Calculating AVS Curves

QEA Boats Module

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Explanation

This file contains Mathematica code for calculating the RM curve of a differently shaped three dimensional boats. First, we define our desired boats. Then, we define a function for finding the moment at a given heal angle. Finally, we map that function to several angles and generate a plot.

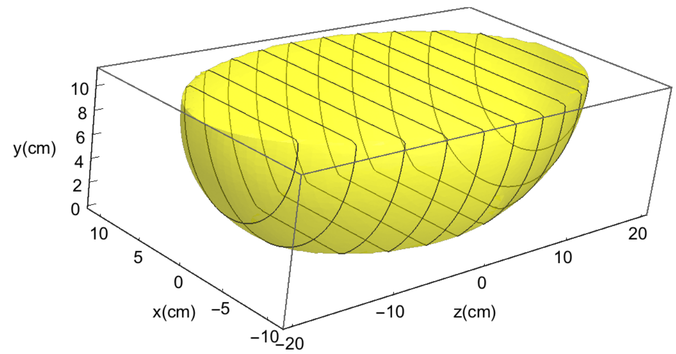
Code

In[2]:=
```
(*boat =
  ImplicitRegion[(x)^2/(10.16)^2+(y-7.62)^2/(7.62)^2 +z^2/(20.32)^2<1 && y < 7.62,
   { {x,-20,20},{y,-20,20},{z,-50,50}}];*)
boat = ImplicitRegion[(x)^2/(11.25)^2 + (y - 10.24)^2/(13.24)^2 + z^2/(20)^2 <
    1 && 0 < y < 11.24, { {x, -20, 20}, {y, -20, 20}, {z, -50, 50}}];
mast = ImplicitRegion[x^2 + (z - 0.9525)^2 ≤ 0.9525^2 && y ≥ 0 && y ≤ 50, {x, y, z}]
```

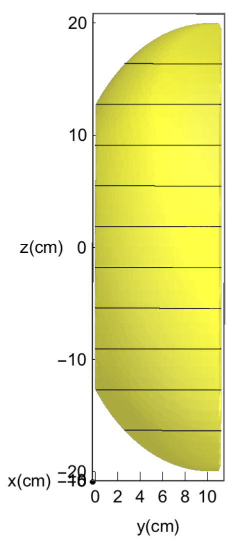
Out[3]=
```
ImplicitRegion[x^2 + (-0.9525 + z)^2 ≤ 0.907256 && y ≥ 0 && y ≤ 50, {x, y, z}]
```

In[∘]:=
```
Show[
 RegionPlot3D[boat, PlotTheme → "Web", AxesLabel → {"x(cm)", "y(cm)", "z(cm)"},
  PlotPoints → 55, PlotStyle → Directive[Yellow, Opacity[0.5]]]]
```

