INTERACTIVE TOOLS FOR ENGINEERING EDUCATION

Pieter Roos, TELT-talk, 16 January 2025

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INTERACTIVE TOOLS FOR ENGINEERING EDUCATION

GRASPLE WORKS FOR MATH, BUT WHAT ABOUT ENGINEERING?

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HOW FAR SHOULD WE GO
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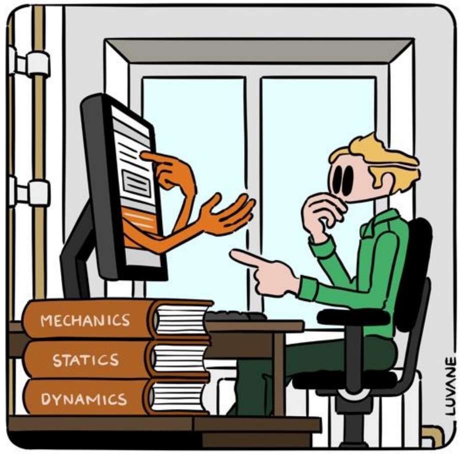

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- MATH VS ENGINEERING
- WHAT IS GRASPLE?
- PILOT STUDY: FLUID MECHANICS
- DISCUSSION: YOUR OPINION?

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MATH VS ENGINEERING

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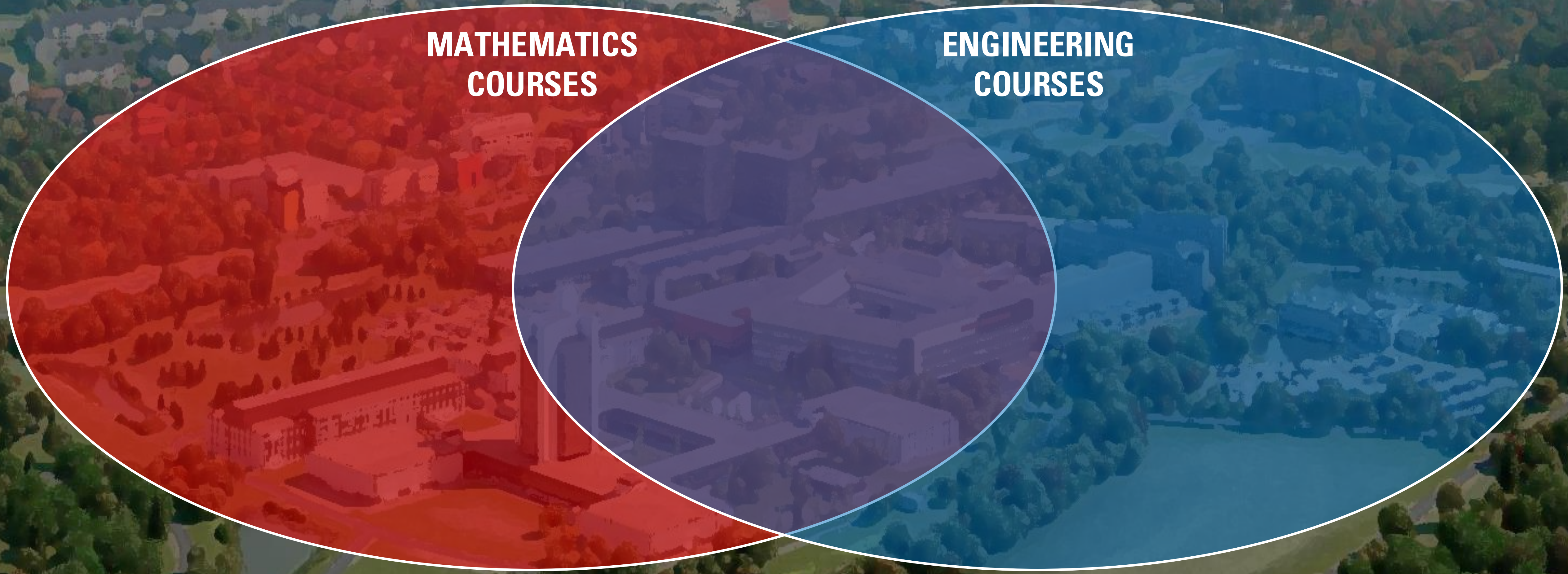
MATH VS ENGINEERING



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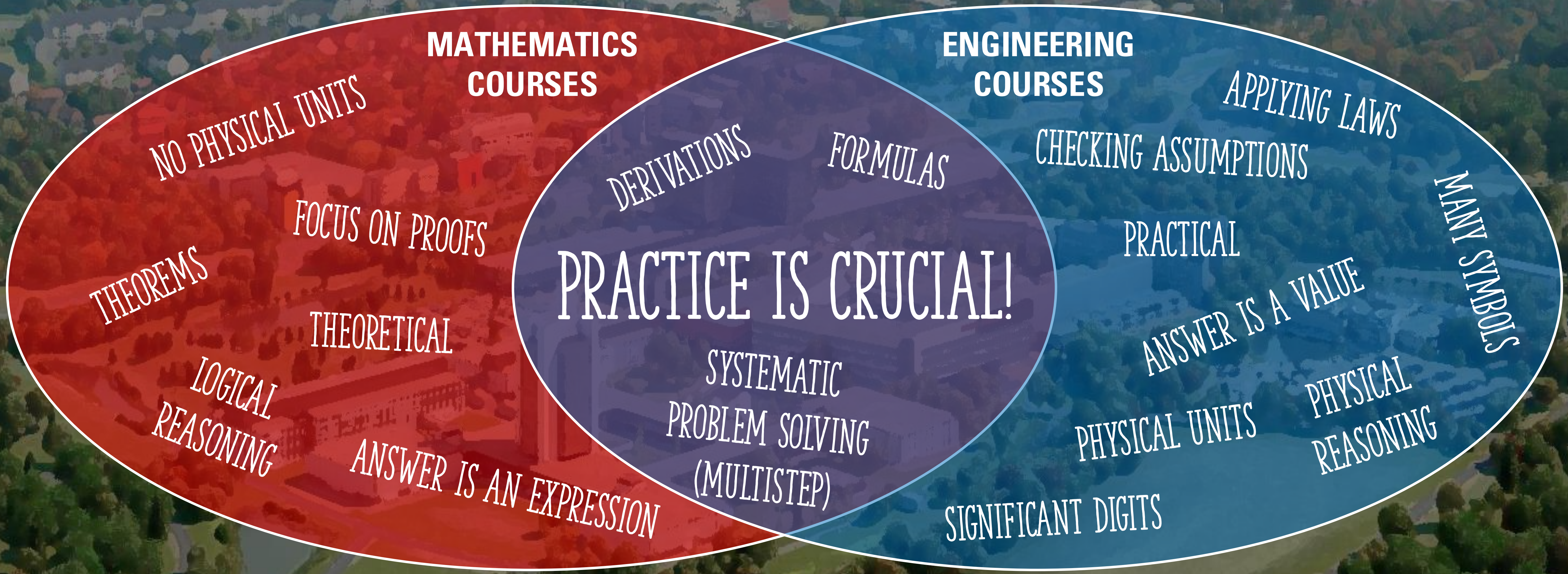
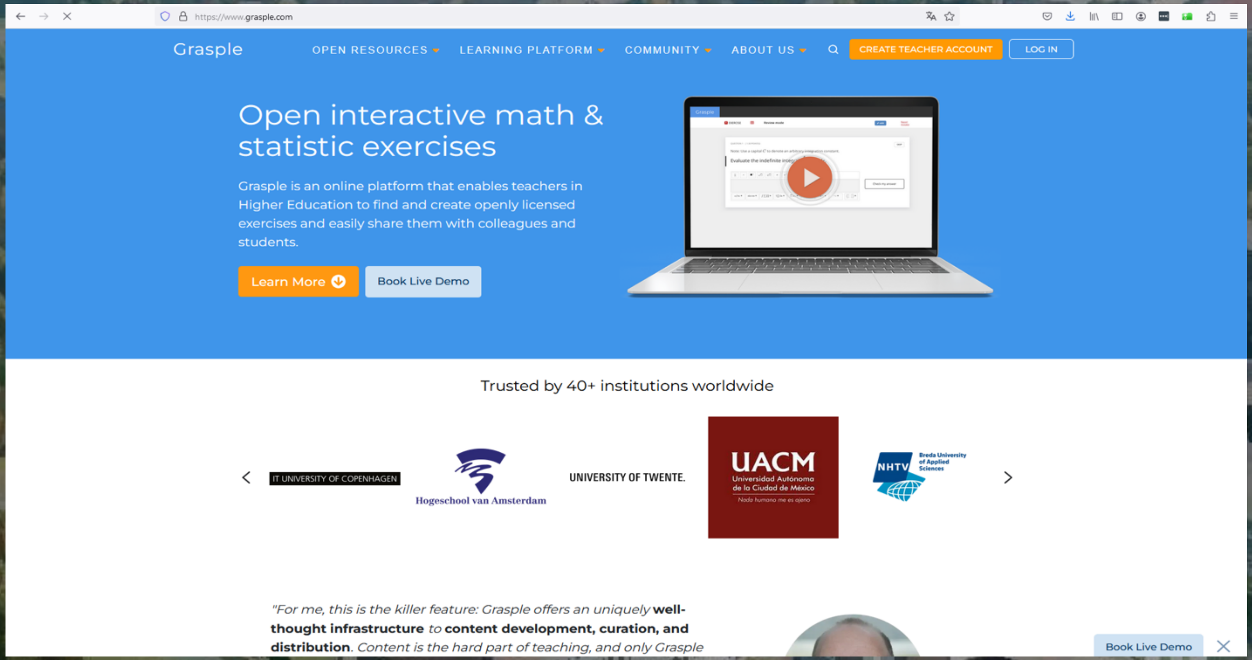
MATH VS ENGINEERING



