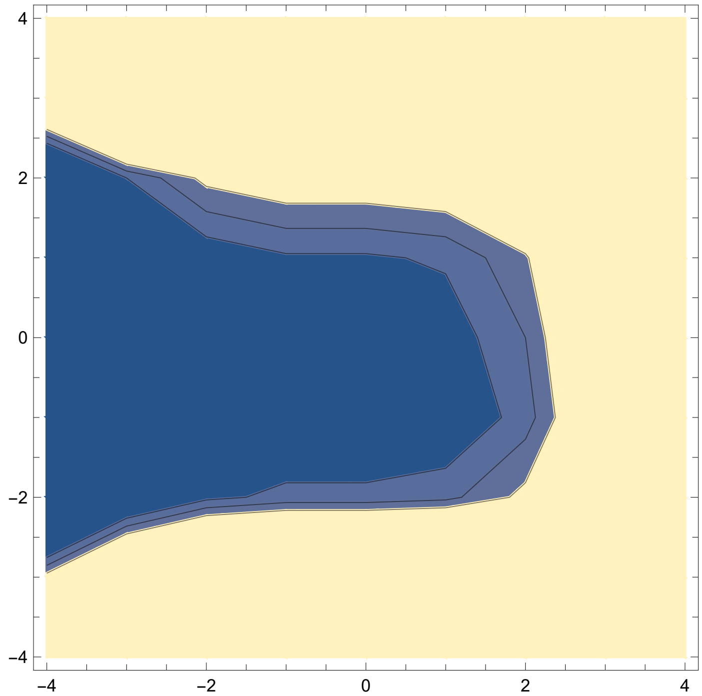
(Debug) Out[ ]=

```
{192, 21, -40, -51, -48, -43, -24, 45, 224, 222, 51, -10, -21, -18, -13, 6, 75, 254,
 236, 65, 4, -7, -4, 1, 20, 89, 268, 240, 69, 8, -3, 0, 5, 24, 93, 272, 240, 69, 8, -3,
 0, 5, 24, 93, 272, 242, 71, 10, -1, 2, 7, 26, 95, 274, 252, 81, 20, 9, 12, 17, 36, 105,
 284, 276, 105, 44, 33, 36, 41, 60, 129, 308, 320, 149, 88, 77, 80, 85, 104, 173, 352}
```

(Debug) In[ ]:=

```
ListContourPlot[gg, Contours → {6, 12, 18}]
```

(Debug) Out[ ]=



(Debug) In[ ]:=

```
Clear[x, y, function]

(*%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%*)
```

Professor Movahed’s Question

(Debug) In[ ]:=

```
function1[x_, y_] = x^3 + y^4 + 4 y + x^2 + x^4;
```

(Debug) In[ ]:=

```
ss = Table[function1[x, y], {y, -4, 4, 1}, {x, -4, 4, 1}];
```

(Debug) In[ ]:=

```
ss // MatrixForm
```

(Debug) Out[ ]//MatrixForm=

$$\begin{pmatrix} 448 & 303 & 252 & 241 & 240 & 243 & 268 & 357 & 576 \\ 277 & 132 & 81 & 70 & 69 & 72 & 97 & 186 & 405 \\ 216 & 71 & 20 & 9 & 8 & 11 & 36 & 125 & 344 \\ 205 & 60 & 9 & -2 & -3 & 0 & 25 & 114 & 333 \\ 208 & 63 & 12 & 1 & 0 & 3 & 28 & 117 & 336 \\ 213 & 68 & 17 & 6 & 5 & 8 & 33 & 122 & 341 \\ 232 & 87 & 36 & 25 & 24 & 27 & 52 & 141 & 360 \\ 301 & 156 & 105 & 94 & 93 & 96 & 121 & 210 & 429 \\ 480 & 335 & 284 & 273 & 272 & 275 & 300 & 389 & 608 \end{pmatrix}$$

(Debug) In[ ]:=

```
ss
```

```
tt = {{448, 303, 252, 241, 240, 243, 268, 357, 576},
  {277, 132, 81, 70, 69, 72, 97, 186, 405}, {216, 71, 20, 9, 8, 11, 36, 125, 344},
  {205, 60, 9, -2, -3, 0, 25, 114, 333}, {208, 63, 12, 1, 0, 3, 28, 117, 336},
  {213, 68, 17, 6, 5, 8, 33, 122, 341}, {232, 87, 36, 25, 24, 27, 52, 141, 360},
  {301, 156, 105, 94, 93, 96, 121, 210, 429}, {480, 335, 284, 273, 272, 275, 300, 389, 608}}
```

(Debug) In[∘]:=

```
Dimensions[%88]
```

(Debug) Out[∘]=

```
{9, 9}
```

(Debug) In[∘]:=

```
Table[function1[x, -4], {x, -4, 4, 1}]
```

(Debug) Out[∘]=

```
{448, 303, 252, 241, 240, 243, 268, 357, 576}
```

(Debug) In[∘]:=

```
Dimensions[ss]
```

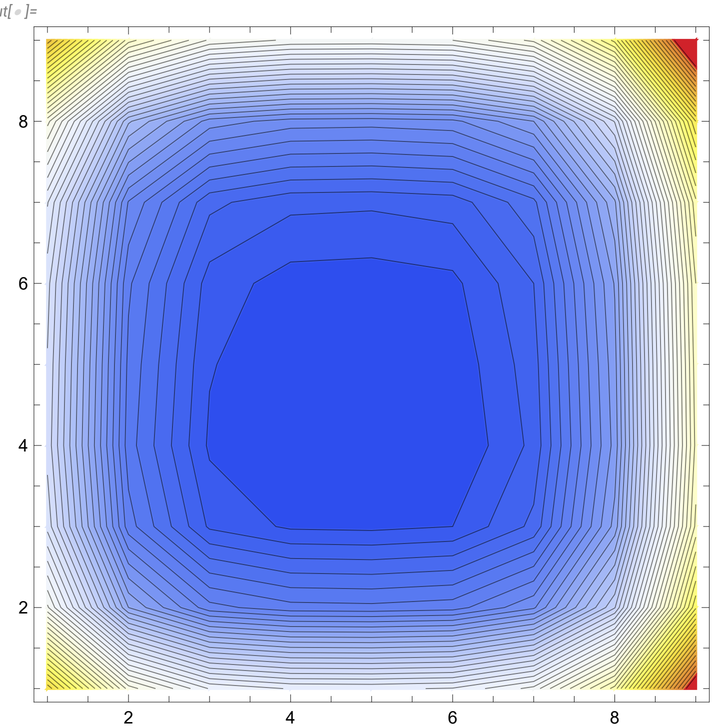
(Debug) Out[∘]=

```
{9, 9}
```

(Debug) In[∘]:=

```
ListContourPlot[ss, Contours → 50, ColorFunction → "TemperatureMap"]
```

(Debug) Out[∘]=




```
(*%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%*)
```

(Debug) In[∘]:=

```
function[x_, y_] = x^3 + y^4 + 4 y^3 + x^2 + y^2 + y;
```

(Debug) In[ ]:=

```
ss1 = Flatten[Table[{x, y, function[x, y]}, {y, -2, 2, 0.1}, {x, -4, 4, 0.1}], 1]
```

(Debug) Out[ ]=

```
{{-4., -2., -62.}, {-3.9, -2., -58.109}, {-3.8, -2., -54.432}, {-3.7, -2., -50.963},
 {-3.6, -2., -47.696}, {-3.5, -2., -44.625}, {-3.4, -2., -41.744},
 {-3.3, -2., -39.047}, {-3.2, -2., -36.528}, {-3.1, -2., -34.181}, {-3., -2., -32.},
 {-2.9, -2., -29.979}, {-2.8, -2., -28.112}, {-2.7, -2., -26.393}, ··· 3294 ···,
 {2.8, 2., 83.792}, {2.9, 2., 86.799}, {3., 2., 90.}, {3.1, 2., 93.401}, {3.2, 2., 97.008},
 {3.3, 2., 100.827}, {3.4, 2., 104.864}, {3.5, 2., 109.125}, {3.6, 2., 113.616},
 {3.7, 2., 118.343}, {3.8, 2., 123.312}, {3.9, 2., 128.529}, {4., 2., 134.}}
```

Full expression not available (original memory size: 0.4 MB)

