




How to make students study during the semester or Interactive sequences in teaching mechanics (with practical examples)

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**Keep your cell phones
handy – we will ask
you to participate!**

Input

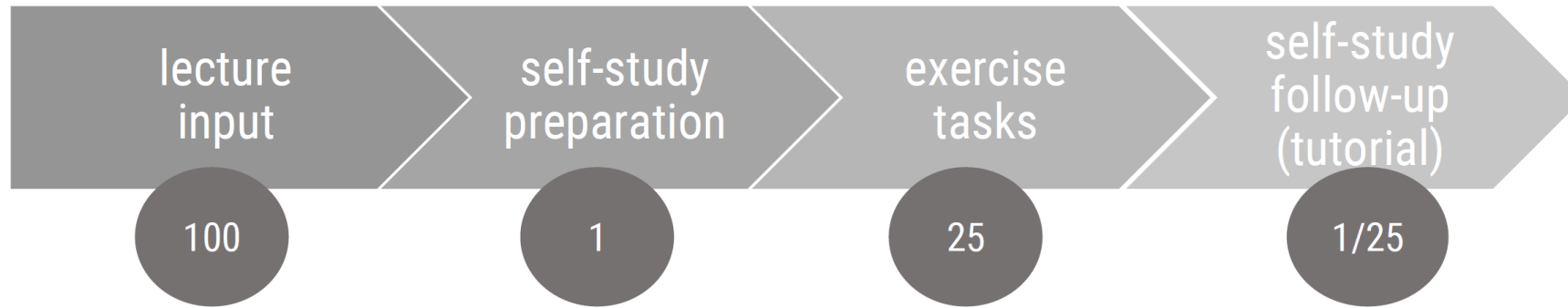
**flipped classroom,
peer-instruction,
just-in-time-teaching**

Learning outcome

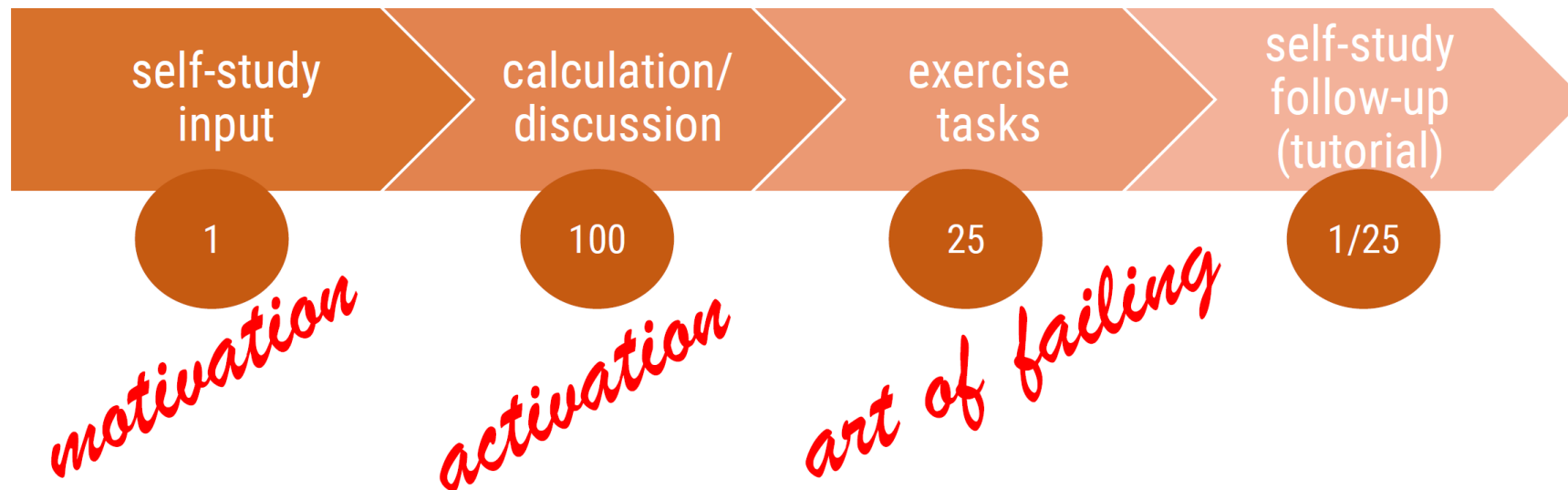
**You can describe the essential components of the
named teaching concepts.**



week in classic classroom



week in flipped classroom



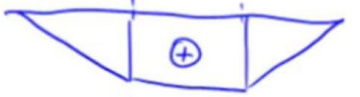
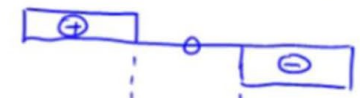
self-study, input

