

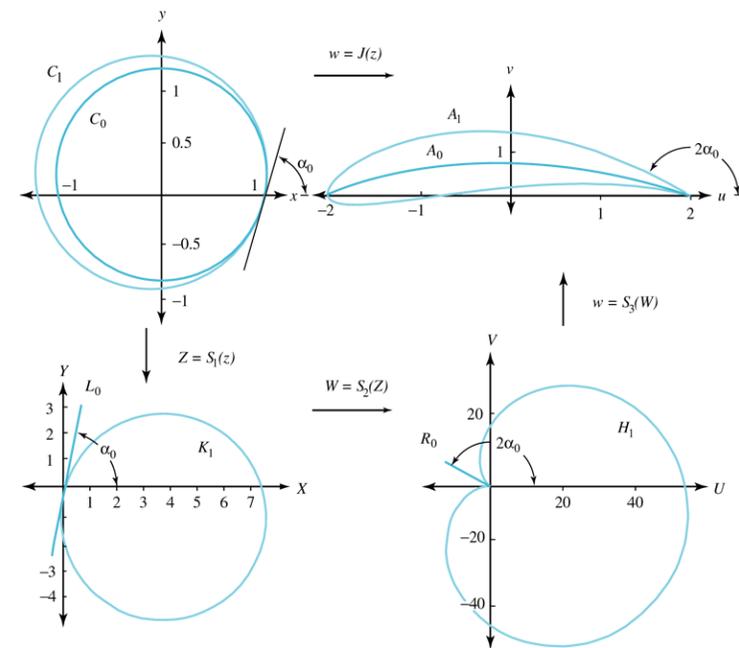


# **GEOMETRIE**

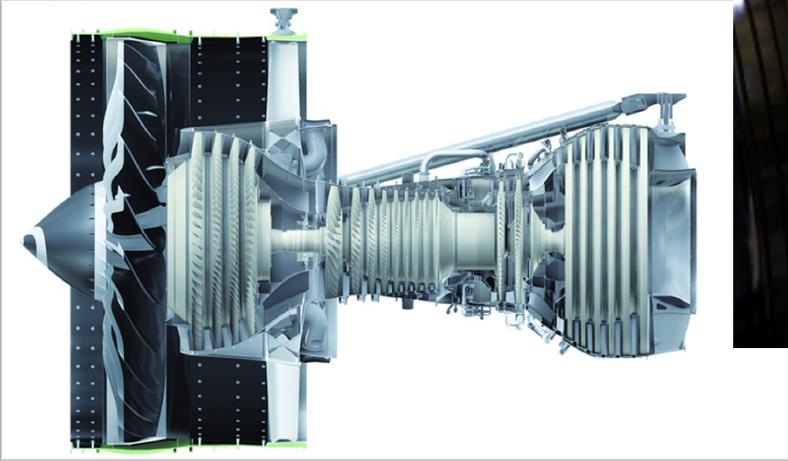
Simulation von Strömungen

# AUFGABEN UND ZIELE

- Wie stelle ich Strömungen dar?
- Welche Elementarströmungen gibt es?
- Wie erhalte ich ein Airfoil Profil?
- Joukowski Transformation



# AIRFOIL



### CONVENTIONAL AIRFOILS

The following illustrations depict a selection of designs of airfoil sections. These are known as conventional airfoils.



Low camber — low drag — high speed — thin wing section  
Suitable for race planes, fighters, interceptors, etc.



Deep camber — high lift — low speed — thick wing section  
Suitable for transports, freighters, bombers, etc.



Deep camber — high lift — low speed — thin wing section  
Suitable as above.



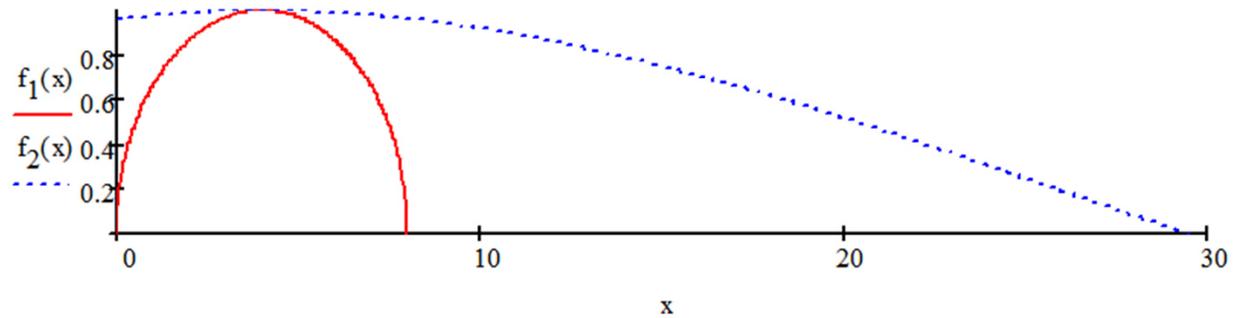
Low lift — high drag — reflex trailing edge wing section.  
Very little movement of centre of pressure. Good stability.