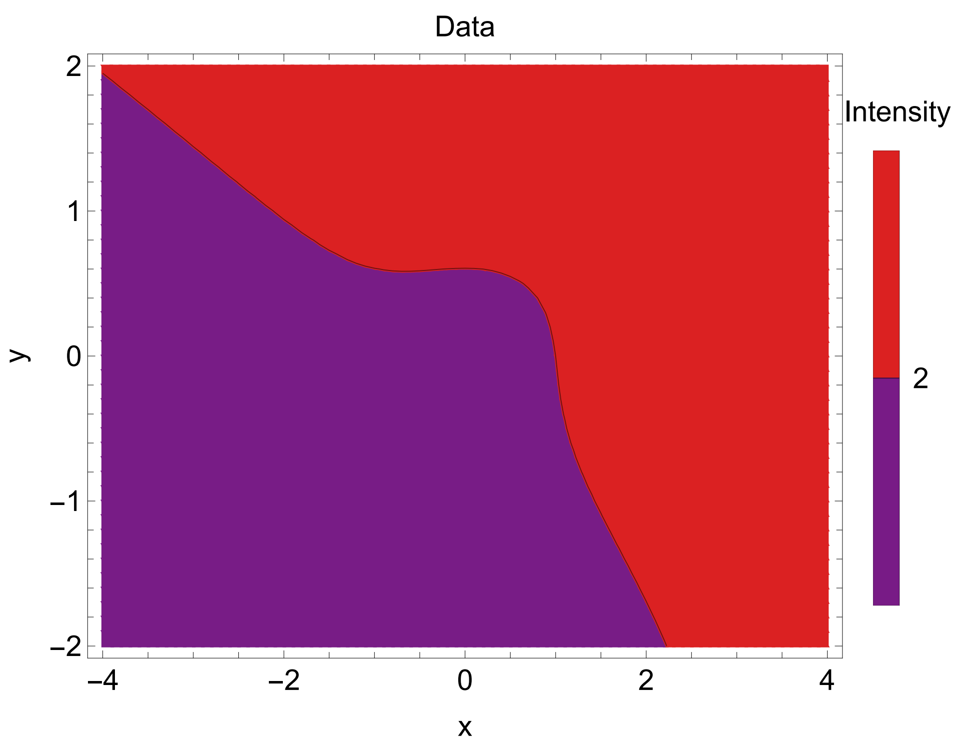
(Debug) In[ ]:=

```
Table[{ss1[[jj, 2]], ss1[[jj, 3]]}, {jj, 1, Length[ss1]}]
```

(Debug) In[ ]:=

```
ListContourPlot[ss1, ColorFunction → "Rainbow", AspectRatio → 0.8,
 Frame → True, FrameLabel → {"x", "y", "Data"}, FrameStyle → Directive[Black, 15],
 ImageSize → 440, PlotLegends → Placed[BarLegend[Automatic,
    LegendLabel → "Intensity", LabelStyle → Directive[FontSize → 15, Black],
    LegendMargins → {{-5, 5}, {10, 5}}, LegendMarkerSize → 260], Right], Contours → {2}]
```

(Debug) Out[ ]=



(Debug) In[ ]:=

```
ddd
```

(Debug) Out[ ]=

```
{{-4, -4, 192}, {-4, -3, 21}, {-4, -2, -40}, {-4, -1, -51}, {-4, 0, -48}, {-4, 1, -43},
 {-4, 2, -24}, {-4, 3, 45}, {-4, 4, 224}, {-3, -4, 222}, {-3, -3, 51}, {-3, -2, -10},
 {-3, -1, -21}, {-3, 0, -18}, {-3, 1, -13}, {-3, 2, 6}, {-3, 3, 75}, {-3, 4, 254},
 {-2, -4, 236}, {-2, -3, 65}, {-2, -2, 4}, {-2, -1, -7}, {-2, 0, -4}, {-2, 1, 1},
 {-2, 2, 20}, {-2, 3, 89}, {-2, 4, 268}, {-1, -4, 240}, {-1, -3, 69}, {-1, -2, 8},
 {-1, -1, -3}, {-1, 0, 0}, {-1, 1, 5}, {-1, 2, 24}, {-1, 3, 93}, {-1, 4, 272},
 {0, -4, 240}, {0, -3, 69}, {0, -2, 8}, {0, -1, -3}, {0, 0, 0}, {0, 1, 5}, {0, 2, 24},
 {0, 3, 93}, {0, 4, 272}, {1, -4, 242}, {1, -3, 71}, {1, -2, 10}, {1, -1, -1},
 {1, 0, 2}, {1, 1, 7}, {1, 2, 26}, {1, 3, 95}, {1, 4, 274}, {2, -4, 252}, {2, -3, 81},
 {2, -2, 20}, {2, -1, 9}, {2, 0, 12}, {2, 1, 17}, {2, 2, 36}, {2, 3, 105}, {2, 4, 284},
 {3, -4, 276}, {3, -3, 105}, {3, -2, 44}, {3, -1, 33}, {3, 0, 36}, {3, 1, 41},
 {3, 2, 60}, {3, 3, 129}, {3, 4, 308}, {4, -4, 320}, {4, -3, 149}, {4, -2, 88},
 {4, -1, 77}, {4, 0, 80}, {4, 1, 85}, {4, 2, 104}, {4, 3, 173}, {4, 4, 352}}
```

(Debug) In[ ]:=

```
SetDirectory[NotebookDirectory[]];

Export["function_1.DAT", ddd];
```

(Debug) In[ ]:=

```
a1 = Import["function_1.DAT"]
```

(Debug) Out[ ]=

```
{{-4, -4, 192}, {-4, -3, 21}, {-4, -2, -40}, {-4, -1, -51}, {-4, 0, -48}, {-4, 1, -43},
 {-4, 2, -24}, {-4, 3, 45}, {-4, 4, 224}, {-3, -4, 222}, {-3, -3, 51}, {-3, -2, -10},
 {-3, -1, -21}, {-3, 0, -18}, {-3, 1, -13}, {-3, 2, 6}, {-3, 3, 75}, {-3, 4, 254},
 {-2, -4, 236}, {-2, -3, 65}, {-2, -2, 4}, {-2, -1, -7}, {-2, 0, -4}, {-2, 1, 1},
 {-2, 2, 20}, {-2, 3, 89}, {-2, 4, 268}, {-1, -4, 240}, {-1, -3, 69}, {-1, -2, 8},
 {-1, -1, -3}, {-1, 0, 0}, {-1, 1, 5}, {-1, 2, 24}, {-1, 3, 93}, {-1, 4, 272},
 {0, -4, 240}, {0, -3, 69}, {0, -2, 8}, {0, -1, -3}, {0, 0, 0}, {0, 1, 5}, {0, 2, 24},
 {0, 3, 93}, {0, 4, 272}, {1, -4, 242}, {1, -3, 71}, {1, -2, 10}, {1, -1, -1},
 {1, 0, 2}, {1, 1, 7}, {1, 2, 26}, {1, 3, 95}, {1, 4, 274}, {2, -4, 252}, {2, -3, 81},
 {2, -2, 20}, {2, -1, 9}, {2, 0, 12}, {2, 1, 17}, {2, 2, 36}, {2, 3, 105}, {2, 4, 284},
 {3, -4, 276}, {3, -3, 105}, {3, -2, 44}, {3, -1, 33}, {3, 0, 36}, {3, 1, 41},
 {3, 2, 60}, {3, 3, 129}, {3, 4, 308}, {4, -4, 320}, {4, -3, 149}, {4, -2, 88},
 {4, -1, 77}, {4, 0, 80}, {4, 1, 85}, {4, 2, 104}, {4, 3, 173}, {4, 4, 352}}
```

Conversion to FORTran and LaTeX

(Debug) In[ ]:=

```
TeXForm[xx^2 + xx^4 - xx^6 + 1]
```

(Debug) Out[ ]//TeXForm=

```
-\text{xx}^6+\text{xx}^4+\text{xx}^2+1
```

(Debug) In[ ]:=

```
(xx^2 + xx^4 - xx^6 + 1) // TeXForm
```

(Debug) Out[ ]//TeXForm=

```
-\text{xx}^6+\text{xx}^4+\text{xx}^2+1
```

(Debug) In[ ]:=

```
FortranForm[xx^2 + xx^4 - xx^6 + 1]
```

(Debug) Out[ ]//FortranForm=

```
1 + xx**2 + xx**4 - xx**6
```

Extras

(Debug) In[ ]:=

```
𝒜 = {{δ}, {δx}, {δy}};
𝒜traspose = Transpose[𝒜];
𝒦 = {{σ0^2, 0, 0}, {0, σ1x^2, 0}, {0, 0, σ1y^2}};
det𝒦 = Det[𝒦];
𝒦2inverse = Inverse[𝒦];
```

(Debug) In[ ]:=

```
{𝒦 // MatrixForm, MatrixForm[𝒦]}
```

(Debug) Out[ ]=

$$\left\{\begin{pmatrix} \sigma0^2 & 0 & 0 \\ 0 & \sigma1x^2 & 0 \\ 0 & 0 & \sigma1y^2 \end{pmatrix}, \begin{pmatrix} \sigma0^2 & 0 & 0 \\ 0 & \sigma1x^2 & 0 \\ 0 & 0 & \sigma1y^2 \end{pmatrix}\right\}$$

(Debug) In[ ]:=

$$\text{Pdf} = \frac{1}{\sqrt{(2\,\pi)^3}\ \sqrt{\text{det}\mathcal{K}}}\ \text{Exp}\left[\frac{-1}{2}\ \mathcal{A}\text{traspose}.\mathcal{K}\text{2inverse}.\mathcal{A}\right][[1, 1]]$$

