SigmaCamp's *Problem of the Month* Contest

## January 2025

**Starting from September 2024, we are requiring all submissions to be `.pdf` files (except for CS, which requires `.py` or `.java` files). If you are using Word, you may export to PDF by clicking File > Export > Create PDF/XPS Document.**

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## Mathematics

For all mathematics problems, please provide full justification. **Do not include any code** in your submission — all code submissions will be awarded no points.

### 5 points:

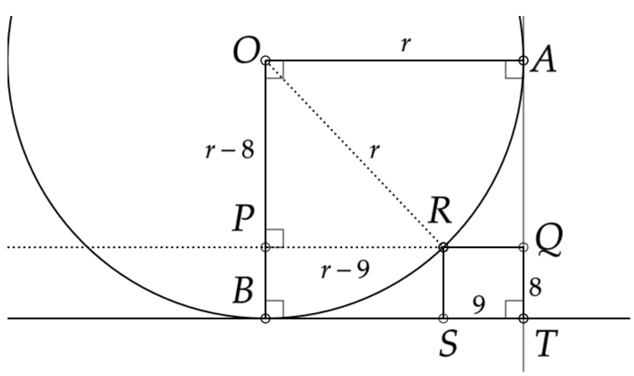
Two tangents $AT$ and $BT$ touch a circle at $A$ and $B$, respectively; $AT$ is perpendicular to $BT$. $Q$ is on $AT$, $S$ is on $BT$, and $R$ is on the circle, so that $QRST$ is a rectangle with $QT = 8$ and $ST = 9$. Determine the radius of the circle.

#### Hint:

Draw a diagram and extend $QR$.

#### Solution:

**Answer: "29" or "5" or "5 or 29"**




Since $TA$ and $TB$ are tangent to the circle, $\angle A$ and $\angle B$ are right angles, and $TAOB$ is a rectangle. Add a point $P$ at the intersection of $QR$ and $OB$.

Suppose the radius of the circle $OA = PQ = OR = OB = r$. Then $OP = QA = r - 8$ and $PR = BS = r - 9$, and triangle $\triangle OPR$ is a right triangle with sides $r-8, r-9, r$.

From Pythagorean theorem

$$(r-8)^2 + (r-9)^2 = r^2,$$

which has solutions 5 and 29. Since 5 is impossible given the diagram above, the answer is $r = 29$.

A different diagram with $O$ inside the rectangle $QRST$ will also satisfy the conditions of the problem, leading to an identical quadratic equation. In this diagram $Q$ is not on the segment on $AT$, but it is on the line $AT$. For this diagram $r = 5$ is the only solution.

If one considers both diagrams, the answer is "5 or 29".

## 10 points:

Bob has unlimited supply of beads of 20 different colors. He needs to place some beads in a row, so that beads of any two different colors will be next to each other somewhere in this row. What is the minimal amount of beads Bob needs for his row?

### Hint:

Some pairs will have to appear more than once (why?).

Make sure to show that your answer is both a lower bound (you must have at least this many beads) and an upper bound (with this many beads Bob's task is doable).

What is a mathematical structure that might be well suited to represent colors and pairs of colors?

### Solution:

**Answer: 200**

We will number the colors $1, \ldots, 20$.

While there are $\binom{20}{2} = 190$ pairs of different colors, 190 or even 191 beads are not enough. Consider color number 20. It has to be next to a bead of every other color $1, \ldots, 19$ somewhere in the row. Since any bead can be next to at most 2 other beads, this means we'll need 10 beads of $20^{\text{th}}$ color. This applies to all otther colors, so we need at least 200 beads.

To show that 200 beads are sufficient, we can represent the different colors as vertices of a graph, and pairs of colors as edges in this graph. A row of colored beads will then be a path in the graph, that goes from vertex to vertex following the edges. Since we want to have all possible pairs, we want to have a path that includes all $\binom{20}{2} = 190$ edges in a complete graph $K_{20}$, ideally an Eulerian path. Unfortunately, this is impossible, since

$$\text{a connected graph has an Eulerian path if and only if} \\ \text{it has 0 or 2 vertices with an odd number of edges connected to them,} \tag{*}$$

and in $K_{20}$ all vertices have 19 edges. We can overcome this by adding the 9 edges $2-3, 4-5, \ldots, 18-19$. In this new multigraph only 1 and 20 have an odd number of vertices, so according to (*) we can connect them by a Eulerian path that visits all 199 edges, so it uses 200 vertices, or beads.