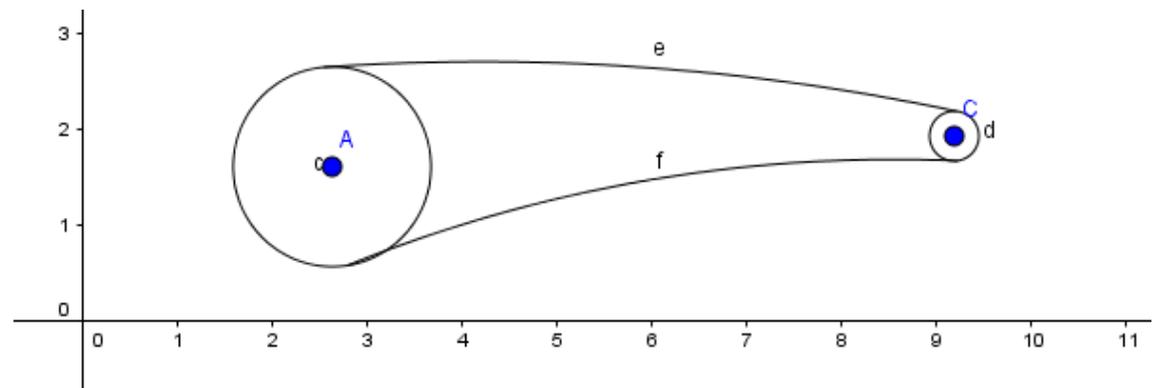
Symmetrical (cambered top and bottom) wing sections.  
Similar to above.



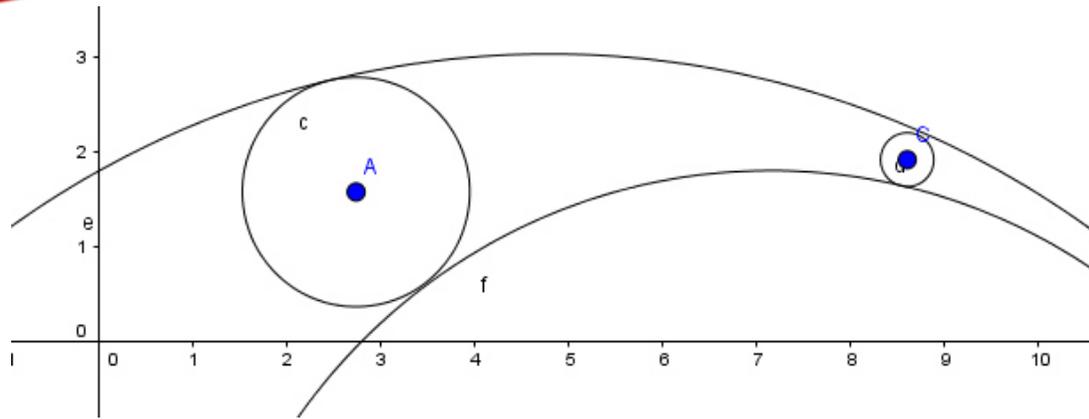
GA(W)-1 airfoil — thicker for better structure and lower weight  
— good stall characteristics — camber is maintained farther rearward which increases lifting capability over more of the airfoil and decreases drag



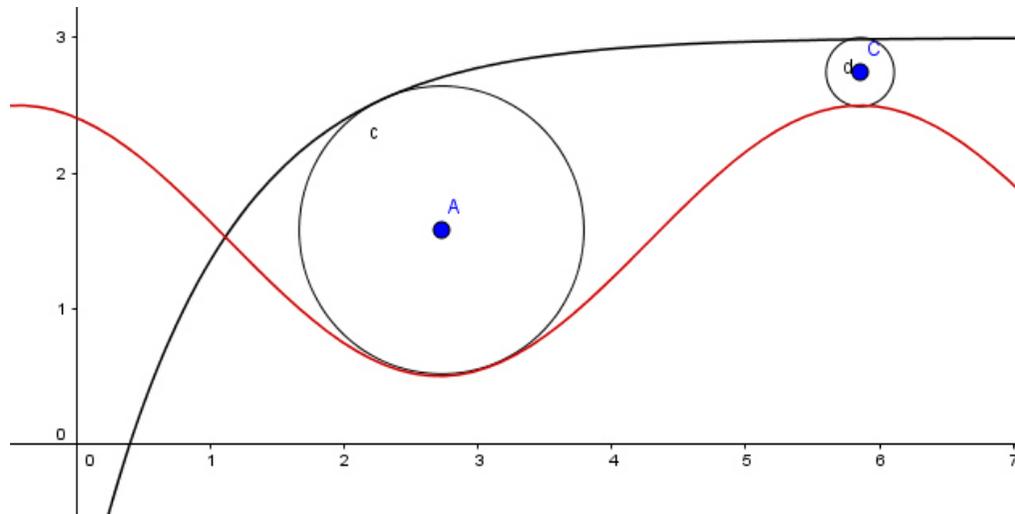
Ellipse + Polynomfunktion (Grad 2)



