Collaborating with other applicants on the EE is prohibited.

Using LLMs or AI (ChatGPT, Claude, Gemini, etc.) to solve EE problems is also prohibited.

Violation of either of these rules will affect your admission.

SigmaNext
Entrance Exam 2026

Please carefully read this page, as it has important information.

This Entrance Exam (EE) is only one part of your application to SigmaNext 2026. For full instructions, please check https://sigmacamp.org/2026next/apply.

The EE contains nine problems from the five semilab disciplines at SigmaNext 2026 – two problems from math, physics, biology, and computer science, and one problem from chemistry. The problems are designed to be directly relevant to the semilabs offered at SigmaNext 2026. **You are only expected to solve THREE problems.** We will evaluate your submission based on your approach to the problems and the quality of reasoning.

How to Approach the Exam

Choose THREE problems that you are interested in and attempt to solve them. You do not need to fully solve a problem — we are most interested in seeing your thought process and your approach. Even if you only make partial progress, please submit your work! Explain your reasoning clearly: even if you arrive at a correct answer, showing your steps and thought process is important.

How Your Solutions Are Used

The Entrance Exam is not used as a strict placement test. Instead, your responses help us match you with the best semilab for your skills and interests. Demonstrating curiosity, effort, and engagement is more important than arriving at perfect solutions.

You can use the Internet, books and even help from someone (who is not another applicant), but **state precisely what sources you have used to solve each problem**. Note that you cannot post the problems to the Internet or other public forums and solicit help that way. **You are also not allowed to use any LLMs (ChatGPT, Claude, Gemini, etc.) to solve any of the problems.**

You cannot collaborate with other applicants.

Video and PDF submissions are required for all problems.

- Videos must be at most **2.5 minutes long** for each problem. Submit one video per problem.
- **Solutions must be narrated**, but you do not need to show your face. Acceptable formats include:
  - Screensharing slides or a drawing app (e.g., MS Paint) with narration.
  - Recording a whiteboard, paper, or easel with narration (contents may be pre-written).
  - Speaking directly to the camera.
- **Submit videos as links** (Google Drive, Youtube, Dropbox, etc.). Other files must be submitted as a single PDF file per problem. **Make sure that the video is viewable with the link.**

The application deadline is March 15, 2026 – all your materials (Entrance Exam, essay, letter of recommendation) must be submitted by that date. We will notify all applicants no later than April 5, 2026.

Good luck with your application!

Mathematics

Problem A

Two campers, Alisa and Ben, each want to schedule a one-on-one meeting with Mark. The meetings last exactly 10 minutes, start at 2:00pm or later, and must finish by 3pm. Alisa and Ben really like probability, so they choose their meeting times uniformly at random, and can choose *any* time between 2:00pm and 2:50pm, such as 2:17:24.57 PM.

(a) What is the probability that Alisa and Ben's meetings do not overlap?

Hint: The best way to solve this problem is to represent the joint probability of the two meetings as a point in a square, and then to figure out the relative area of the parts of the square that correspond to non-overlapping meetings. This method is shown e.g. in Cut the Knot (for a slightly different problem).

(b) On the next day, there are now **three** campers, Alisa, Ben, and Denis, who each want to schedule a meeting with Mark. What is the probability that their three meetings do not overlap?

Submission Instructions: Video + PDF Required

- **Video (max 2.5 minutes total):** Do not introduce the problem — jump straight to your solution.

  For both parts, state your answer and explain why it is correct. Furthermore, explain how you represent the campers' choices. When referring to your diagram, avoid using "this triangle" and "that triangle"; label your objects, and refer to "triangle ABC" or "triangle 4" or "green triangle" etc.

- **PDF:** Include all of your detailed computations, and any drawings and diagrams that you use in your video or in your computations.

Problem B

Two comedians, Hannah and Maria, are performing a stand-up routine together. They alternate turns; on each turn, the current comedian delivers one joke of either type Slapstick (S) or Wordplay (W). To keep the routine fresh, they agree that no sequence of three consecutive joke types may ever repeat in the routine. Once this happens, the routine is considered "spoiled". The routine therefore is spoiled the first time the last three joke types equal some earlier consecutive triple of jokes.

For example, the routine $SWWSSWW$ became spoiled on the 7th joke, since "SWW" is repeated twice.

(a) What is the maximum possible length (number of jokes) of a routine that is not spoiled (i.e., in which every consecutive triple of jokes appears at most once)? Prove your answer.

