Second period of examinations
Winter semester 2021/22 / March

HOCHSCHULE RHEIN-WAAL
Rhine-Waal University of Applied Sciences

Study Course: ______________________________

Module Title: **2710 Fluid Mechanics B.Sc. (Prof. Gebel)**

Family Name: ____________________

First Name: ____________________

Student No.: ____________________

I am in compliance with the conditions specified on the exam coversheet with regards to time and authorised aides and materials as well as the examination rules presented by the invigilator.

Date: 09.03.2022 **Signature:** ______________________________

Examination form:	Written exam
Points:	84
Duration:	120 Minutes

Authorised aides:

- Non-programmable pocket calculator
- Geometrical tools
- Ballpoint pen or fountain pen (all colours but red)

The exam consists of 20 pages. First, check that your copy contains all pages.

All calculations and sketches should be done on the sheets provided for that purpose. If more than one solution is given, mark clearly which one should be rated.

Please write legibly. Thank you very much and good luck.

Register No.: ____________

FOR INTERNAL USE ONLY:

	Q1	Q2	Q3	Q4	Q5	Q6	Written exam	Practical Training	Total
Max. Points	12	16	16	14	14	12	84	16	100
Achieved									
							$\geq$ 42 Yes | No	Grade	

Graded by		Checked by

Final Grade

Regular grading key.	
Adjusted grading key. (Please add the adjusted grading key to the exam-results)	×

Register No.: ____________

Question 1 … Question/Answer Session **Points: 12**

<u>There is only one correct answer for each question.</u>

1. What happens if the flow of water within a horizontal tube changes from laminar to turbulent?

   - ☐ The pressure losses remain constant.
   - ☒ The pressure losses will increase.
   - ☐ The pressure losses will decrease.

2. Consider laminar flow of water under steady-state conditions. What happens if the diameter of a horizontal tube smoothly increases?

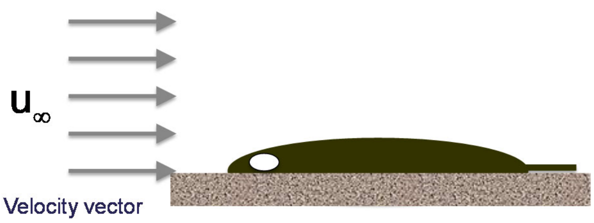
   - ☐ The pressure will decrease and the velocity will increase.
   - ☐ Pressure and velocity remain constant.
   - ☐ Pressure and velocity will decrease.
   - ☒ The pressure will increase and the velocity will decrease.

3. Consider laminar flow of air under steady-state conditions through a horizontal tube. What happens if the temperature of the air decreases due to cooling of the tube?

   $T\downarrow \rightarrow \eta\downarrow \rightarrow \lambda\downarrow \rightarrow \Delta p\downarrow$

   - ☐ The pressure losses will increase.
   - ☒ The pressure losses will decrease.
   - ☐ The pressure remains constant.

4. Plaice are bottom-living flatfish similar to flounder. At rest they constitute low, rounded humps on smooth, sandy bottoms. What happens if the current passing over the fish becomes stronger, i.e. higher flow velocity?



   - ☐ The flatfish is pressed on the ground.
   - ☒ The flatfish is lifted up into the current.
   - ☐ The flatfish remains quiescent.

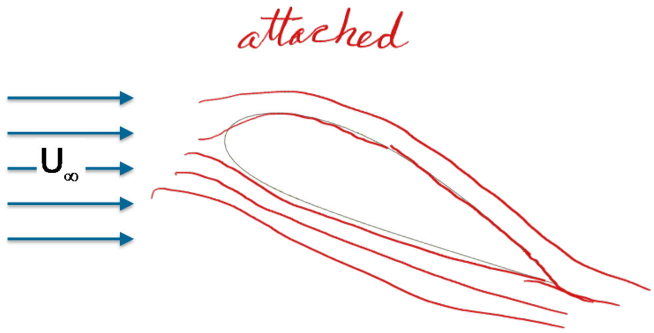
5. A streamline is a line in the flow possessing the following property:

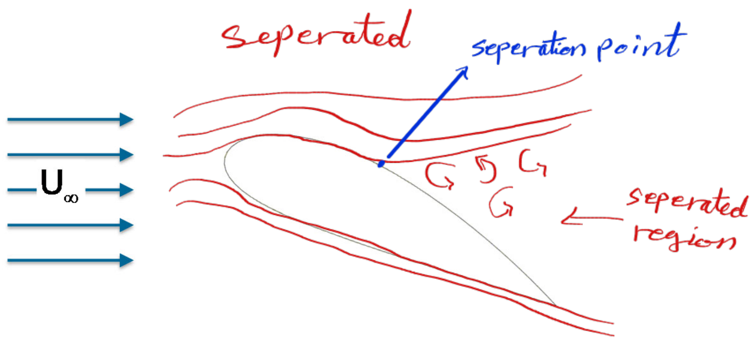
   - [ ] The velocity vector of each particle occupying a point on the streamline is normal to the streamline.
   - [x] The velocity vector of each particle occupying a point on the streamline is tangent to the streamline.
   - [ ] The velocity vector of each particle occupying a point on the streamline is shifted by 45° with respect to the streamline.

6. Consider a Newtonian fluid contained between two large parallel plates of area A, which are everywhere separated by a very small distance Y. The system is at rest. Then the lower plate is set in motion at a constant velocity v. What velocity profile will appear at steady state, i.e. after acceleration?

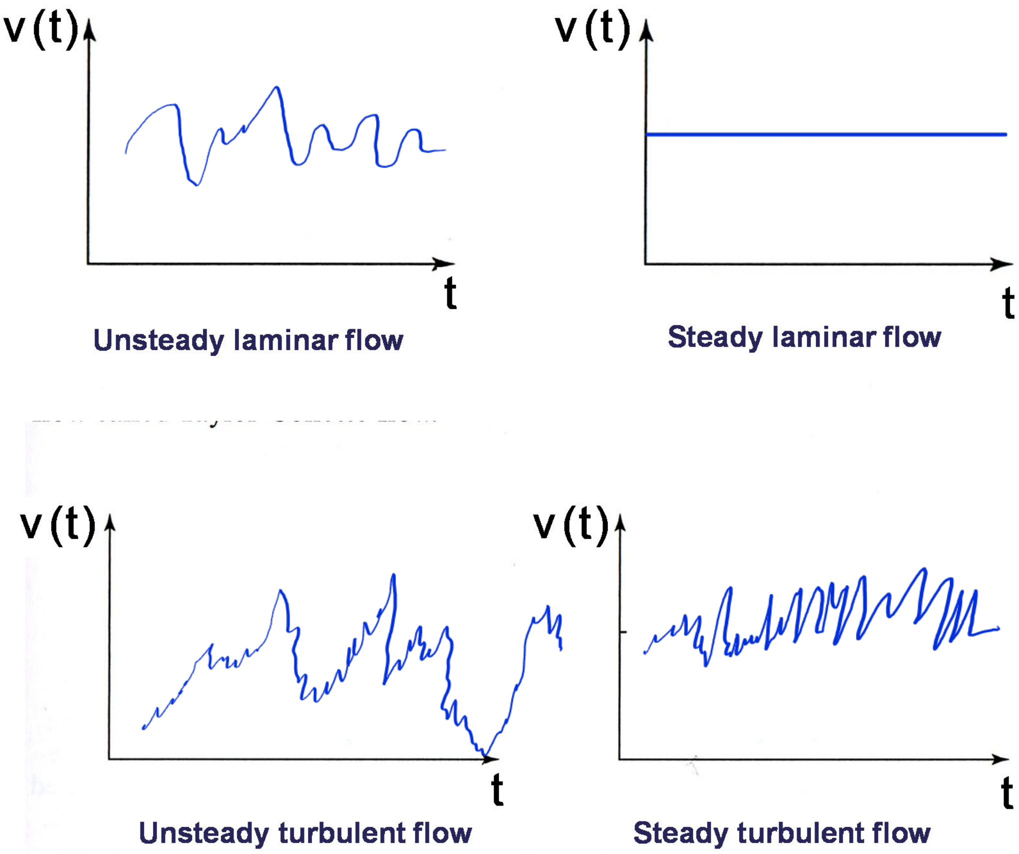
   - [ ] A parabolic velocity profile.
   - [x] A linear velocity profile.
   - [ ] A hyperbolic velocity profile.