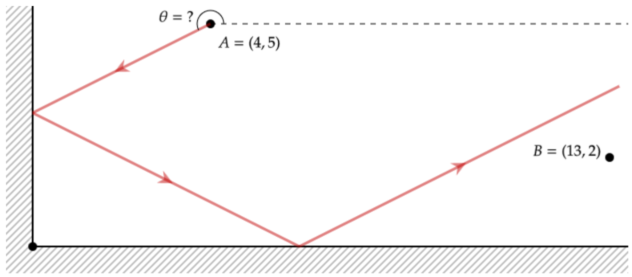
The easiest way to prove (*) is to follow Hierholzer's algorithm, see also this example.

The same argument will work for any even number of colors. If the number of colors $n$ is odd, the same argument shows that exactly $\binom{20}{2}$ beads will be needed, since in this case all vertices in the complete graph $K_n$ will have an even number of edges and the condition of (*) is satisfied.

# Physics

## 5 points:

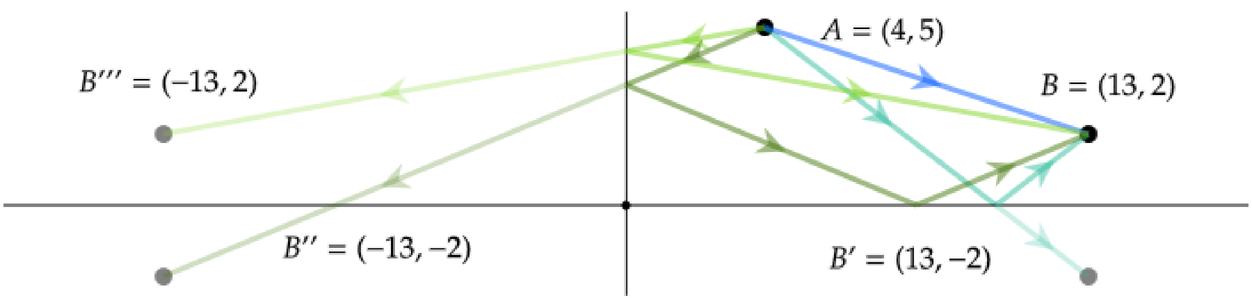
A mirror that lies along the positive $x$-axis and a mirror that lies along the positive $y$-axis are connected at a $90°$ angle as shown in the diagram. How many angles are there such that light shone from $A$ will pass through $B$? The angles at $A$ are measured from the positive horizontal direction as shown in the diagram.




**Hint:**

Try plotting $B$'s images in the mirrors.

**Solution:**




There are three images of $B$ in the mirrors, which we label $B'$, $B''$, and $B'''$. Light will pass through $B$ if the light would've passed through $B$ or one of its images with the mirrors removed. Therefore, there are four possible angles. We determine them by first finding the slope of each line, then using arctan to calculate the angle.

| Line | Slope | Angle |
|---|---|---|
| $A \to B$ | $\frac{5-2}{4-13} = -\frac{1}{3}$ | $\arctan\left(-\frac{1}{3}\right) + 2\pi \approx 5.96 \approx 342°$ |
| $A \to B'$ | $\frac{5-(-2)}{4-13} = -\frac{7}{9}$ | $\arctan\left(-\frac{7}{9}\right) + 2\pi \approx 5.62 \approx 322°$ |
| $A \to B''$ | $\frac{5-(-2)}{4-(-13)} = \frac{7}{17}$ | $\arctan\left(\frac{7}{17}\right) + \pi \approx 3.53 \approx 202°$ |
| $A \to B'''$ | $\frac{5-2}{4-(-13)} = \frac{3}{17}$ | $\arctan\left(\frac{3}{17}\right) + \pi \approx 3.32 \approx 190°$ |

## 10 points:

A strange-looking funnel, shaped like a pyramid with three segments, is placed upside-down on a horizontal rubber surface. Each segment is a rectangular prism (see Figure 1 on the left). All segments have the same height of 5 cm and different horizontal dimensions (length $\times$ width): 20 cm $\times$ 20 cm at the bottom, 10 cm $\times$ 10 cm in the middle and 5 cm $\times$ 5 cm at the top. There are no internal walls, and the funnel can be filled with water through the thin tube attached to the top of the pyramid (the cross-sectional area of this tube is negligible). When the water level reaches a total height of $H = 20\,\text{cm}$ (15 cm inside the funnel and an additional 5 cm in the tube), the water lifts the funnel and starts leaking at the base. Find the mass $M_p$ of this pyramid-shaped funnel without the water. What would be the mass $M_c$ if we took a standard cone-shaped funnel with the same base area 20 cm $\times$ 20 cm and the same height of 15 cm (see Figure 1 on the right)?