+ short tests, open questions

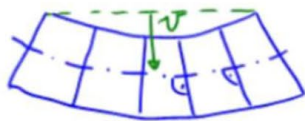
Voraussetzungen und Annahmen

- Querschnitt über Länge konstant
- Querschnittsabmessungen \ll Balkenlänge (meist $\frac{H}{L} \ll \frac{1}{4}$)
- Material linear elast. und homogen
- reine Biegung (nur Moment, ohne Querkraft/-verformung)

Bsp:



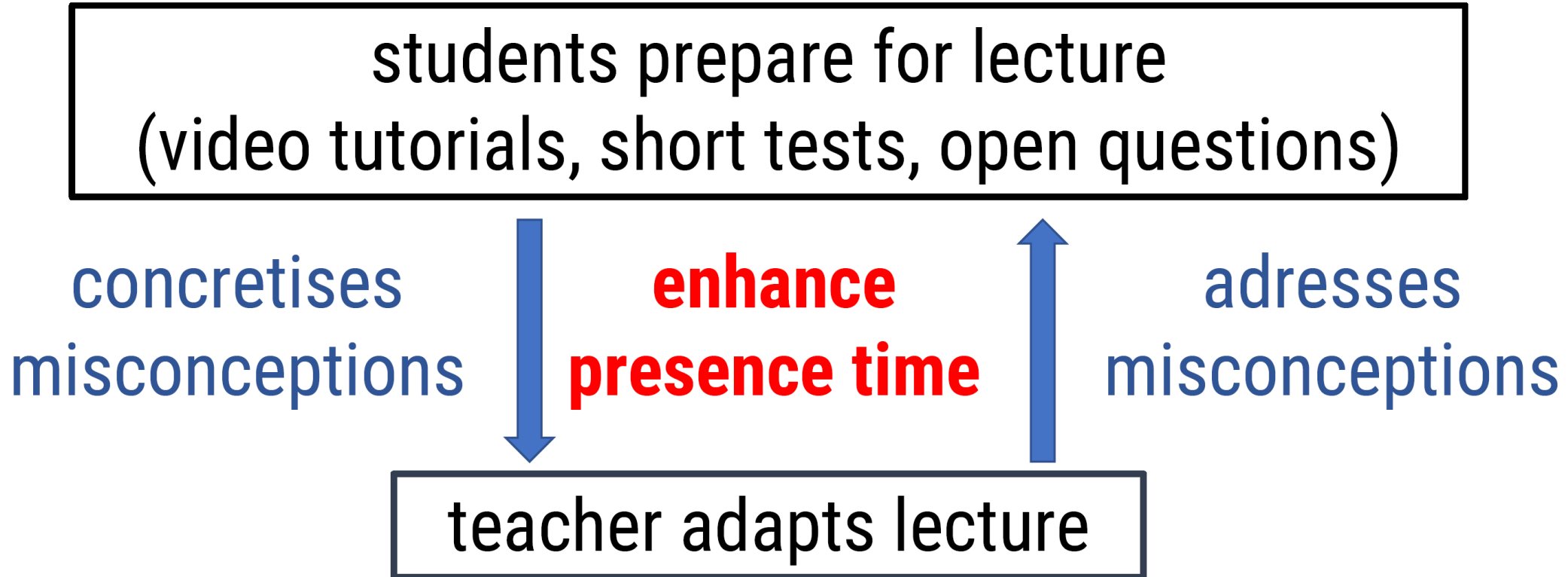
kleine Verschiebungen v



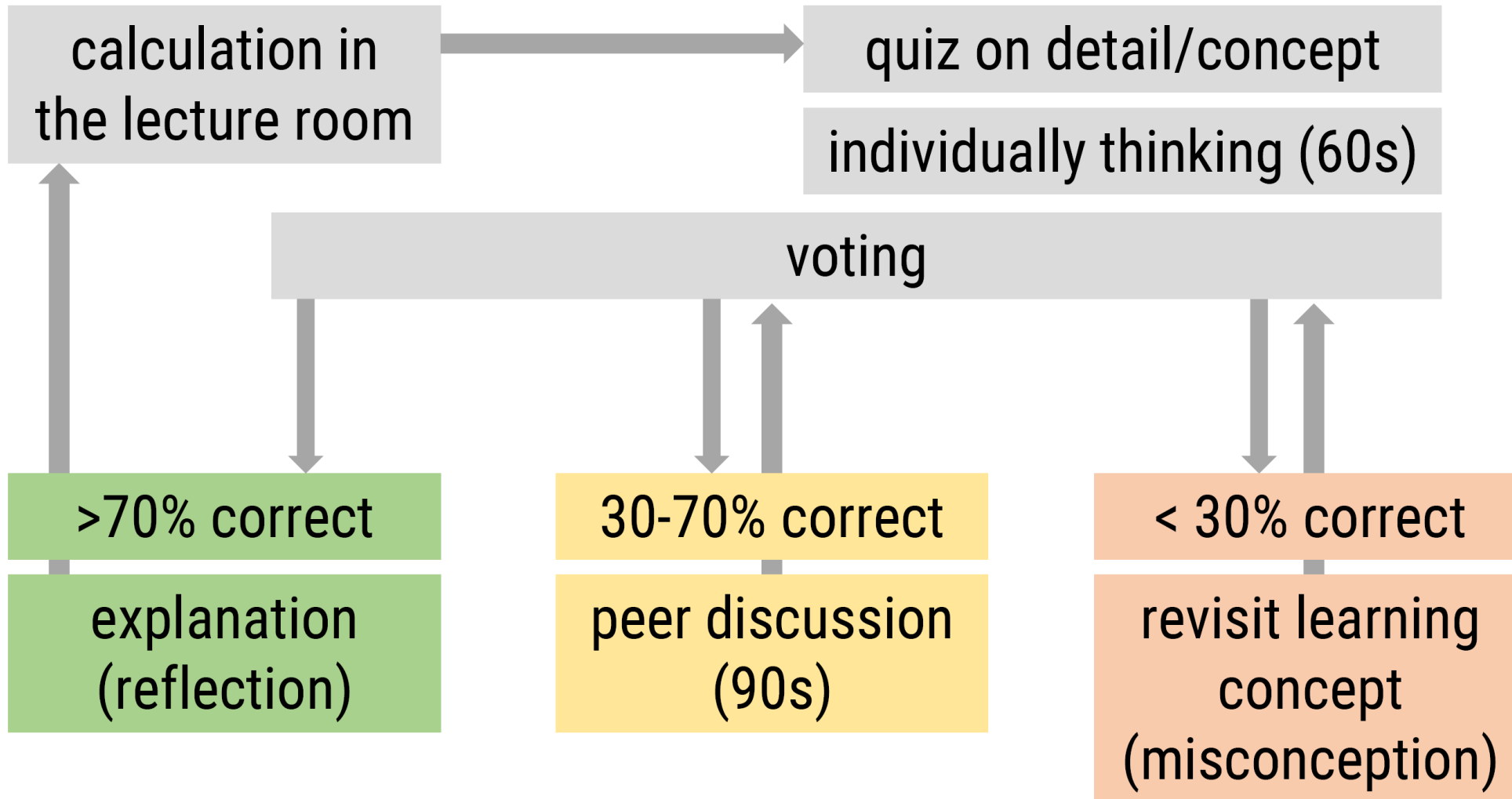
Vorlesung zum Modul
Baumechanik 1 - Festigkeitslehre 1
Prof. Dr.-Ing. Andreas Franze

Normalspannungen infolge Biegung
Voraussetzungen und Annahmen

activation: just-in-time-teaching (JIT, Novak et al., 1999)



activation: peer instruction (PI, Mazur et. al.)



Interactive Sequences in Large Basic Mechanics Classes – at the example of *Dynamics* at ETH Zurich

The Starting Point: *Dynamics (Mechanics III)*

The course:

- mandatory for all Mechanical/Civil Engineering Bachelor students
- ca. 600 students (and counting)
- 2 × 2h lectures per week
- 2h small-group exercises per week
- written final exam

The challenge:

- Students lack **time on task** and **regular feedback**.
- Homework graded is a logistic nightmare; lecturing lacks **concept assimilation**.
- **Problem solving** (under time pressure) is key to passing the final exam.
- Students believe (and are being told) that studying old exams right before taking the exam is sufficient.
- Ironically, the better the offered course materials, the higher the overestimated self-perceived learning.