(Debug) Out[ ]=

$$\frac{e^{\frac{1}{2}\left(-\frac{\delta^2}{\sigma0^2}-\frac{\delta x^2}{\sigma1x^2}-\frac{\delta y^2}{\sigma1y^2}\right)}}{2\,\sqrt{2}\,\pi^{3/2}\,\sqrt{\sigma0^2\,\sigma1x^2\,\sigma1y^2}}$$

(Debug) In[ ]:=

```
normalrsd = Integrate[Pdf, {δ, -Infinity, Infinity}, {δx, -Infinity, Infinity},
   {δy, -Infinity, Infinity}, Assumptions → {σ0^2 > 0, σ1x^2 > 0, σ1y^2 > 0}]
```

(Debug) Out[ ]=

$$\sqrt{2\,\pi}$$

(Debug) Out[ ]=

$$\frac{1}{\sqrt{\frac{1}{\sigma0^2}}\ \sqrt{\frac{1}{\sigma1x^2}}\ \sqrt{\frac{1}{\sigma1y^2}}\ \sqrt{\sigma0^2\,\sigma1x^2\,\sigma1y^2}}\quad \text{if } \text{Re}\left[\sigma0^2\right] > 0$$

Crossing Statistics in (1+2)D

(Debug) In[ ]:=

```
Ncr1 = Abs[δx];
Ncr1Gauss = Integrate[Pdf * Ncr1 * DiracDelta[δ - σ0 * θ],
  {δ, -Infinity, Infinity}, {δx, -Infinity, Infinity},
  {δy, -Infinity, Infinity}, Assumptions → {σ0 > 0, σ1x > 0, σ1y > 0, θ > 0}]
```

(Debug) Out[ ]=

$$\frac{e^{-\frac{\theta^2}{2}}\,\sigma 1x}{\pi\,\sigma 0}$$

(Debug) Out[ ]=

$$\frac{1}{2\sqrt{2}\,\pi^{3/2}\sqrt{\sigma 0^2\,\sigma 1x^2\,\sigma 1y^2}}$$

$$\text{Integrate}\Big[\text{DiracDelta}[\delta-\theta\,\sigma 0]\left(\begin{cases}\dfrac{2\,e^{-\frac{\delta^2}{2\sigma 0^2}}\sqrt{2\pi}\,\sigma 1x^2}{\sqrt{\frac{1}{\sigma 1y^2}}} \\ \text{Integrate}\Big[\dfrac{e^{-\frac{\delta^2}{2\sigma 0^2}-\frac{\delta x^2}{2\sigma 1x^2}}\sqrt{2\pi}\,\text{Abs}[\delta x]}{\sqrt{\frac{1}{\sigma 1y^2}}},\ \{\delta x,-\infty,\infty\}, \\ \quad \text{Assumptions}\to \text{Re}[\sigma 1y^2]>0\ \&\&\ \text{Re}[\sigma 1x^2]\le 0, \\ \quad \text{GenerateConditions}\to \text{True},\ \text{PrincipalValue}\to \text{False}\Big]\end{cases}\right),$$
$$\text{GenerateConditions}\to \text{Automatic},\ \text{PrincipalValue}\to \text{False}\Big]\ \text{if}\ \text{Re}[\sigma 1y^2]>0$$

(Debug) In[ ]:=

```
a = 1;
Which[a == 1, x, a == 2, b]
```

(Debug) Out[ ]=

x

(Debug) In[ ]:=

```
cc = 100;
Which[cc > 200, 0, True, Exp[-cc]]
```

(Debug) Out[ ]=

$$\frac{1}{e^{100}}$$

(Debug) In[ ]:=

```
Normal[Series[Exp[x1], {x1, 0, 6}]]
```

(Debug) Out[ ]=

$$1 + x1 + \frac{x1^2}{2} + \frac{x1^3}{6} + \frac{x1^4}{24} + \frac{x1^5}{120} + \frac{x1^6}{720}$$

(Debug) In[ ]:=

```
Expand[(1 + x)^3 (5 x^2 + 1) (x^5 + 1)]
```

(Debug) Out[ ]=

$1 + 3 x + 8 x^2 + 16 x^3 + 15 x^4 + 6 x^5 + 3 x^6 + 8 x^7 + 16 x^8 + 15 x^9 + 5 x^{10}$

(Debug) In[ ]:=

```
ExpToTrig[ⅇ^x1]
```

(Debug) Out[ ]=

```
Cosh[x1] + Sinh[x1]
```

(Debug) In[ ]:=

```
TrigToExp[Cosh[x1] + Sinh[x1]]
```

(Debug) Out[ ]=

e^{x1}

Ctrl + 4

(Debug) In[ ]:=

```
a\times b 10^{-3}
```

(Debug) Out[ ]=

$\frac{a \times b}{1000}$

(Debug) In[ ]:=

```
sd=1;
d=2;
sd**d*2
```

(Debug) Out[ ]=

2

(Debug) In[ ]:=

Sinh

Assuming "Sinh" is referring to a mathematical definition | Use as a math function instead

Input interpretation:

hyperbolic sine

Alternate name:

sh

Definition: More details

The hyperbolic sine is defined as

$\sinh z = \frac{1}{2}(e^z - e^{-z})$

$\sinh z \equiv \frac{1}{2}(e^{z} - e^{-z})$.

The notation sh z is sometimes also used (Gradshteyn and Ryzhik 2000, p. xxix). It is implemented in the Wolfram Language as `Sinh`[z].

Special values include

$$\sinh 0 = 0$$

$$\sinh(\ln \phi) = \frac{1}{2},$$

where ϕ is the golden ratio.

More information »

Related terms:

beta exponential function | bipolar coordinates | bipolar cylindrical coordinates | bispherical coordinates | catenary | catenoid | conical function | cubic equation | de Moivre’s identity | Dixon-Ferrar formula | elliptic cylindrical coordinates | Elsasser function | Gudermannian | helicoid | Helmholtz differential equation—elliptic cylindrical coordinates | hyperbolic cosecant | hyperbolic functions | inverse hyperbolic sine | Laplace’s equation—bispherical coordinates | Laplace’s equation—toroidal coordinates | Lebesgue constants | Lorentz group | Mercator projection | Miller cylindrical projection | modified Bessel function of the second kind | modified spherical Bessel function of the first kind | modified Struve function | Nicholson’s formula | oblate spheroidal coordinates | parabola involute | partition function P | Poinsot’s spirals | prolate spheroidal coordinates | Schläfli’s formula | Shi | sine | sine-Gordon equation | surface of revolution | tau function | toroidal coordinates | toroidal function | tractrix | Watson’s formula

Related Wolfram Language symbol:

Sinh

Subject classifications: Show details

MathWorld:

hyperbolic functions

MSC 2010:

33B10

WolframAlpha

Wolfram|Alpha doesn't know how to interpret your input. ?

WolframAlpha

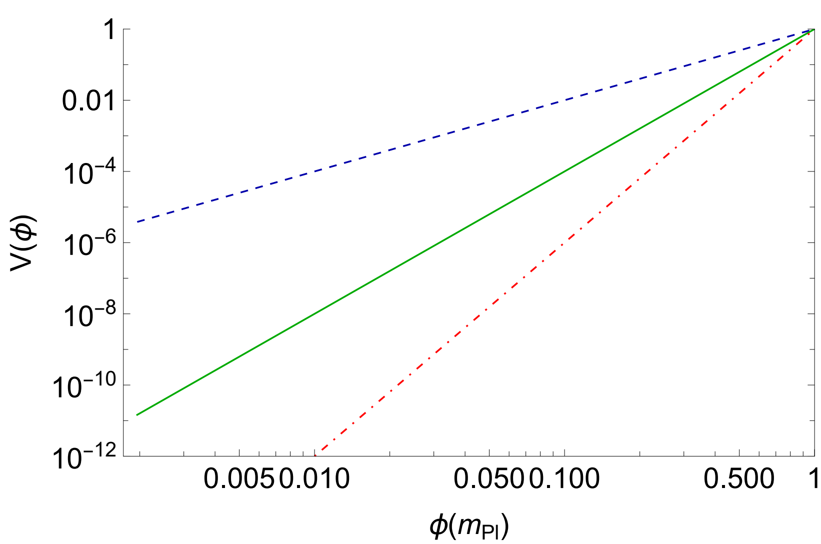
Plotting

Plotting With Padding

(Debug) In[ ]:=

```
PP = LogLogPlot[{xx^2, xx^4, xx^6}, {xx, -1, 1},
  Frame → {{True, True}, {True, False}}, PlotRange → {{-1, 1}, {10^-12, 10^0}},
  PlotStyle → {{Darker[Blue], Thickness[0.0025], Dashed},
    {Darker[Green], Thickness[0.0025]}, {Red, Thickness[0.0025], DotDashed},
    {Blue, Dashing[0.006]}, {Red}, {Red, Dashing[0.006]}}, FrameLabel → {"ϕ(mPl)", "V(ϕ)"},
  FrameStyle → Directive[Black, 15], ImagePadding → 65, ImageSize → 490]
```

