```
(*###########################################################*)

(*### ¥1. INITIAL SETUP & SYSTEM CONFIGURATION                 ###*)

(*###       ' F48(2,9)T(1,200,400)phase.nb                         ###*)

(*###########################################################*)

$HistoryLength = 0;

ClearAll["Global`*"];

ClearSystemCache[];

(*---Computation Start Timer---*)

sTime = AbsoluteTime[];

Print["(0) System Initialization: Computing Started..."];

(*---Directory& Kernel Setup---*)

targetDir = FileNameJoin[{$HomeDirectory, "Desktop", "Torus_Works"}];

If[! FileExistsQ[targetDir], CreateDirectory[targetDir]];

If[Length[Kernels[]] > 0, CloseKernels[]];

LaunchKernels[];

(*###########################################################*)

(*### 2. PARAMETERS& STRUCTURE DEFINITION                     ###*)

(*###########################################################*)

(*---Animation Settings---*)

rate = 48;
```

```
myBackground = White;

sz = 800;

(*---Rendering Mode Configuration---*)

renderMode = "F";

{pps0, pps1, pps2, pps3} =

  Switch[renderMode, "D", {20, 40, 60, 100}, "E", {20, 100, 200, 400}, "F", {50, 100, 200, 400}];

{mr0, mr1, mr2, mr3} =

  Switch[renderMode, "D", {1, 1, 1, 1}, "E", {1, 2, 3, 3}, "F", {2, 3, 4, 5}];

(*---Structural Parameters---*)

a = 900; b = 300; c = 125; d = 60; k = 4.5; l = 50; m = 500;

{tubeRadius0, tubeRadius1, tubeRadius2, tubeRadius3} = {80, 60, 30, 20};

(*---Phase Frequency Settings (Layer 1,2,3)---*)

f1 = 1; f2 = 200; f3 = 400;

phase1 = f1;(*Fixed:Removed redundant 4Pi/rate to ensure perfect loop*)

phase2 = f2;

phase3 = f3;

(*---Automatic File Naming---*)

fName = renderMode <> ToString[rate] <> "(2,9)T(" <> ToString[f1] <> "," <> ToString[f2] <> ","
<> ToString[f3] <> ")phase";

(*---Visual Styles& Colors---*)

myStyle[col_] := Directive[col, Specularity[White, 12], Glow[Darker[col, 0.8]]];
```

```
goldStyle = Directive[RGBColor["#FFD700"], Specularity[RGBColor["#FFA500"], 50],

 AmbientAppearance[RGBColor["#8B4513"]]];

color0 = goldStyle;

color1 = myStyle[RGBColor["#0000ff"]];(*Blue*)color2 =

 myStyle[RGBColor["#ff0044"]];(*Pink/Red*)color3 =

 Directive[RGBColor["#006600"], Specularity[White, 40],

  Glow[RGBColor["#003300"]]];(*Green*)

(*###########################################################*)

(*### 3. MATHEMATICAL MODEL DEFINITION                    ###*)

(*###########################################################*)

(*---Layer 1:Base Torus Formula---*)

p1[x_, phi1_] := {a Cos[x + phi1] + b Cos[k x] Cos[x + phi1],

   a Sin[x + phi1] + b Cos[k x] Sin[x + phi1], b Sin[k x]};

(*---Layer 2:Template (Numerical Differentiation)---*)

p2Template[x_, phi1_, phi2_] :=

  Module[{v1, v1u, v2, v2u, v3u, dt = 0.001, p0, pp, pm},

   p0 = p1[x, phi1]; pp = p1[x + dt, phi1]; pm = p1[x - dt, phi1];

   v1 = (pp - pm)/(2 dt); v1u = v1/Sqrt[v1.v1];

   v2 = (pp - 2 p0 + pm)/(dt^2); v2u = v2/Sqrt[v2.v2];

   v3u = Cross[v1u, v2u];
```

```
    p0 + c (v2u Cos[l x + phi1 + phi2] + v3u Sin[l x + phi1 + phi2])];

(*---Layer 3:Template (Numerical Differentiation)---*)

p3Template[x_, phi1_, phi2_, phi3_] :=