Kreise & Polynominterpolation  
(Grad 2 & 4)



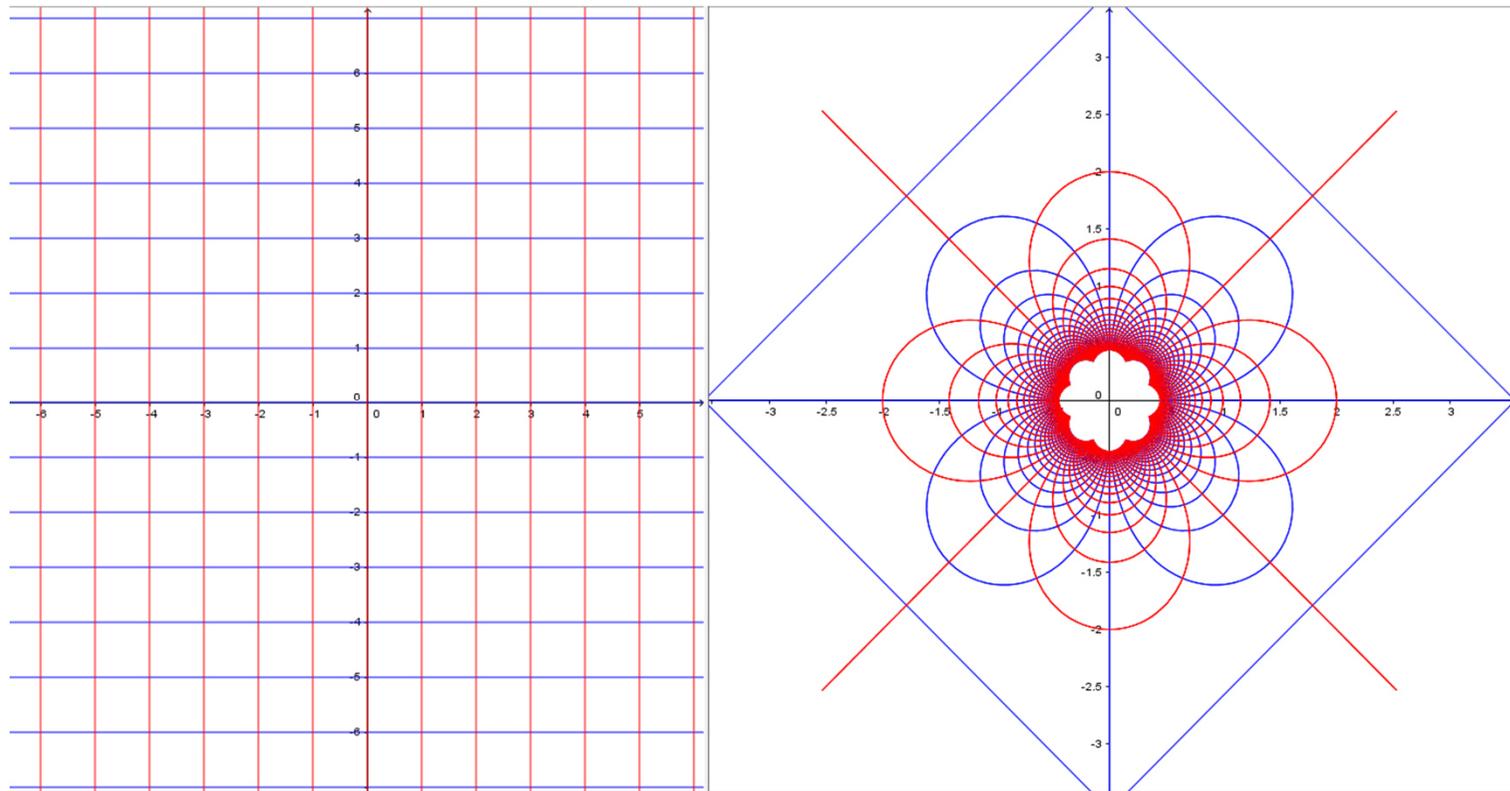
Zusammensetzen von  
 Kreisen bzw. Kreisbögen