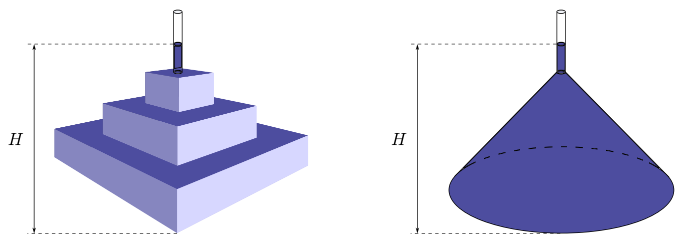



Figure 1: Pyramid-shaped and cone-shaped funnels

**Hint:**

The funnel lifts when the water pressure creates enough upward force to balance the weight of the funnel. Start by finding an expression for this lifting force.

**Solution:**

The first question we must answer is what causes the funnel to lift off the rubber surface. The funnel lifts when the water pressure creates enough upward force to balance the weight of the funnel. In the case of the pyramid-shaped funnel, it is straightforward to compute this lifting force. There are three horizontal segments upon which the water pressure acts upwards. Starting from the top, we compute the corresponding areas:

$$S_1 = (5\,\text{cm})^2 = 25 \times 10^{-4}\,\text{m}^2, \quad \Delta S_2 = (10\,\text{cm})^2 - (5\,\text{cm})^2 = 75 \times 10^{-4}\,\text{m}^2,$$
$$\Delta S_3 = (20\,\text{cm})^2 - (10\,\text{cm})^2 = 300 \times 10^{-4}\,\text{m}^2.$$

Since the water pressure at a given depth $h$ is $P = \rho\, g\, h$, we can write down the following balance of forces:

$$M_p\, g = \rho\, g \left(S_1\, h_1 + \Delta S_2\, h_2 + \Delta S_3\, h_3\right), \tag{1}$$

where $\rho = 1000\,\frac{\text{kg}}{\text{m}^3}$ and

$$h_1 = 5\,\text{cm}, \quad h_2 = 10\,\text{cm}, \quad h_3 = 15\,\text{cm}.$$

At this point, we can compute the mass of the pyramid-shaped funnel to be $M_p = 5.375\,\text{kg}$. However, this approach would be hard to apply to the case of the cone-shaped funnel.

The reason we denoted the areas of the second and third horizontal segments as $\Delta S_2$ and $\Delta S_3$ is that they are the following differences:

$$\Delta S_2 = S_2 - S_1, \quad \Delta S_3 = S_3 - S_2,$$

where $S_2 = 100 \times 10^{-4}\,\text{m}^2$ and $S_3 = 400 \times 10^{-4}\,\text{m}^2$. Now, we can rewrite the right-hand side of (1) as

$$\rho\, g \left(S_1\, h_1 + (S_2 - S_1)\; h_2 + (S_3 - S_2)\; h_3\right) = \rho\, g \left(S_1\,(h_1 - h_2) + S_2\,(h_2 - h_3) + S_3 h_3\right).$$

Notice that the total volume of water inside the pyramid-shaped funnel is

$$V_p = S_1\,(h_2 - h_1) + S_2\,(h_3 - h_2) + S_3\,(H - h_3) = 26.25\,\mathrm{m}^3.$$

Thus, we continue rewriting the right-hand side of (1) as

$$\rho\, g\, (S_1\, h_1 + \Delta S_2\, h_2 + \Delta S_3\, h_3) = \rho\, g\, (-V_p + S_3 H)\,.$$

Plugging this back in (1) gives us a new way of writing the balance of forces:

$$M_p\, g = -\rho\, g\, V_p + \rho\, g\, H\, S_3$$

or

$$M_p\, g + \rho\, g\, V_p = \rho\, g\, H\, S_3.$$

This can be understood as follows: the total force acting on the rubber surface at the base of the funnel is equal to the weight of the funnel plus the weight of the water inside it. Indeed, suppose we put the funnel on a scale when the funnel lifts and water starts to leak (due to the symmetric weight distribution, all the sides of the funnel will lift simultaneously). Since no pressure is coming from the sides of the funnel, the total weight shown on the scale must be equal to the pressure created by the water at the base of the funnel times the corresponding area.

