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.

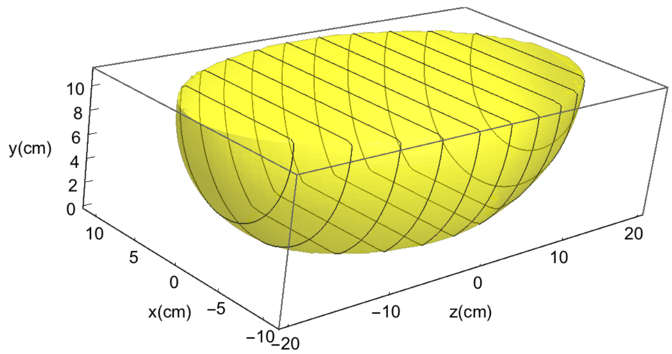
Code

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}]
```

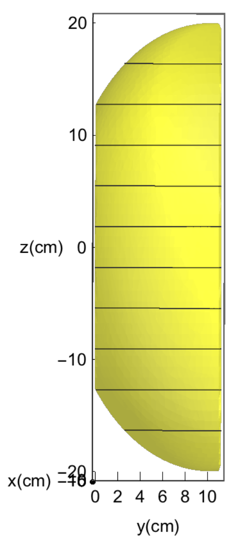
Out[3]= ImplicitRegion$\left[x^2 + (-0.9525 + z)^2 \le 0.907256 \,\&\&\, y \ge 0 \,\&\&\, y \le 50,\ \{x, y, z\}\right]$

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

Out[∘]=

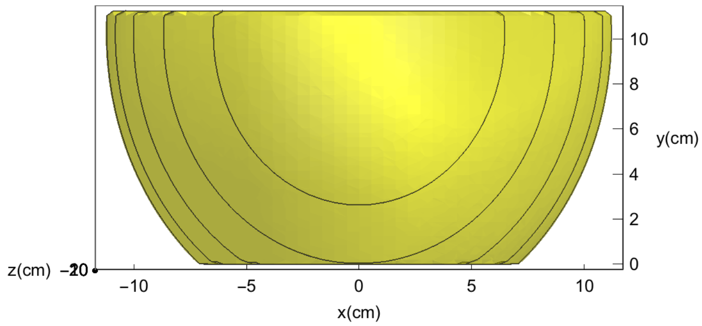


In[∘]:=
```
Show[%42, ViewPoint → {∞, 0, 0}]
```



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

Out[∘]=

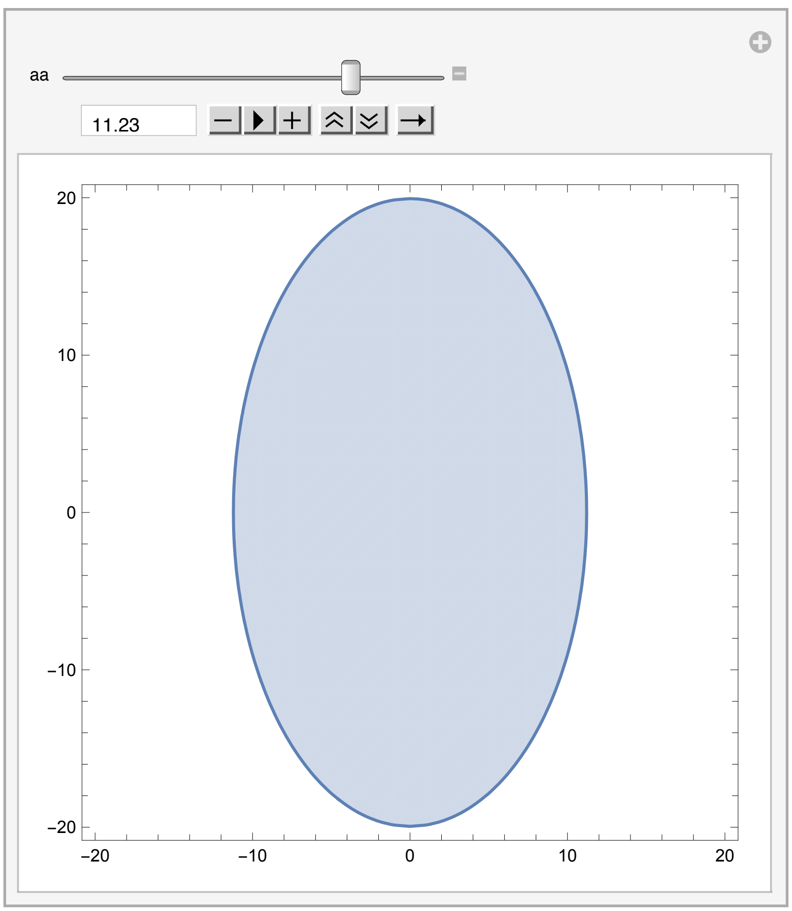



```
In[11]:= Volume[boat]

Out[11]= 6500.52
```

```
In[26]:= Manipulate[RegionPlot[
    (x) ^2 / (11.25) ^2 + (aa - 10.24) ^2 / (13.24) ^2 + (z) ^2 / (20) ^2 < 1 && 0 < aa < 11.24,
    {x, -20, 20}, {z, -20, 20}], {aa, -19.8, 19.8}]
```

Out[26]=



- 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[94]:=
```
boatmass[boatregion_, density_] :=
  mass = N[(Volume[boatregion] * density) + 834.61, 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[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]]]
   ]]
 ]
```

```
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[84]:=
```
boatmass[boat, N[0.0251]]
Volume[boat]
boatcom[boat, N[0.0251]]
```

Out[84]= 863.163

Out[85]= 6500.52

Out[86]= {0.0000294853, 1.18917, -0.000077762}

In[93]:=
```
avsangle = plotAVS[boat, 0.0251]
```

1

21

41

61

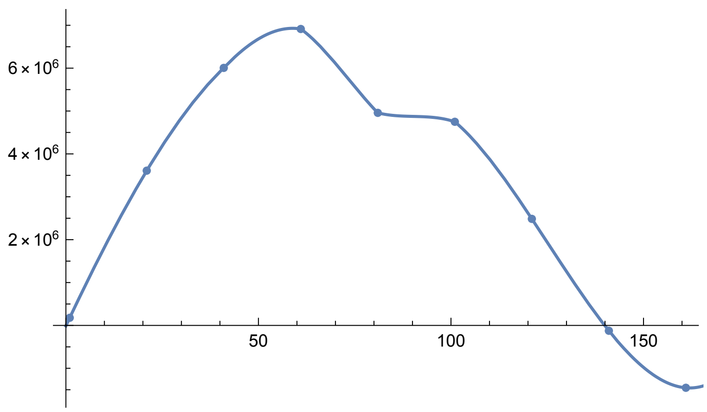
81

101

121

141

161



Out[93]= 139.904

In[99]:=
```
momentrender[boat, boatmass[boat, N[0.0251, 1]],
 boatcom[boat, N[0.0251, 1]], N[0.0251, 1], N[45, 1]]
```

draft (cm): -15.5205 then ``

Mass (g): 1097.7729371112298`

cob (cm): $\{6.33877, 3.79964, -3.05937 \times 10^{-16}\}$

com (cm): {0.0000255063, 1.02869, -0.0000672682}

Buoyancy Force (g/cm/s^2): {-760718., 760718., 0.}

Gravitational Force (g/cm/s^2): 977817.4783690051`

Net Torque (g/cm^2/s^2): 1.0758174783690053`*^6