7. Sketch the streamlines over an airfoil at a large angle of attack for both attached flow and separated flow. (2 P)





8. Sketch the development of velocity with time, v(t), for the four cases shown in the schematic below. Assume that a high-resolution speed sensor is available. Mark the average velocity for each case. (4 P)



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Question 2 … Flow between two reservoirs **Points: 16**

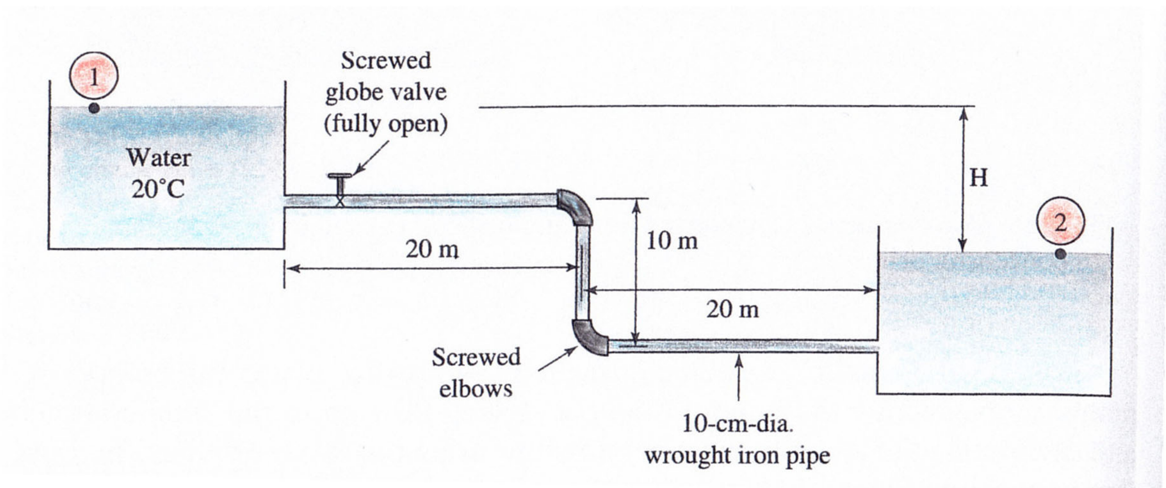
If the flow rate of water through a 10-cm-diameter wrought iron pipe (→ commercial steel) is 0.04 m³/s, find the difference in elevation H of the two reservoirs.

Given:

Density of water:	$\rho = 1{,}000 \frac{kg}{m^3}$
Kinematic viscosity	$\nu = 1.002 \cdot 10^{-6} \frac{m^2}{s}$
Roughness	$e = 0.046\,mm$
Loss coefficient for minor losses	see attached table
Friction factor	see attached Moody diagram

Assumptions:

- Both reservoirs are large and open to the atmosphere
- Squared-edged entrance
- Standard elbow