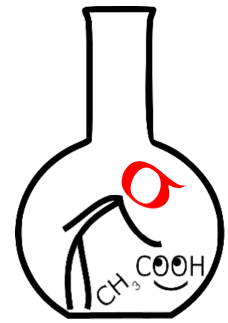
Using the same logic, we can write the balance of forces for the standard cone-shaped funnel:

$$M_c\, g + \rho\, g\, V_c = \rho\, g\, H\, S_3,$$

where the total volume of water inside the cone is $V_c = \frac{1}{3}\, S_3 \times 15\,\mathrm{cm} = 20 \times 10^{-4}\,\mathrm{m}^3$. Cancelling $g$, we can write for both masses:

$$M_p = \rho\, (H\, S_3 - V_p) = 5.375\,\mathrm{kg}, \quad M_c = \rho\, (H\, S_3 - V_c) = 6\,\mathrm{kg}.$$

# Chemistry




## 5 points:

A chemist set out on an expedition to a remote location, bringing along various supplies, including a 1 M solution of NaCl and a 1 M solution of potassium sulfate for his experiments. He had prepared these solutions beforehand, distributing the first solution into two bottles and the second into one bottle. Unfortunately, he forgot to label them. Since all the bottles are identical and he has no additional solutions or equipment other than test tubes, suggest a simple method for determining which solution is in each bottle.

### Hint:

No hint this month.

### Solution:

Since you don't have any chemicals available, testing the chemical properties of the solutions is unlikely. Therefore, it's more practical to consider their *physical* properties. The two different solutions will clearly possess distinct refractive indices and/or densities, which is crucial. The chemist can proceed as follows:

1. Pour 2-3 mL of the first solution into a test tube.
2. Gradually add a few drops of the second solution without mixing.
3. Observe the liquid. If the two solutions are the same, the contents of the test tube will appear completely transparent and homogeneous. However, if the solutions differ, the liquid will appear blurry and inhomogeneous for the first 5-10 seconds.

This method is universally applicable, simple and highly sensitive, allowing for the distinction between solutions of two different compounds, or even between solutions of the same compound at different concentrations. Just remember that both liquids must be at the same temperature, so keep them in the same location prior to testing.

## 10 points:

Iodized salt is an important way to introduce iodine in diets, especially for populations that do not have access to sea food. Propose a way to prove that table salt actually contains iodine (in any form), and check it experimentally.

### Hint:

It is hard to obtain chemicals that allow easy detection of $I^-$, but it is very easy to detect $I_2$.

### Solution:

It can be challenging to find chemicals that easily detect ($I^-$), but ($I_2$) is straightforward to identify. The key chemical for this detection is starch, a biopolymer made up of glucose molecules linked together in a long chain. Its structure allows it to form long channels that can accommodate ($I_2$) molecules. When ($I_2$) dissolves in water, it interacts with water molecules, resulting in a faint brown color. However, when ($I_2$) binds to starch, the starch protects ($I_2$) from water, changing the iodine color to a deep blue.

The issue is that iodized salt does not contain ($I_2$); it typically has ($I^-$) or ($IO_3{}^-$) (for instance, in Brazil). Both ($I^-$) and ($IO_3{}^-$) are colorless and do not bind to starch. Thus, to visualize iodine, we must first convert it into ($I_2$).

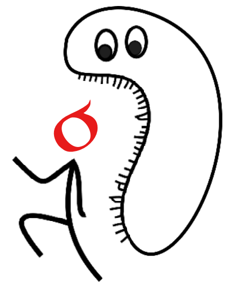
To convert ($I^-$) into ($I_2$), we need to oxidize ($I^-$) by removing an electron. This can be accomplished by adding hydrogen peroxide:

$$2\,H^+ + 2\,I^- + H_2O_2 \longrightarrow I_2 + 2\,H_2O$$

In this reaction, two protons are consumed, so it is necessary to add an acid, such as vinegar, to speed up the process.

As an example, you may watch this video, where one PoM participant makes this experiment.