WHAT IS GRASPLE?



GRASPLE

- Interactive online practice platform
- For mathematics and statistics
- UT is client
- Formative and summative testing
- Sharing exercises among teachers
- Strong point: symbolic algebra

Example: The four expressions

$$V = \sqrt{2g(z_2 - z_1)}$$

$$V = \sqrt{2gz_2 - 2gz_1}$$

$$V = \sqrt{2(gz_2 - gz_1)}$$

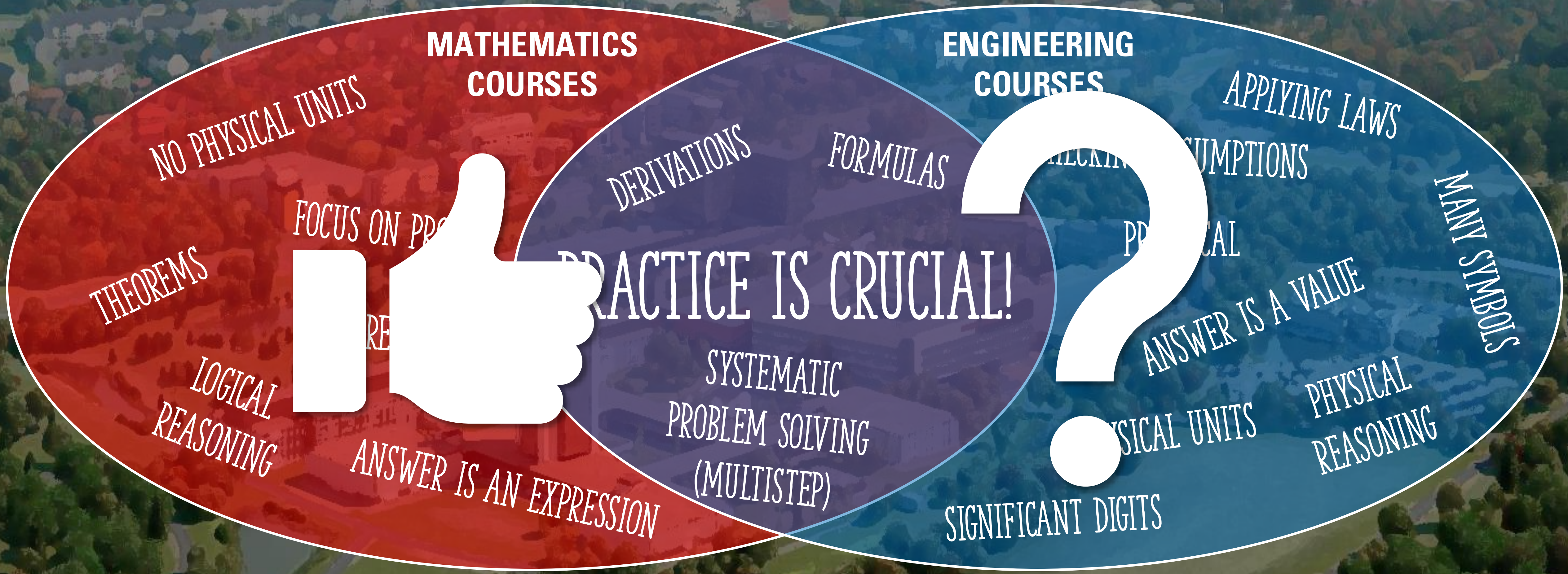
$$V = (2g(z_2 - z_1))^{1/2}$$

are all **mathematically equivalent**, but they differ in syntax. Grasple's **Computer Algebra System** automatically detects this equivalence, which aids the digital assessment of student's answers.

GRASPLE

- Interactive online practice platform
- For mathematics and statistics
- UT is client
- Formative and summative testing
- Sharing exercises among teachers
- Strong point: symbolic algebra
- Another strong point: conditional logic
- Question: "Grasple works for math, but what about engineering?"

WHAT IS GRASPLE?



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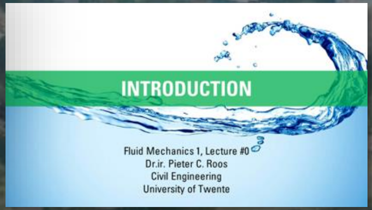
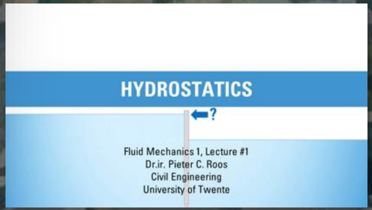
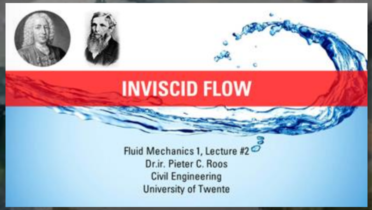
PILOT STUDY: FLUID MECHANICS

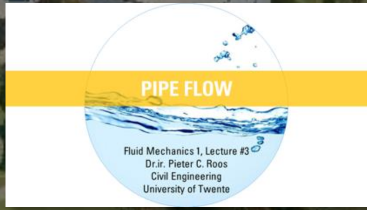
Goal:
to explore how Grasple can support self-study in Fluid Mechanics 1

<< N.B.: not intended to replace tutorials! >>









FLUID MECHANICS 1

1st year BSc Civil Engineering
Number of students: ~100
Study load: 2 EC
4x Lecture, 3x Tutorial
- General Principles
- Hydrostatics
- Inviscid Flow
- Pipe Flow

Assessment: written exam

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PILOT STUDY: FLUID MECHANICS

1. Literature review
2. Teaching FM1 in 2022/23
3. Interviewing FM-teachers
4. Exploring Grasple
5. Panel meeting with students
6. Develop and test new tool
7. Teaching FM1 in 2023/24
8. Evaluation of new tool

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PILOT STUDY: FLUID MECHANICS

Main challenges:

- Resemble self-study setting that students would have without a computer
- Stimulate 'good behaviour'
- Systematic problem-solving
- Allow for multiple solution paths (conditional logic)
- Do not give away answers!
- Avoid visual confusion

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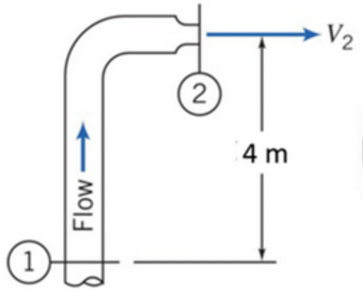
PILOT STUDY: FLUID MECHANICS