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Answer sheet

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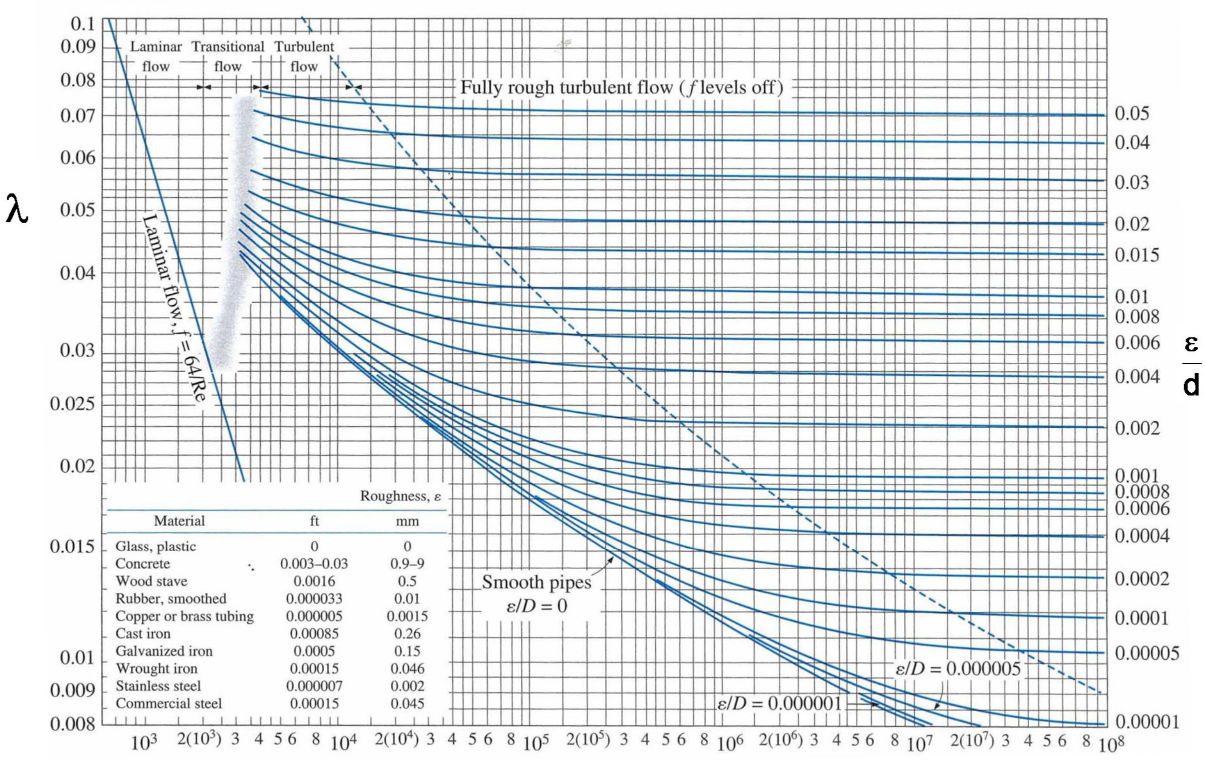
TABLE 7.2 Nominal Loss Coefficients K (Turbulent Flow)[a]

Type of fitting		*Screwed*		*Flanged*		
Diameter		2.5 cm	10 cm	5 cm	10 cm	20 cm
Globe valve	(fully open)	8.2	5.7	8.5	6.0	5.8
	(half open)	20	14	21	15	14
	(one-quarter open)	57	40	60	42	41
Angle valve (fully open)		4.7	1.0	2.4	2.0	2.0
Swing check valve (fully open)		2.9	2.0	2.0	2.0	2.0
Gate valve (fully open)		0.24	0.11	0.35	0.16	0.07
Return bend		1.5	0.64	0.35	0.30	0.25
Tee (branch)		1.8	1.1	0.80	0.64	0.58
Tee (line)		0.9	0.9	0.19	0.14	0.10
Standard elbow		1.5	0.64	0.39	0.30	0.26
Long sweep elbow		0.72	0.23	0.30	0.19	0.15
45° elbow		0.32	0.29			
Square-edged entrance			0.5			
Reentrant entrance			0.8			
Well-rounded entrance			0.03			
Pipe exit			1.0			



$$Re = \frac{\rho v d}{\eta}$$

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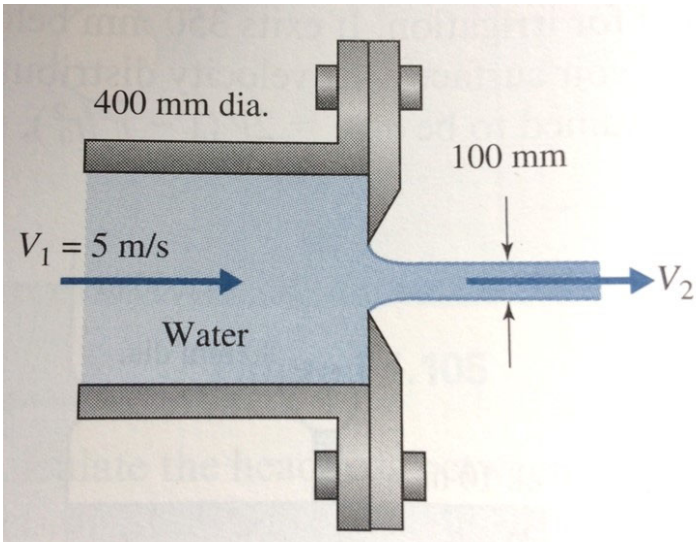
Question 3 … Eq. of momentum / Bernoulli equation **Points: 16**