(b) Hannah and Maria have made a bet: the comedian who first repeats a sequence of three consecutive jokes (and spoils the routine) must give all of their earnings from that day's show to the other. Hannah started the routine, and the current sequence of jokes is SWW, so it is now Maria's turn. Which comedian has a strategy that guarantees they will win the bet, no matter how the other performs? Explain the winning strategy and why it succeeds against any play by the opponent.

Submission Instructions: Video + PDF Required

- **Video (max 2.5 minutes total):** Do not introduce the problem — jump straight to your solution.

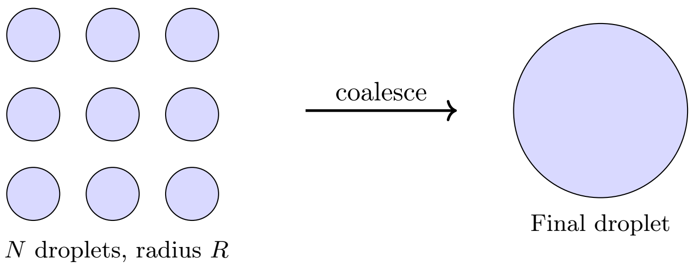
  For both parts, state your answer and justify why it is correct. If your solution includes any diagrams or equations, include them in the video.

- **PDF:** For both parts, write your answer, show how you derived it, and justify that it is correct. Include all of your detailed computations, and the full proof for the maximum length in part (a). For part (b), provide a formal explanation of the winning strategy, and thoroughly justify why it succeeds.

Physics

Problem A

A grid of N spherical water droplets are arranged on a flat, hydrophobic surface, each with the same radius R and initial temperature $T = 20°\text{C}$. They are gently pushed together, initiating coalescence between adjacent droplets, until eventually one large spherical droplet is formed.



(a) How small must R be for the final water droplet to reach a temperature of $T = 21°\text{C}$?

Hint: The surface tension of water is $\gamma = 0.07\ \text{J/m}^2$*, the density is* $\rho = 1000\ \text{kg/m}^3$*, and the specific heat capacity is* $c_P = 4100\ \text{J/(kg} \cdot \text{K)}$.

(b) What is the net cost in gravitational potential energy during the coalescence process? How does it compare to the surface energy released?

Submission Instructions: Video + PDF Required

- **Video:** Do not introduce the problem — jump straight to your solution.

  State your final numerical answer, and justify why it is correct. Explain the steps that you took to arrive to the solution.

- **PDF:** Include all of your detailed computations, and any equations, drawings, diagrams that you use in your video or in your computations.

Problem B

You are a scientist working for SigmaLand during Project Sigmanhattan, tasked with helping to create a large energy-release apparatus. In the course of your research, you discover two new types of particles: *Sigmoids* and *Floobs*, which can transform reversibly into each other.

Careful experiments reveal the following reversible transformation rules:

Rule A: Two Sigmoids $\longleftrightarrow$ one Floob **Rule B:** Three Sigmoids $\longleftrightarrow$ one Floob

To model complex processes, you draw *interaction diagrams* (similar to Feynman diagrams, but simpler) made of line segments (representing particles) and junctions (representing transformations). Sigmoids and Floobs are represented with solid and dashed lines, respectively:

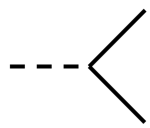


Figure 1: One Floob $\longleftrightarrow$ two Sigmoids (g).

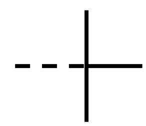
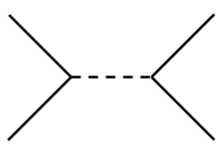
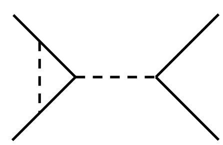


Figure 2: One Floob $\longleftrightarrow$ three Sigmoids (λ).

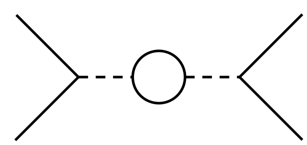
Along with line segments and junctions, interaction diagrams can also have *loops*, which are connected portions of the diagram that form a closed curve (see figures (b)-(f) below). Interaction diagrams are assigned a *value* as follows: each occurrence of **Rule A** (Two Sigmoids $\longleftrightarrow$ one Floob) **contributes a factor of** g, **Rule B** (Three Sigmoids $\longleftrightarrow$ one Floob) **contributes a factor of** λ, and each loop **contributes a factor of** $\hbar$. To find the value of a diagram, multiply together all of the factors contributed by its junctions and loops.



