Lecture # 1: Syllabus and Policies & Introductions of Similitude of Experiments

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Course Introduction

- ***Syllabus.***
- ***Course policy.***
- ***Lab attendance is mandatory. Unexcused absences from lab exercises will result in an "F" in the grade for the entire course!***
- ***AerE344 group assignment***
- ***AerE344 lab report***
  - ***Pre-lab report***
  - ***Formal lab report***

AerE344 Course Policy

- ***Lectures time:***

- *In-person class lectures will be given on Tuesdays only.*
- *The lecture time on Thursday mornings is reserved for each group to meet to prepare/write lab reports.*

- ***Office Hours:***

Tuesdays 3:10pm ~ 4:00 pm
Thursdays 3:10pm ~ 4:00 pm

- ***Grading Policies:***

The final grade of AerE344 will be calculated as:

- **Lab reports (including pre-lab work for 20%): 65%**
- **In-class quizzes: 10%**
- **Final exam: 25%**

- ***Final Exam of AerE344:***

- AerE344 final exam is scheduled ****.
- Please see following link for details: http://www.registrar.iastate.edu/students/exams/sp

About AerE344 Course Policy

- ***Attendance of AerE344 Lab Experiments are required!!***
  - *AerE344 lab experiments will involve in conducting lab experiments for data acquisition, processing measurement data, measurement uncertainty analysis, and lab report writing.*
  - *In-person attending the lab exercises is required for AerE344.*
  - *Unexcused absences of lab exercises will result in an "F" for the course!*

- ***How to get approval for excusable final exam & lab absences***
  - *Contact the course instructor as soon as possible when you know that you may have a possible lab absences.*
    - ***Lab absences due to COVID-19**: Follow ISU policy!*
    - *Providing a doctor's note to state explicitly about your sickness is an example to justify the excusable lab or exam absence.*
    - *You can also provide other reasonable evidence to justify your lab or exam absence.*
  - *You will need to do makeup lab experiments after you return to campus.*

About AerE344 Group Division

- ***5~6 students will be assigned to work together as a group.***
- ***Some commonly asked questions:***
  - *Can I change my group assignment in order to have my friends assigned to the same group?*
  - *When, where and how should our group meet?*
  - *How to distribute the working loads? Who should be in charge of the group work?*
  - *What should we do if one of the group members really does not contribute to the teamwork?*

About AerE344 Group Division

IOWA STATE UNIVERSITY
Department of Aerospace Engineering

LAB EXERCISE ATTENDANCE RECORD

Date: _______________

Lab Exercise Number: ________

Lead Operators:

________________________________ ________________________________
Print Name Signature

________________________________ ________________________________
Print Name Signature

Group Members Present:

________________________________ ________________________________

________________________________ ________________________________

________________________________ ________________________________

________________________________ ________________________________

________________________________ ________________________________
Print Name Signature

Pre-Lab Homework turned in? YES NO

AerE344: Group Work Participation Form

Lab section:___________________________

Lab group:____________________________

Lab #:________________________________

Lead Operator:_________________________

All group lab work and reports should be a collaborative effort from all members in each lab group. This form is used to indicate the participation or nonparticipation of all members of the group in the completion of the lab work and report writing. This form can be signed and handed with each group lab report.

	Group member	Satisfactory Participation? (Circle one)	Signature
#1		Yes / No	
#2		Yes / No	
#3		Yes / No	
#4		Yes / No	
#5		Yes / No	
#6		Yes / No	

Peer Review Form

Your name: ____

Write the name of each of your group members in a separate column. For each person, indicate the extent to which you agree with the statement on the left, using a scale of 1~4 (1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree). Total the numbers in each column.

Evaluation Criteria	**Group member:**	**Group member:**	**Group member:**	**Group member:**	**Group member:**	**Self-evaluation score**
Attends group meetings regularly and arrives on time.						
Contributes meaningfully to group discussions.						
Completes group assignments on time.						
Prepares work in a quality manner.						
Demonstrates a cooperative and supportive attitude.						
Contributes significantly to the success of the project.						
TOTALS						

About AerE344 Lab Report

- ***Prelab Assignment***
  - *Go over the prelab assignment carefully to understand the contents of the lab experiments.*
  - *Watch the videos of the pre-lab assignment*
  - *Prepare a 1-page pre-lab report, which is due by the time you come to the lab to do experiments.*

- ***Formal Lab report***
  - *Please follow the procedure to prepare a formal lab report for each group.*
  - *The lab report is due at 5:00pm on Fridays.*
  - *Unexcused late lab report submission will cause a score deduction of the lab report.*

About AerE344 Lab Report

Guidelines for Formal Lab Reports

(Used for AerE344 and AerE545)

The following is the format for a formal lab report. It is not significantly different than the format expected for an engineering journal publication.

ADVICE: Within many of the sections listed below, subheadings can be an effective means of organizing the report. Subheadings can help the reader follow your presentation more easily.

1. **Title Page:** List the course and course number, the lab experiment name, all group members' names, and the date.

2. **Abstract:** This should be a brief (<100 words) summary of the results of the work. The abstract should stand on its own. This means that it must not reference equations or figures in the main body of the report. A good way to write an abstract is to write it after the rest of the report is finished.