Water flows through an orifice out of a tube into the environment as shown in the figure:



Calculate the net force needed to hold the orifice plate onto the pipe.

Hint: *Start with a sketch of the system, mark the control surface and introduce all relevant forces.*

Neglect viscous effects and losses.

Given:

Velocity v_1	$v_1 = 5\ \frac{m}{s}$
Diameter of the pipe	$d_1 = 400\ mm$
Diameter of the jet	$d_2 = 100\ mm$
Density of water:	$\rho = 1{,}000 \frac{kg}{m^3}$

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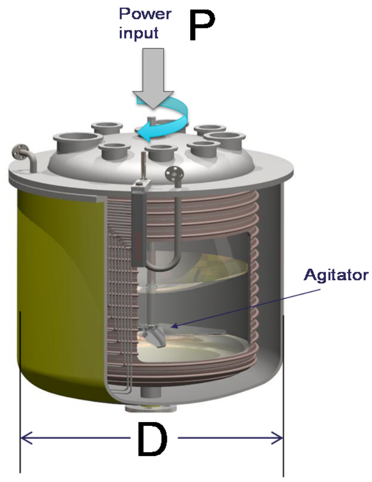
Question 4 … Dimensional analysis **Points: 14**

The mixing time t to homogenize a liquid substance, for instance motor oil or paint, depends on:

- Power input P
- Diameter of mixing vessel D
- Density of the two liquids ρ
- Dynamic viscosity of the two liquids η



a) Determine the number of dimensionless π - terms for the problem.

b) Define the repeating variables.

c) Provide an explicit step-by-step description of the procedure for the determination of the relevant π - terms

Use the following table for your solution as template.

M						
L						
T						

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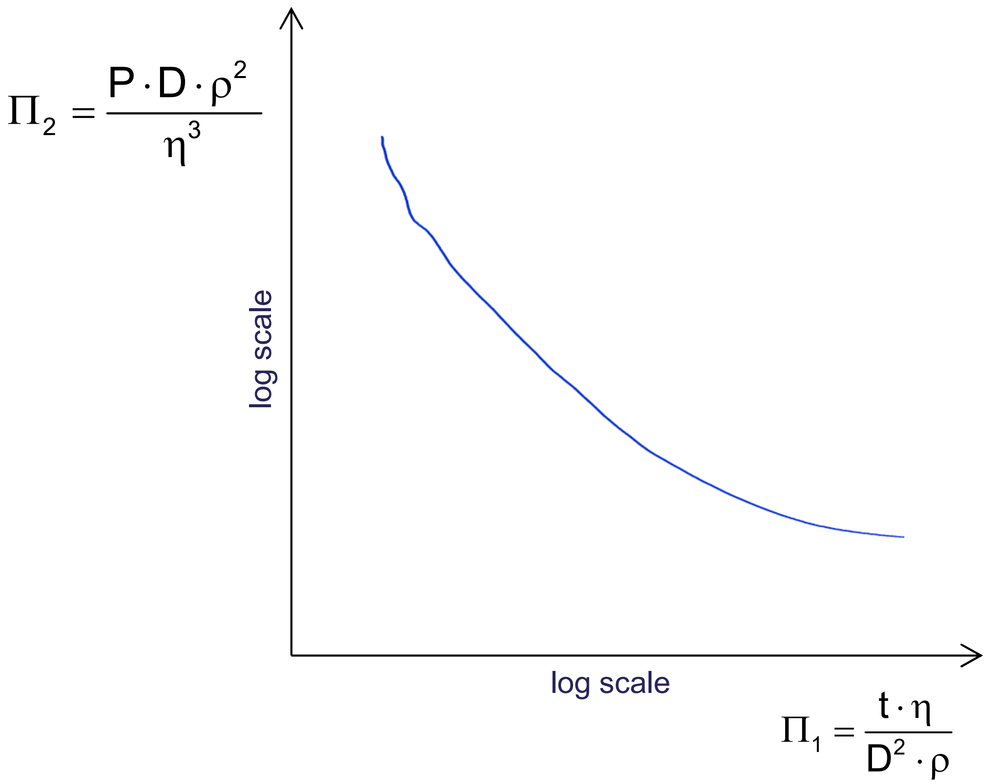
d) Sketch the curve Π_2 versus Π_1 in a double logarithmic reference frame (see template) if the development is supposed to follow a power law.



