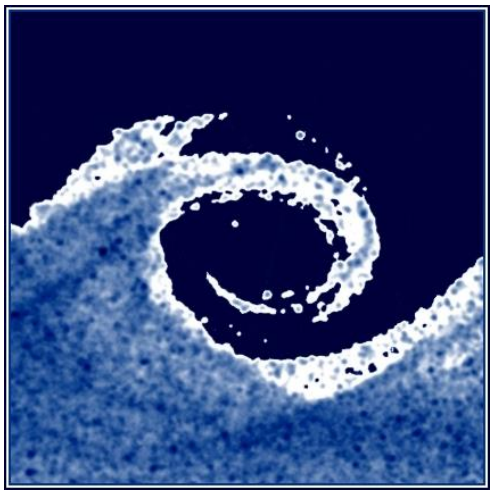

Budapesti University of Technology and Economics

Department of Fluid Mechanics

Pre-measurement class I.

Bence TÓTH *tothbence@ara.bme.hu*

2015.

General information

- Department webpage: **www.ara.bme.hu**
- Student information page: **www.ara.bme.hu/poseidon**

  (materials, test scores, etc.)
- Measurement groups need to be formed. One can sign up for a given measurement group on the department web site. The changing of courses is not permitted.
- The measurement groups can be freely chosen, in accordance with a neptun message which will be sent at a later time.

EVERYONE MUST SIGN FOR A MEASUREMENT GROUP BY THE END OF THE 4TH WEEK!

- The measurement mid-term exam shall be taken during the 3rd laboratory session.
  - Having a passing grade on the measurement mid-term exam is a prerequisite for participating in the measurements. Makeup measurement mid-term exams will be taken in the 6th week.

Downloadable materials

www.ara.bme.hu/poseidon

english

login → username: neptun code (lower case letters), password: NEPTUN CODE (capital letters)

„Egyéb tantárgyinformációk”

BMEGEATAG11 (or AM06) → english

Or www.ara.bme.hu

In english

Download

„Tantárgyak”

BMEGEATAG11 (or AM06) → english

Measurement supervisors

M1	Péter FÜLE	fule@ara.bme.hu
M2	Tamás KALMÁR-NAGY	kalmarnagy@ara.bme.hu
M3	Balász ISTÓK	istok@ara.bme.hu
M4	Árpád VARGA	varga@ara.bme.hu
M5, M13	Bence TÓTH	tothbence@ara.bme.hu
M7	Szandra MIKÓ	miko@ara.bme.hu
M8	Balázs FARKAS	farkas@ara.bme.hu
M9	András TOMOR	tomor@ara.bme.hu
M10	Márton NAGY	nagymarton@ara.bme.hu
M11	László NAGY	nagy@ara.bme.hu
M12	Tamás BENEDEK	benedek@ara.bme.hu

General information

- **Timetable:**
  - 1st session: Measurement devices, measurement methods
  - 2nd session: Introduction to the measurement facilities, measurement uncertainty
  - 3rd session: Measurement mid-term exam
  - 4th session: A measurement
  - 5th session: B measurement
  - 6th session: Makeup measurements (X)
  - 7th session: A+B measurement presentations

  (Details can be found in the syllabus)

Preparing for the laboratory measurements

- The poseidon network needs to be checked, in order to find out which measurement assignment is given to the group (e.g. M03/c).
- In preparing for the laboratory measurements, all members of the measurement group must read and understand the measurement which is to be made.
- Make sure you read the assignment in a separate sheet!
- A hand written outline of the measurement needs to be prepared by the lab leader. This outline should contain the following:
  - The measurement groups information (names, neptun codes), leaving a space for checking attendance
  - Space where the measurement supervisor can sign each page.
  - A list of the instruments which will be used during the measurement, leaving room for the serial numbers, which will be documented during the measurement
  - Tables for documenting the measured and calculated values, including atmospheric conditions (e.g. atmospheric pressure and temperature, etc.)
  - The equations which are necessary in order to complete the measurement and the associated calculations, leaving room for verification calculations.

Preparing for the laboratory measurements

- Millimeter paper needs to be brought to the laboratory measurements

During the laboratory measurement

- At the beginning of the laboratory the hand written outline will be checked by the instructor supervising the measurement, and questions will be asked in order to determine whether the group is prepared for the measurement.
    - If the group is unprepared, they will be sent away
- During the laboratory the faculty member supervising the laboratory session will evaluate the groups preparedness by asking questions regarding the measurement and evaluating the properness of the measurement by conducting sample calculations with the groups as well as having them graph certain values. If the group is deemed unprepared, they will be sent away.
- The measurements need to be completed during the allotted time.
- The proper calibration of the digital manometer needs to be assessed during the laboratory measurement, with the help of the Betz micro manometer.
- During the measurement, department personnel supervising the measurements will assign a task to each group, by which some values measured during the laboratory measurement will be drawn on the millimeter paper, in order to check the correctness of the measurement and the understanding of the measured results. If the task can not be completed in a satisfactory manner, the measurements must be repeated.