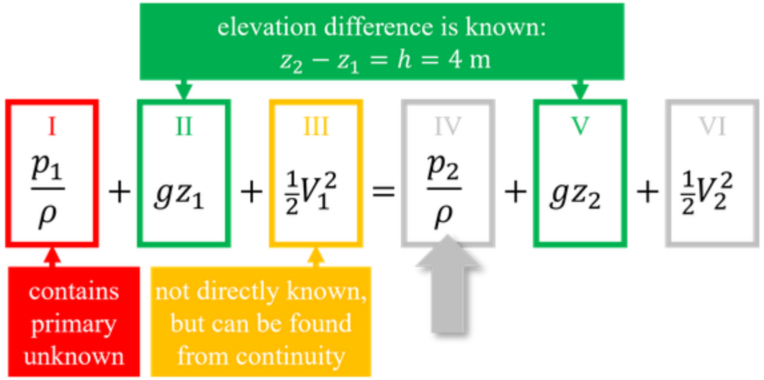
1. **1** Literature review
2. **2** Teaching FM1 in 2022/23
3. **3** Interviewing FM-teachers
4. **4** Exploring Grasple
5. **5** Panel meeting with students
6. **6** Develop and test new tool
7. **7** Teaching FM1 in 2023/24
8. **8** Evaluation of new tool

You are done with this question. A follow-up question is shown below.

QUESTION #87353 | ATTEMPTS USED: 0 OUT OF 2

Problem description: Water flows steadily through the vertical 0.10 m diameter pipe and out the 0.050 m in diameter nozzle to the atmosphere. See figure below, showing a side view with gravity pointing downward. Determine the minimum gage pressure required at section 1 to produce a velocity at the nozzle exit (section 2) of 20 m/s.





Step 3.5: Let us now turn to Term IV in the *Bernoulli equation* above.

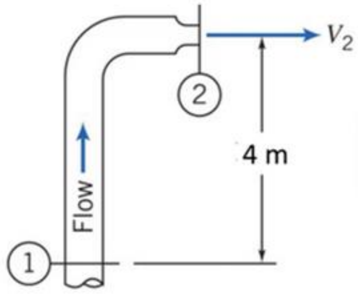
In one word, what can you say about the pressure p_2 in term IV?

atmospheric

Check my answer

QUESTION #87354 | ATTEMPTS USED: 0 OUT OF 2

Problem description: Water flows steadily through the vertical 0.10 m diameter pipe and out the 0.050 m in diameter nozzle to the atmosphere. See figure below, showing a side view with gravity pointing downward. Determine the minimum gage pressure required at section 1 to produce a velocity at the nozzle exit (section 2) of 20 m/s.



elevation difference is known: $z_2 - z_1 = h = 4$ m

$$\underbrace{\frac{p_1}{\rho}}_{\text{I}} + \underbrace{gz_1}_{\text{II}} + \underbrace{\tfrac{1}{2}V_1^2}_{\text{III}} = \underbrace{\frac{p_2}{\rho}}_{\text{IV}} + \underbrace{gz_2}_{\text{V}} + \underbrace{\tfrac{1}{2}V_2^2}_{\text{VI}}$$

- I: contains primary unknown
- III: not directly known, but can be found from continuity
- IV: nozzle open to atmosphere, so $p_2 = p_{atm}$

Step 3.6: Finally, we analyse term VI in the *Bernoulli equation* above.

What can you say about the quantity V_2 in term VI?

Directly given in problem description | Not directly known, but can be obtained from physical principle | Fully unknown

PILOT STUDY: FLUID MECHANICS

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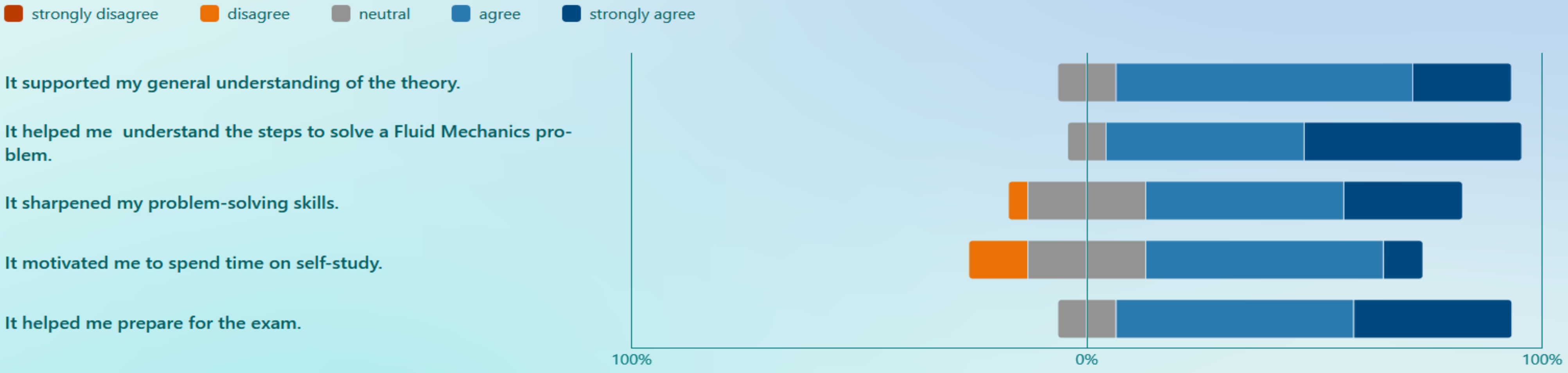
26 verzonden antwoorden

What is your opinion on the learning effect of Grasple in Fluid Mechanics 1?



PILOT STUDY: FLUID MECHANICS

Main conclusions:
- Promising tool
- Students satisfied
- Multistep solutions
- Multiple solution paths
- Grasple needs further modification (physical units, significant digits, ...)
- Time-consuming
- (Un)desired side effects...?

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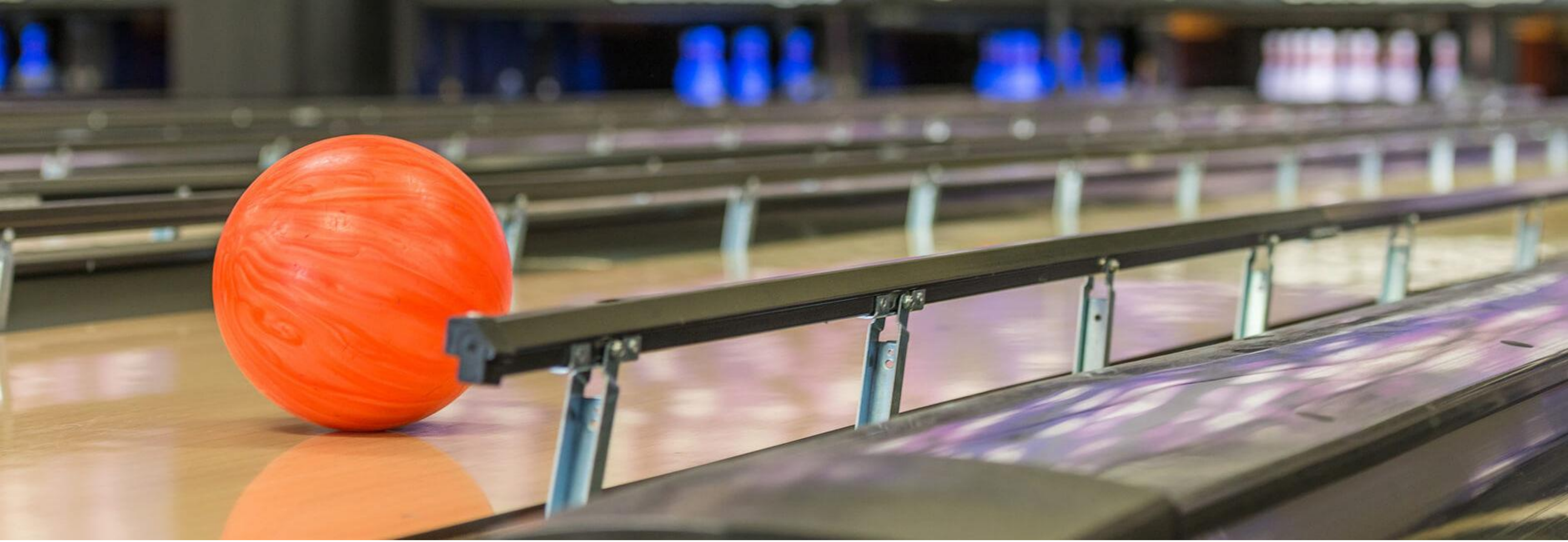
DISCUSSION: YOUR OPINION?