3. **List of symbols (nomenclature):** All English variables/symbols should be listed in alphabetical order followed by Greek symbols in alphabetical order.

4. **Introduction:** This section describes the relevance and importance of the work that was conducted. In this section, relevant journal or textbook publications should be cited. The general objectives of the project should be stated here.

5. **Methodology:** This section should briefly describe the methods used to conduct the experiments and reduce the data. Rather than describe every detail of each method (for example, a numerical integration scheme), it is sufficient to summarize the approach taken (for example, "integration was conducted using the trapezoidal rule"). Diagrams or bulleted lists are often good ways of showing the steps of a method. If computer programs are used, they should be mentioned in this section but listed in an appendix.

6. **Results:** In this section, the results of the experiments and data reduction are presented. Present data in the clearest form possible. Usually this means presenting data graphically. Do not present raw data in this section. Put raw data in appendices. Present only final results in this section.

7. **Discussion:** In this section, the results of the project are discussed in light of any relevant theory or published data. Each table or figure from the Results section should be discussed. State your opinions about the value and/or limitations of the results. Describe what you might do to improve the results in future work. Describe what you learned from the results.

8. **Conclusions:** This should be a brief summary of the major findings of the project. Do not discuss results here.

9. **References:** Provide complete citations for all references.

10. **Appendices:** This section should include sample calculations illustrating the methodology. This will include data reduction schemes and uncertainty analysis calculations. Raw data that may be of use to the reader should go here.

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Department of Aerospace Engineering

Report Being Graded: _____

REPORT GRADING

Grading of reports is divided into the following topics:

Writing:	20 points
Plots:	20 points
Numbers:	20 points
Explanations:	30 points
Appendices:	10 points

Keep the following things in mind as you grade the reports:

WRITING ____ [out of 20]

Are sentences well written and clear?
Good section headings for clear organization?
Does introduction have a clear presentation of goals?
Are all sources cited?
Figures showing primary results should not be in appendices.
Are figures in logical order?
Well written and helpful intro and conclusions?
Discussion should not be in figure captions.
General approach explained? Assumptions stated? Equations explained?

PLOTS ____ [out of 20]

Symbols and lines chosen well? Are data sets clearly distinguishable from each other?
Units on all axis labels?
Captions adequately detailed?

NUMBERS ____ [out of 20]

Reasonable values?

EXPLANATIONS ____ [out of 30]

Each figure discussed? Helpful observations made?
Have required comparisons been made?
Are comparisons quantified or just vague? For example, "Predictions were within 5% of actual values" versus "Predictions were good."
Conclusions concise and helpful? Or just vague?

APPENDICES ____ [out of 10]

If computer codes are included, are commented sufficiently?
Calculations are clearly presented?
Well organized?

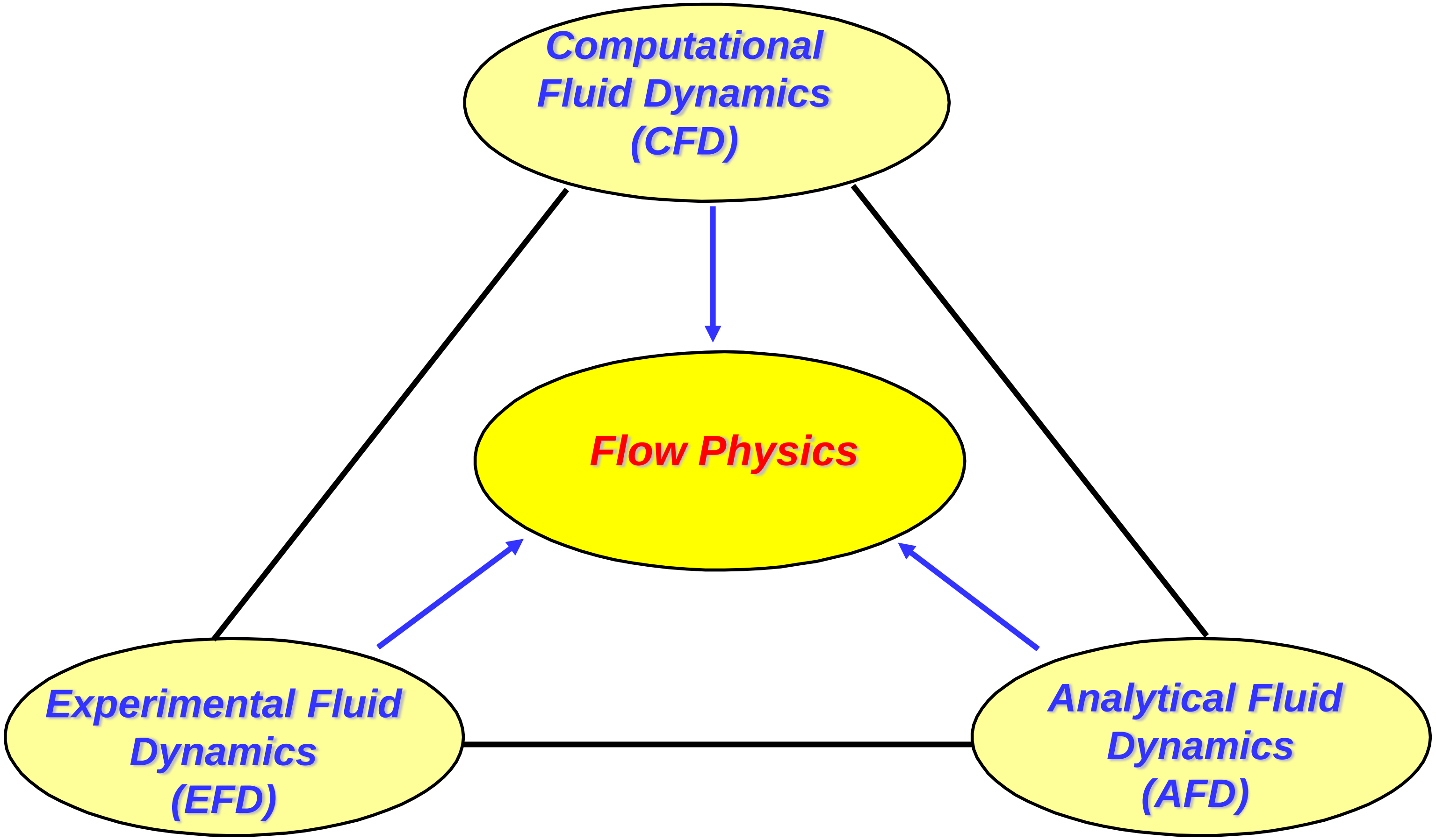
TOTAL SCORE: ____ [out of 100]