Out[∘]=

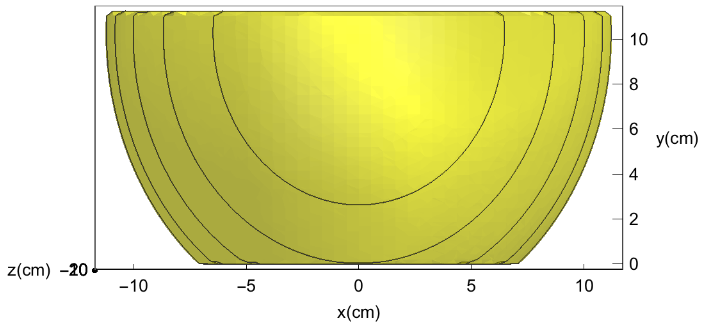


In[∘]:=
```
Show[%42, ViewPoint → {∞, 0, 0}]
```



In[•]:=
```
Show[%42, ViewPoint → {0, 0, ∞}]
```

Out[•]=

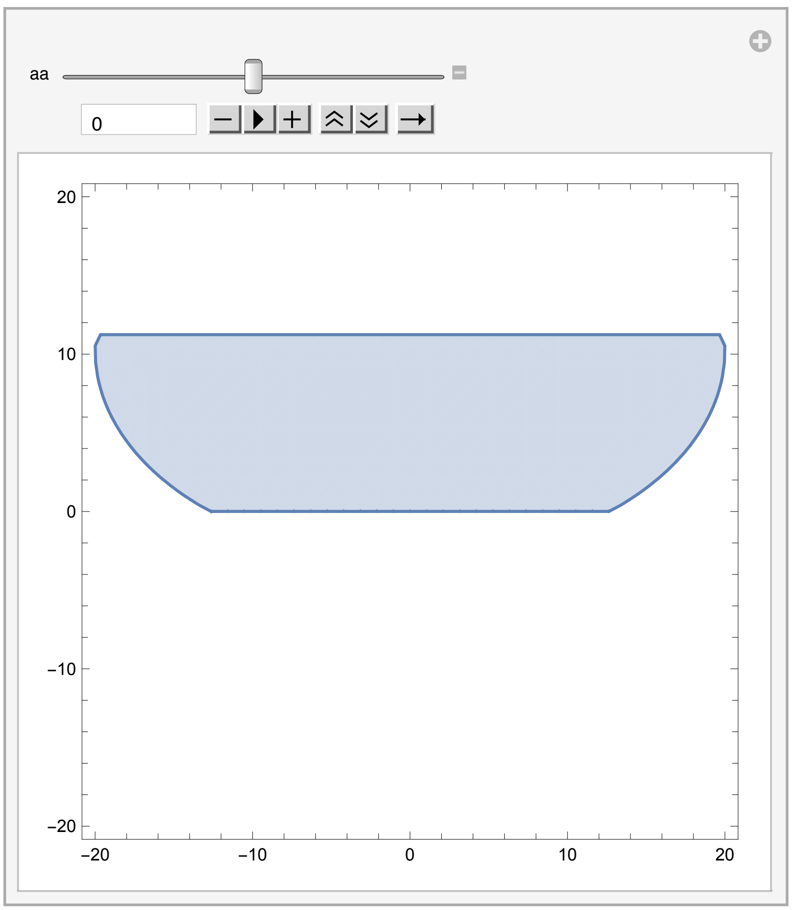


In[11]:=
```
Volume[boat]
```

Out[11]= 6500.52

In[1]:=
```
Manipulate[RegionPlot[
  (aa)^2/(11.25)^2 + (y - 10.24)^2/(13.24)^2 + (z)^2/(20)^2 < 1 && 0 < y < 11.24,
  {z, -20, 20}, {y, -20, 20}], {aa, -19.8, 19.8}]
```

Out[1]=



- Code for calculating moment of arbitrary ImplicitRegion boat at a heel angle

In[∘]:=
```
UnitConvert[Quantity[9.8, "Meters"/"Seconds"^2], "Centimeters"/"Seconds"^2]
```

Out[∘]= 980. cm/s^2

In[14]:=
```
boatmass[boatregion_, density_] :=
 mass = N[(Volume[boatregion] * density) + 700., 5]
boatcom[boatregion_, density_] :=
 com = N[1/boatmass[DiscretizeRegion[boatregion], density] *
    NIntegrate[density * {x, y, z}, {x, y, z} ∈ DiscretizeRegion[boatregion]], 5]
moment[hullshape_, mass_, com_, density_, theta_] := Module[{},
  rads = theta * (Pi / 180);
  water = ImplicitRegion[If[rads < Pi / 2, y < Tan[rads ] * x + d, y > Tan[rads ] * x + d],
    { {x, -20, 20}, {y, -20, 20}, {z, -25, 25}}];
  under = RegionIntersection[hullshape, water];
  disp = Integrate[1, {x, y, z} ∈ under];
  draft = N[d /. FindRoot[disp == mass, {d, -20, 20}][[1]]];
  cob = RegionCentroid[under /. {d → draft}];
  (* consider the mast as part of the equation*)
  com[[2]] = ((mass * com[[2]]) + (100 * 25))/(mass + 100);
  (*Should the gravity here be 980 cm/s^2?*)
  buoyancy = mass * 980 * {-Sin[rads], Cos[rads], 0};
  torque = Cross[cob - com, buoyancy][[3]];
  torque
 ]
momentrender[hullshape_, mass_, com_, density_, theta_] := Module[{},
  rads = theta * (Pi / 180);
  (*TODO: add var for the draft offset due to moving the origin*)
  water = ImplicitRegion[If[rads < Pi / 2, y < Tan[rads ] * x + 15.24 + d,
     y > Tan[rads ] * x + d], { {x, -20, 20}, {y, -20, 20}, {z, -25, 25}}];
  under = RegionIntersection[hullshape, water];
  (* we should define units globally or something,
  I forgot to change the density of water here earlier*)
  disp = Integrate[1, {x, y, z} ∈ under];
  draft = N[d /. FindRoot[disp == mass, {d, -20, 20}][[1]]];
  cob = RegionCentroid[under /. {d → draft}];
  com[[2]] = ((mass * com[[2]]) + (100 * 25))/(mass + 100);
  buoyancy = (mass + 100) * 980 * {-Sin[rads], Cos[rads], 0};
  torque = Cross[cob - com, buoyancy][[3]];
  Print[StringForm["draft (cm): `` then ``", N[draft, 1]]];
  Print[StringForm["Mass (g): ``", N[mass + 100, 1]]];
  Print[StringForm["cob (cm): ``", N[cob, 1]]];
```

```
    Print[StringForm["com (cm): ``", N[com, 1]]];
    Print[StringForm["Buoyancy Force (g/cm/s^2): ``", N[buoyancy, 1]]];
    Print[StringForm["Gravitational Force (g/cm/s^2): ``", N[mass * 980, 1]]];
    Print[StringForm["Net Torque (g/cm^2/s^2): ``", N[(mass + 100) * 980, 1]]];
    Print[Rotate[Show[
       RegionPlot3D[boat, PlotTheme → "Web", AxesLabel → {"x", "y", "z"},
        PlotPoints → 55, PlotStyle → Directive[Yellow, Opacity[0.2]]],
       RegionPlot3D[water /. {d → draft}, PlotTheme → "Web", AxesLabel → {"x",
          "y", "z"}, PlotPoints → 55, PlotStyle → Directive[Blue, Opacity[0.3]]],
       RegionPlot3D[under /. {d → draft}, PlotTheme → "Web", AxesLabel →
         {"x", "y", "z"}, PlotPoints → 55, PlotStyle → Directive[Blue, Opacity[0.2]]],
       RegionPlot3D[mast, PlotTheme → "Web", AxesLabel → {"x(cm)", "y(cm)", "z(cm)"},
        PlotPoints → 55, PlotStyle → Directive[Yellow, Opacity[0.2]]],
       ListPointPlot3D[{com}, PlotStyle → Directive[Cyan, Opacity[1]]],
       ListPointPlot3D[{cob}, PlotStyle → Directive[Red, Opacity[1]]],
       ListPointPlot3D[{{0, 25, 0}}, PlotStyle → Directive[Red, Opacity[1]]]
      ], rads]]
   ]

In[8]:= findAVS[boat_, density_] := (
     a = {};
     b = {1, 21, 41, 61, 81, 101, 121, 141, 161};
     For[i = 1, i < 180, i += 20, Print[i];
      a = Append[a, Quiet[moment[boat, boatmass[boat, N[density, 1]],
          boatcom[boat, N[density, 1]], N[density, 1], N[i, 1]]]]];
     data = Transpose@{b, a};
     boatfunction = Interpolation[data];
     Values@FindRoot[boatfunction[x] == 0, {x, 100}]) [[1]]
   plotAVS[boat_, density_] := (
     a = {};
     b = {1, 21, 41, 61, 81, 101, 121, 141, 161};
     For[i = 1, i < 180, i += 20, Print[i];
      a = Append[a, Quiet[moment[boat, boatmass[boat, N[density, 1]],
          boatcom[boat, N[density, 1]], N[density, 1], N[i, 1]]]]];
     data = Transpose@{b, a};
     boatfunction = Interpolation[data];
     Print[Show[
       ListPlot[data], Plot[boatfunction[x], {x, 0, 180}]]];
     Values@FindRoot[boatfunction[x] == 0, {x, 100}]) [[1]]
```