(Debug) Out[ ]=

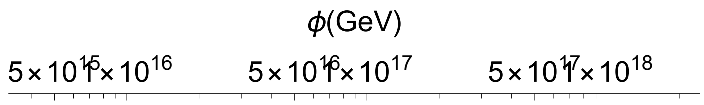



```
mpl = 2.435515 * 10^18 (*GeV*)
```

(Debug) In[ ]:=

```
a22 = ListLogLogPlot[{Centrald1p5pm5},
  Joined → True, FrameLabel → {{"", ""}, {"", "ϕ(GeV)"}},
  FrameStyle → Directive[Black, 15], PlotStyle → {{Black, Opacity[0]}},
  PlotRange → {{-2.435515 * 10^18, 2.435515 * 10^18}, {10^-12, 10^0}}, ImageSize → 490,
  ImagePadding → 65, Frame → {{False, False}, {False, True}}, Axes → False, FrameTicks → All]
```

(Debug) Out[ ]=

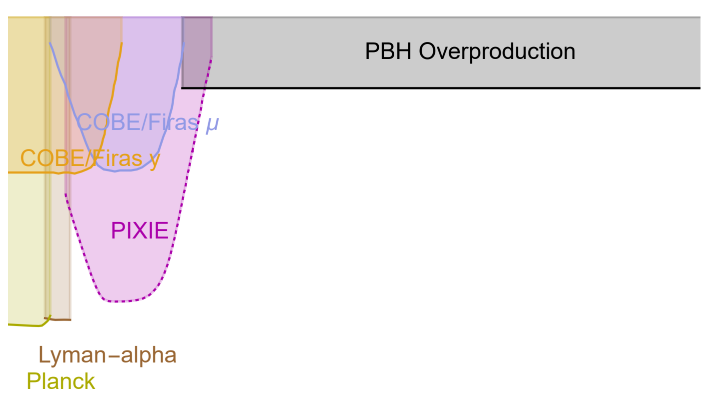


(Debug) In[ ]:=

```
Pixe = Import[
   "C:\\Users\\adeel\\OneDrive\\Desktop\\Notes_CS_PBH\\CSs_Bounds_Program_code\\PBHbounds
     -master\\PBHbounds-master\\bounds\\PowerSpectrum\\PIXIE_1.DAT"];
Lyalpha = Import[
   "C:\\Users\\adeel\\OneDrive\\Desktop\\Notes_CS_PBH\\CSs_Bounds_Program_code\\PBHbounds
     -master\\PBHbounds-master\\bounds\\PowerSpectrum\\Lyman-alpha_1.DAT"];
Lyalpha2 = Import[
   "C:\\Users\\adeel\\OneDrive\\Desktop\\Notes_CS_PBH\\CSs_Bounds_Program_code\\PBHbounds
     -master\\PBHbounds-master\\bounds\\PowerSpectrum\\Lyman-alpha2_1.DAT"];
PBHDM = Import[
   "C:\\Users\\adeel\\OneDrive\\Desktop\\Notes_CS_PBH\\CSs_Bounds_Program_code\\PBHbounds
     -master\\PBHbounds-master\\bounds\\PowerSpectrum\\PBHDM_1.DAT"];
Planck = Import[
   "C:\\Users\\adeel\\OneDrive\\Desktop\\Notes_CS_PBH\\CSs_Bounds_Program_code\\PBHbounds
     -master\\PBHbounds-master\\bounds\\PowerSpectrum\\planck_1.DAT"];
Planck2 = Import[
   "C:\\Users\\adeel\\OneDrive\\Desktop\\Notes_CS_PBH\\CSs_Bounds_Program_code\\PBHbounds
     -master\\PBHbounds-master\\bounds\\PowerSpectrum\\planck2_1.DAT"];
Lisa = Import[
   "C:\\Users\\adeel\\OneDrive\\Desktop\\Notes_CS_PBH\\CSs_Bounds_Program_code\\PBHbounds
     -master\\PBHbounds-master\\bounds\\PowerSpectrum\\LISA_1.DAT"];
Lyalpha2mod = Table[{Lyalpha2[[jj, 1]], Lyalpha2[[jj, 2]]}, {jj, 1, Length[Lyalpha2]}];
Lyalphamod = Table[{Lyalpha[[jj, 1]], Lyalpha[[jj, 2]]}, {jj, 1, Length[Lyalpha]}];
COBEmu = Import[
   "C:\\Users\\adeel\\OneDrive\\Desktop\\Notes_CS_PBH\\CSs_Bounds_Program_code\\PBHbounds
     -master\\PBHbounds-master\\bounds\\PowerSpectrum\\COBE_mu.csv"];
```

```
COBEy = Import[
   "C:\\Users\\adeel\\OneDrive\\Desktop\\Notes_CS_PBH\\CSs_Bounds_Program_code\\PBHbounds
     -master\\PBHbounds-master\\bounds\\PowerSpectrum\\COBE_y.csv"];
BNSBBH = Import[
   "C:\\Users\\adeel\\OneDrive\\Desktop\\PBH_An_Gh\\Neutrino_Physics\\Bounds\\2306-15555-
     fig6-SMBHB.csv"];
PSBounds = ListLogLogPlot[{Pixe, Lyalphamod, PBHDM, Planck, COBEmu, COBEy}, Joined → True,
  Frame → {False, False, False, False}, FrameLabel → {"k [Mpc]^-1", "𝒫_R (k)", "N_k", None},
  FrameStyle → Directive[Black, 15], PlotStyle →
   {{Darker[Magenta], Thickness[0.003], Dashing[0.005]}, {Brown, Thickness[0.003]},
    {Black, Thickness[0.003]}, {Darker[Yellow], Thickness[0.003]},
    {Hue[0.65, 0.37, 0.9], Thickness[0.003]}, {Hue[0.11, 0.89, 0.9], Thickness[0.003]}},
  Epilog → {Style[Text["Lyman-alpha", {Log[1 * 10^2], Log[3 * 10^-10]}], Brown, 12],
    Style[Text["Planck", {Log[1.3], Log[6 * 10^-11]}], Darker[Yellow], 12],
    Style[Text["PIXIE", {Log[2 * 10^3], Log[1 * 10^-6]}], Darker[Magenta], 12],
    Style[Text["COBE/Firas μ", {Log[4 * 10^3], Log[1 * 10^-3]}], Hue[0.65, 0.37, 0.9], 12],
    Style[Text["COBE/Firas y", {Log[2 * 10^1], Log[1 * 10^-4]}], Hue[0.11, 0.89, 0.9], 12],
    Style[Text["PBH Overproduction", {Log[4 * 10^16], Log[1 * 10^-1]}], Black, 12]},
  ImagePadding → 65, ImageSize → 490, Axes → False, Filling → Top,
  PlotRange → {{10^-2, 6.9 * 10^25}, {10^-12, 10^0}}]
```

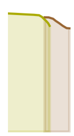
(Debug) Out[ ]=



(Debug) In[ ]:=

```
PSBounds1 = ListLogLogPlot[{(*Pixe,*)Lyalpha2mod, Planck2},
  Joined → True, Frame → {False, False, False, False},
  FrameLabel → {"k  [Mpc]^-1", "𝒫s", "Nk", None}, FrameStyle → Directive[Black, 15],
  PlotStyle → {{Brown, Thickness[0.003]}, {Darker[Yellow], Thickness[0.003]},
    {Blue, Thickness[0.003]}, {Blue, Thickness[0.003]}},
  (*Epilog→{Style[Text["M=0.055 mp",{Log[2*10^15],Log[1*10^-8]}],Darker[Gray],15]},*)
  PlotRange → {{10^-2, 6.9 * 10^25}, {10^-12, 10^0}}, ImagePadding → 65,
  ImageSize → 490, Axes → False, Filling → Bottom]
```