Kreise + Log-Funktion  
 + Sinus-Funktion

# FUNKTIONEN MIT KOMPLEXEN ZAHLEN

$$F(c) = \sqrt{\frac{2}{c}}$$



# JOUKOWSKY TRANSFORMATION EINES KREISES

- Funktion zum Umwandeln von Kreis zu Airfoilprofil

- Joukowski Transformation:

$$f(z) := z + \frac{1}{z}$$

$$f(z) := x + \frac{x}{x^2 + y^2} + i \cdot \left( y - \frac{y}{x^2 + y^2} \right)$$

- In Polarkoordinaten:

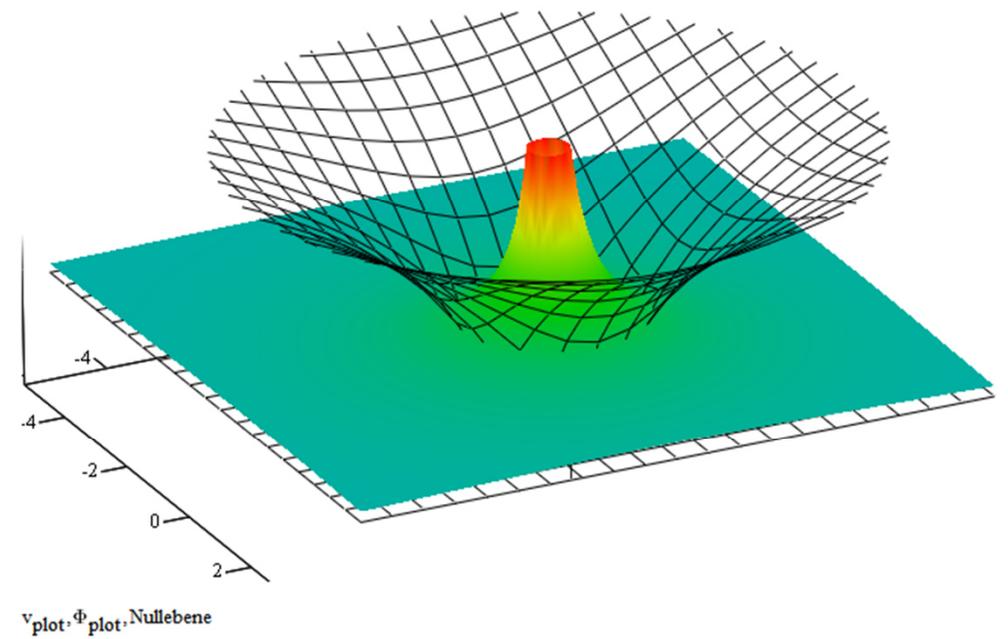
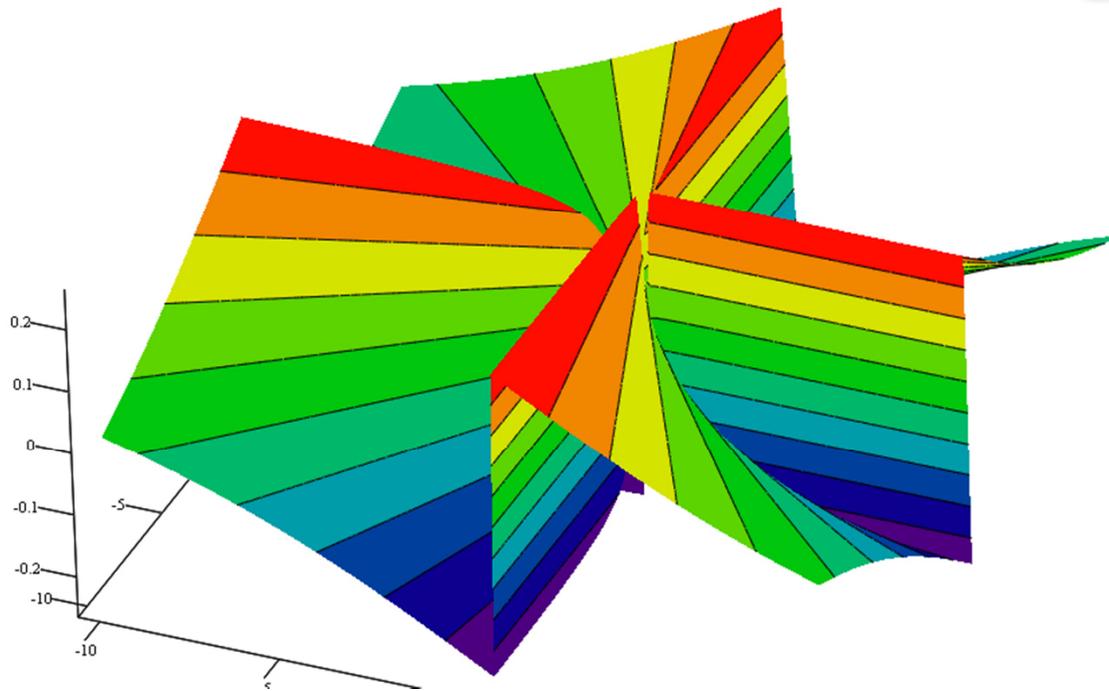
$$f(z) := r \cdot \cos(\phi) + \frac{r \cdot \cos(\phi)}{(r \cdot \cos(\phi))^2 + (r \cdot \sin(\phi))^2} + i \cdot \left( r \cdot \sin(\phi) - \frac{r \cdot \sin(\phi)}{(r \cdot \cos(\phi))^2 + (r \cdot \sin(\phi))^2} \right)$$