In the second scenario, where the salt is iodized by adding ($NaIO_3$), an extra step is necessary. First, we need to *reduce* the iodate to iodide, which can be achieved by adding a reducing agent (a.k.a. an "antioxidant"—vitamin C is effective for this purpose). Once all the iodate has been converted to iodide, we can follow the same procedure as outlined earlier.



# Biology

## 5 points:

When Tarika was a young child, she cut planaria worms and sent them into space aboard a spaceship mission. What might have been the scientific objectives behind this project? Additionally, how would you propose measuring the rate of regeneration in these worms under microgravity conditions? Do you think the regeneration rate in space would be faster, slower, or unchanged compared to Earth's gravity?

### Hint:

We won't limit your imagination, so there won't be any hints for this problem.

### Solution:

1. What might have been the scientific objectives behind this project? (2pts)

For the given project, the objective was to determine how microgravity changes the regeneration rate of planaria. Since it is increasingly likely that humanity will become a space-faring civilization, it is important to answer these questions before embarking on long space voyages. Planaria are a good model organism for studying regeneration, given their incredible regenerative capacity. These experiments pave the way for more human-oriented experiments in the future.

2. How would you propose measuring the rate of regeneration in these worms under microgravity conditions? (2pts)

Keeping the worms in an enclosure with a camera positioned over the enclosure, then analyzing regrowth during pre-selected time intervals. It is important to have a control group experiencing the same experimental setup on Earth as well.

3. Do you think the regeneration rate in space would be faster, slower, or unchanged compared to Earth's gravity? (1pt)

The literature is mixed, but the general opinion at the moment is that regeneration is slower in microgravity.

## 10 points:

Numerous films and books feature undead humans, commonly known as zombies. Often, these portrayals are extreme and stretch the bounds of biological plausibility. Recalling your knowledge of zombies from movies or books, identify and describe an example of the most biologically plausible and the most biologically implausible zombies. Explain what features contribute to their plausibility or implausibility. Some movies or books you could explore are *The Walking Dead*, *Angel Heart*, *Zombieland*, *The Serpent and the Rainbow*, and *The Dead Don't Die*.

### Hint:

Consider zombies in the context of fundamental principles like the laws of energy and matter conservation.

### Solution:

From the list provided, the most biologically plausible zombie is likely from *The Serpent and the Rainbow*. These zombies are based on real-world accounts of Haitian Vodou practices. Rather than being supernatural, these "zombies" are individuals who have been poisoned using tetrodotoxin, a neurotoxin found in pufferfish that blocks the sodium channels in muscles and nerves, leading to almost full arrest of all any muscle contraction, to induce a death-like state. These "zombies" are not able to move or attack, for the unfamiliar observer their state is very similar to "death".

*The Walking Dead* (TWD) relies on a pathogen to explain the reanimation, likely a virus or a prion, although the mechanism is not ever fully explored. The show does reveal that everyone in the TWD universe is already infected with the agent and that zombie bites do not infect people with the agent. Rather, the infection from the zombie bite kills (post-antibiotic resistant bacteria apocalypse?), and death is the trigger for the release of the dormant agent. *Zombieland* also uses a virus to explain the outbreak. There are viruses that change host behavior, such as the rabies virus.

Some other zombie movies (e.g., *The Girl with All the Gifts*, *The Last of Us*) rely on a fungal infection, likely inspired by the Ophiocordyceps fungus, a parasite of ants that changes the host's behavior drastically and eventually kills the infected ant. However, the "ant-zombies" are much less robust than many of the zombies portrayed in movies – the "zombie" stage of the ant's life takes between four to ten days to complete, after which the host is no longer moving and the fungus enters the reproductive stage to search for a new host.

As depicted in some movies, walking skeleton zombies, without flesh, cannot possess the function of moving/running/jumping, since there is no muscle tissue left. Similar is for vision or hearing. Unless there is some powerful, but yet unknown force, actively moving bones-only zombies are unlikely.

Most critically, other movies portray dead, decaying hosts as capable of movement (implying some muscle tissue is left). This would require some sort of ongoing metabolic processes to be present to provide energy for muscle contraction. Energy-generating metabolic processes require some structural support and compartmentalization- i.e undisrupted cells, functional proteins, impermeable membranes, etc., However, the decay process breaks down these components. It is pretty much impossible for enough metabolism to be sustained to move a human body at the advanced stage of decomposition most zombies display.