Main conclusions:

- Promising tool
- Students satisfied
- Multistep solutions
- Multiple solution paths
- Grasple needs further modification (physical units, significant digits, ...)
- Time-consuming
- (Un)desired side effects...?

IF FM1 WERE CYCLING, THEN USING GRASPLE IS…



IF FM1 WERE BOWLING, THEN USING GRASPLE IS…

Thanks to Cas Jansen, Jolanda van de Kooij, Sofie Bastiaansen, Robin van Emmerloot, Cornelise Vreman-de Olde, Cindy Poortman, Kirsten Stadermann, UT's Fluid Mechanics teachers, FM1-students and TAs.

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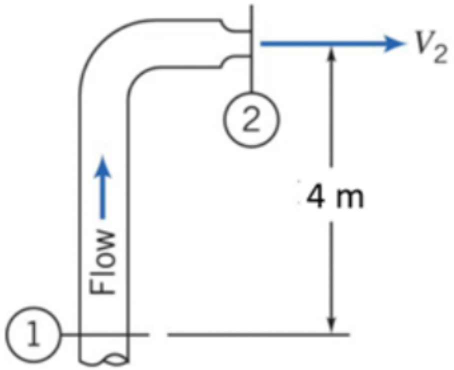
Appendix A

Example of FM1-exercise in Grasple

QUESTION #77141 | ATTEMPTS USED: 0 OUT OF 2

Problem description: Water flows steadily through the vertical 0.10 m diameter pipe and out the 0.050 m in diameter nozzle to the atmosphere. See figure below, showing a side view with gravity pointing downward. Determine the minimum gage pressure required at section 1 to produce a velocity at the nozzle exit (section 2) of 20 m/s.



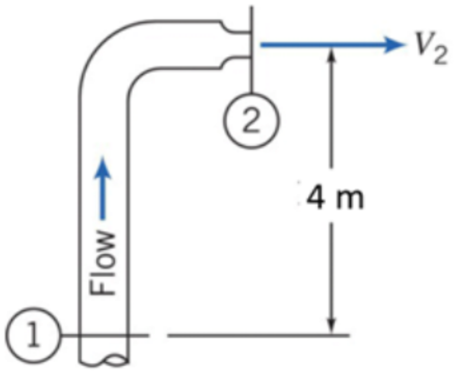
Step 1: Let us first characterize the above problem within the context of **FM1**.

What type of problem is this?

Hydrostatics | Inviscid flow (open channel) | Pipe flow (with losses) | Inviscid flow (pipe)

QUESTION #87313 | ATTEMPTS USED: 0 OUT OF 2

Problem description: Water flows steadily through the vertical 0.10 m diameter pipe and out the 0.050 m in diameter nozzle to the atmosphere. See figure below, showing a side view with gravity pointing downward. Determine the minimum gage pressure required at section 1 to produce a velocity at the nozzle exit (section 2) of 20 m/s.



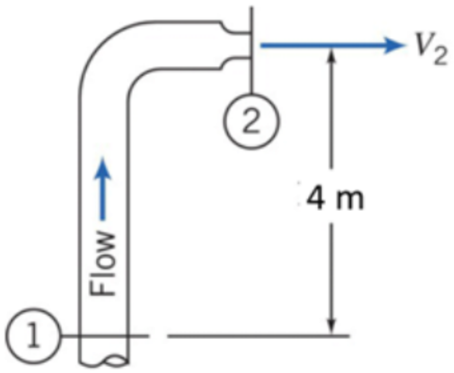
Step 2.1: We must now identify the overall law or principle.

Which law/principle would you apply here?

Bernoulli's law

Check my answer

velocity at the nozzle exit (section 2) of 20 m/s.

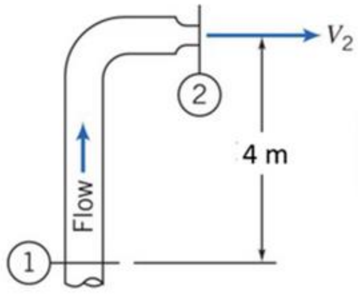


Step 2.2: Let us verify whether the conditions for application of the *Bernoulli equation* are indeed satisfied.

What are these conditions?

- Inviscid+Unsteady+Incompressible
- Inviscid+Steady+Incompressible
- Viscous+Steady+Compressible
- Viscous+Unsteady+Incompressible
- Iniviscid+Unsteady+Compressible
- Inviscid+Steady+Compressible
- Viscous+Unsteady+Compressible
- Viscous+Steady+Incompressible

Problem description: Water flows steadily through the vertical 0.10 m diameter pipe and out the 0.050 m in diameter nozzle to the atmosphere. See figure below, showing a side view with gravity pointing downward. Determine the minimum gage pressure required at section 1 to produce a velocity at the nozzle exit (section 2) of 20 m/s.



$$\underbrace{\frac{p_1}{\rho}}_{\text{I}} + \underbrace{g z_1}_{\text{II}} + \underbrace{\tfrac{1}{2}V_1^2}_{\text{III}} = \underbrace{\frac{p_2}{\rho}}_{\text{IV}} + \underbrace{g z_2}_{\text{V}} + \underbrace{\tfrac{1}{2}V_2^2}_{\text{VI}}$$

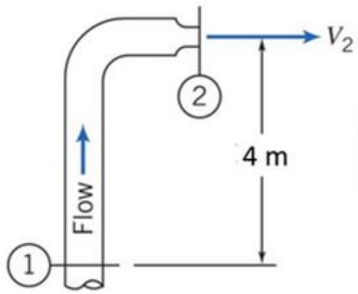
Step 3.1: Let us now analyse the *Bernoulli equation* for the flow along a streamline between section 1 and section 2. See above, where we have identified six terms I, II, III, IV, V and VI.
N.B.: you must know this equation by heart!

Which of the six terms contains the primary unknown of this problem?

Term I | Term II | Term III | Term IV | Term V | Term VI

QUESTION #87350 | ATTEMPTS USED: 0 OUT OF 2

Problem description: Water flows steadily through the vertical 0.10 m diameter pipe and out the 0.050 m in diameter nozzle to the atmosphere. See figure below, showing a side view with gravity pointing downward. Determine the minimum gage pressure required at section 1 to produce a velocity at the nozzle exit (section 2) of 20 m/s.



$$\underbrace{\frac{p_1}{\rho}}_{\text{I}} + \underbrace{g z_1}_{\text{II}} + \underbrace{\tfrac{1}{2}V_1^2}_{\text{III}} = \underbrace{\frac{p_2}{\rho}}_{\text{IV}} + \underbrace{g z_2}_{\text{V}} + \underbrace{\tfrac{1}{2}V_2^2}_{\text{VI}}$$

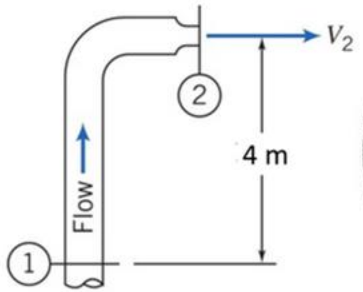
Term I: contains primary unknown

Step 3.2: Let us now move to the second term in the *Bernoulli equation* above.

What can you say about Term II?