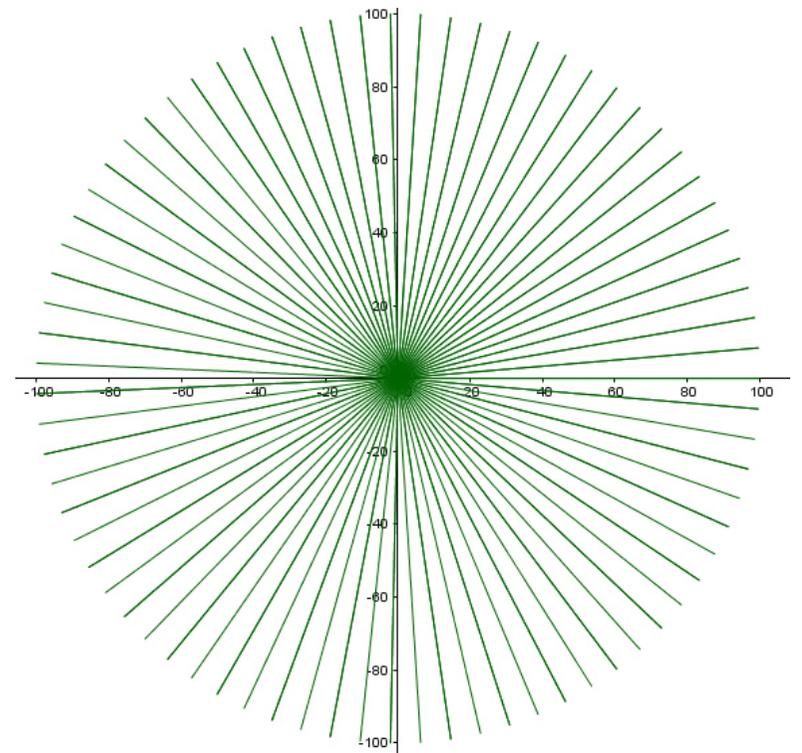
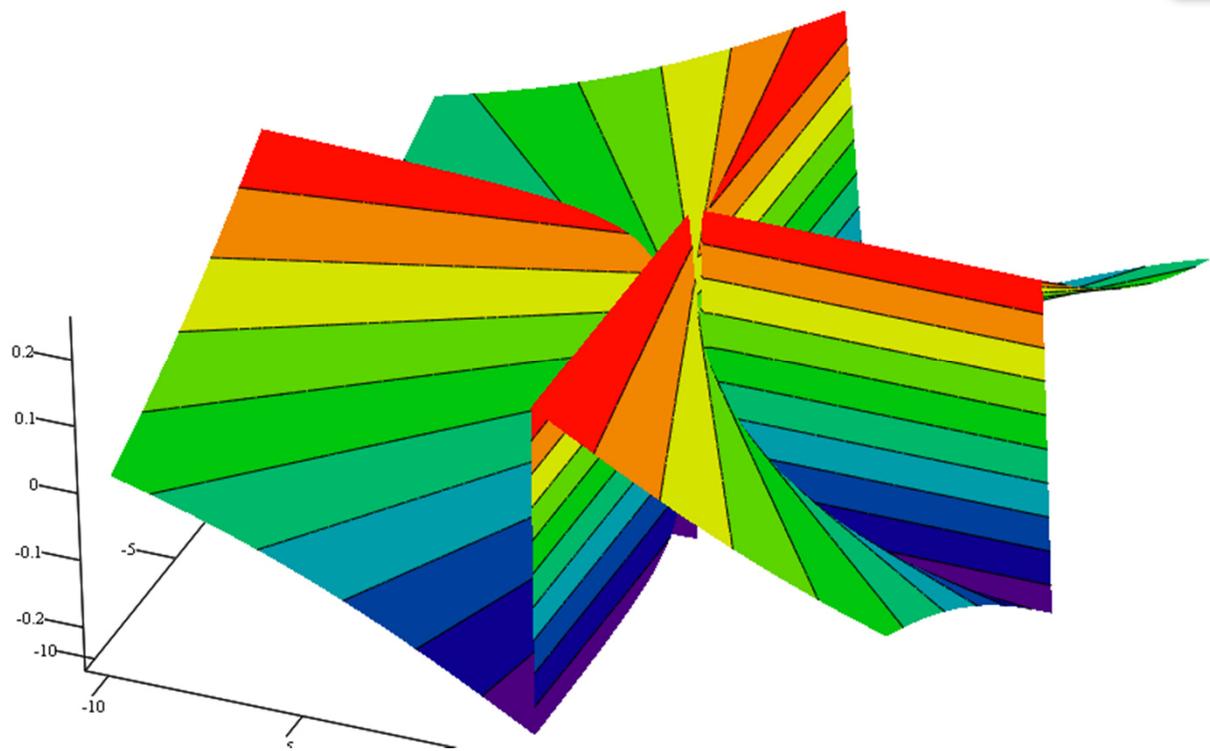
- Geogebra:

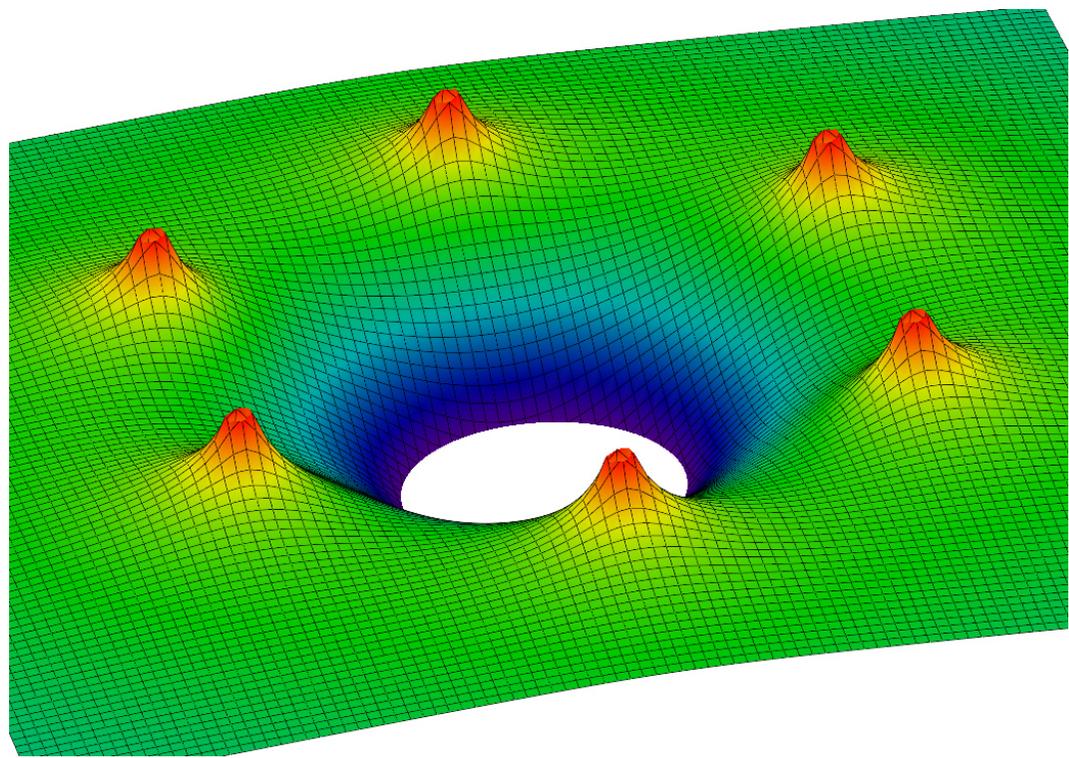
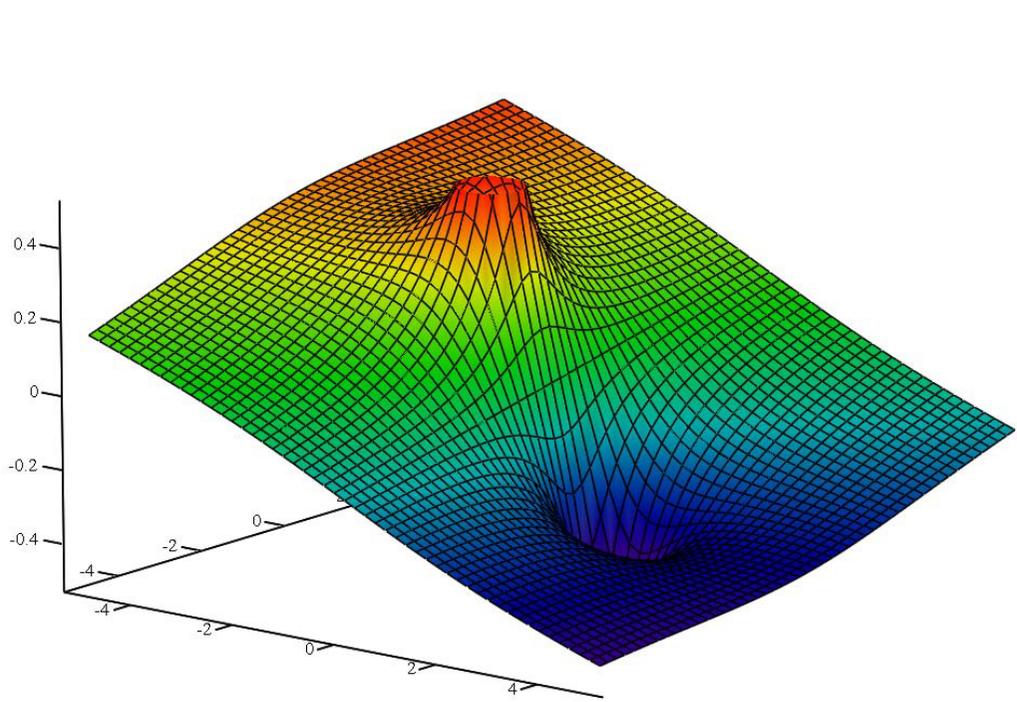
- X-Achse: Realteil
- Y-Achse: Imaginärteil