Our solution = interactive sequences:

- concept tests in each lecture
- concept tests with peer instruction during exercises
- weekly voluntary Moodle/STACK homework problems

Interactive Sequences in Lectures: Clicker Question / Concept Test

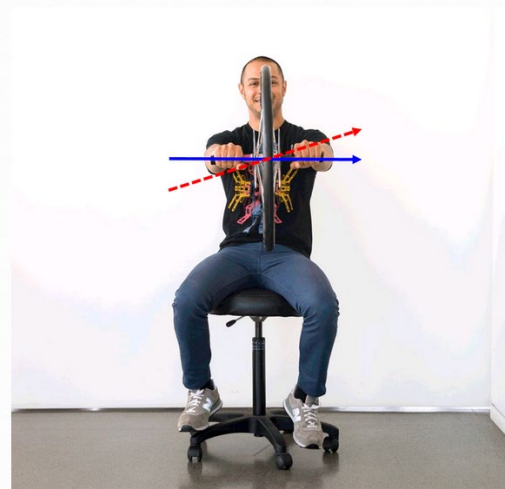
- 1-2 questions/concept tests per 45min lecture
- ca. 5 min per question:
1 min (intro) + 2 min (answering) + 2 min (explanation)
- generate (and recycle) the **pool of questions**

Why do I use clicker questions?

- check student **intuition**
(before an experiment/a solution)
- check students' **methodological skills**
(let them solve a problem)
- check student **understanding**
(transfer/interpret a concept)
- prompt student **reflection**
(when answering incorrectly)
- receive **feedback** on lecture pace

The person holds a quickly spinning bicycle wheel, while resting on a rotating chair.

What happens when he turns the axis of the wheel as shown (from blue to red)?



"Before I run the experiment, let's think about what will happen..."

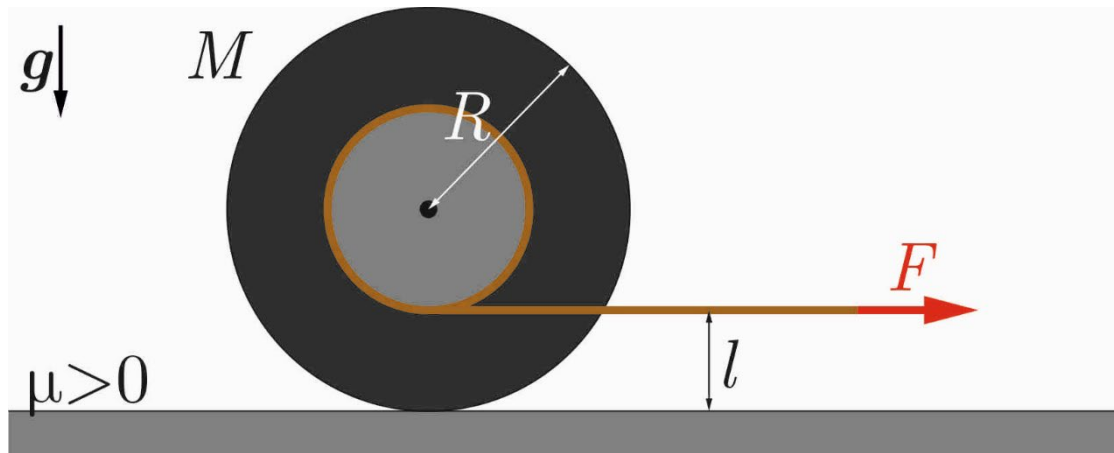
"Here is an example problem. I give you 2 min to solve it..."

"Let's reconsider what happens if we change this..."

"Oh no, you got it all wrong. I'm sorry! Let's understand why..."

An Example Clicker Question

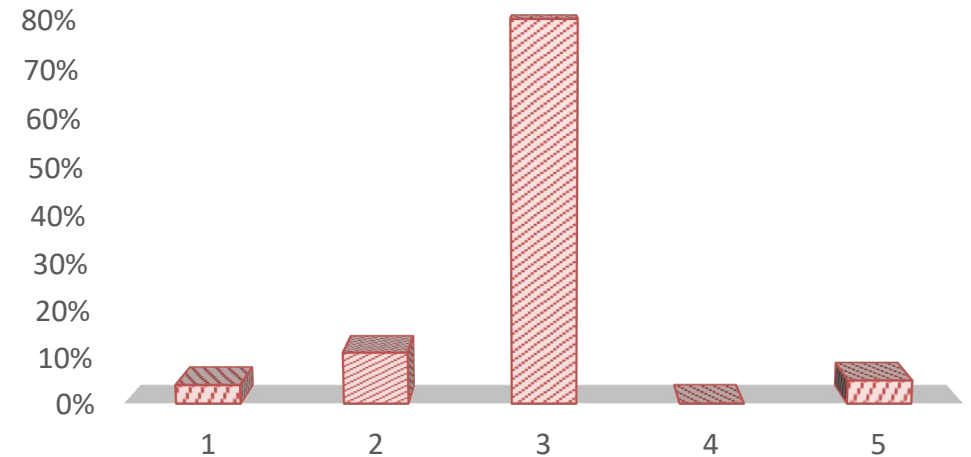
(after introducing linear & angular momentum balance)



Consider a yo-yo, approximated as a homogeneous solid cylinder, lying on a flat frictional plane.