In[∘]:=
```
boatmass[boat, N[0.01]]
boatcom[boat, N[0.01]]
```

Out[∘]= 1047.59

Out[∘]= $\{3.58863 \times 10^{-6}, 0.269909, -8.42422 \times 10^{-6}\}$

In[10]:=
```
avsangle = plotAVS[boat, 0.01]
```

1

21

41

61

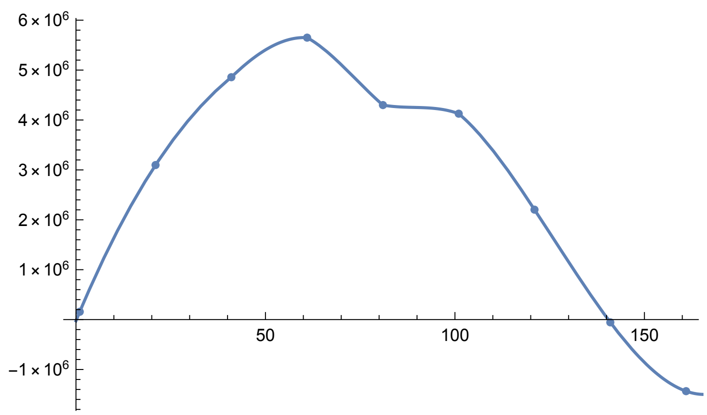
81

101

121

141

161



Out[10]= 140.455

In[22]:=
```
momentrender[boat, boatmass[boat, N[0.1, 1]],
  boatcom[boat, N[0.1, 1]], N[0.1, 1], N[45, 1]]
```

draft (cm): -14.3988 then ``

Mass (g): 1450.0515422758158`

cob (cm): $\{5.9668, 4.16628, -6.5953\times10^{-17}\}$

com (cm): {0.0000751428, 3.03057, -0.000198175}

Buoyancy Force (g/cm/s^2): $\{-1.00483\times10^{6}, 1.00483\times10^{6}, 0.\}$

Gravitational Force (g/cm/s^2): 1.3230505114302994`*^6

Net Torque (g/cm^2/s^2): 1.4210505114302994`*^6