

# MAE 4230-5230

## Lecture 1 - Notes

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Monday, January 24th, 2011

Presented by: Prof. Jane Wang

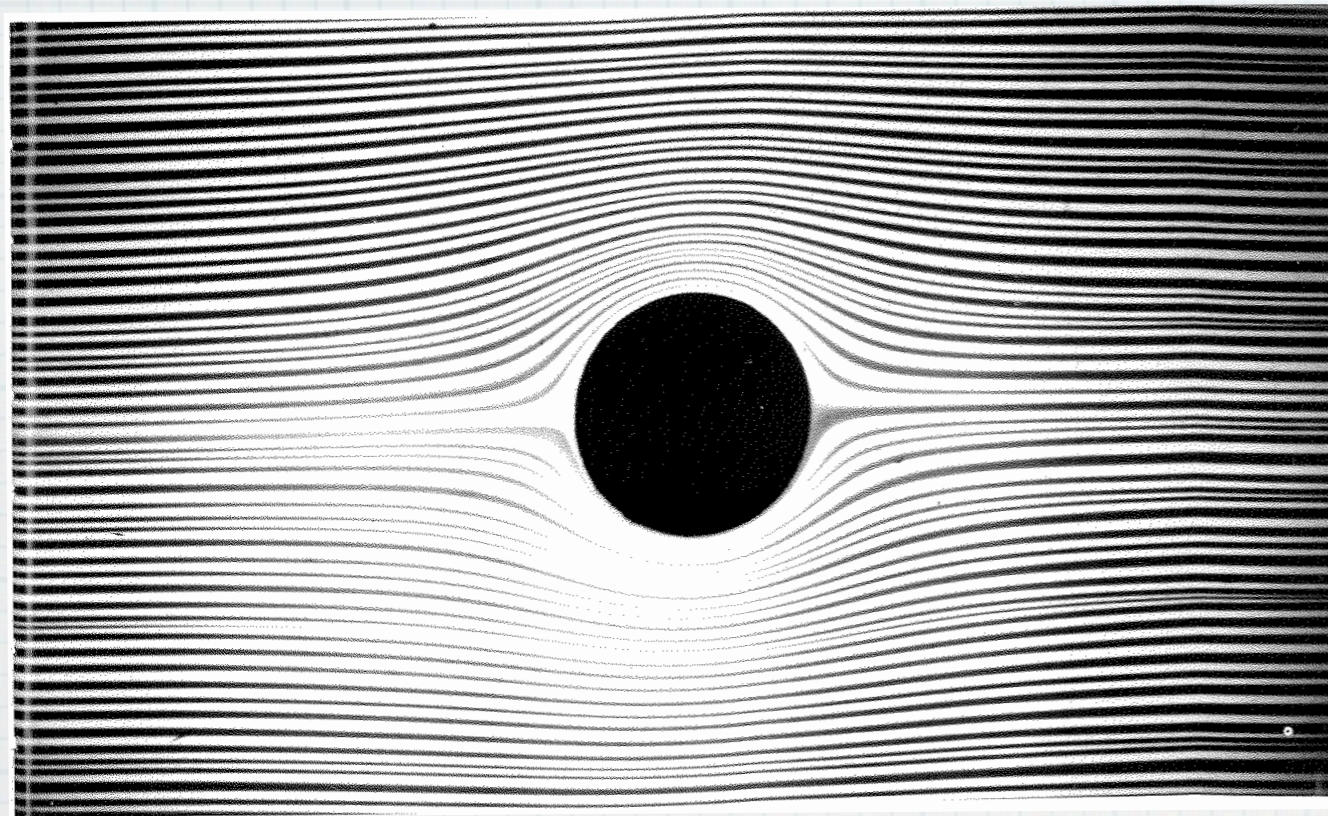
Compiled by: Acmae El Yacoubi

Cornell University, Spring 2011



# Flow patterns

## Flow past a cylinder: potential flow limit

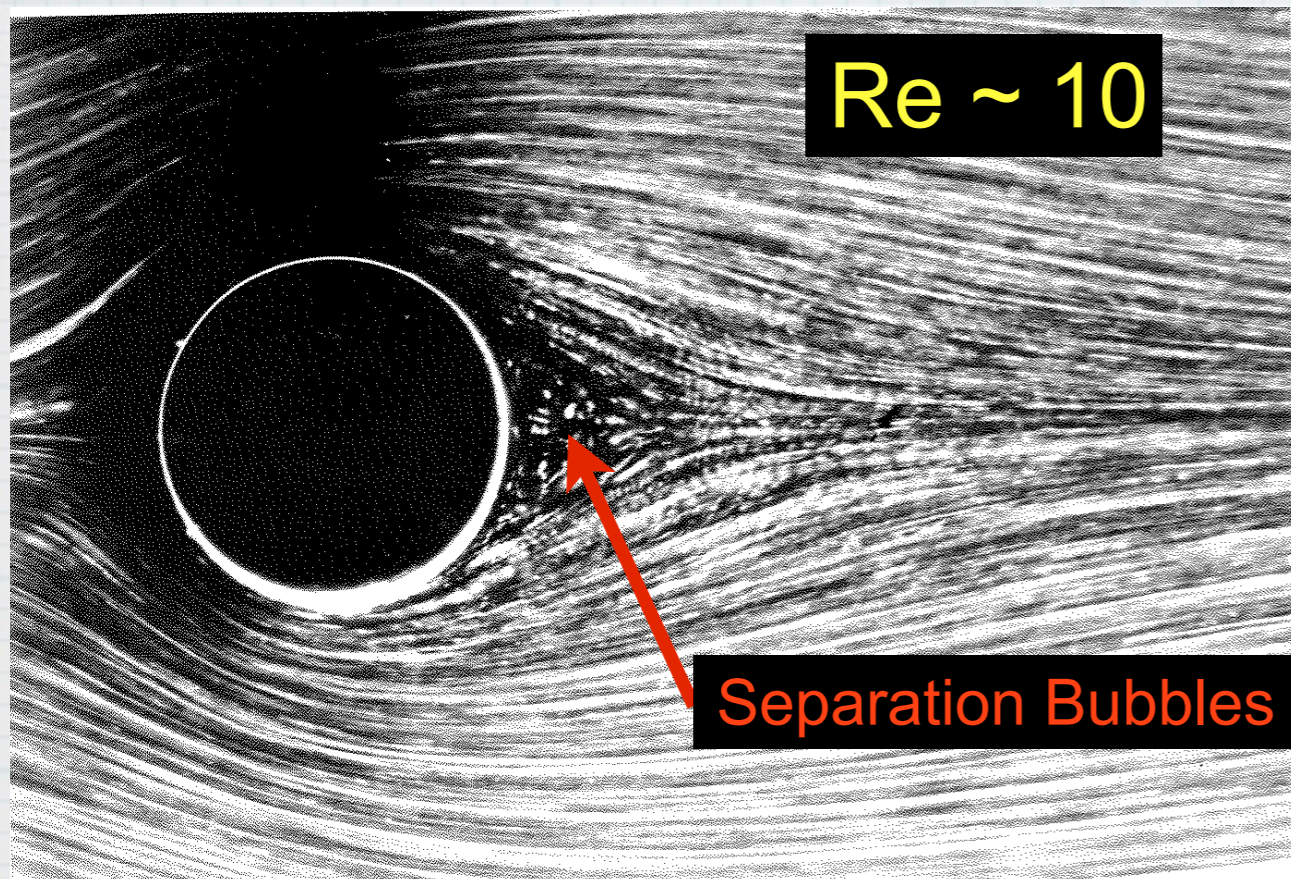


- \* left-right and top-bottom symmetries of the flow
- \* difficult to determine flow direction
- \* upstream and downstream streamlines are parallel: uniform flow
- \* flow is warped close to the object
- \* potential flow: no vorticity (irrotational), seemingly no boundary layer (inviscid), and flow is independent of time.