  Module[{p20, p2p, p2m, r1, r1u, r2, r2u, r3u, dt = 0.001},

    p20 = p2Template[x, phi1, phi2];

    p2p = p2Template[x + dt, phi1, phi2];

    p2m = p2Template[x - dt, phi1, phi2];

    r1 = (p2p - p2m)/(2 dt); r1u = r1/Sqrt[r1.r1];

    r2 = (p2p - 2 p20 + p2m)/(dt^2); r2u = r2/Sqrt[r2.r2];

    r3u = Cross[r1u, r2u];

    p20 + d (r2u Cos[m x + phi1 + phi2 + phi3] + r3u Sin[m x + phi1 + phi2 + phi3])];

DistributeDefinitions["Global`"];

(*##########################################################*)

(*### 4. PARALLEL RENDERING PROCESS                          ###*)

(*##########################################################*)

Print["(1) Rendering Progress: Generating Animation Frames..."];

frames = ParallelTable[Module[{phi1, phi2, phi3, progress, b0, b1, b2, b3},progress = i/rate;

     phi1 = progress*(2 Pi*phase1);

     phi2 = progress*(4 Pi*phase2);

     phi3 = progress*(4 Pi*phase3);
```

```
   b0 = ParametricPlot3D[Evaluate[a {Cos[t], Sin[t], 0}], {t, 0, 2 Pi}, PlotStyle -> color0,

   PlotPoints -> pps0, MaxRecursion -> mr0, NormalsFunction -> "Average"] /.

   Line[pts_] :> Tube[pts, tubeRadius0];

   b1 = ParametricPlot3D[Evaluate[p1[t, phi1]], {t, 0, 4 Pi}, PlotStyle -> color1,

  PlotPoints -> pps1, MaxRecursion -> mr1,   NormalsFunction -> "Average"] /.

     Line[pts_] :> Tube[pts, tubeRadius1];

   b2 = ParametricPlot3D[Evaluate[p2Template[t, phi1, phi2]], {t, 0, 4 Pi},

   PlotStyle -> color2, PlotPoints -> pps2, MaxRecursion -> mr2, NormalsFunction -> "Average"] /.

   Line[pts_] :> Tube[pts, tubeRadius2];

   b3 = ParametricPlot3D[Evaluate[p3Template[t, phi1, phi2, phi3]], {t, 0, 4 Pi}, PlotPoints ->

   pps3, MaxRecursion -> mr3, NormalsFunction -> "Average"] /. Line[pts_] :> {color3, Tube[pts,

   tubeRadius3]}];

   Show[b0, b1, b2, b3, Lighting -> "Neutral", ViewPoint -> {0, 0, 2.0}, ViewVertical -> {0, 0, 1},

    PlotRange -> 1100, ViewCenter -> {0.5, 0.5, 0.5},SphericalRegion -> True, Boxed -> False,

    Axes -> False, ImageSize -> sz, Background -> White]], {i, 0, rate - 1}];

(*##############################################################*)

(*### 5. EXPORT& FINAL REPORT                                  ###*)

(*##############################################################*)

(*---Exporting GIF---*)

exportPath = FileNameJoin[{targetDir, fName <> ".gif"}];

Print["(2) Exporting GIF: ", exportPath];Export[exportPath, frames, "DisplayDurations" -> 0.05];
```

```
(*---Exporting High-Quality PNG---*)

exportPathSingle = FileNameJoin[{targetDir, fName <> ".png"}];

Print["(3) Exporting High-Quality PNG: ", exportPathSingle];

Export[exportPathSingle, Last[frames], ImageSize -> 2000,"CompressionLevel" -> 0];

(*---Saving Project Notebook---*)

nbPath = FileNameJoin[{targetDir, fName <> ".nb"}];

Print["(4) Saving Notebook File: ", nbPath];

NotebookSave[EvaluationNotebook[], nbPath];

(*---Final Computation Report---*)

eTime = AbsoluteTime[];

wTime = eTime - sTime;

Print["(5) Mission Accomplished! All files saved to 'Torus_Works' folder."];

Print["(6) Total Computation Time: ", Round[wTime, 1], " sec"];
```