After the laboratory measurement

- A measurement report must be produced from the measured data
- Laboratory calculations must be checked utilizing the departments online evaluation tools.

  www.ara.bme.hu/lab

  - **Use of the control tools is mandatory**. The control tools only evaluate whether the equations were applied properly.
  - **If the calculations were deemed invalid**, they must be repeated.
    - There is no limit as to the number of attempts which can be made, but the attempts are logged, and can be taken into account when giving grades. (fair use policy)
    - In previous semesters each measurement had students who were able to complete the calculations correctly upon their first attempt.
  - **Once the calculations are correct**, a code is provided to the student.
    - This code must be included on the laboratory report cover.
    - The number of attempts, and the calculation error [%], as compared to the expected calculated value, will be taken into consideration when grades are assigned.

After the laboratory measurement

- Example:

Sajnos a számítása helytelen. Kérjük ellenőrizze a bevitt adatokat és próbálja újra!
Próbálkozások száma: 7.

* Beszívóelemen mért nyomásesés (3. térfogatáram):	300	[Pa]	
* Mérőperemen mért nyomásesés (1. térfogatáram):	400	[Pa]	
* Mérőperemen mért nyomásesés (2. térfogatáram):	500	[Pa]	
* Mérőperemen mért nyomásesés (3. térfogatáram):	600	[Pa]	

Származtatott mérési adatok

Hőmérséklet:	kihagy	[K]	
* Levegő sűrűsége:	1.18	[kg/m^3]	Elfogadva!
* Levegő kinematikai viszkozitása:	1.507e-5	[m^2/s]	Elfogadva!

Kalibráció (1. térfogatáram)

Mérőperem átfolyási tényező, C (1. lépés):	0.6	[-]	Elfogadva!
Térfogatáram (1. lépés szerint):	kihagy	[m^3/s]	
Sebeség (1. lépés szerint):	kihagy	[m/s]	
* Reynolds-szám (1. lépés szerint):	30e3	[-]	Pontatlan számítási eredmény!
Mérőperem átfolyási tényező, C (2. lépés):	kihagy	[-]	
* Mérőperem átfolyási tényező, C (végleges):	0.65	[-]	Elfogadva!
* Térfogatáram (végleges):	0.025	[m^3/s]	Pontatlan számítási eredmény!
* Beáramlási tényező:	1.8	[-]	Pontatlan számítási eredmény!

Kalibráció (2. térfogatáram)

Mérőperem átfolyási tényező, C (1. lépés):	0.6	[-]	Elfogadva!
Térfogatáram (1. lépés szerint):	kihagy	[m^3/s]	
Sebeség (1. lépés szerint):	kihagy	[m/s]	
* Reynolds-szám (1. lépés szerint):	31e3	[-]	Elfogadva!

- It is not mandatory to fill out the grey cells..
- If the program deems the calculations incorrect, then it might be useful to fill out these cells, in order to help one find the source of the error.

After the laboratory measurement

- After the calculations are accepted, the reports must be submitted through the poseidon network.
- Reports must be submitted by midnight of the second Sunday following the measurements.
- Consultations:
  - The faculty members grading the reports will provide one consultation opportunity per week for each measurement (one hour per measurement per week) they are grading. Consultation timetables can be found on the department web site.
  - The measurement groups can also come to the laboratory to consult with the supervisors overseeing the given measurements during the last 15 minutes of any regular measurement session.

After the laboratory measurement

- Requirements of laboratory reports
  - The cover of the laboratory report must be downloaded from the web site.
  - The lab report can only be 6 pages long plus the required report cover and mandatory annex
  - A mandatory annex to the 6 pages needs to contain the following:
    - A scanned copy of the hand written notes which were signed upon completion of the laboratory measurement, and which contain all the tables of all the data which was recorded.
  - **The uploaded zip file must contain an excel file in which the calculations were made and the pdf of the laboratory report.**
- ALL LABORATORY REPORTS NEED TO BE ORIGINAL AND MADE BY THE LAB GROUP! ANY MEASUREMENT LEADERS SUBMITTING WORK WHICH WAS NOT SOLELY PRODUCED BY THE GROUP, WITHOUT CITING THE APPROPRIATE SOURCE, WILL BE REPORTED TO THE DEAN'S OFFICE AND THE ETHICS COMMITTEE IN ACCORDANCE WITH THE RULES OF THE TVSz.

After the laboratory measurement

- The reports are evaluated within 2 working days, and a message is sent to the student through the poseidon network informing the student whether the report was accepted or not. If the report is unacceptable, there is one opportunity to resubmit the report by the following Sunday at midnight.
- Please note that in some cases the reports need to be submitted earlier in order to make sure that presentations can be presented when needed.
- **EXCEL: USE SCATTER PLOT!**

Presentation

- The template for the presentations, which is also an example for a typical presentation, can be downloaded from the webpage.
- You may use the departmental template, but don’t need to
- 8 minutes
- The measurement needs to be summarized.
- The personal measurement assignment needs to be presented and explained.
- The measurement stand and the used equipment needs to be presented.
- Error calculations need to be presented.
- The evaluation of the results needs to be presented.
- The results need to be shown
- The conclusions and results need to be summarized.
- Try to make it unique and interesting!