About Lab Report

- ***About teamwork***
  - *Good communication among group members*
  - *Rotating roles within the group*
  - *Peer review*

- ***About plagiarism***
  - *Please respect other people's original work and intellectual property.*
  - *Never "copy-and-paste" other's work in your lab report.*
  - *Use ~ 5 same words in a sentence as the reference materials will be counted as plagiarism unless it is noted clearly as the direct quote from the reference materials.*

AFD, CFD and EFD



Measurable Properties

- ***Material Properties:*** $\rho, m,$ **specific volume**, $\mu, \gamma,$ **D**
  (Most of them can be found in handbooks)

- ***Kinematic Properties:*** ***Describes the fluid motion w/o considering the force. (Position, V, displacement, acceleration, momentum, volume flow rate, mass flow rate, etc)***

- ***Dynamic properties:*** ***Related to applied forces. (Pressure, shear stress , Torque)***

- ***Thermodynamic properties:*** ***Heat and Work. (T, e, h, S)***

Descriptions of Flow Motion

- ***Lagrangian Method*** — ***Focused on fluid particles***

$$V = \lim_{\Delta t \to 0} \frac{\Delta L}{\Delta t}$$

- ***Eulerian Method:*** — ***Focused on space location.***

$$U(x_i, t) = V(x_{0i}, t)$$

Acceleration:

$$\begin{cases} \vec{a} = \dfrac{D\vec{V}}{Dt} \Rightarrow \quad \text{Langragian domain} \\ \vec{a} = \dfrac{\partial \vec{U}}{\partial t} + (\vec{U} \bullet \nabla)\vec{U} \\ \quad = \dfrac{\partial \vec{U}}{\partial t} + U_1 \dfrac{\partial \vec{U}}{\partial x_1} + U_2 \dfrac{\partial \vec{U}}{\partial x_2} + U_3 \dfrac{\partial \vec{U}}{\partial x_3} \Rightarrow \quad \text{Eulerian domain} \end{cases}$$

Rate of Strain:

$$e_{ij} = \frac{1}{2}\left(\frac{\partial U_i}{\partial x_j} + \frac{\partial U_i}{\partial x_j} \right)$$

Shear stress:

$$\tau_{ij} = \mu \left(\frac{\partial U_i}{\partial x_j} + \frac{\partial U_i}{\partial x_j} \right)$$

❑ Primary Properties and Secondary properties

- *Primary Properties:* *Properties which are independent to each other*

Name	*Abbreviations*	*Unit*
Length	*L*	*M*
Mass	*m*	*kg*
Time	*t*	*s*
Temperature	*T*	*K*
Electric current	*I*	*A*
Amount of substance	*mole*	*mol*
Luminous intensity	*Candela*	*Cd*
Plane Angle	*Radius*	*rad*
Solid Angle	*Storadian*	*Sr*