# Flow patterns

## Flow past a cylinder: flow separation

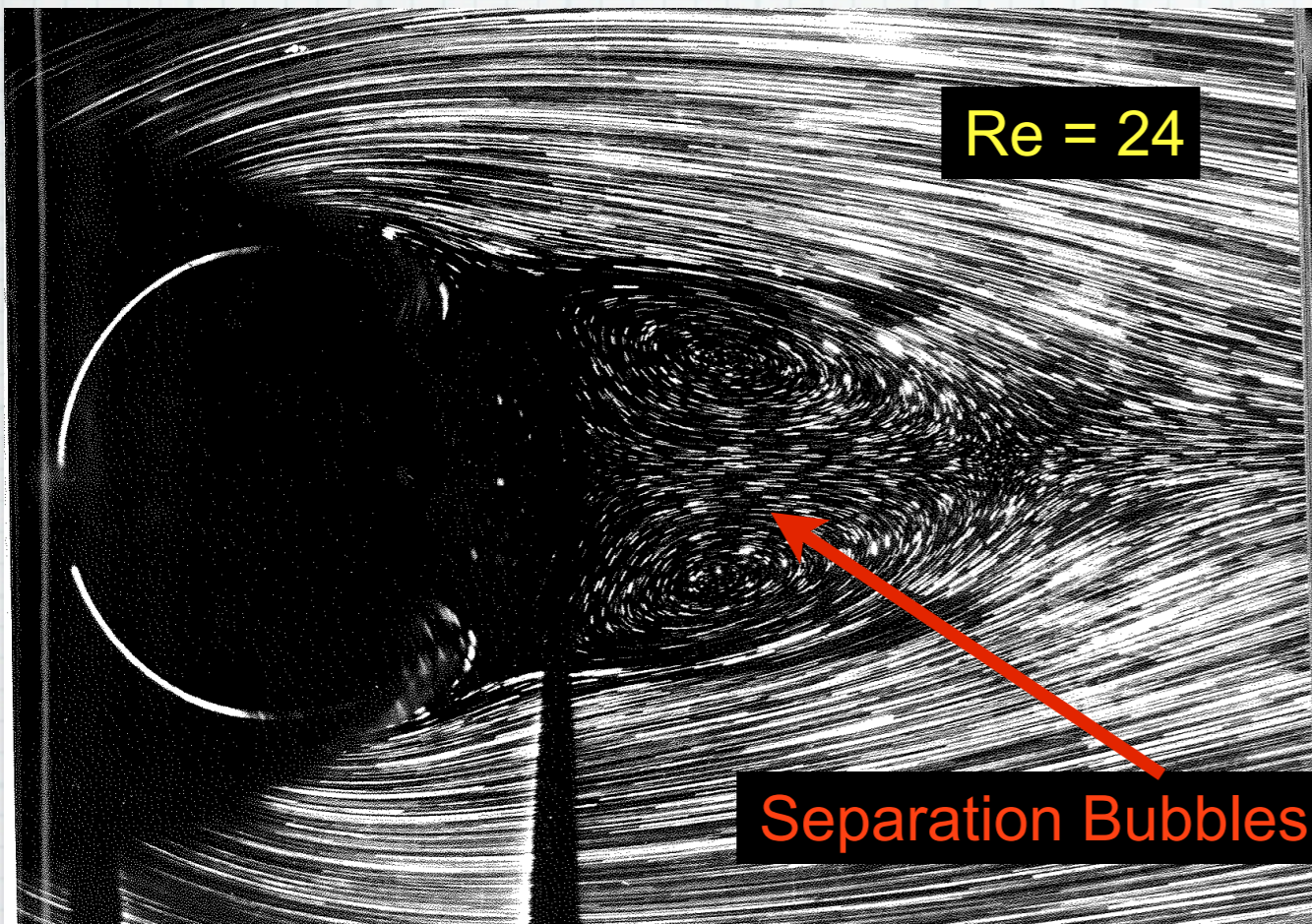


- \* top and bottom symmetry only
- \* breaking of the left-right symmetry and appearance of counter-rotating vorticity bubbles at the back
- \* flow is from left to right: deviation of streamlines at the front (over-pressure) and suction of the flow at the back (under-pressure)
- \* flow is warped further upstream