Checklist

At the measurement:

- In preparing for the measurement (hand written measurement plan): assignment, neptun code, name, documentation, personal assignment, mm paper, signature. CHECK
- The laboratory instructor checks your preparedness with 1 or 2 questions CHECK
- Record atmospheric conditions (p_0, T_0) before and after the laboratory CHECK
- Calibrate to the Betz micro manometer CHECK
- You can ask questions from any of the laboratory instructors at the laboratory session, but it is advised to ask from the one leading your measurement
- Check the list of supplies in your measurements box. The box will be opened and closed by the laboratory instructor. The laboratory instructor will provide manometers, and will replace those which need to be charged. Do not connect digital manometers to chargers!

Consultation

- Consultations can be made with the appropriate instructor during consultation hours. (prior to the measurements (!) you can also turn to the fluid mechanics student group)
- Calculation results need to be checked www.ara.bme.hu/lab
- Once calculations are correct and the report is complete, submit the report: www.ara.bme.hu/poseidon (pdf+xls)
- pdf name = surname_NEPTUNCODE_ AorB_DAY_time_ODDorEVEN_M#.pdf

Determining the uncertainty of the results (error calculation) I.

Example: Velocity measurement uncertainty

Dynamic pressure measured using a Pitot-static (Prandtl) tube:
p_d =486.2Pa

Atmospheric conditions experienced in the lab:
p_0 =1010hPa ; T=20°C (293K);
Specific gas constant of air
R=287 J/kg/K

$$v = \sqrt{\frac{2}{\rho_{air}} \cdot \Delta p_d} \qquad \rho_{air} = \frac{p_0}{R \cdot T}$$

$$v = \sqrt{\frac{2}{p_0} \cdot \Delta p_d RT}$$

$$v = 28.45 \ \frac{m}{s} \qquad \rho_{air} = 1.2 \frac{kg}{m^3} \qquad v = f\left(T, p_0, \Delta p_d, const.values\right)$$

Quantities having uncertainties (X_i):

-The measurement uncertainty of the atmospheric pressure comes from the error arising when reading the scale: δp_0=100Pa

- The measurement uncertainty of the atmospheric temperature in the lab: δT=1K

- The pressure measurement uncertainty arising when making a measurement using a Pitot-static (Prandtl) probe and a EMB-0XY digital manometer: $\delta(\Delta p_i)$=2Pa

Determining the uncertainty of the results (error calculation) II.

Example: Velocity measurement uncertainty

Typical calculation of absolute error:

$$\delta R = \sqrt{\sum_{i=1}^{n}\left(\delta X_i \cdot \frac{\partial R}{\partial X_i}\right)^2}$$

$R = v$

$X_1 = T;\ X_2 = p_0;\ X_3 = \Delta p_d$ $\quad (\delta p,\ \delta T,\ \delta(\Delta p_d)$

$$\frac{\partial v}{\partial T} = \sqrt{2\mathrm{R}} \cdot \frac{1}{2} \cdot T^{-\frac{1}{2}} \cdot \frac{1}{\sqrt{p_0}} \cdot \sqrt{\Delta p_d} = 0{,}00366 \frac{m}{s \cdot K}$$

$$\frac{\partial v}{\partial p_0} = \sqrt{2\mathrm{R}} \cdot \sqrt{T} \cdot \frac{-1}{2} \cdot p_0^{-\frac{3}{2}} \cdot \sqrt{\Delta p_d} = 1{,}4 \cdot 10^{-4} \frac{m}{s \cdot Pa}$$

$$\frac{\partial v}{\partial \Delta p_d} = \sqrt{2\mathrm{R}} \cdot \sqrt{T} \cdot \frac{1}{\sqrt{p_0}} \cdot \frac{1}{2} \cdot \Delta p_d^{-\frac{1}{2}} = 0{,}029 \frac{m}{s \cdot Pa}$$

Determining the uncertainty of the results (error calculation) III.

Example: Velocity measurement uncertainty

The absolute uncertainty of the velocity measurement:

$$\delta v = \sqrt{\left(\delta T \cdot \sqrt{\frac{2R}{p_0}\Delta p_d} \cdot \frac{1}{2} \cdot T^{-\frac{1}{2}}\right)^2 + \left(\delta p_0 \cdot \sqrt{2 \cdot R \cdot T \cdot \Delta p_d} \cdot \frac{-1}{2} \cdot p_0^{-\frac{3}{2}}\right)^2 + \left(\delta(\Delta p_d) \cdot \sqrt{\frac{2 \cdot R \cdot T}{p_0}} \cdot \frac{1}{2} \cdot \Delta p_d^{-\frac{1}{2}}\right)^2}$$

$$\delta v = 0.05977 \quad \frac{m}{s}$$

The relative uncertainty of the velocity measurement:

$$\frac{\delta v}{v} = 0.0021 = 0.21\%$$

The result of the velocity measurement:

$$v = 28.45 \pm 0.05977 \quad \frac{m}{s}$$