When pulling the yo-yo to the right from rest by a force F as shown, what motion will the yo-yo follow?

Productive failure can be very effective.
(Results from class in HS 2022)

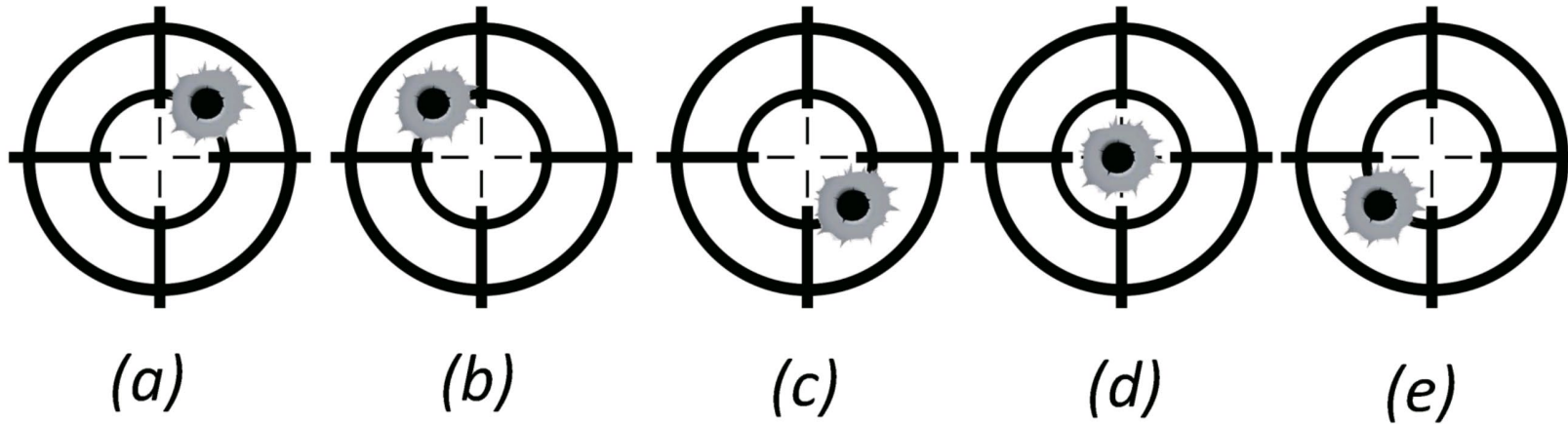
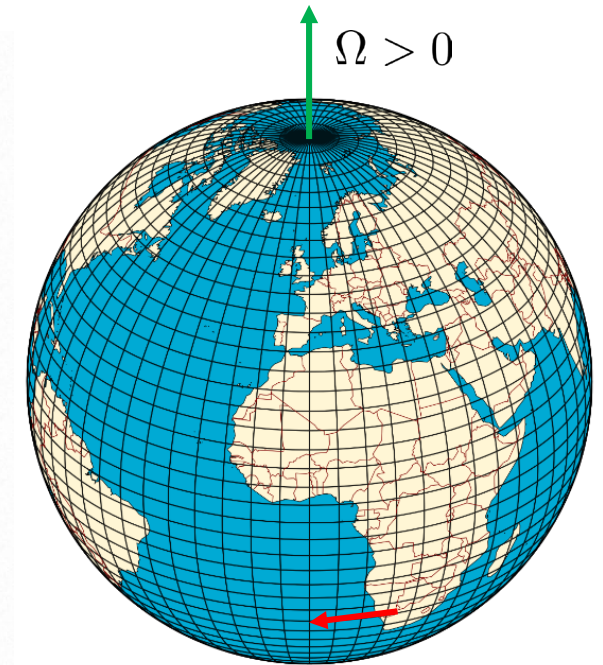


1. Move to the right while rotating counter-clockwise.
2. Move to the right while rotating clockwise.
3. Move to the left while rotating counter-clockwise.
4. Move to the left while rotating clockwise.
5. Note move at all.