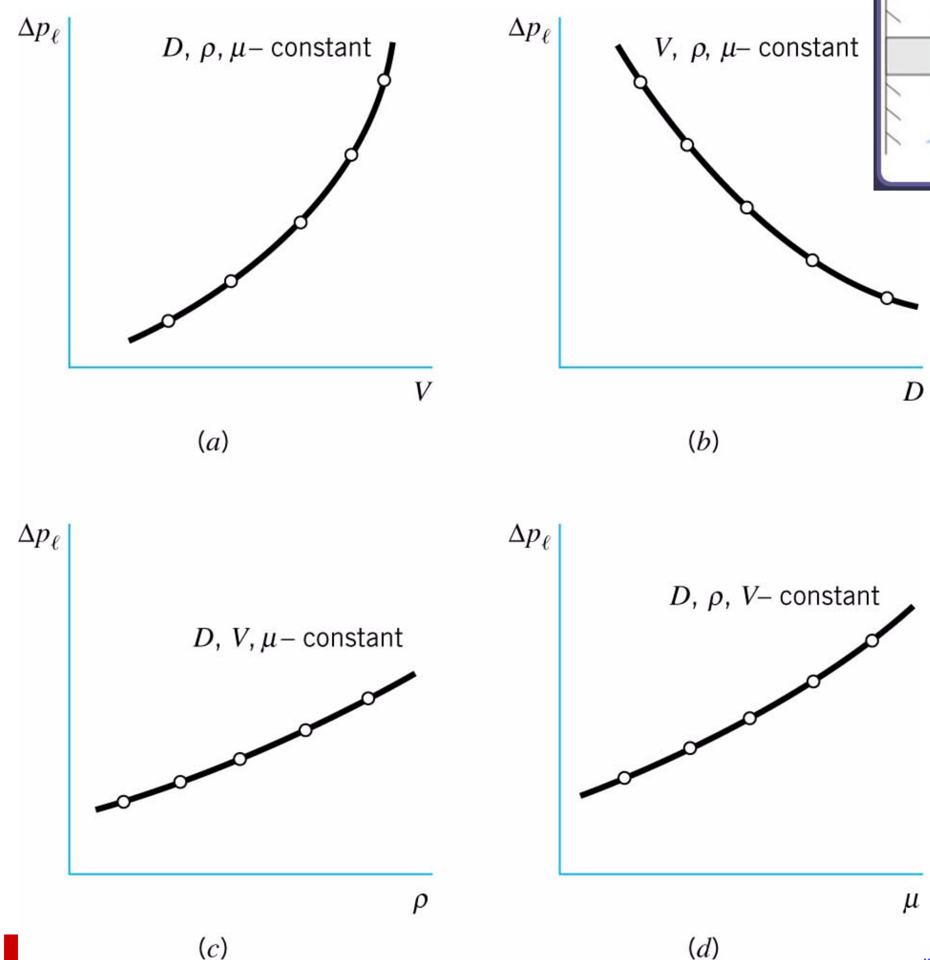
- *Secondary Properties:* *Related to other properties through their definition or basic principles*

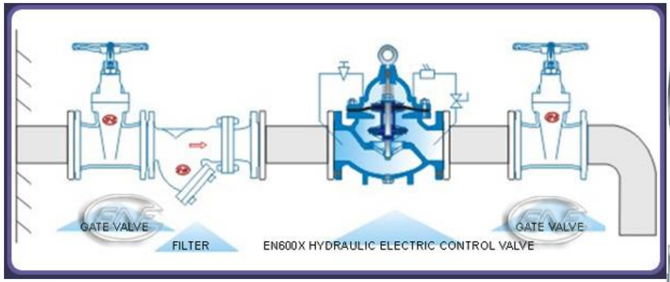
- ***Similitude:***
    - ***The study of predicting prototype conditions from model observations.***