- Fully unknown
- Fully known from problem description
- Unknown, but difference between II and V is known

Problem description: Water flows steadily through the vertical 0.10 m diameter pipe and out the 0.050 m in diameter nozzle to the atmosphere. See figure below, showing a side view with gravity pointing downward. Determine the minimum gage pressure required at section 1 to produce a velocity at the nozzle exit (section 2) of 20 m/s.



elevation difference is known: $z_2 - z_1 = h = 4$ m

$$\underbrace{\frac{p_1}{\rho}}_{\text{I}} + \underbrace{g z_1}_{\text{II}} + \underbrace{\tfrac{1}{2}V_1^2}_{\text{III}} = \underbrace{\frac{p_2}{\rho}}_{\text{IV}} + \underbrace{g z_2}_{\text{V}} + \underbrace{\tfrac{1}{2}V_2^2}_{\text{VI}}$$

I: contains primary unknown

Step 3.3: The next step is to analyse Term III in the *Bernoulli equation* above.

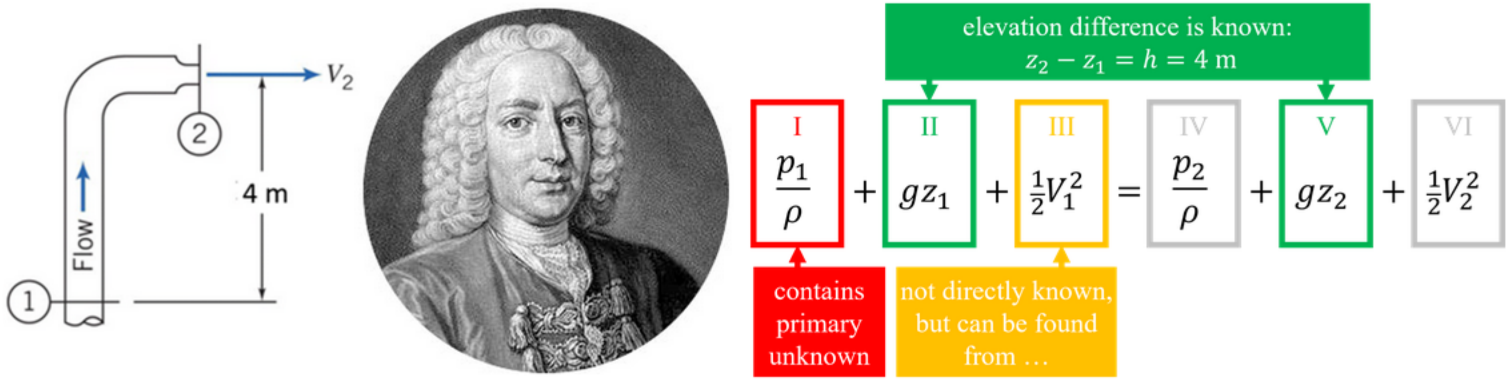
What is the most accurate statement about Term III?

- Fully unknown
- Not directly known, but can be readily obtained from another physical principle
- Directly given in problem description

You are done with this question. A follow-up question is shown below.

QUESTION #87352 | ATTEMPTS USED: 0 OUT OF 10

Problem description: Water flows steadily through the vertical 0.10 m diameter pipe and out the 0.050 m in diameter nozzle to the atmosphere. See figure below, showing a side view with gravity pointing downward. Determine the minimum gage pressure required at section 1 to produce a velocity at the nozzle exit (section 2) of 20 m/s.



Step 3.4: Indeed, term III can be obtained by applying a physical principle.

What is the name of that physical principle?

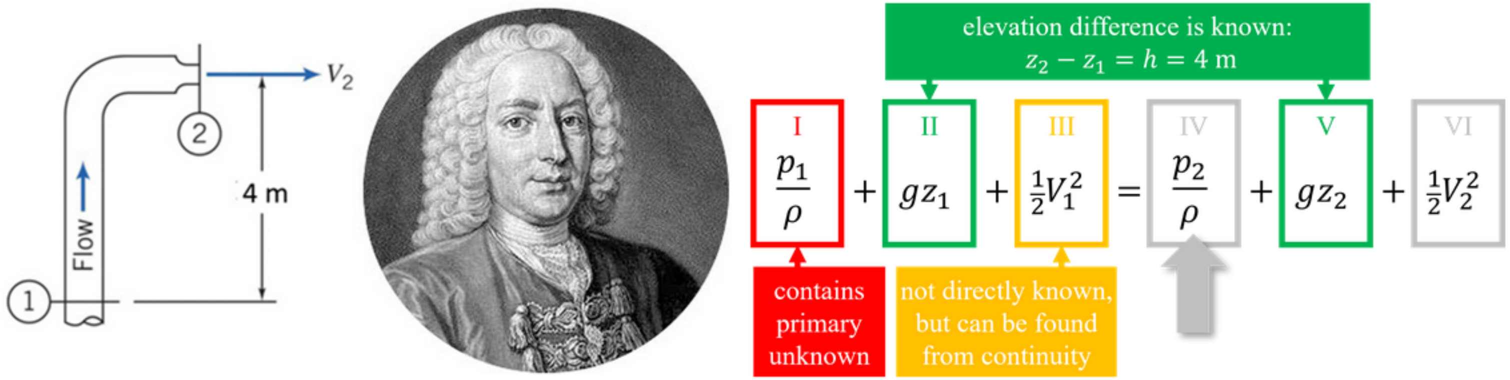
continuity

Check my answer

You are done with this question. A follow-up question is shown below.

QUESTION #87353 | ATTEMPTS USED: 0 OUT OF 2

Problem description: Water flows steadily through the vertical 0.10 m diameter pipe and out the 0.050 m in diameter nozzle to the atmosphere. See figure below, showing a side view with gravity pointing downward. Determine the minimum gage pressure required at section 1 to produce a velocity at the nozzle exit (section 2) of 20 m/s.



Step 3.5: Let us now turn to Term IV in the *Bernoulli equation* above.

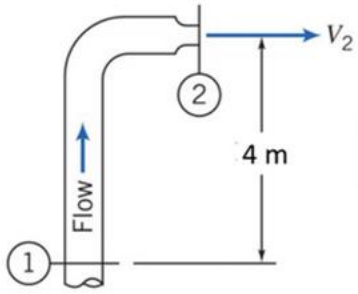
In one word, what can you say about the pressure p_2 in term IV?

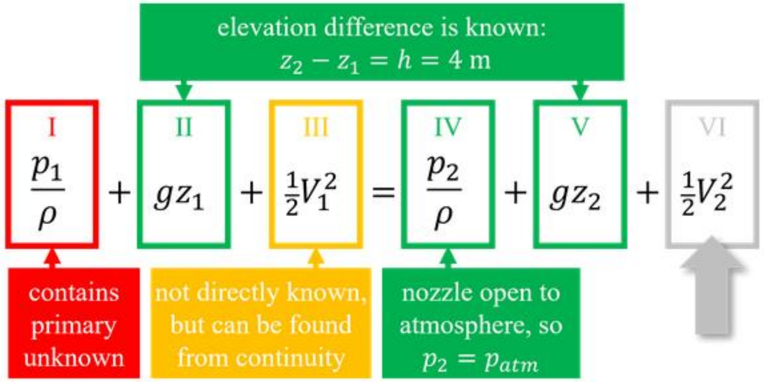
atmospheric

Check my answer

QUESTION #87354 | ATTEMPTS USED: 0 OUT OF 2

Problem description: Water flows steadily through the vertical 0.10 m diameter pipe and out the 0.050 m in diameter nozzle to the atmosphere. See figure below, showing a side view with gravity pointing downward. Determine the minimum gage pressure required at section 1 to produce a velocity at the nozzle exit (section 2) of 20 m/s.