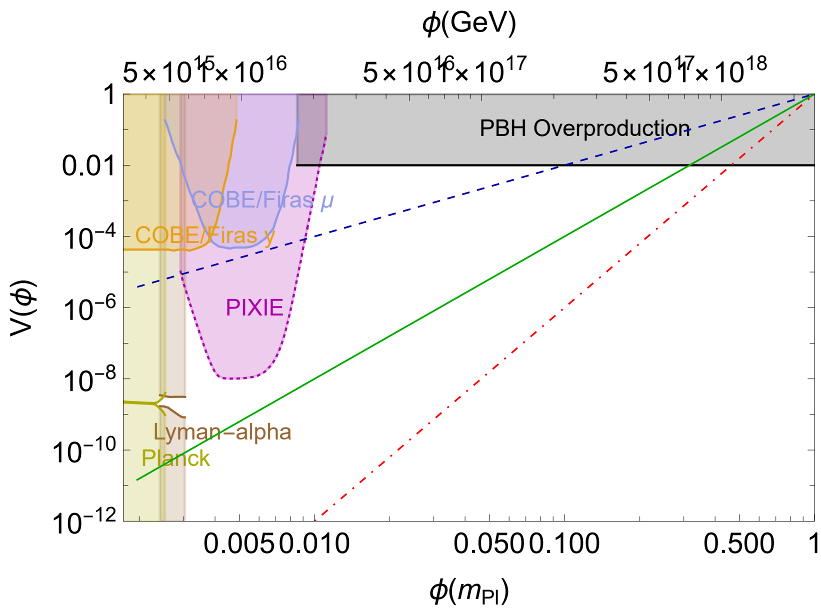
(Debug) Out[ ]=



(Debug) In[ ]:=

```
ee = Overlay[{a22, PSBounds, PSBounds1, PP}]
```

(Debug) Out[ ]=

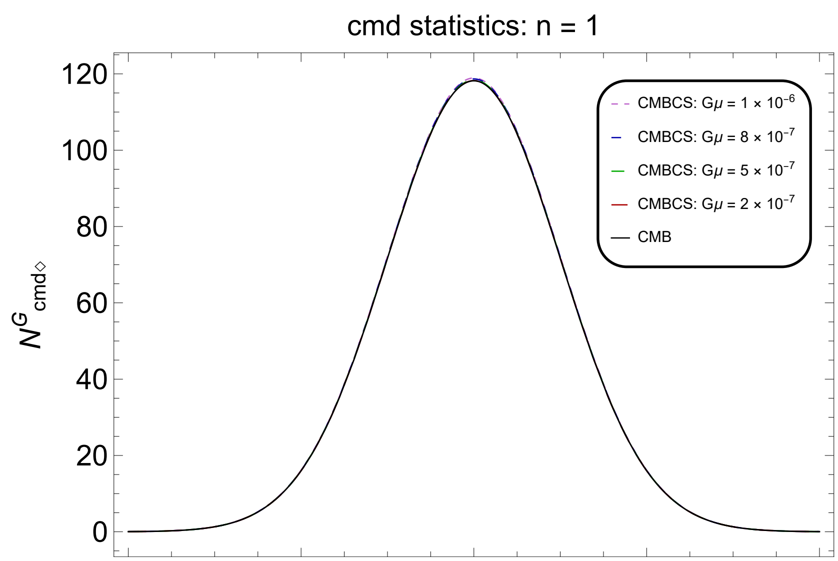


Plotting Residuals

(Debug) In[ ]:=

```
n1 = 1;
PNcmdn1 = Plot[{NcmdGaussTot[Gμ, n1] /. {Gμ → 1 * 10^-6},
    NcmdGaussTot[Gμ, n1] /. {Gμ → 8 * 10^-7}, NcmdGaussTot[Gμ, n1] /. {Gμ → 5 * 10^-7},
    NcmdGaussTot[Gμ, n1] /. {Gμ → 2 * 10^-7}, NcmdGaussCMB[n1]}, {θ, -4, 4},
   PlotRange → All, FrameLabel → {"", "N^G_cmd◇", "cmd statistics: n = 1"},
   FrameStyle → Directive[Black, 15], ImageSize → 450, Axes → False,
   PlotLegends → Placed[LineLegend[{"CMBCS: Gμ = 1 × 10^-6",
       "CMBCS: Gμ = 8 × 10^-7", "CMBCS: Gμ = 5 × 10^-7", "CMBCS: Gμ = 2 × 10^-7", "CMB"},
      LabelStyle → {8, Background → White}, LegendMarkerSize → {{10, 10}},
      LegendFunction → (Framed[#, RoundingRadius → 15] &), LegendMargins → 2], {0.82, 0.76}],
   PlotStyle → {{Hue[0.81, 0.5, 0.8], Thickness[0.002], Dashing[0.01]},
     {Darker[Blue], Thickness[0.002], Dashing[0.015]}, {Darker[Green], Thickness[0.002],
      Dashing[0.02]}, {Darker[Red], Thickness[0.002], Dashing[0.025]},
     {Darker[Black], Thickness[0.002]}, {Darker[Yellow], Thickness[0.008], Dotted},
     {Darker[Black], Thickness[0.002], Dotted}},
   Frame → True, AspectRatio → 0.7, ImagePadding → {{65, 10}, {0, 40}}]
```

(Debug) Out[ ]=

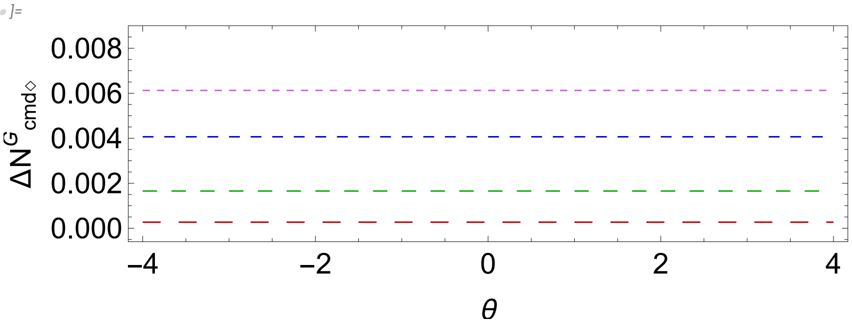


Residual

(Debug) In[ ]:=

```
PNcmdResdn1 =
 Plot[{NcmdGaussResd[Gμ, n1] /. {Gμ → 1 * 10^-6}, NcmdGaussResd[Gμ, n1] /. {Gμ → 8 * 10^-7},
   NcmdGaussResd[Gμ, n1] /. {Gμ → 5 * 10^-7}, NcmdGaussResd[Gμ, n1] /. {Gμ → 2 * 10^-7}},
  {θ, -4, 4}, PlotRange → {-0.0006, 0.009}, FrameLabel → {"θ", "ΔN^G_cmd◇", ""},
  FrameStyle → Directive[Black, 15], ImageSize → 450, Axes → False,
  PlotStyle → {{Hue[0.81, 0.5, 0.8], Thickness[0.002], Dashing[0.01]},
    {Darker[Blue], Thickness[0.002], Dashing[0.015]}, {Darker[Green], Thickness[0.002],
     Dashing[0.02]}, {Darker[Red], Thickness[0.002], Dashing[0.025]}},
  Frame → True, AspectRatio → 0.3, ImagePadding → {{65, 10}, {40, 0}}]
```