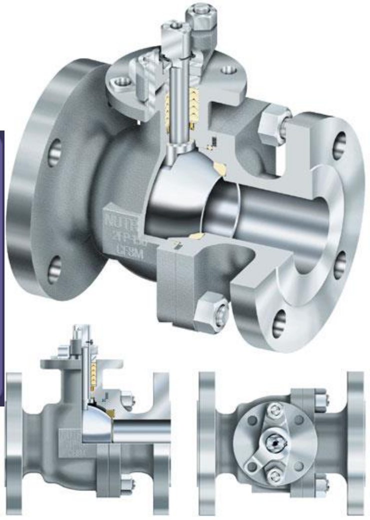
F-22 Raptor Air Superiority Fighter

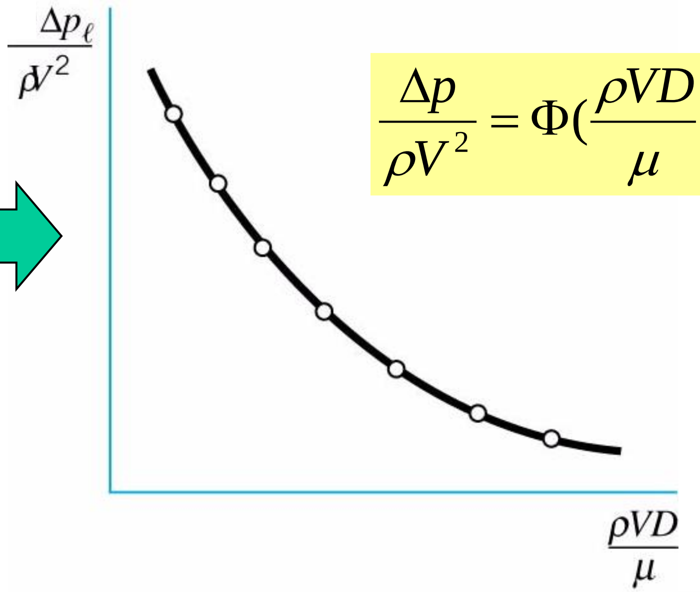
Similitude and Dimensional Analysis

$$\Delta p_l = f(D, \rho, \mu, V)$$









$$\frac{\Delta p}{\rho V^2} = \Phi\left(\frac{\rho V D}{\mu}\right)$$

Buckingham π - Theorem

- *Step 1:* *List all the variables that are involved in the problem.*
- *Step 2:* *Express each of the variables in terms of basic dimensions.*
  - *Basic dimension: M, L,T, F*
  - *Force - $F=MLT^{-2}$, density - $\rho=ML^{-3}$; or $\rho=FL^{-3}T^{2}$.*
- *Step 3:* *Determine the required number of pi-terms.*
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- *Step 6:* *Repeat Step 5 for each of the remaining non-repeating variables.*
- *Step 7:* *Check all the resulting pi terms to make sure they are dimensionless*
- *Step 8:* *Express the final form as a relationship among the pi-terms, and think about what it means.*

$$\Pi_1 = \Phi(\Pi_2, \Pi_{3,} \ldots \Pi_{k-r})$$

Buckingham π - Theorem

- ***Example***

$$\Delta p_l = f(D, \rho, \mu, V)$$

$$\Delta p_l = FL^{-3}$$
$$D = L$$
$$\rho = FL^{-4}T^2$$
$$V = LT^{-1}$$
$$\mu = FL^{-2}T$$

$$K = 5; \quad r = 3 \quad \Rightarrow \quad 2\ \pi - terms\ is\ needed$$

$$\Pi_1 = \Delta p_l D^a V^b \rho^c$$

$$(FL^{-3})(L)^a(LT^{-1})^b(FL^{-4}T^2)^c = F^0T^0L^0 \quad \Rightarrow \quad \begin{cases} 1 + c = 0 \\ -3 + a + b - 4c = 0 \\ -b + 2c = 0 \end{cases} \Rightarrow \begin{cases} a = 1 \\ b = -2 \\ c = -1 \end{cases} \Rightarrow \quad \Pi_1 = \frac{\Delta p_l D}{\rho V^2}$$

$$\Pi_2 = \mu D^a V^b \rho^c$$

$$(FL^{-2}T)(L)^a(LT^{-1})^b(FL^{-4}T^2)^c = F^0T^0L^0 \quad \Rightarrow \quad \begin{cases} 1 + c = 0 \\ -2 + a + b - 4c = 0 \\ 1 - b + 2c = 0 \end{cases} \Rightarrow \begin{cases} a = -1 \\ b = -1 \\ c = -1 \end{cases} \Rightarrow \quad \Pi_2 = \frac{\mu}{D\rho V}$$

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- ***Rate of Strain:***

$$e_{ij} = \frac{1}{2}\left(\frac{\partial U_i}{\partial x_j} + \frac{\partial U_i}{\partial x_j}\right)$$

- ***Shear stress:***

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❑ Primary Properties and Secondary properties

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Plane Angle	*Radius*	*rad*
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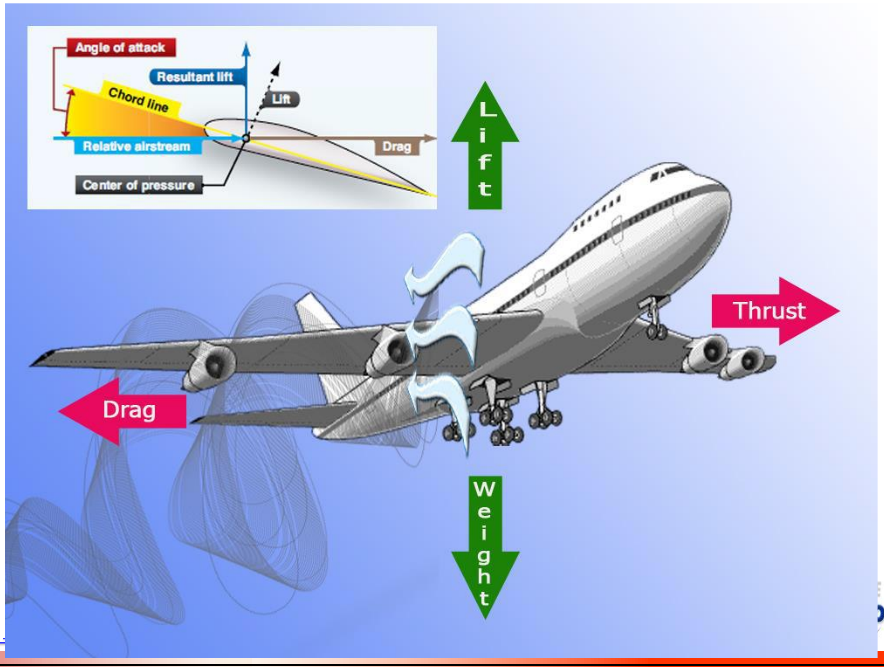
- ***Secondary Properties:*** ***Related to other properties through their definition or basic principles***

Base properties:

- Length: L, SI unit m
- Mass: m, SI unit kg
- Time: t, SI unit s
- Temperature: T, SI unit K
- Electric current: I, SI unit A
- Amount of substance: mole, SI unit mol
- Luminous intensity: I, SI unit Cd