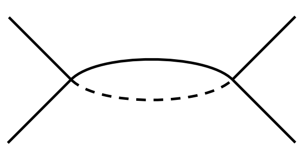
(a) 0 loops, value $g \cdot g = g^2$.



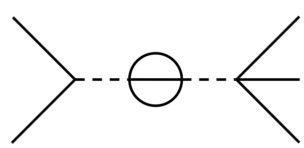
(b) 1 loop, value $\hbar g \cdot g \cdot g \cdot g = \hbar g^4$.



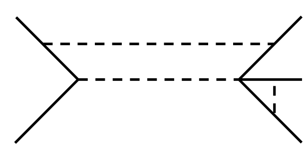
(c) 1 loop, value $\hbar \cdot g \cdot g \cdot g \cdot g = \hbar g^4$.



(d) 1 loop, value $\hbar \cdot \lambda \cdot \lambda = \hbar\lambda^2$.



(e) 2 loops, value $\hbar^2 g\lambda^3$.



(f) 2 loops, value $\hbar^2 g^5\lambda$.

Your goal is to characterize how **two incoming Sigmoids** (from the left) can transform into **three outgoing Sigmoids** (to the right), like in (e) and (f) above.

(a) Draw all the unique interaction diagrams with **zero loops**. Write their values in the form $g^a\lambda^b$.

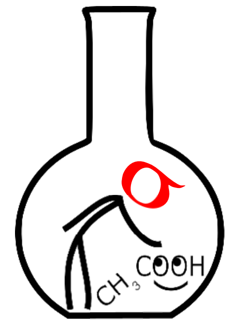
(b) Now, draw all such unique diagrams with **one loop**, and write their values in the form $\hbar g^a\lambda^b$.

(c) Lastly, draw as many unique diagrams as you can that have **two loops**, and write their values.

For all parts, make sure you do not overcount by drawing equivalent (e.g. rotated or flipped) diagrams!

Submission Instructions: Video + PDF Required

- **Video (max 2.5 minutes):** Do not introduce the problem — begin immediately with your solution. Show your diagrams, explain how you came up with them, and how you ensure used to ensure that you found all such diagrams.
- **PDF:** Include all of your diagrams and their corresponding values.



Chemistry

Note: There is only ONE Chemistry problem on the EE.

Problem A

Organic molecules are typically colorless. However, they can function as *dyes* (absorbing visible light, roughly $400 - 700$ nm) if their electrons are allowed to move across large parts of the molecule. This occurs in *conjugated systems*, which are chains of atoms where single and double bonds alternate (e.g., $-C = C - C = C-$).

Consider the organic compound X shown in Figure 4.

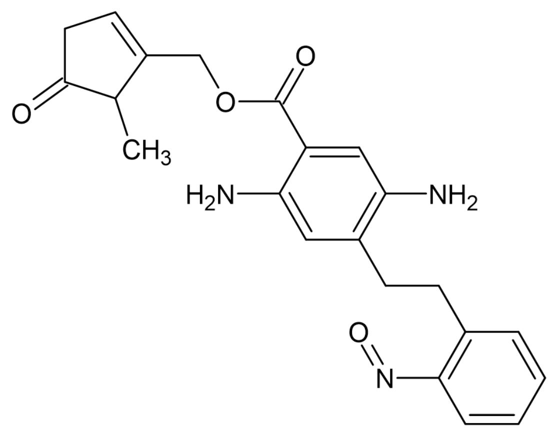


Figure 4: The structure of the organic compound X.

Isomers of X are compounds that have the same molecular formula (same number of each kind of atom) as X, but a different arrangement of those atoms. Answer the questions below; draw any structures you propose and explain your answers.

(a) Is there an isomer of X that would be a dye? If yes, draw that isomer and explain why it absorbs in the visible part of the spectrum. If no, explain why.

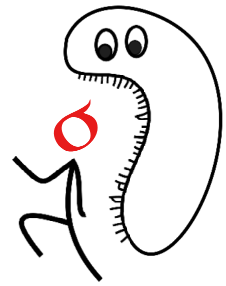
(b) Which isomer of X would have its main absorption at the most red (longest) wavelength in the visible range? Draw that isomer and explain your answer.

Submission Instructions: Video + PDF Required

- **Video (max 2.5 minutes):** Do not introduce the problem — begin immediately with your solution.

  For both parts, show the corresponding isomer and explain why it exhibits the desired property.