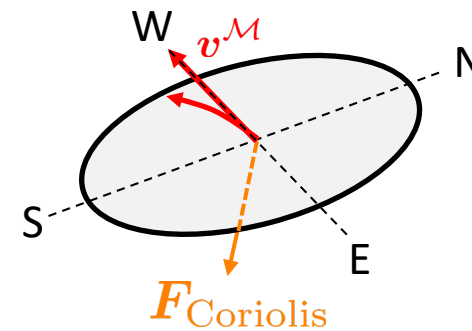
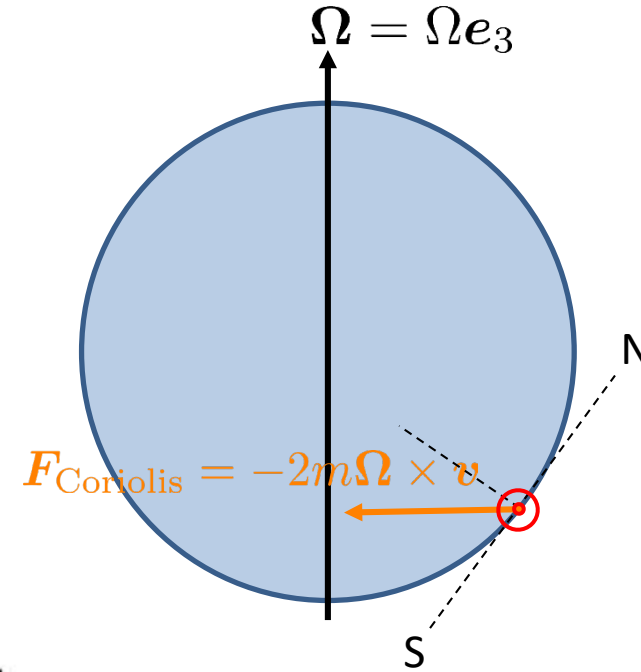
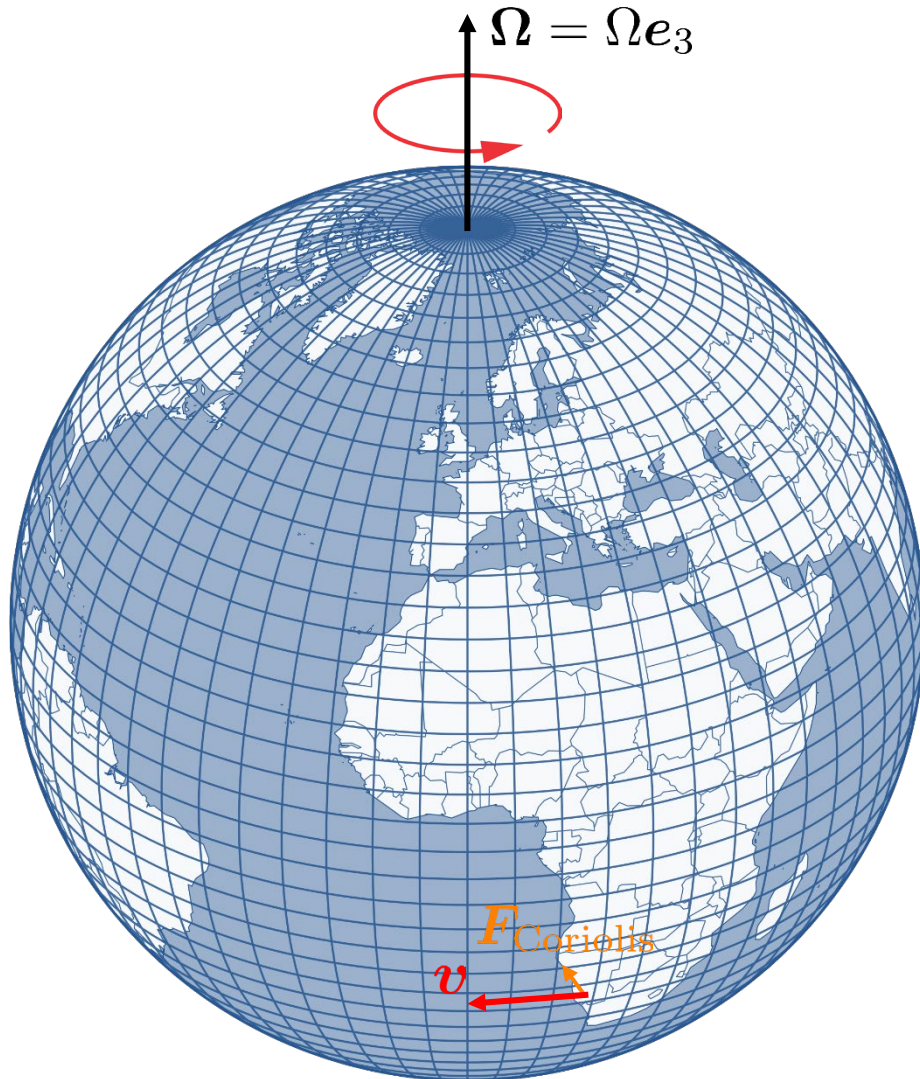
Clicker Questions with Peer Instruction in Small-Group Exercises

(after explaining Coriolis, Euler & centrifugal forces in rotating frames)

A bullet is fired near Capetown, South Africa, to hit a target placed 500 meters to the West. The rifle is aimed exactly at the target. Neglecting wind effects, what is the expected hit location relative to the center of the target?