- Airfoil als Ergebnis

# ELEMENTARSTRÖMUNGEN







# SIMULATION VON STRÖMUNGEN AM AIRFOIL

- Geogebra → nicht möglich
- Komplexere Programme → z. B. Wolfram Mathematica

```
In[23]= Solve[w == z + 1/z, z]
```

```
Out[23]= {{z -> 1/2 (w - Sqrt[-4 + w^2]), {z -> 1/2 (w + Sqrt[-4 + w^2])}}
```

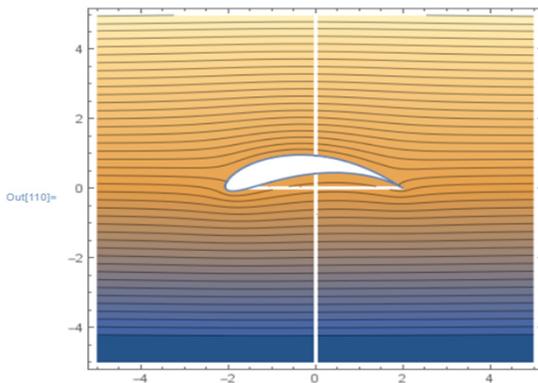
```
In[104]= z1[a_, b_] := 1/2 * (a + I * b - Sqrt[(a + I * b)^2 - 4]);  
z2[a_, b_] := 1/2 * (a + I * b + Sqrt[(a + I * b)^2 - 4]);  
mp = -0.14 + 0.38 * I; R = 1.2; Uinf = 1.1;
```

```
In[107]= p1 = ContourPlot[Uinf * (Im[z1[a, b]] - Im[mp]) * (1 - R^2 / ((Re[z1[a, b]] - Re[mp])^2 + (Im[z1[a, b]] - Im[mp])^2)), {a, -5, 5}, {b, -5, 5}, Contours -> Table[c, {c, -5, 5, 0.25}],  
RegionFunction -> Function[{a, b, f}, Abs[z1[a, b] - mp] >= R];
```