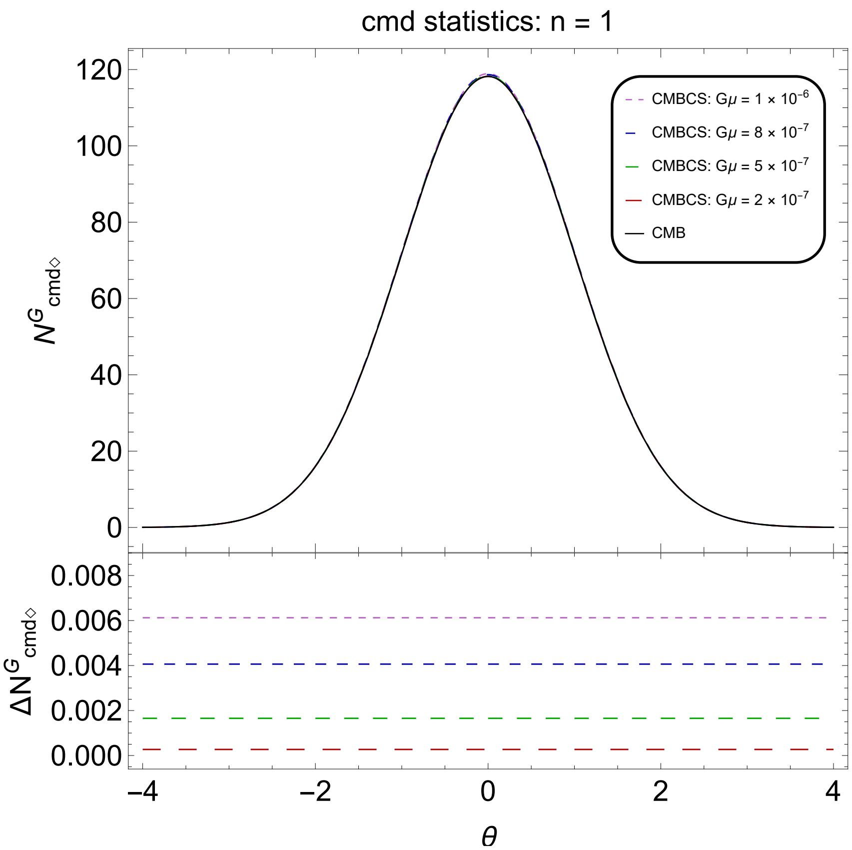
(Debug) Out[ ]=



(Debug) In[ ]:=

```
Column[{PNcmdn1, PNcmdResdn1}, Spacings → 0]
```

(Debug) Out[ ]=

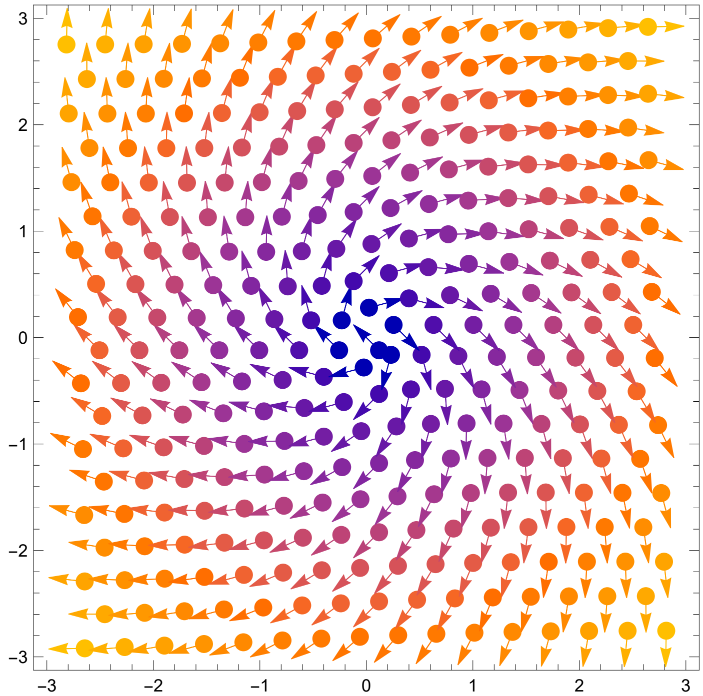


Vector/ Stream Plots

(Debug) In[ ]:=

```
f1 = VectorPlot[{x1 + y1, y1 - x1}, {x1, -3, 3},
  {y1, -3, 3}, PlotLayout → "Row", VectorMarkers → "DotArrow"]
```

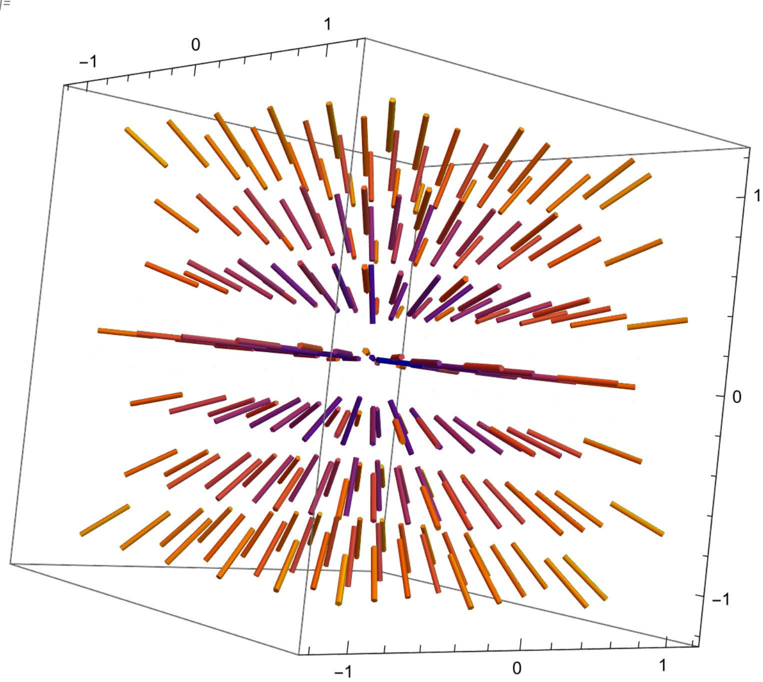
(Debug) Out[ ]=



(Debug) In[ ]:=

```
VectorPlot3D[{x, y, z}, {x, -1, 1}, {y, -1, 1}, {z, -1, 1}, VectorMarkers → "Tube"]
```

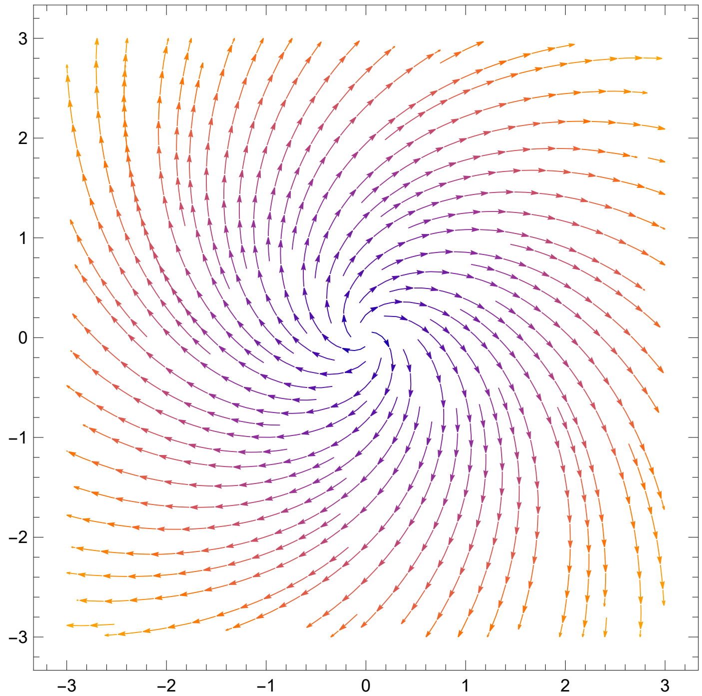
(Debug) Out[ ]=



(Debug) In[ ]:=

```
f2 = StreamPlot[{x1 + y1, y1 - x1}, {x1, -3, 3}, {y1, -3, 3}, StreamScale → Small]
```

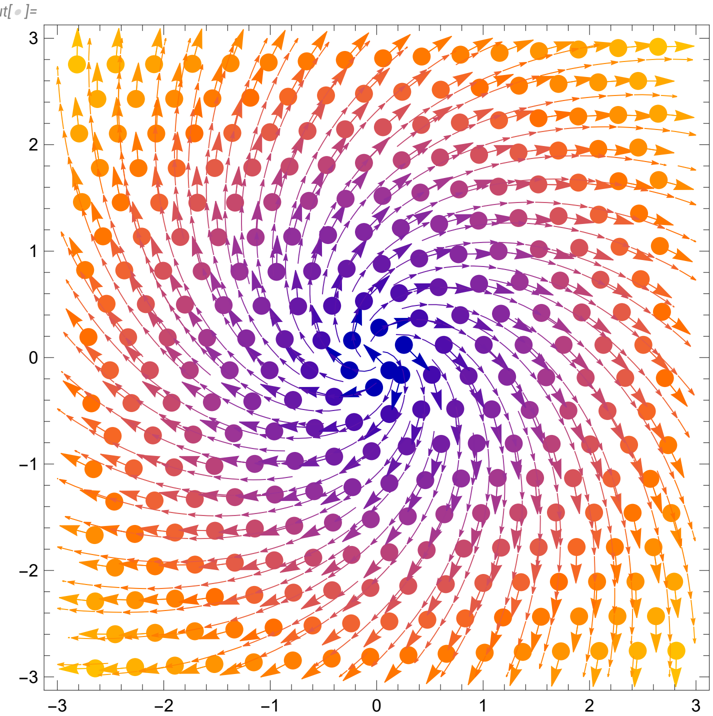
(Debug) Out[ ]=



(Debug) In[ ]:=

```
Show[f1, f2]
```

(Debug) Out[ ]=



Plotting with LATEX fonts

(Debug) In[ ]:=

```
SetDirectory[NotebookDirectory[]];
<< MaTeX`
ConfigureMaTeX["pdfLaTeX" → "C:\\Program Files\\MiKTeX\\miktex\\bin\\x64\\pdflatex.exe",
 "Ghostscript" → "C:\\Program Files\\gs\\gs10.01.2\\bin\\gswin64c.exe"


]
SetOptions[MaTeX, "Preamble" → {"\\usepackage{color}"}]
SetOptions[MaTeX, "Preamble" → {"\\usepackage{xcolor}"}]
```

(Debug) Out[ ]=

```
{CacheSize → 100, WorkingDirectory → Automatic,
 pdfLaTeX → C:\Program Files\MiKTeX\miktex\bin\x64\pdflatex.exe,
 Ghostscript → C:\Program Files\gs\gs10.01.2\bin\gswin64c.exe}
```

(Debug) Out[ ]=

```
{BasePreamble → {\usepackage{lmodern,exscale}, \usepackage{amsmath,amssymb}},
 Preamble → {\usepackage{color}}, DisplayStyle → True,
 ContentPadding → True, LineSpacing → {1.2, 0}, FontSize → 12,
 Magnification → 1, LogFileFunction → None, TeXFileFunction → None}
```