Interesting properties:

- Lift
- Drag
- Moments



❑ SIMILITUDE AND DIMENSIONAL ANALYSIS

- **Similitude:**
  - **The study of predicting prototype conditions from model observations.**

- *F-22 Raptor Air Superiority Fighter*

❑ SIMILITUDE AND DIMENSIONAL ANALYSIS

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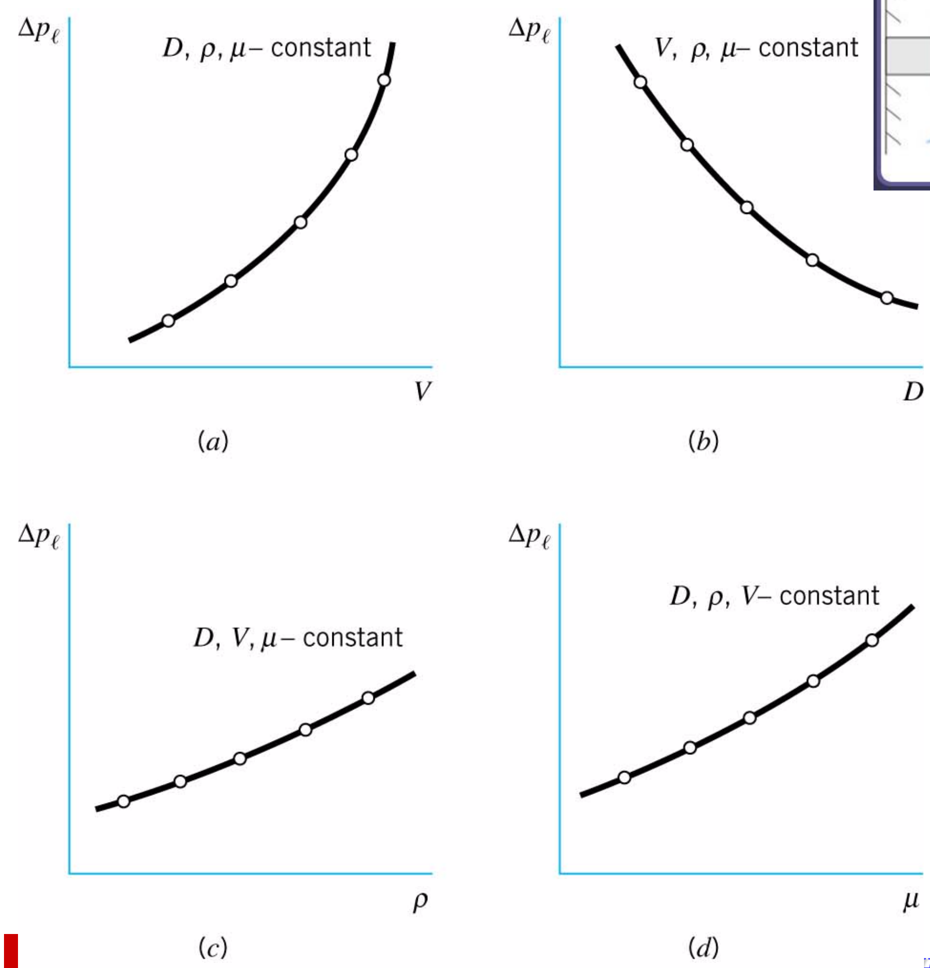

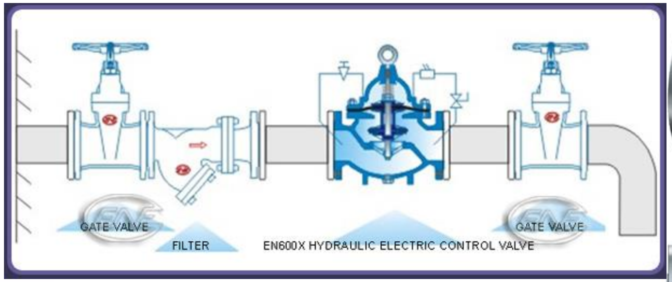

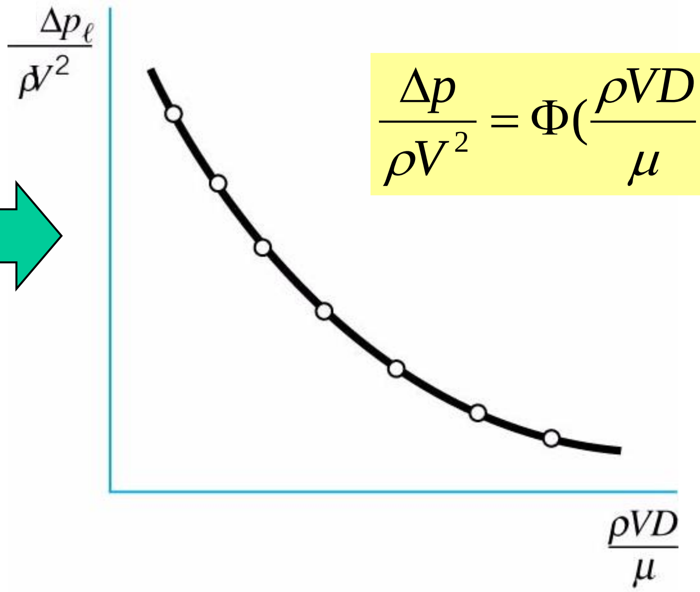

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❑ BUCKINGHAM π - THEOREM

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Commonly used dimensionless parameters