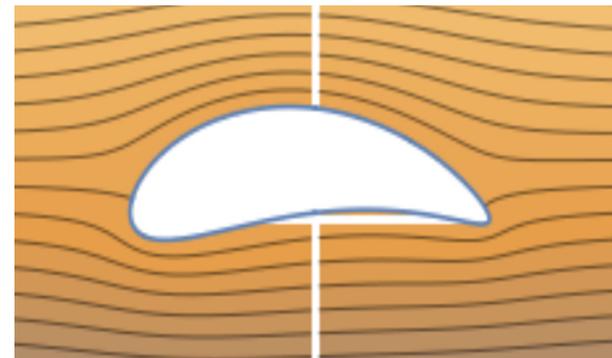
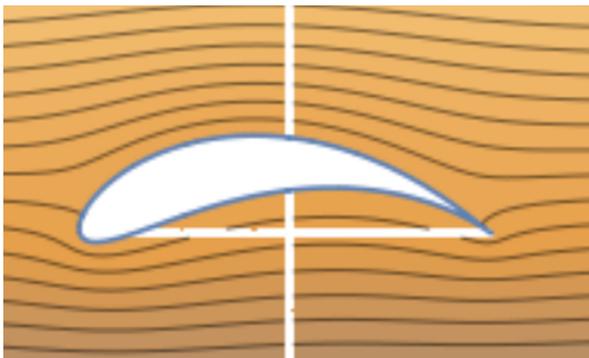
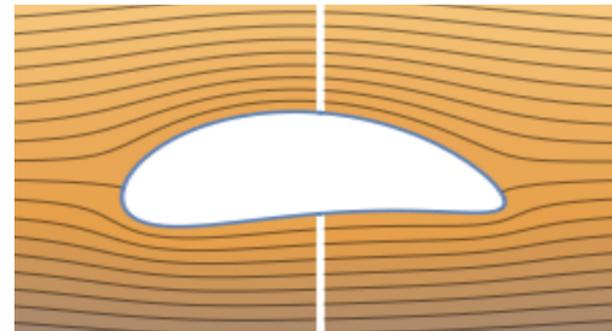
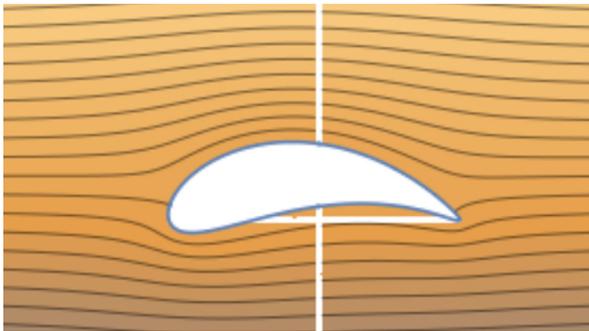
```
In[108]= p2 = ContourPlot[Uinf * (Im[z2[a, b]] - Im[mp]) * (1 - R^2 / ((Re[z2[a, b]] - Re[mp])^2 + (Im[z2[a, b]] - Im[mp])^2)), {a, -5, 5}, {b, -5, 5}, Contours -> Table[c, {c, -5, 5, 0.25}],  
RegionFunction -> Function[{a, b, f}, Abs[z2[a, b] - mp] >= R];
```

```
In[109]= J = ParametricPlot[{Re[R * Exp[I * phi] + mp + 1 / (R * Exp[I * phi] + mp)], Im[R * Exp[I * phi] + mp + 1 / (R * Exp[I * phi] + mp)]}, {phi, -Pi, Pi};
```

```
In[110]= Show[p1, p2, J]
```

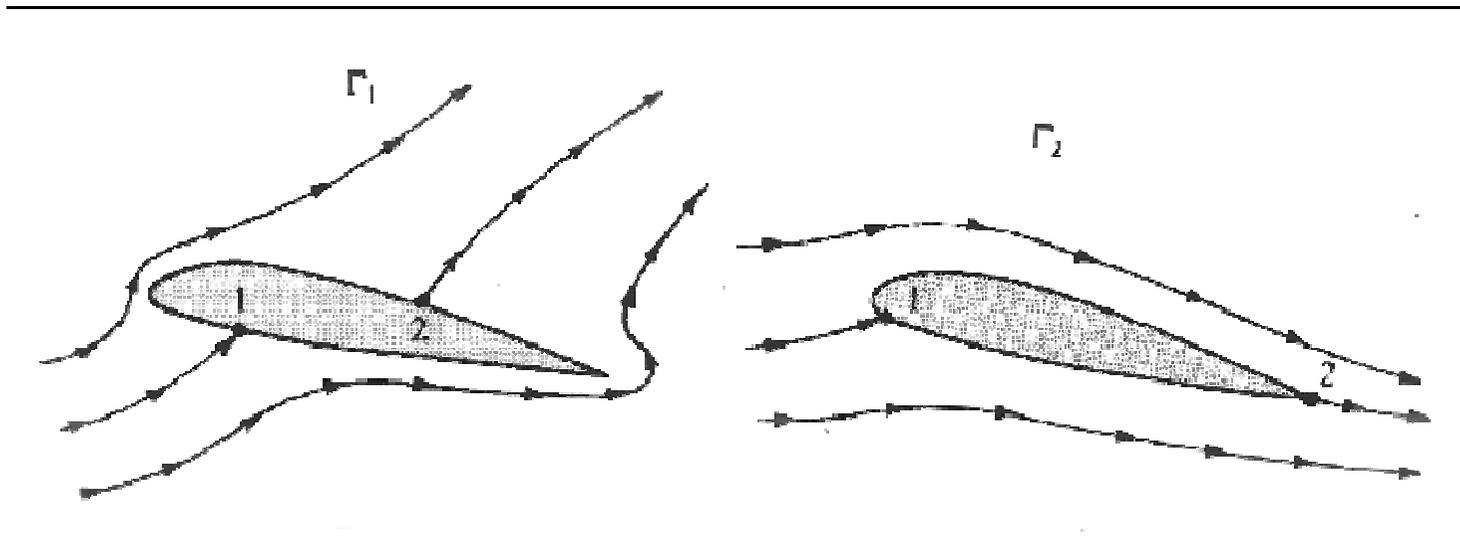


# STRÖMUNGEN DURCH VERSCHIEDENE AIRFOILS



# BETRACHTUNG VON GENAUEREN MODELLEN

- Kutta Bedingung:
  - Airfoil + Wirbelströmung





**Danke!**

FÜR DIESE TOLLE WOCHE!