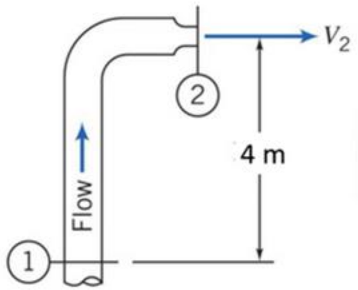


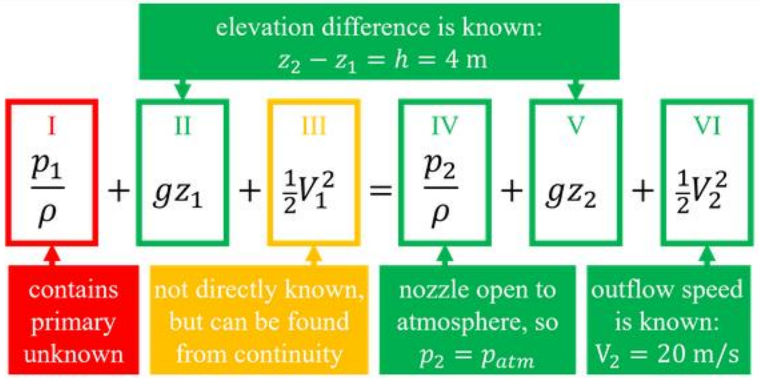


Step 3.6: Finally, we analyse term VI in the *Bernoulli equation* above.

What can you say about the quantity V_2 in term VI?

Directly given in problem description | Not directly known, but can be obtained from physical principle | Fully unknown





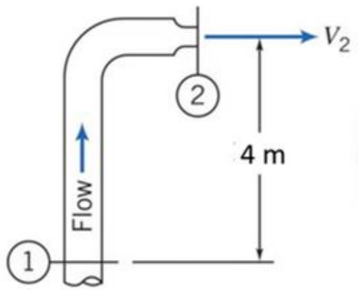
Step 4.1: Let us now return to term III, and obtain it using the principle of *continuity*. To this end, we will first derive an expression for the *flow velocity* at section 1: $V_1 = \ldots$

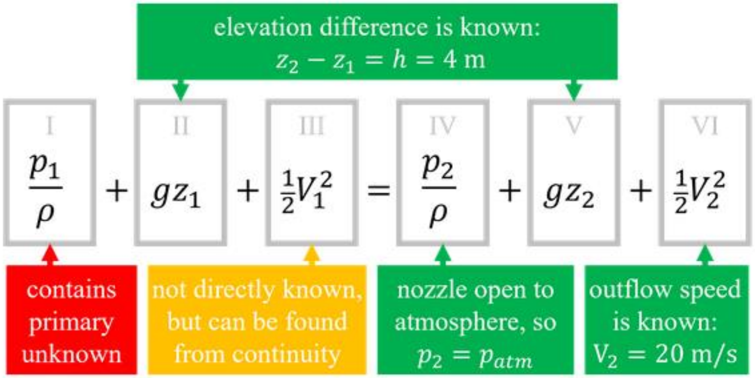
We let D_1 denote the pipe diameter (e.g., at section 1) and D_2 the nozzle diameter (at section 2).

Complete the above equation by providing an expression for V_1.

[N.B.: do this in terms of D_1 and D_2; do not insert numerical values.]

Check my answer





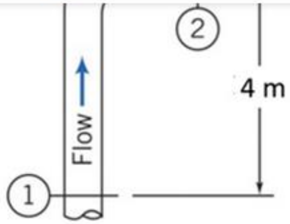
Step 4.2: The result you just obtained can also be written as $V_1 = C^2 V_2$,

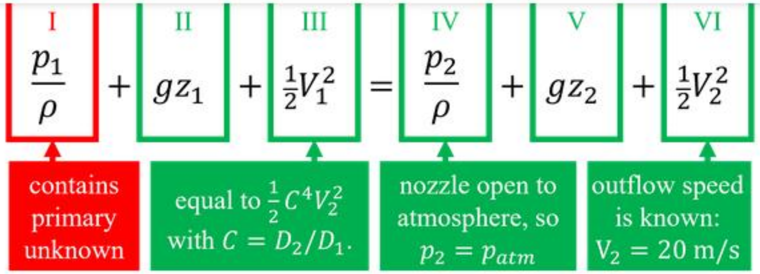
where for convenience we have introduced the *diameter ratio* $C = D_2/D_1$.

In terms of V_2 and this diameter ratio C, let us now rewrite term III.

What is the correct expression for term III?

Check my answer





Step 5.1: After having completed the analysis of all six terms in the *Bernoulli equation*, we must combine all information gathered. This leads to

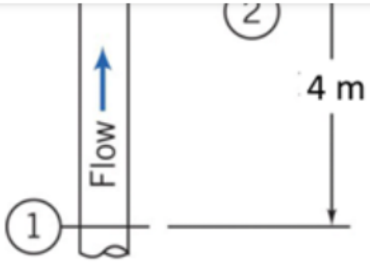
$$\frac{p_1}{\rho} + \frac{1}{2}C^4V_2^2 = \frac{p_{atm}}{\rho} + gh + \frac{1}{2}V_2^2.$$

This last result can be rearranged to find an expression for the pressure at section 1: $p_1 = \dots$

Complete the expression above.

[N.B.: do not insert values and keep the diameter ratio C and height h.]

Check my answer



Step 5.2: We may thus write $p_1 = p_{atm} + \rho g h + \frac{1}{2}\rho\left(1 - C^4\right) V_2^2$,

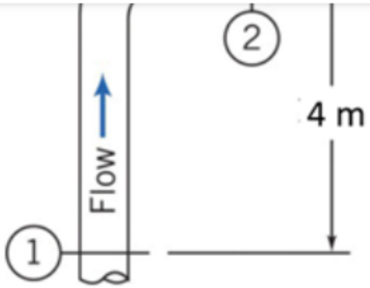
in which all parameters on the right-hand side are known.

However, since the **gage pressure** at section 1 is requested, we must rearrange the above result into $p_{1,gage} = \dots$

Complete the expression for the gage pressure.

[N.B.: do not insert values and keep the diameter ratio C and height h.]

Check my answer



Step 6.1: We have obtained $p_{1,gage} = \rho g h + \frac{1}{2}\rho\left(1 - C^4\right)V_2^2$

with $C = D_2/D_1$ such that all parameter values on the right-hand side are known.

The last step is to provide the correct answer, in which three aspects are important:

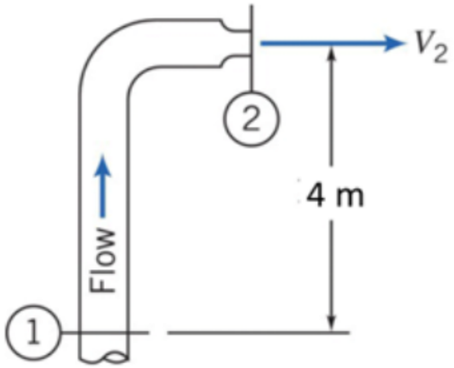
- correct value
- appropriate number of significant digits
- appropriate physical units.

What are the correct **number of digits** and the correct **physical units**?

2 digits, N | 3 digits, N/m | 3 digits, N/m² | 1 digit, N | 3 digits, N | 1 digit, N/m² | 2 digits, N/m

2 digits, N/m² | 1 digit, N/m

0.050 m in diameter nozzle to the atmosphere. See figure below, showing a side view with gravity pointing downward. Determine the minimum gage pressure required at section 1 to produce a velocity at the nozzle exit (section 2) of 20 m/s.



Step 6.2: We have obtained $p_{1,gage} = \rho g h + \frac{1}{2}\rho\left(1 - C^4\right) V_2^2$, and know that we must provide the answer in N/m^2 with one significant digit.

Finally, calculate the numerical value of the gage pressure

[N.B.: value only, no physical units]

Check my answer

Step 6.2: We have obtained $p_{1,gage} = \rho g h + \frac{1}{2}\rho\left(1 - C^4\right)V_2^2$, and know that we must provide the answer in N/m^2 with one significant digit.

Finally, calculate the numerical value of the gage pressure
[N.B.: value only, no physical units]

Your answer: 227000

Yeah! That's right. The correct answer is 226740

next

And, using one significant digit and the correct physical units, this should be finally written as: $p_{1,gage} = 2 \times 10^5$ Pa.