$$\text{Mach Number, M} = \frac{V}{c} \propto \frac{\text{inertial force}}{\text{compressibility force}}$$

$$\text{Reynolds number, Re} = \frac{\rho V L}{\mu} \propto \frac{\text{inertial force}}{\text{viscous force}}$$

$$\text{Euler number, Eu} = \frac{\Delta p}{\frac{1}{2}\rho V^2} \propto \frac{\text{pressure force}}{\text{inertial force}}$$

$$\text{Drag Coefficient}: C_D = \frac{D}{\frac{1}{2}\rho V^2 S} = \frac{\text{Drag}}{\text{inertial force}}$$

$$\text{Lift Coefficient}: C_L = \frac{L}{\frac{1}{2}\rho V^2 S} = \frac{\text{Lift}}{\text{inertial force}}$$

$$\text{Prandtl Number}: \Pr = \frac{V}{\gamma} = \frac{\text{momentum diffusion}}{\text{heat diffusion}}$$

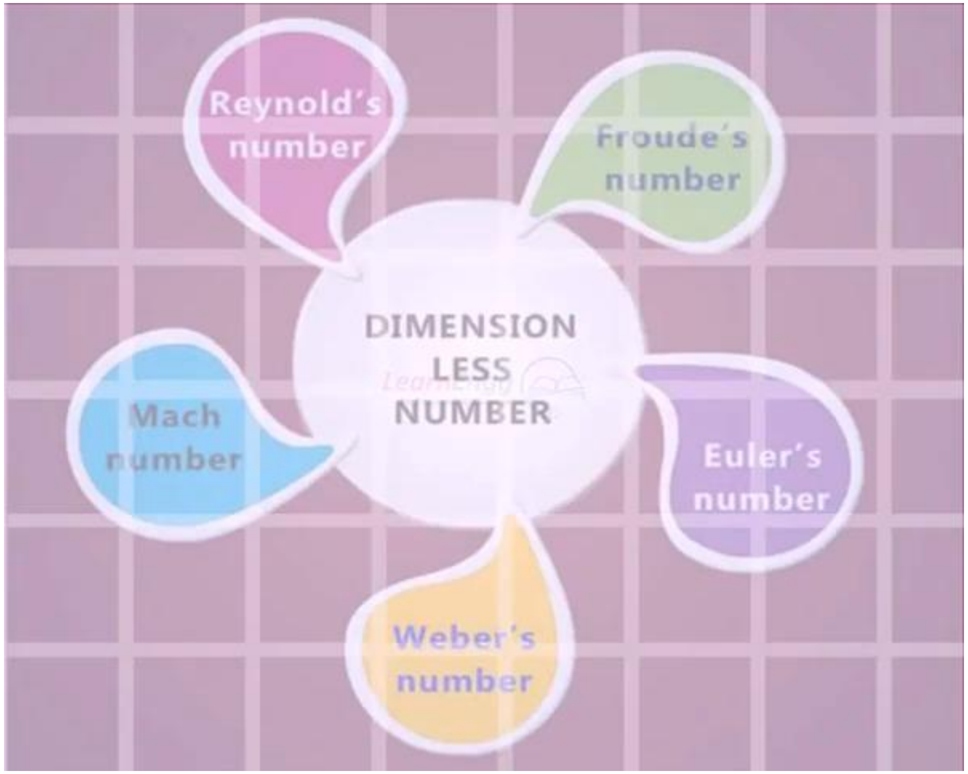
$$\text{Schmidt Number}: Sc = \frac{U}{\gamma_c} = \frac{\text{momentum}}{\text{mass}}$$

$$\text{Froude Number, Fr} = \frac{V}{\sqrt{\lg}} \propto \frac{\text{inertial force}}{\text{gravity force}}$$

$$\text{Strohal Number, Str} = \frac{l\varpi}{V} \propto \frac{\text{centrifugal force}}{\text{inertial force}}$$

$$\text{Weber Number, We} = \frac{V^2 l \rho}{\sigma} \propto \frac{\text{inertial force}}{\text{surface tension force}}$$