- **PDF:** For both parts, include a drawing of your isomers along with an explanation of why they satisfy the desired properties.



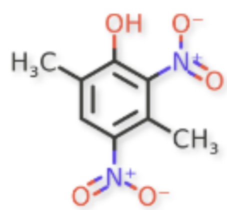
Biology

Problem A

You are studying cancer cells taken from a tumor in a patient's brain. When these cancer cells are grown in the lab under normal air conditions, they consume glucose but produce very little lactatic acide (lactate). However, when the same cells are grown in low-oxygen conditions (3% oxygen), they still consume glucose but now produce lactate.

(a) What is lactate production, and how is it connected to glycolysis? Explain why lowering the oxygen level causes cells to produce more lactate.

(b) To specifically target these cancer cells, your colleagues from a chemistry department suggested the following drug. This compound has a **pKa of 6.8**.



You tested this compound on cancer cells and found that it is very effective: cancer cells die quickly, independent of the concentration of oxygen. However, when healthy (non-cancerous) neuronal cells were treated with even lower concentrations of this compound, they die too. You also found that after the treatment with this compound, intracellular ATP (adenosine triphosphate) concentration in healthy cells dropped almost to zero.

Why might healthy neuronal cells be more sensitive to this compound than cancer cells? Suggest several explanations for these observations.

Submission Instructions: Video + PDF Required

- **Video (max 2.5 minutes):** Do not introduce the problem — begin immediately with your solution.

  State your answers and explain them. If you include any diagrams or figures in your solutions, show them in your video.

- **PDF:** For both parts, include a short written justification of your answers for both parts, as well as any information that you did not include in your video.

Problem B

Figure 5 shows the relationship between the chronological age of healthy, cognitively normal individuals and their cortical thickness of their brain's medial prefrontal cortex (mPFC). Each point represents an individual's chronological age vs. cortical thickness. The points lie close to a straight line, meaning that as healthy people get older, the thickness of this brain region decreases in a fairly predictable way. Because of this, cortical thickness can be used as a rough measure of how a healthy brain is aging.

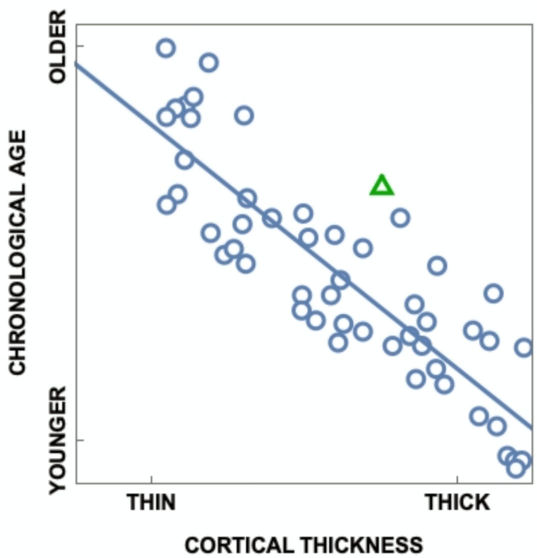


Figure 5: Chronological age versus cortical thickness of the medial prefrontal cortex (mPFC).

(a) One individual is shown as a green triangle in Figure 5. Suppose you only know this person's age and mPFC thickness as in the figure. Does this person appear to be aging faster or slower than average? Explain your reasoning.

(b) Modify Figure 5 to include data for $N = 30$ patients diagnosed with mild cognitive impairment (MCI). Assume that a large portion of MCI patients later develop Alzheimer's Disease, a condition in which brain tissue shrinks significantly, and, as a result, brain measurements such as cortical thickness decrease more rapidly with age than in cognitively normal individuals.

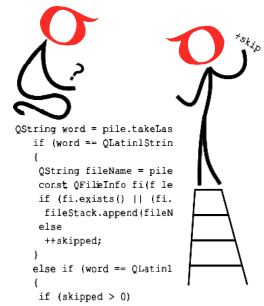
Sketch how you would add the $N = 30$ MCI patients to the graph. Explain your decisions about the placement of these individuals' datapoints, touching upon the range of values on x- and y-axes. You may draw directly on a copy of the figure, or sketch a new graph with the same axes.

Submission Instructions: Video + PDF Required

- **Video (max 2.5 minutes):** Do not introduce the problem — begin immediately with your solution.

  For part (a), state your answer and explain it using the figure and description. For part (b), include your modified figure and justify your modifications.