This completes the exercise, which we have solved in six steps:

1. Note that this is an **inviscid pipe flow** problem.
2. Identify **Bernoulli's law** as the governing principle, and verify that it is indeed applicable.
3. **Analyse all terms** in the Bernoulli equation, when applied to a streamline between section 1 (pipe) and section 2 (nozzle).
4. Specifically, apply **continuity** to express the velocity in at section 1 in terms of that in the nozzle and the diameter ratio.
5. **Rearrange** the terms in the Bernoulli equation to obtain an expression for the **gage pressure** at section 1.
6. Substitute values to compute the value of the gage pressure at section 1.

You have completed the whole exercise.

Appendix B

Results from evaluation among FM1-students

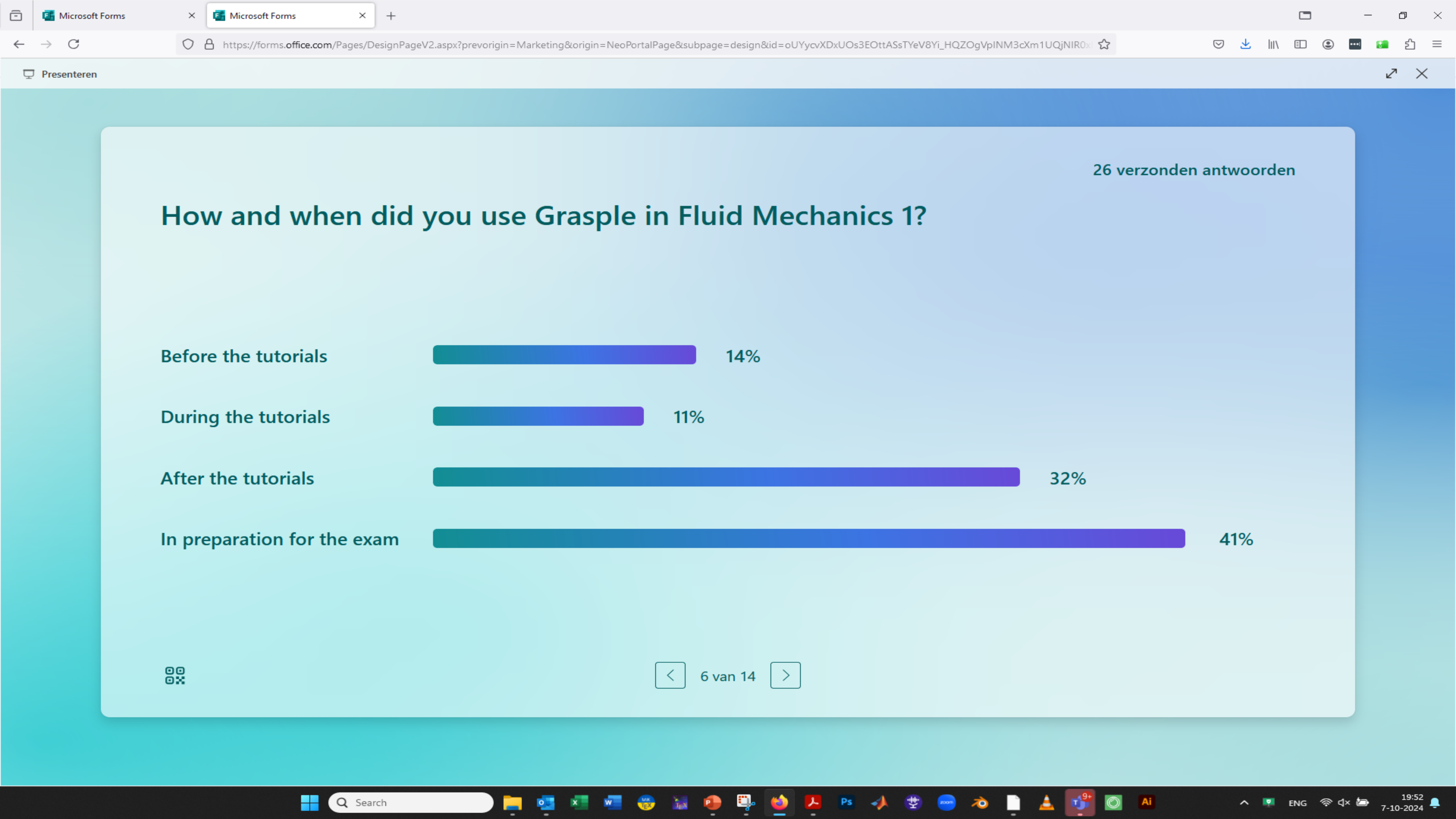
Presenteren

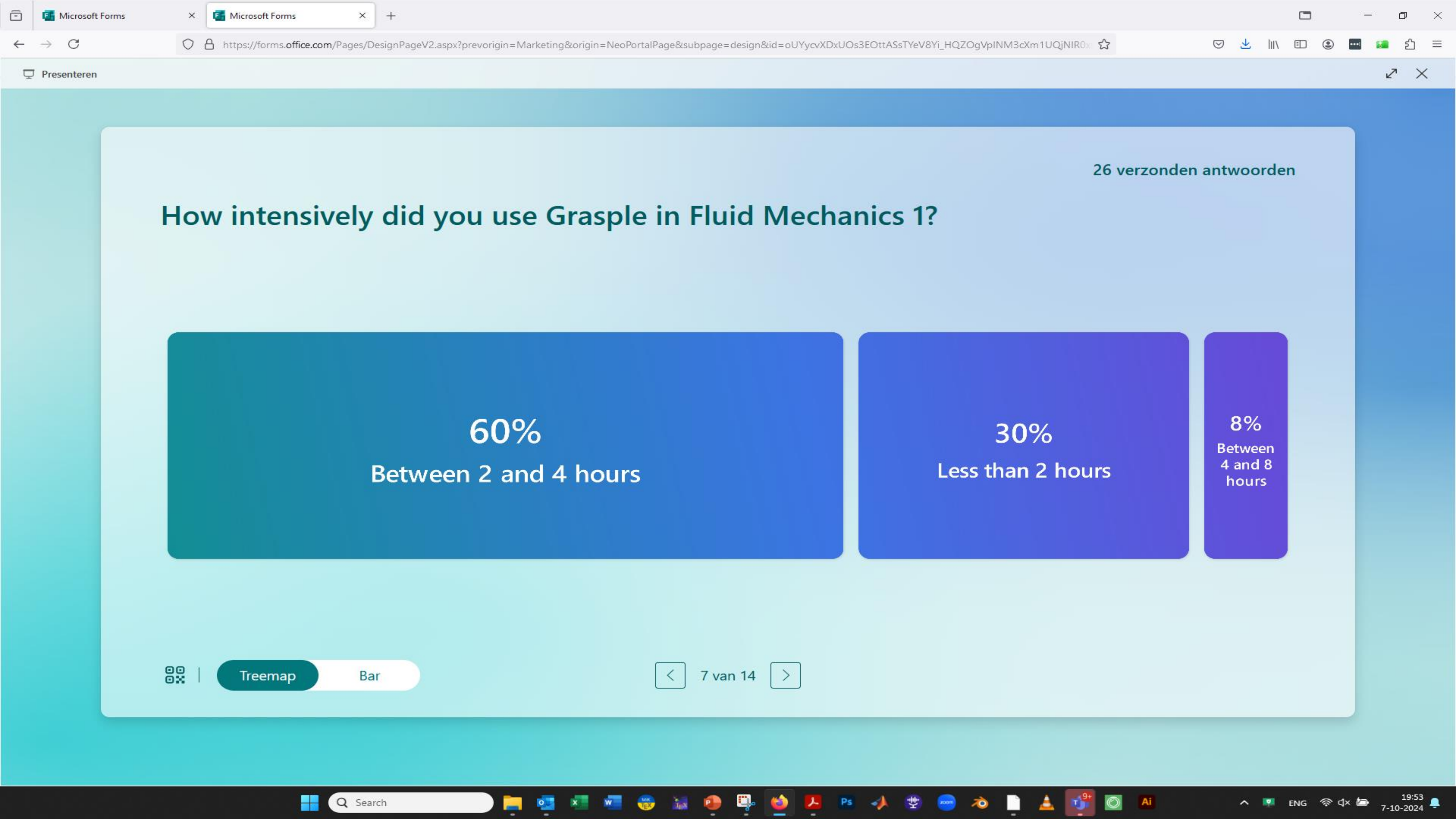
26 verzonden antwoorden

Did you use Grasple in Fluid Mechanics 1?