…



❑ SIMILITUDE

- **Geometric similarity:** **the model have the same shape as the prototype.**

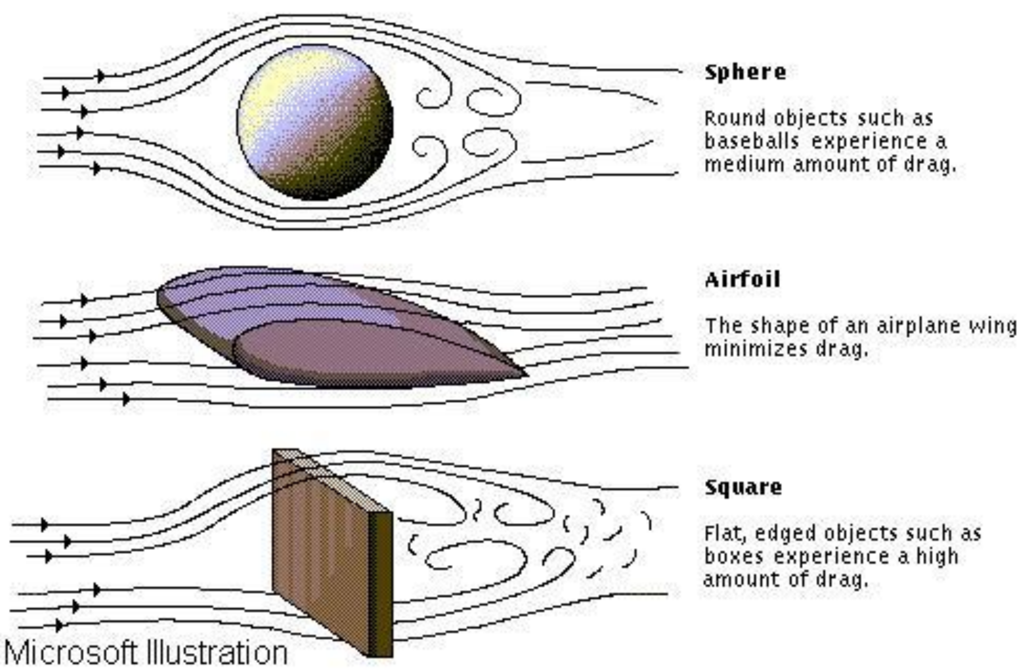
- F-16

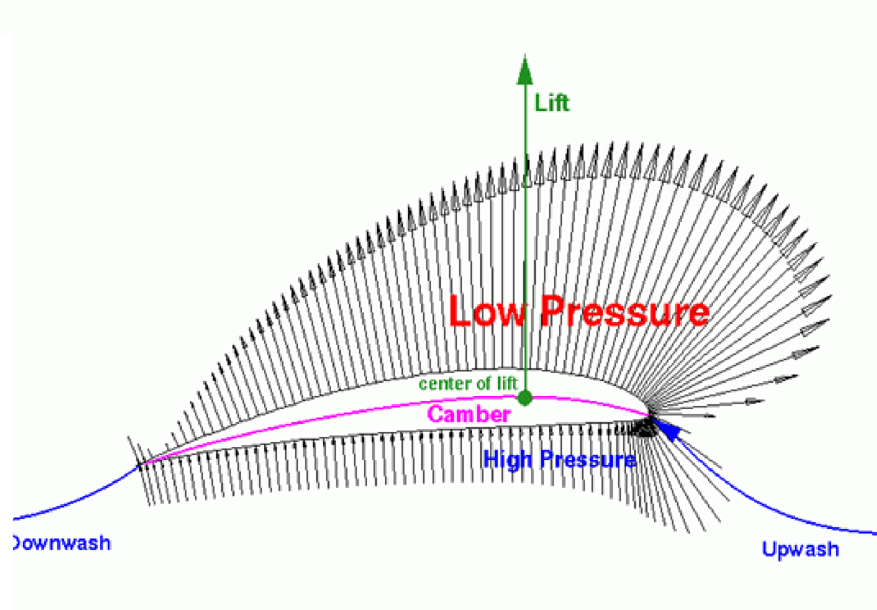
- F-16

- F-22

❑ SIMILITUDE

- ***Kinematic similarity:* condition where the velcoity ratio is a constant between all corresponding points in the flow field.**
  - ***The streamline pattern around the model is the same as that around the prototype***





Pressure vectors and flow over a cambered section.

❑ SIMILITUDE

- **Dynamic similarity:** Forces which act on corresponding masses in the model flow and prototype flow are in the same ratio through out the entire flow.

$$\frac{(F_I)_m}{(F_I)_p} = \frac{(F_p)_m}{(F_p)_p} = \frac{(F_\mu)_m}{(F_\mu)_p} = \frac{(F_g)_m}{(F_g)_p} = \text{constant}$$

$$\Rightarrow \quad \frac{(F_I)_m}{(F_I)_p} = \frac{(F_p)_m}{(F_p)_p} \quad \Rightarrow \quad \frac{(F_I)_m}{(F_p)_m} = \frac{(F_I)_p}{(F_p)_p} \quad \Rightarrow \quad Eu_m = Eu_p$$

$$\Rightarrow \quad \frac{(F_I)_m}{(F_I)_p} = \frac{(F_\mu)_m}{(F_\mu)_p} \quad \Rightarrow \quad \frac{(F_I)_m}{(F_\mu)_m} = \frac{(F_I)_p}{(F_\mu)_p} \quad \Rightarrow \quad \text{Re}_m = \text{Re}_p$$

$$\Rightarrow \quad \frac{(F_I)_m}{(F_I)_p} = \frac{(F_g)_m}{(F_g)_p} \quad \Rightarrow \quad \frac{(F_I)_m}{(F_g)_m} = \frac{(F_I)_p}{(F_g)_p} \quad \Rightarrow \quad Fr_m = Fr_p$$