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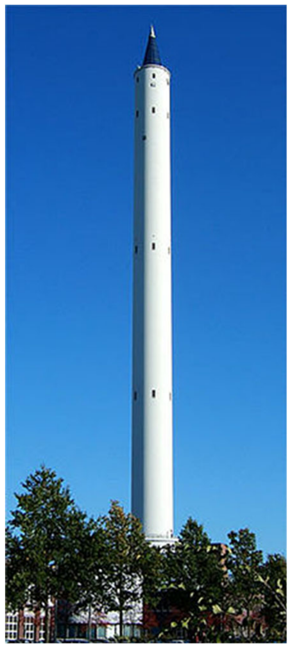
Question 5 … Drag and terminal velocity **Points: 14**

Determine the stationary sinking rate, the so-called terminal velocity of a 20-cm-diameter smooth sphere if it is released from rest in air at 20°C.

Hint: Start with a force balance for the falling sphere.



Given:

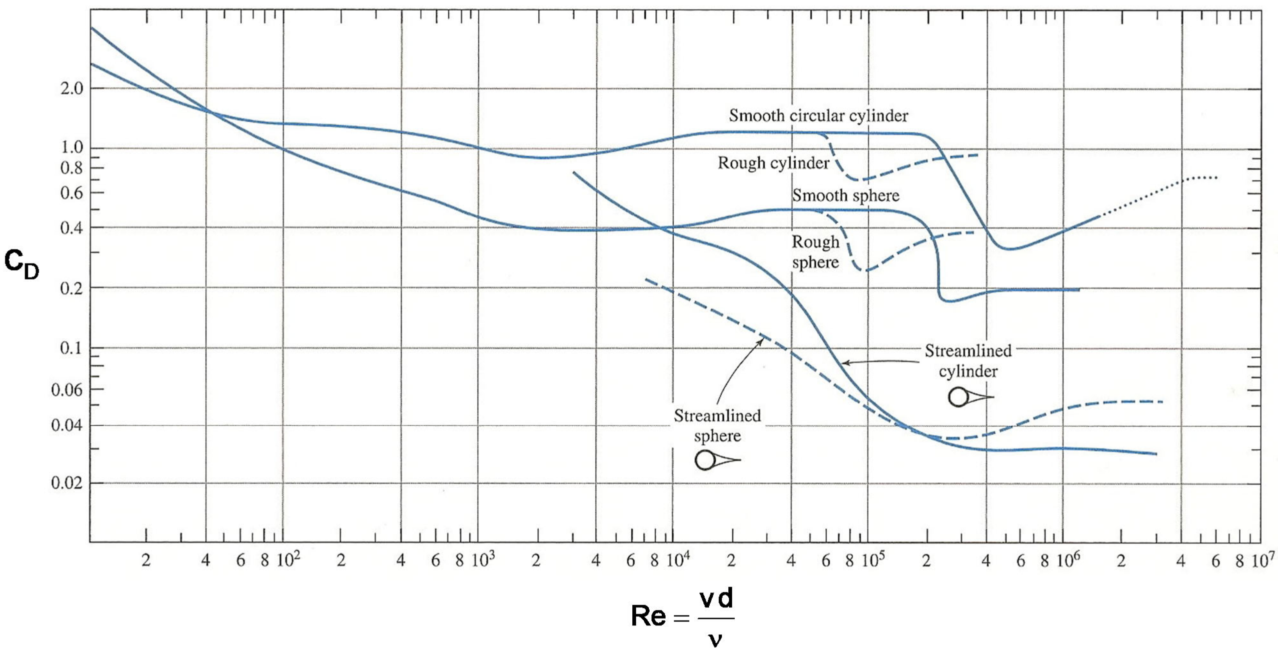
Density of sphere: $\rho_{Sphere} = 1{,}050 \frac{kg}{m^3}$