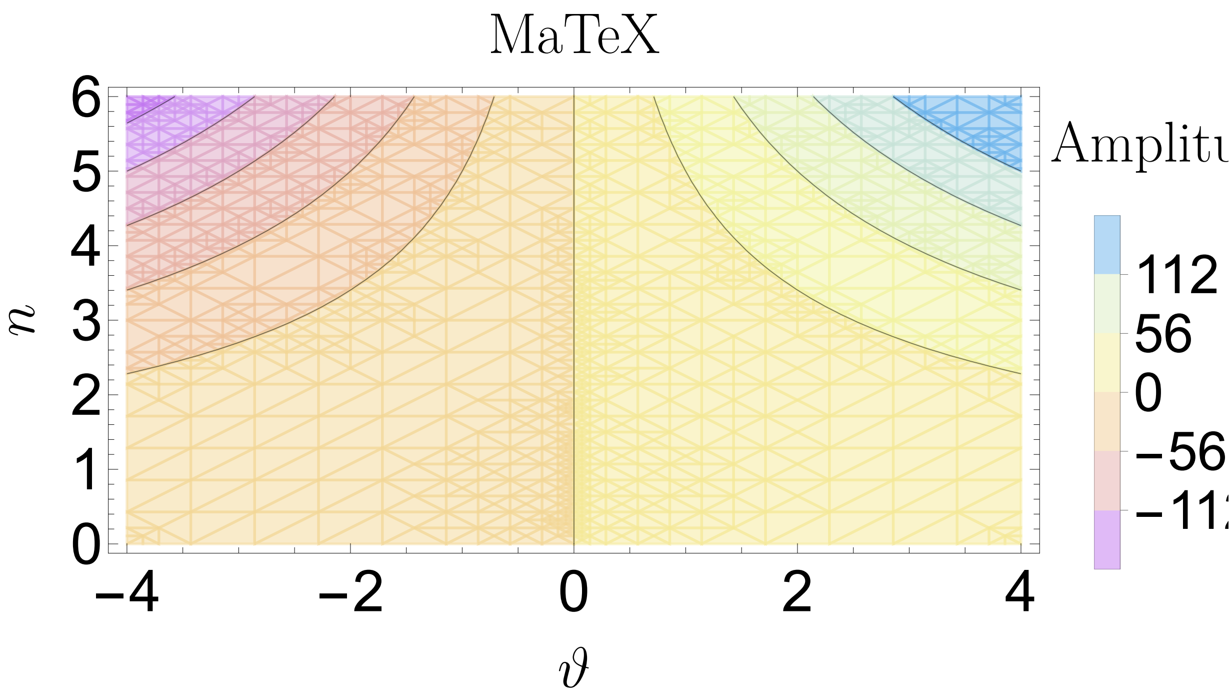
(Debug) Out[ ]=

```
{BasePreamble → {\usepackage{lmodern,exscale}, \usepackage{amsmath,amssymb}},
 Preamble → {\usepackage{xcolor}}, DisplayStyle → True,
 ContentPadding → True, LineSpacing → {1.2, 0}, FontSize → 12,
 Magnification → 1, LogFileFunction → None, TeXFileFunction → None}
```

(Debug) In[ ]:=

```
ContourPlot[θ * n + n^2 * θ, {θ, -4, 4}, {n, 0, 6},
 ColorFunction → (Opacity[0.5, ColorData["Pastel"][#1]] &),
 Contours → 10, ColorFunctionScaling → True, PlotLegends →
  Placed[BarLegend[5, LegendLabel → MaTeX["\\text{Amplitude}", FontSize → 30], LabelStyle →
     Directive[FontSize → 28, Black], LegendMarkerSize → 205, LegendMargins → -1], Right],
 Frame → True, FrameStyle → Directive[Black, 30], ImageSize → 550,
 AspectRatio → 0.5, FrameTicks → {True, True, False, False},
 FrameLabel → {{MaTeX["n", FontSize → 30], None},
   {MaTeX["\vartheta", FontSize → 30], MaTeX["\\text{MaTeX}", FontSize → 30]}}]
```

(Debug) Out[ ]=



Plotting with Animation

Projectile Motion

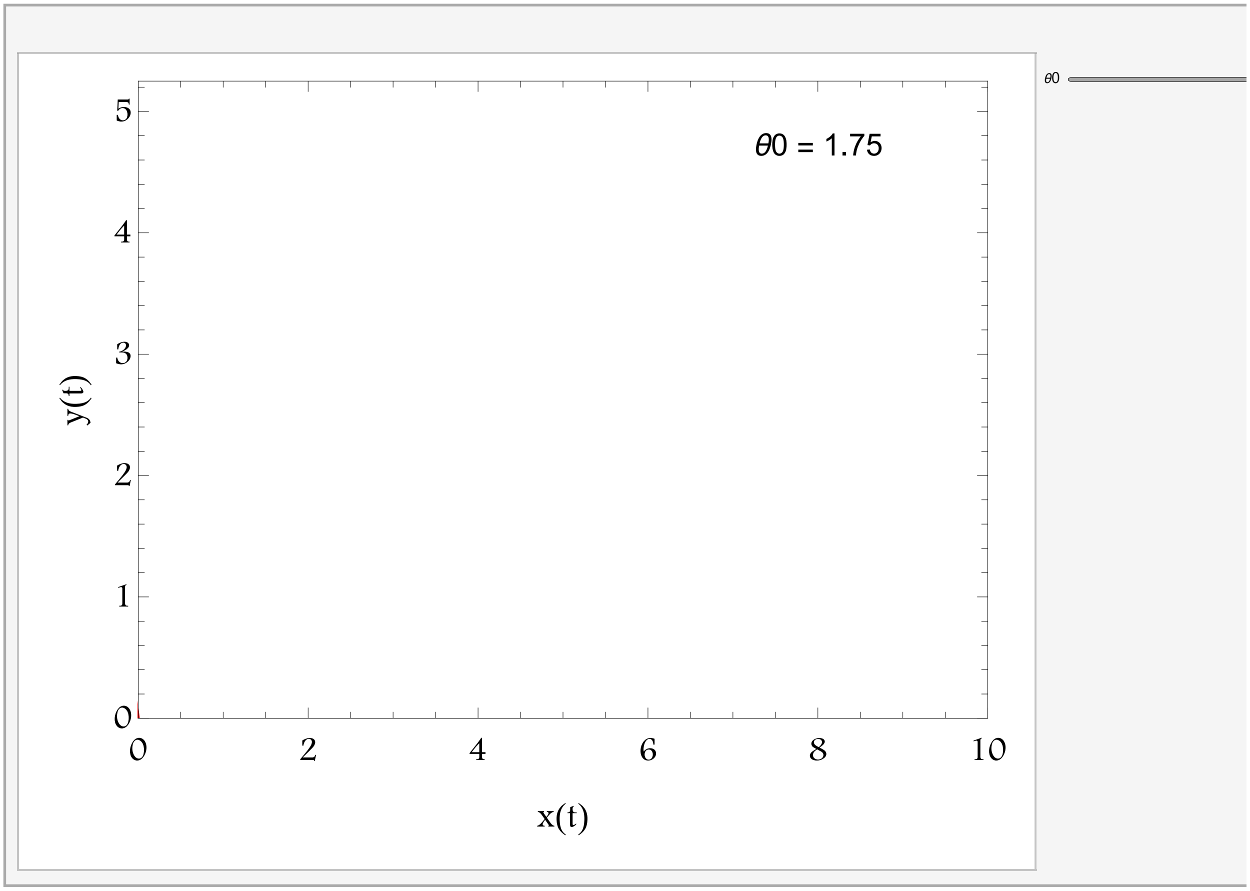
(Debug) In[ ]:=

```
x[t_] = t v0 Cos[θ0];
y[t_] = 1/2 (-g t^2 + 2 t v0 Sin[θ0]);
```

(Debug) In[ ]:=

```
{x[t], y[t]} /. {v0 → 10, g → 9.8};
Manipulate[ParametricPlot[%, {t, 0, 3}, AspectRatio → 0.75,
  Frame → True, FrameLabel → {"x(t)", "y(t)"}, PlotRange → {{0, 10}, {0, 5.25}},
  FrameStyle → Directive[Black, 18, FontFamily → "Andalus"],
  PlotStyle → {Red}, ImageSize → 500,
  Epilog → {Text[Style["θ0 = " <> ToString[NumberForm[θ0, {3, 2}]], 16, Black],
     Scaled[{0.8, 0.9}]]}], {θ0, -π, π}]
```