The Solution



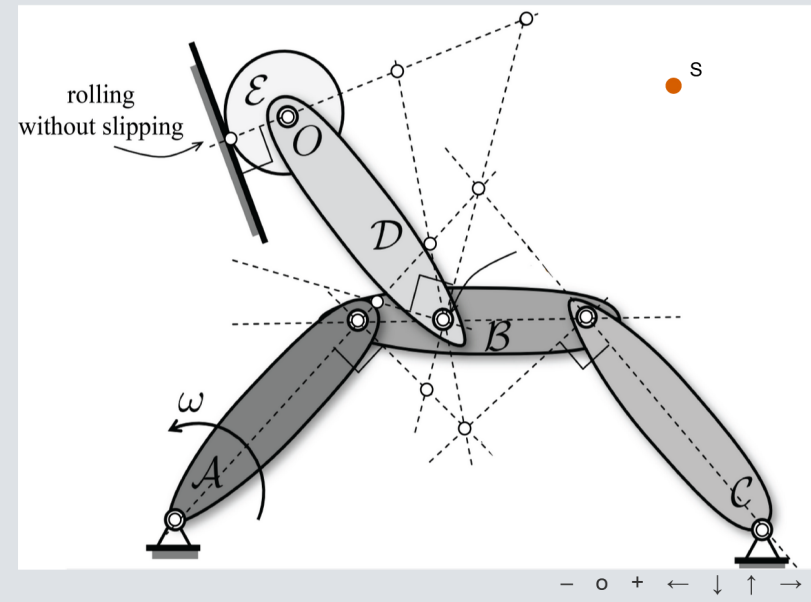
Weekly Moodle/STACK Homework Problems

Logistics:

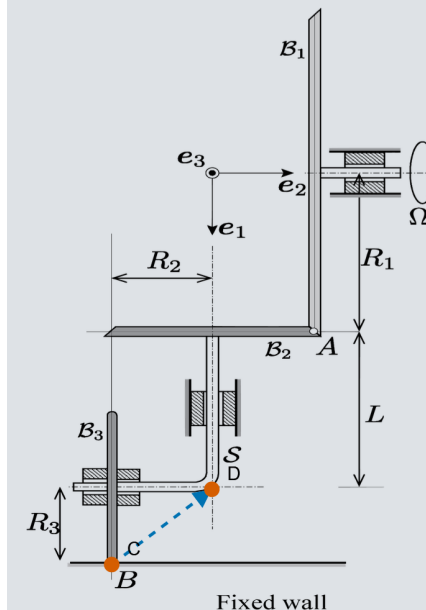
- 5-8 weekly voluntary homework problems
- **one attempt per problem** (but many more problems than needed)
- individual **feedback**, complex decision trees
- mix of **single-/multiple-choice**, **quantitative**, **graphical** problems, etc.
- max. +0.25 **grade bonus** (if >75% correct)
- **gamification** by *LevelUp*

The planar

multibody system depicted in the figure consists of 5 rigid bodies \mathcal{A} , \mathcal{B} , \mathcal{C} , \mathcal{D} and \mathcal{E} connected to each other with rotational hinges, as shown. The bodies \mathcal{A} and \mathcal{C} are hinged to the ground at one of their tips, while the disk \mathcal{E} rolls without slipping. At the instant depicted, the body \mathcal{A} rotates about its hinge with angular velocity ω . Indicate the center of instantaneous rotation of body \mathcal{D} in the figure below. For that, simply move point S to the corresponding location; the results will be assumed correctly if it is within the square centered at the correct location within a sidelength of 0.25.



The shown system consists of the three wheels \mathcal{B}_1 , \mathcal{B}_2 , and \mathcal{B}_3 of radii R_1 , R_2 , and R_3 , respectively. Wheel \mathcal{B}_1 rotates with angular velocity $\Omega = \Omega \mathbf{e}_2$ about its axis, while shaft \mathcal{S} is rigidly attached to \mathcal{B}_2 and hence rotates around the \mathbf{e}_1 -axis. Wheel \mathcal{B}_3 rotates with respect to \mathcal{S} about \mathbf{e}_2 . Rolling without slipping is enforced at points A and B between \mathcal{B}_1 and \mathcal{B}_2 , and between \mathcal{B}_3 and a fixed wall. Draw the instantaneous axis of rotation (IAR) of \mathcal{B}_3 by moving the starting-point C and end-point D into reasonable positions. Note that the direction of the vector must coincide with the positive direction of rotation (right-hand-rule).