- **PDF:** For both parts, include a short written justification of your answers for both parts, as well as any information that you did not include in your video. Include the modified figure in part (b).



Computer Science

Problem A

In the future, buses are dispatched and driven autonomously—but traffic and delays, sadly, still exist. You decide to model the delay on each road segment (block) as uniformly distributed between 0 and 10 minutes, and to treat delays experienced by different buses as independent from one another. These assumptions are not highly realistic, but provide a reasonable benchmark for understanding how randomness accumulates.

You are located 100 blocks away from the bus station, and buses leave the station every 10 minutes.

(a) Define the *waiting time* as the time between buses passing your location, measured to the number of *whole minutes* that passed (for example, a waiting time of 5 minutes means the actual time was between 5 and 6 minutes).

Let $p(w)$ denote the fraction of waiting times that fall between w and $w + 1$ minutes. The collection of values $p(w)$ describes the distribution of waiting times.

Write a simulation (using Python or Java) to estimate $p(w)$, and provide a plot of the distribution. Use it to estimate (to the nearest 1%) the fraction of time you would need to wait 30 minutes or more between buses.

(b) Now suppose that you have five friends who live 25, 50, 75, 100, and 125 blocks away from the station, respectively.

For each location, simulate the waiting times and compute the entropy

$$H = -\sum_{w} p(w)\, \ln p(w).$$

As we often hear, entropy tends to increase as systems become more random. Does the entropy of the waiting times increase the further away someone lives from the station? Explain what you observe.

In general, for a finite set of outcomes, the uniform distribution (where all waiting times are equally likely) has the largest possible entropy. Do you expect the waiting times to become uniform for someone who lives extremely far away? Why or why not?

Submission Instructions: Video + Code + PDF Required

Unlike the other problems on the EE, this problem requires a code submission along with a video and PDF.

- **Video (max 2.5 minutes total):** Do not introduce the problem — jump straight to your solution.

  For part (a), state your answers, and give an overview of how your simulation code works. Describe how you implemented it, and what external resources you used (if any).

  For part (b), state your answers and justify why they are correct.

- **Code:** For part (a), include a Python (`.py`) or Java (`.java`) file containing your code that you used for your simulation and generating the plot of the distribution $p(w)$, along with instructions on how to run it (in comments at the start of the file).

- **PDF:** For part (a), provide a plot of the distribution of $p(w)$. For part (b), include all of your detailed computations, and any drawings and diagrams that you use in your video or in your computations.

Problem B

At SigmaNext, you have just finished a quantum mechanics lecture and are lost in thought. So deep in thought, that you wander completely at random around the camp.

The camp is represented by an $M \times N$ grid. Each cell has one of the following values:

- Open space (represented by `0`),
- Obstacle (represented by `-1`),
- Staff who will stop you to ask if you are OK (represented by `-2`), and
- The snack station (represented by `1`).

Starting at a given position (x_0, y_0), you move one cell up, down, left, or right with equal probability. If you try to move in a way would leave the grid or hit an obstacle, you instead do not move on that step. The walk ends if you reach the snack station, run into a staff member, or take $1,000$ steps (after which you get tired).

(a) Using Python, simulate this random wandering many times and return the probabilities of the following three events:

  (i) You reach the snack station.

  (ii) You run into a staff member.

  (iii) You take $1,000$ steps without running into a snack station or a staff member.

  You should create a function that takes in a grid as input (represented as a 2-D array), a start position in the grid, and the number of times to simulate the random walk on this grid.

(b) Consider the following 3×3 grid:

$$\begin{bmatrix} 0 & 0 & -2 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

  Suppose you start from the top left coordinate $(0, 0)$. If there is no 1,000-step limit (that is, you have unlimited time and energy), mathematically determine the exact probabilities of the events in part (a). Justify your answer. Make sure to compare your answer with your simulation in part (a).

Submission Instructions: Video + Code + PDF Required

Unlike the other problems on the EE, this problem requires a **code submission, a video, and a PDF**.

- **Video (max 2.5 minutes total):** Do not introduce the problem — jump straight to your solution.

  For part (a), give an overview of how your simulation code works. Describe how you implemented it, and what external resources you used (if any).

  For part (b), state your answer and justify it is correct. Describe the methods you used to arrive at the solution.

- **Code:** For part (a), include a Python (`.py`) file containing your code that you used for your simulation, along with instructions on how to run it (in comments at the start of the file).
- **PDF:** For part (b), include all of your detailed computations, and any drawings and diagrams that you use in your video or in your computations.