# Flow patterns

## Flow past a cylinder as $Re$ increases

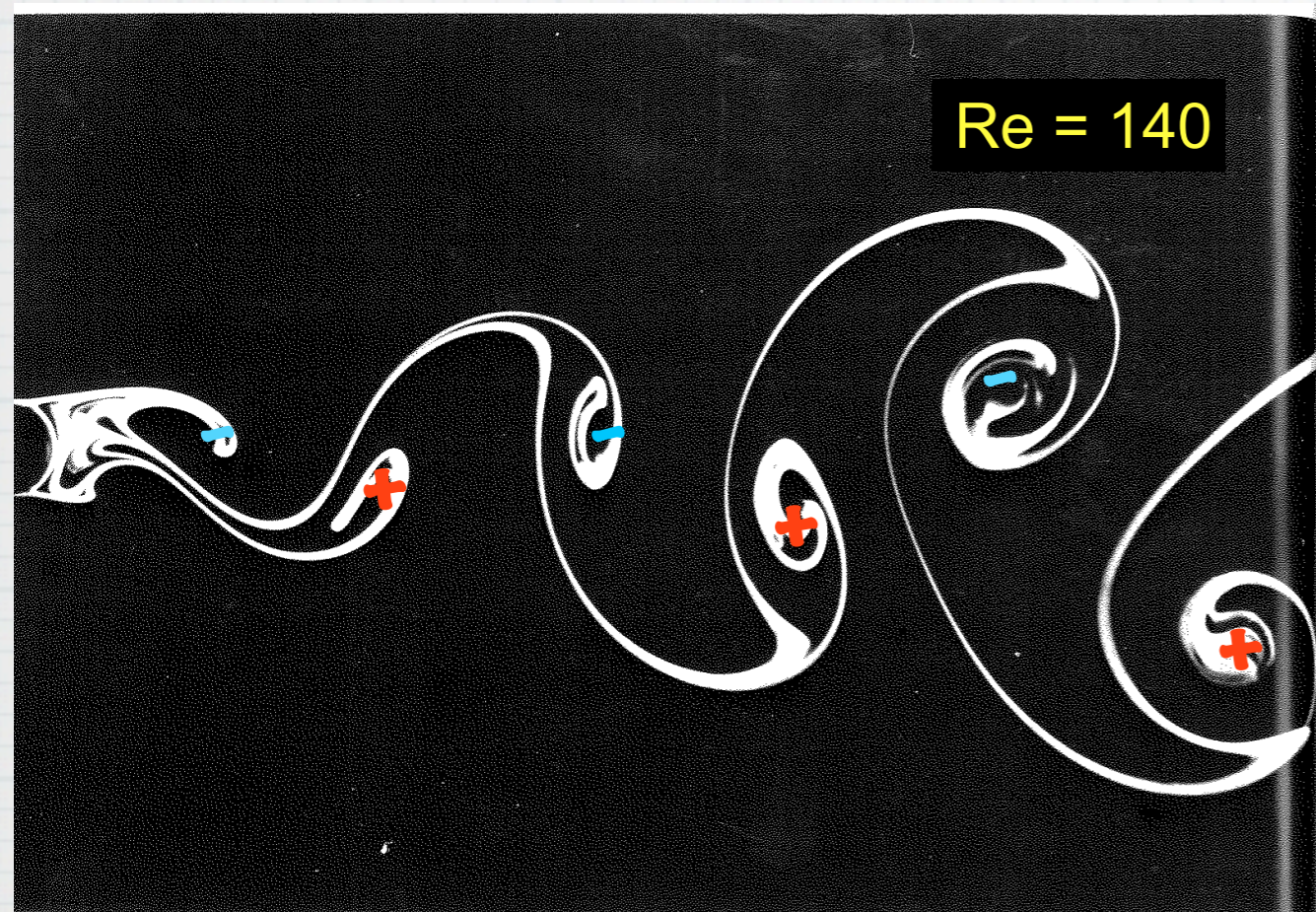


- \* same remarks as previous slide, with an increase in size and an elongation of vorticity bubbles
- \* flow remains steady
- \*  $Re < Re_{cr}$  : the bubbles are still attached to the body
- \* flow at the front: laminar
- \* flow at the back is separated into two regions: the separation bubbles and outside the bubbles (laminar)