Treemap Bar

4 van 14


Microsoft Forms
Microsoft Forms
https://forms.office.com/Pages/DesignPageV2.aspx?prevorigin=Marketing&origin=NeoPortalPage&subpage=design&id=oUYycvXDxUOs3EOttASsTYeV8Yi_HQZOgVpINM3cXm1UQjNIR0
Presenteren
26 verzonden antwoorden
How and when did you use Grasple in Fluid Mechanics 1?
Before the tutorials
14%
During the tutorials
11%
After the tutorials
32%
In preparation for the exam
41%
6 van 14
Search
ENG
19:52
7-10-2024



Microsoft Forms
Microsoft Forms
https://forms.office.com/Pages/DesignPageV2.aspx?prevorigin=Marketing&origin=NeoPortalPage&subpage=design&id=oUYycvXDxUOs3EOttASsTYeV8Yi_HQZOgVpINM3cXm1UQjNIR0
Presenteren
26 verzonden antwoorden
How intensively did you use Grasple in Fluid Mechanics 1?
60%
Between 2 and 4 hours
30%
Less than 2 hours
8%
Between 4 and 8 hours
Treemap
Bar
7 van 14
Search
ENG
19:53
7-10-2024

26 verzonden antwoorden

How did you experience working with Grasple in Fluid Mechanics 1?

strongly disagree · disagree · neutral · agree · strongly agree

Logging onto the platform was easy.

The landing page was clear and easy to navigate.

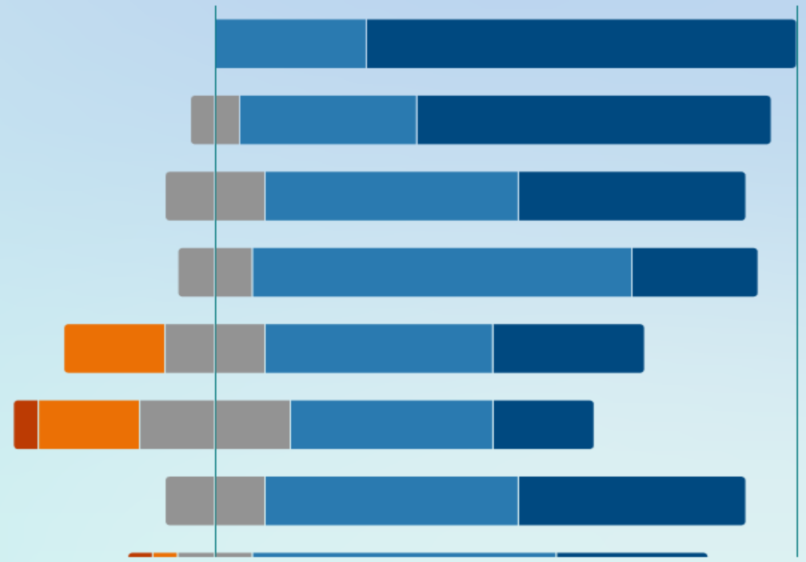
The information provided at the start of each exercise was clear.

The break-down of exercises into subquestions was logical.

The equation editor was easy to use.

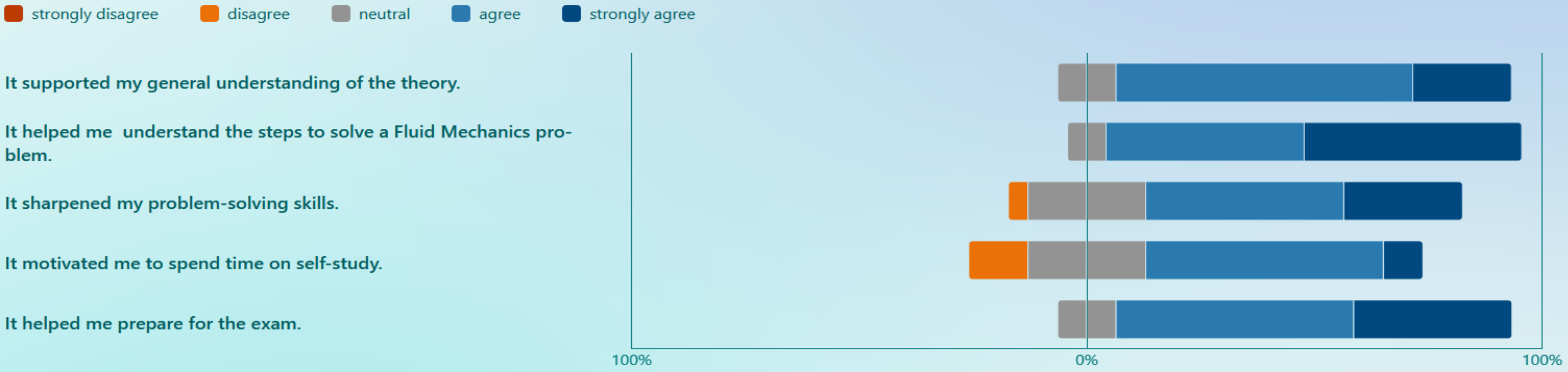
The feedback to the answers was clear and helpful.

The visual support (including colors, images, equations) within the exercises is clear.



26 verzonden antwoorden

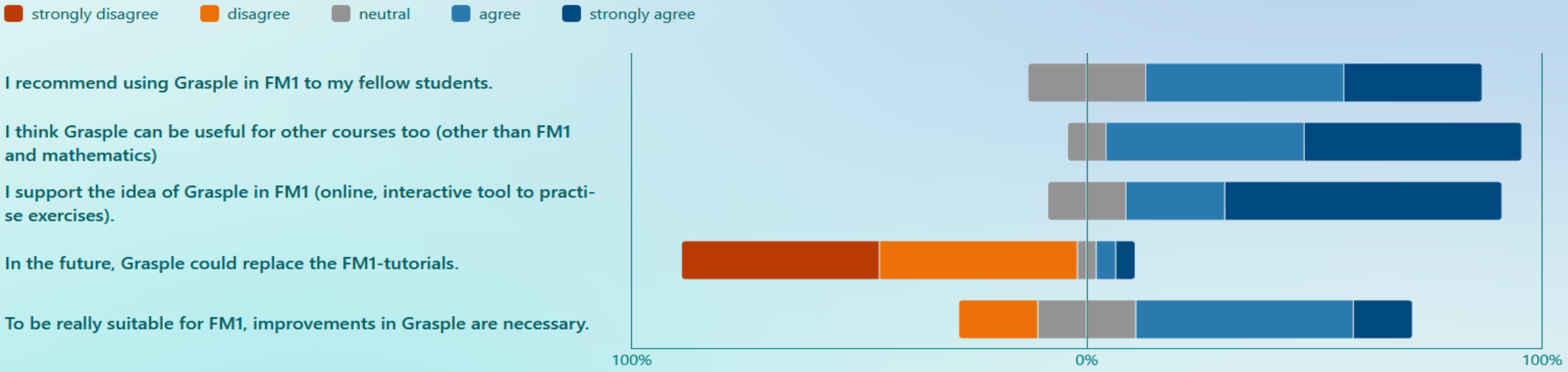
What is your opinion on the learning effect of Grasple in Fluid Mechanics 1?



Presenteren

26 verzonden antwoorden

How do you evaluate this Grasple pilot in Fluid Mechanics 1?



Presenteren

26 verzonden antwoorden

What is, in your opinion, the best aspect of Grasple in Fluid Mechanics 1?

Wordcloud | Alle antwoorden

12 van 14

Microsoft Forms | Microsoft Forms

Presenteren

26 verzonden antwoorden

What should, in your opinion, be improved regarding Grasple in Fluid Mechanics 1?

additional exercises
answers are helpful
actual answer
multiple times
wrong attempts
correct answer
exercises
intermediate answers
answers
way
answers to the questions
Grasple
final answers
wrong answer
needed
wrong Grasple
right answer
answer and an explanation
answer of the problem
exercises similar

Wordcloud | Alle antwoorden

13 van 14