(Debug) Out[∘]=



Kousha Ebrahimi's Integral

$$\text{Integrate}\left[\sqrt{1+\frac{x}{c^2-x^2}},\ x\right]$$

(Debug) In[∘]:=

$$dd = \left(2\sqrt{\frac{c^2+x-x^2}{c^2-x^2}}\left(\frac{1}{8}c\left(1-2c+\sqrt{1+4c^2}\right)\left(1+\sqrt{1+4c^2}-2x\right)(c+x)\left(-1+\sqrt{1+4c^2}+2x\right)-\right.\right.$$

$$c^2\left(1+2c+\sqrt{1+4c^2}\right)(c-x)^2\sqrt{-\frac{c\left(1+\sqrt{1+4c^2}-2x\right)}{\left(1+2c+\sqrt{1+4c^2}\right)(-c+x)}}$$

$$\sqrt{\frac{\left(1-2c+\sqrt{1+4c^2}\right)(c+x)}{\left(1+2c+\sqrt{1+4c^2}\right)(-c+x)}}\sqrt{\frac{c\left(-1+\sqrt{1+4c^2}+2x\right)}{\left(-1-2c+\sqrt{1+4c^2}\right)(c-x)}}$$

$$\text{EllipticF}\left[\text{ArcSin}\left[\sqrt{\frac{\left(1-2\,c+\sqrt{1+4\,c^2}\right)\,(c+x)}{\left(1+2\,c+\sqrt{1+4\,c^2}\right)\,(-c+x)}}\right],\ \frac{2\,c+\sqrt{1+4\,c^2}}{2\,c-\sqrt{1+4\,c^2}}\right]-$$

$$c\left(1+2\,c+\sqrt{1+4\,c^2}\right)\,(c-x)^2\,\sqrt{-\frac{c\left(1+\sqrt{1+4\,c^2}-2\,x\right)}{\left(1+2\,c+\sqrt{1+4\,c^2}\right)\,(-c+x)}}$$

$$\sqrt{\frac{\left(1-2\,c+\sqrt{1+4\,c^2}\right)\,(c+x)}{\left(1+2\,c+\sqrt{1+4\,c^2}\right)\,(-c+x)}}\ \sqrt{\frac{c\left(-1+\sqrt{1+4\,c^2}+2\,x\right)}{\left(-1-2\,c+\sqrt{1+4\,c^2}\right)\,(c-x)}}$$

$$\left(\text{EllipticF}\left[\text{ArcSin}\left[\sqrt{\frac{\left(1-2\,c+\sqrt{1+4\,c^2}\right)\,(c+x)}{\left(1+2\,c+\sqrt{1+4\,c^2}\right)\,(-c+x)}}\right],\ \frac{2\,c+\sqrt{1+4\,c^2}}{2\,c-\sqrt{1+4\,c^2}}\right]-2\,\text{EllipticPi}\left[\right.\right.$$

$$\left.\left.\frac{1+2\,c+\sqrt{1+4\,c^2}}{1-2\,c+\sqrt{1+4\,c^2}},\ \text{ArcSin}\left[\sqrt{\frac{\left(1-2\,c+\sqrt{1+4\,c^2}\right)\,(c+x)}{\left(1+2\,c+\sqrt{1+4\,c^2}\right)\,(-c+x)}}\right],\ \frac{2\,c+\sqrt{1+4\,c^2}}{2\,c-\sqrt{1+4\,c^2}}\right]\right)-$$

$$\frac{1}{2}\,c\left(1+2\,c+\sqrt{1+4\,c^2}\right)\,(c-x)^2\,\sqrt{-\frac{c\left(1+\sqrt{1+4\,c^2}-2\,x\right)}{\left(1+2\,c+\sqrt{1+4\,c^2}\right)\,(-c+x)}}$$

$$\sqrt{\frac{\left(1-2\,c+\sqrt{1+4\,c^2}\right)\,(c+x)}{\left(1+2\,c+\sqrt{1+4\,c^2}\right)\,(-c+x)}}\ \sqrt{\frac{c\left(-1+\sqrt{1+4\,c^2}+2\,x\right)}{\left(-1-2\,c+\sqrt{1+4\,c^2}\right)\,(c-x)}}\ \left(\left(-2\,c+\sqrt{1+4\,c^2}\right)\right.$$

$$\text{EllipticE}\left[\text{ArcSin}\left[\sqrt{\frac{\left(1-2\,c+\sqrt{1+4\,c^2}\right)\,(c+x)}{\left(1+2\,c+\sqrt{1+4\,c^2}\right)\,(-c+x)}}\right],\ \frac{2\,c+\sqrt{1+4\,c^2}}{2\,c-\sqrt{1+4\,c^2}}\right]-\left(1+\right.$$

$$\left.\sqrt{1+4\,c^2}\right)\,\text{EllipticF}\left[\text{ArcSin}\left[\sqrt{\frac{\left(1-2\,c+\sqrt{1+4\,c^2}\right)\,(c+x)}{\left(1+2\,c+\sqrt{1+4\,c^2}\right)\,(-c+x)}}\right],\ \frac{2\,c+\sqrt{1+4\,c^2}}{2\,c-\sqrt{1+4\,c^2}}\right]+$$

$$2\,\text{EllipticPi}\left[\frac{1+2\,c+\sqrt{1+4\,c^2}}{1-2\,c+\sqrt{1+4\,c^2}},\ \text{ArcSin}\left[\sqrt{\frac{\left(1-2\,c+\sqrt{1+4\,c^2}\right)\,(c+x)}{\left(1+2\,c+\sqrt{1+4\,c^2}\right)\,(-c+x)}}\right],\right.$$

$$\frac{2\,c + \sqrt{1+4\,c^2}}{2\,c - \sqrt{1+4\,c^2}}\Bigg]\Bigg)\Bigg)\Bigg)\Bigg/ \left(c\left(1-2\,c+\sqrt{1+4\,c^2}\right)\left(c^2+x-x^2\right)\right);$$

$$\text{Solve}\left[\left(dd\ /.\ x\to \frac{1}{2} - dd\ /.\ x\to -\frac{1}{2}\right) == \frac{\pi}{4},\ c\right]$$

(Debug) Out[ ]=

```
$Aborted
```

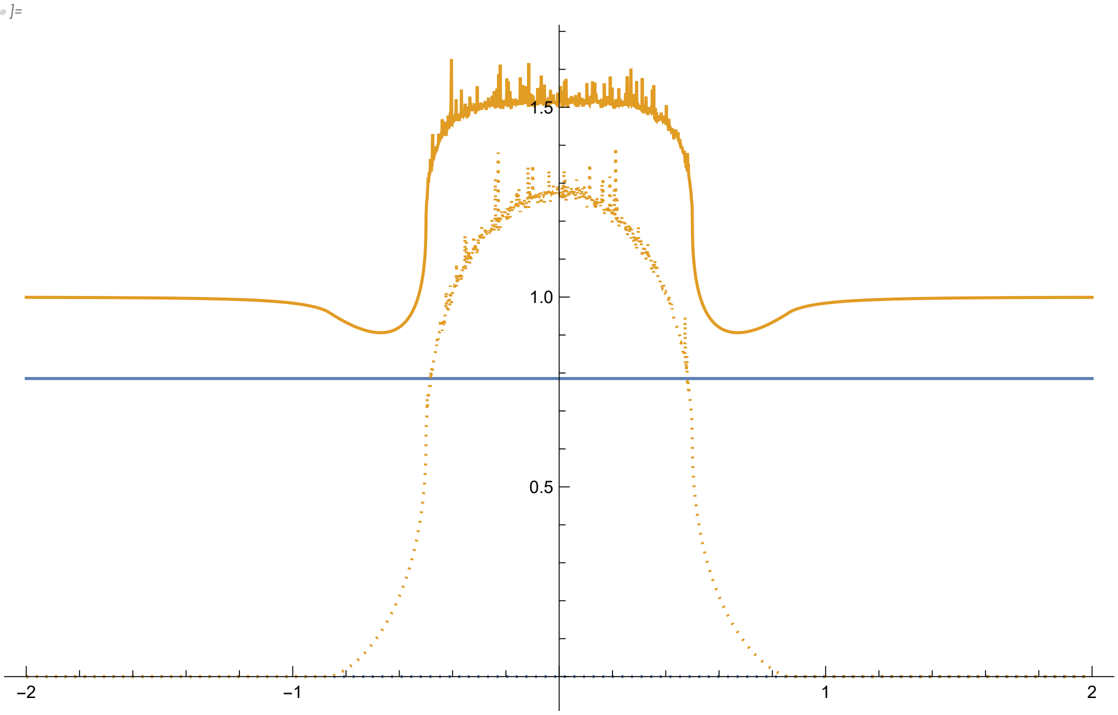
(Debug) In[ ]:=

$$\text{ff}[c\_?\text{NumericQ}] := \text{NIntegrate}\left[\sqrt{1+\frac{x}{c^2-x^2}},\ \left\{x,\ \frac{-1}{2},\ \frac{1}{2}\right\}\right]$$

(Debug) In[ ]:=

$$\text{ReImPlot}\left[\left\{\frac{\pi}{4},\ \text{ff}[c]\right\},\ \{c,\ -2,\ 2\}\right]$$

(Debug) Out[ ]=



(Debug) In[ ]:=

```
Style["End of the Begenning ⟶ پایان آغاز  ",
 FontFamily → "Cambria Math", FontSize → 37, FontWeight → "Bold"]
```

(Debug) Out[ ]=

End of the Begenning ⟶ پایان آغاز

(Debug) In[ ]:=

```
Speak["End of the Begenning"]
```