# Flow patterns

## Flow past a cylinder: *von Karman* wake instability

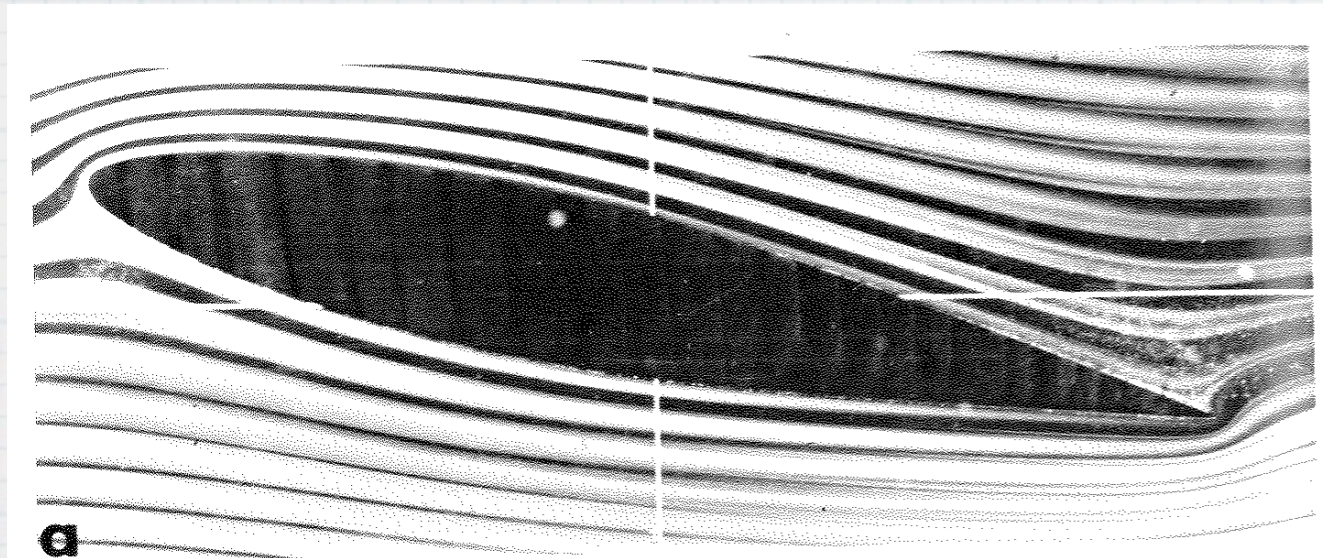


- \* all symmetries (up-down, left-right) are broken
- \* the flow is unsteady
- \*  $Re > Re_{cr}$  : *von Karman* street - shedding of counter-rotating vortices
- \* diffusion of vorticity can be noticed from the growth in the size of vortices as they drift downstream
- \* **positive** vorticity (ccw), **negative** vorticity (cw)