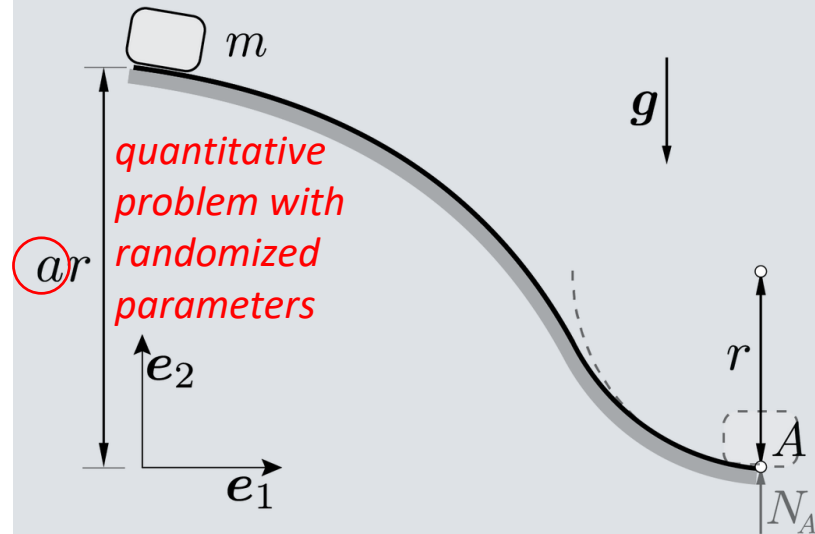


*graphical problems:
place points/lines
at the correct
positions*

Weekly Moodle/STACK Homework Problems

A particle of mass m slides down a curved, frictionless track. The block is released from rest at an initial height ar above the bottom of the track, where $a = 10$ and slides towards point A , where the track follows a circular path of radius r . Gravity acts downwards.

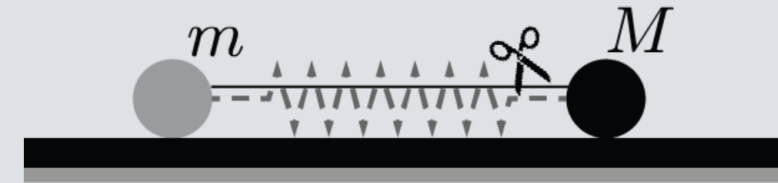
Given: $m, r, a = 10, g$



What is the magnitude N_A of the force \mathbf{N}_A applied by the track onto the particle, when it reaches the bottom point A ?

$N_A =$

A system of two particles of masses m and $M > m$, as shown, lies on a smooth ground. The particles are connected by an elastic spring. The spring is initially compressed via a string in between and suddenly released when the string is cut. Which of the following statements are true?



After release, the particle of mass M will move faster than the other particle of mass m .

- True
 False

Throughout the whole process, the center of mass of the two particles will not move.

- True
 False

Students receive individual feedback for each question.

Conclusion

- **student engagement during the semester** is essential for sustainable and effective learning
- **various strategies:**
 - *flipped classroom*
 - *clicker questions/concept tests* during lectures
 - *peer instruction* during lectures and/or exercises
 - *STACK homework* problems
- not discussed today (but also used):
 - *student projects* (e.g. programming in FEM classes)
 - *problem solving in teams* during exercises
 - animations and solutions using *Jupyter notebooks*
 - many more...
- **If not done yet, just try it out yourself!**

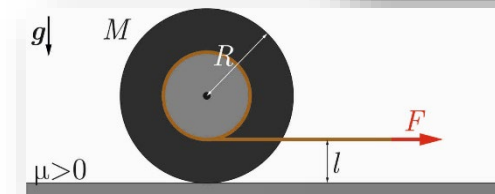
week in classic classroom



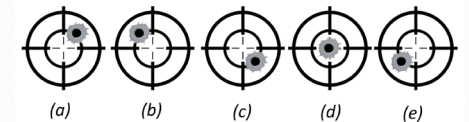
week in flipped classroom



motivation
activation
art of failing



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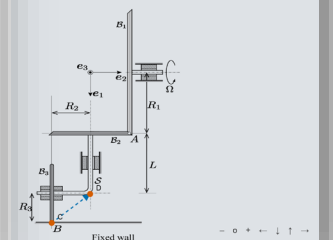
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Thank you for your interest & attention!

Questions & Comments?

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