Density of air: $\rho_{Air} = 1.28 \frac{kg}{m^3}$

Kinematic viscosity of air: $\nu_{Air} = 1.6 \times 10^{-5} \frac{m^2}{s}$

Volume of sphere: $V_{Sphere} = \frac{\pi}{6} d^3$

Give rationale for your assumptions!



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Question 6 … Wind energy **Points: 12**

The torque of a windmill can be generated by rotating blades at a certain speed.

a) Assuming the wind is moving from left to right, indicate the direction of rotation of the windmill shown in the picture. Is it clockwise or counter clockwise?

b) Why are the blades twisted from the root to the tip? Use three velocity polygons at different radii for your explanations. Use the template shown below for the drawing (- and a ruler!).

c) Determine the diameter of a wind turbine under the following conditions:

Power output: $P_T = 2.5\ \text{MW}$

Wind velocity: $v = 30\ \frac{\text{km}}{\text{h}}$

Density of air: $\rho_{Air} = 1.2\ \frac{\text{kg}}{\text{m}^3}$

Betz coefficient: $c_P = 0.5$

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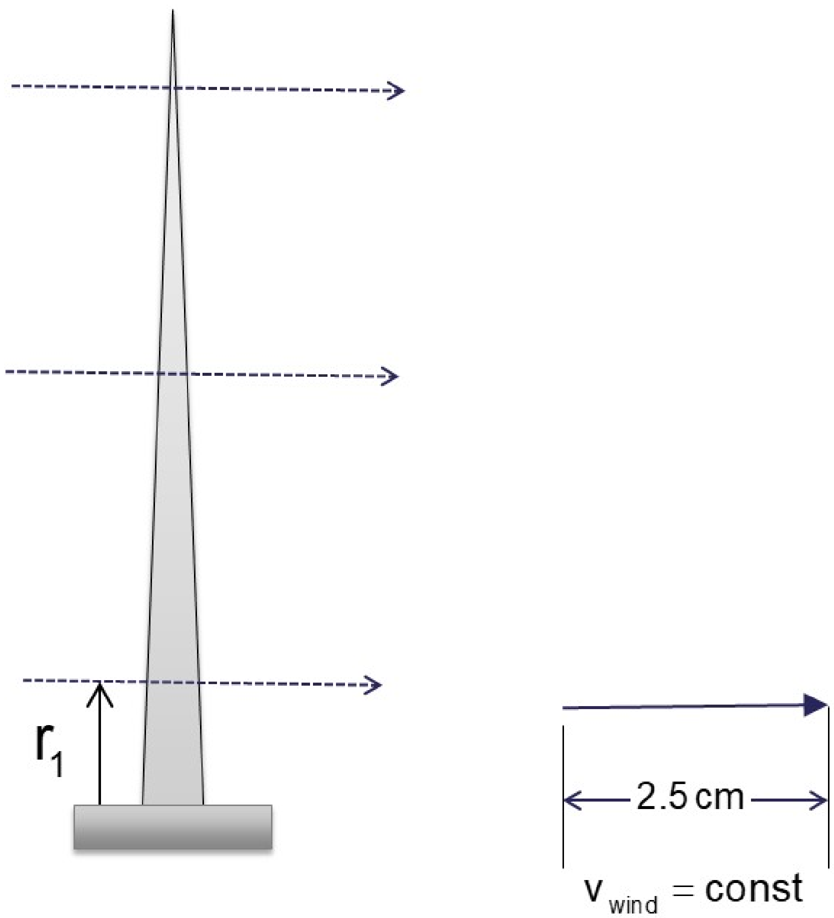

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End of exam