# Flow patterns

## Flow past an airfoil

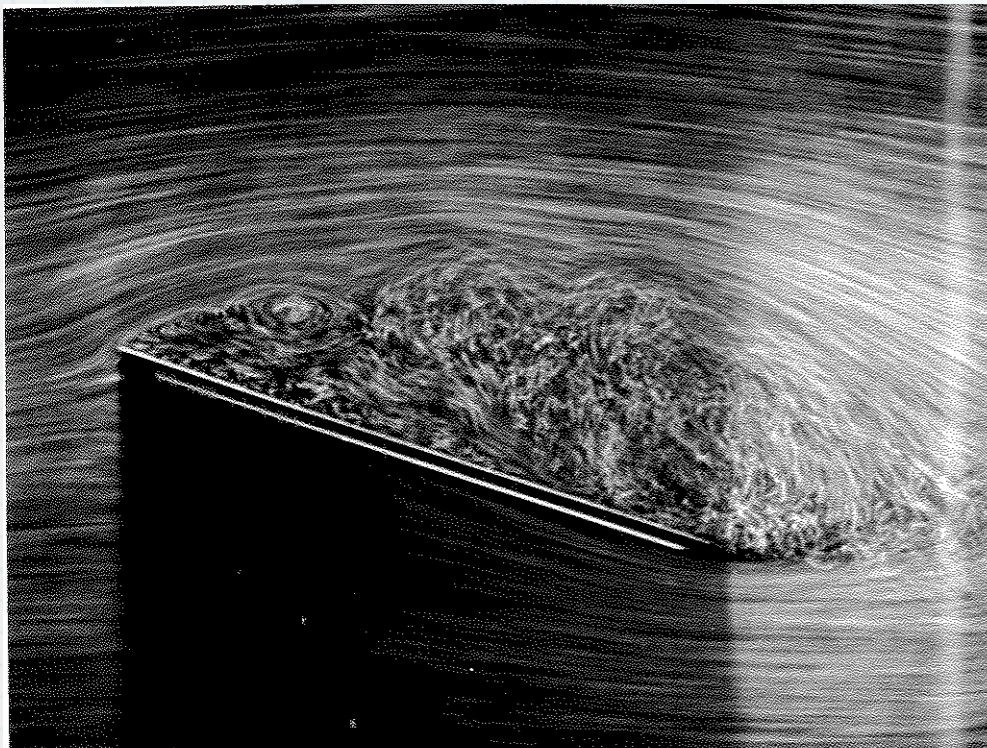


- \* airfoil inclined w.r.t incoming flow: non zero angle of attack
- \* front stagnation point shifts to the bottom side
- \* flow leaves the airfoil at the trailing edge (TE)
- \* onset of separation near (TE)

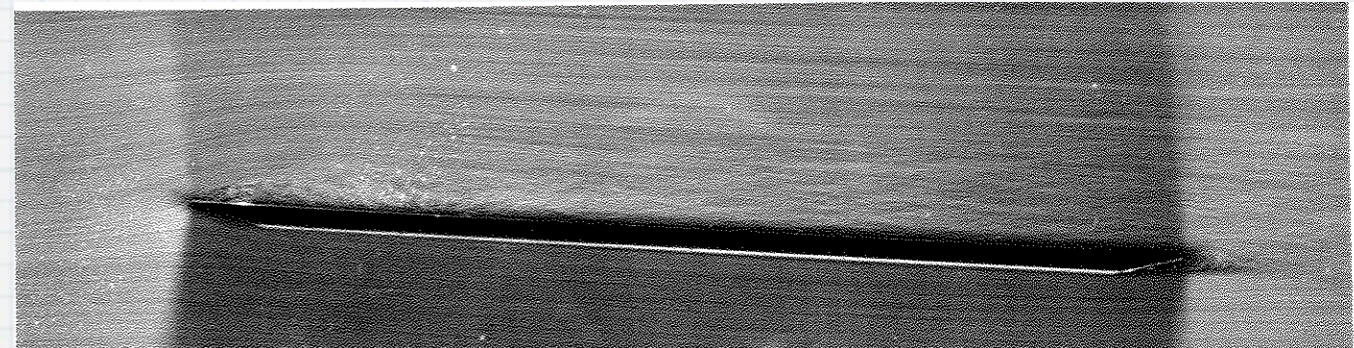


# Flow patterns

## Flow separation



- \* flow separation: appearance of region of turbulence
- \* high mixing and stirring of the flow
- \* appearance of large eddies and smaller structures within them



- \* attached (laminar) flow: flow is smooth, streamlines are parallel to the plate