Another important issue with zombies, that they can retain for days (in some movies for years) in dormant state and wake up when they sense prey (live animal or human). What was the source of energy for keeping zombie in dormant, but still sensitive state?

If we assume that zombies are using the same principle of aerobic metabolism for energy production it is not clear how oxygen is delivered to the insides of the tissue leftovers - there is no visible transportation system (no circulation) and no breathing movements to send oxygen to the lungs. The question of zombie's food preference - usually they like brain tissue is also not completely clear unless they are getting some sort of unknown "chi/dao" energy directly from the human mind itself and this energy can support zombie's activity. Otherwise, they could have eaten anything (bacon is more caloric than brain tissue).

From the list provided, the most biologically implausible zombie is *Angel Heart*, given that it relies on supernatural forces to reanimate the zombies. The premise from *The Dead Don't Die* is similar, so it is similarly implausible. It the latter one, however, zombies were not completely brainless, they were trying to perform activities they were doing when they were alive, implying some residual memory and reflective/reflexive action control.

An interesting issue that in many movies to kill a zombie it is necessary to destroy or cut off the head. This indicates the presence or central nervous system and brain function. The question of energy supply and waste management is crucial here in the absence of circulation. One would argue, that zombies can use only a tiny fraction of the brain to hunt/eat, but these operations still require very complex, concerted brain activity (2/3 of our neurons are responsible for movement performance).

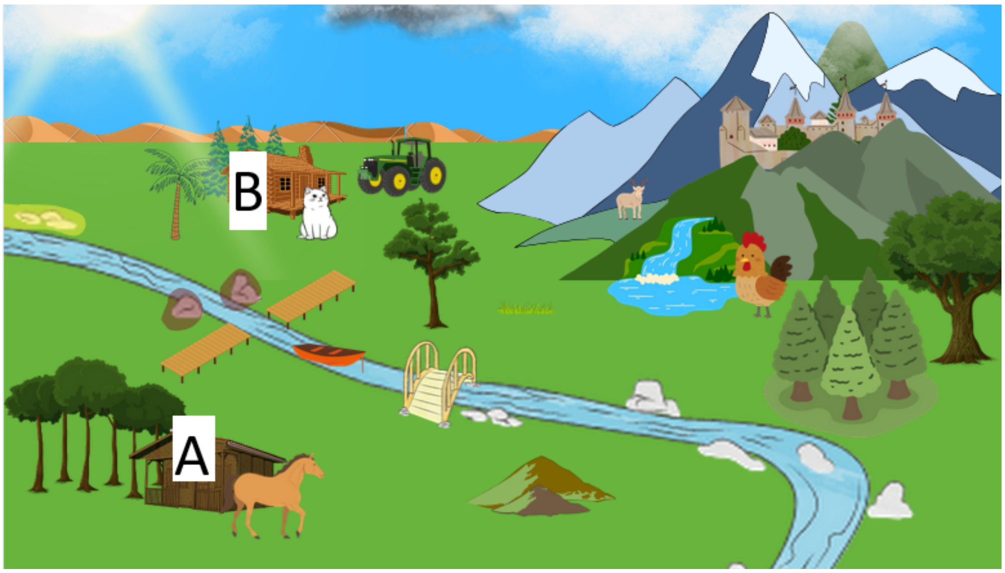
However, it might be possible, to make undead zombies. Invasive and non-invasive neural interfaces, transcranial EM stimulation, hypnosis - all these techniques can manipulate human behavior and actions already.

Of course, this is all up for debate :)

## Linguistics & Applied Sciences

**5 points:**

Two sisters, Anabelle and Beatrice live in Sunny Valley, (depicted in the image below).




Anabelle and Beatrice are the last remaining speakers of an endangered language that used to be spoken in the valley. This language contains many *demonstrative words* (such as ‘this’, ‘that’, ‘there’) that change depending on what place or thing a person is talking about. Here are some demonstratives Anabelle and Beatrice used yesterday:

**Anabelle and Beatrice are talking on the phone from their homes. Anabelle lives in house A and Beatrice lives in House B.**

| | |
|---|---|
| Anabelle is talking about the desert | aighkash |
| Beatrice is talking about the desert | aukash |
| Anabelle is talking about the river dock | eis |
| Beatrice sees the stretch of river between the colored rocks | eikash |
| Anabelle is talking about a cat near house B | aus |
| Anabelle is talking about a lake near house B | auzna |
| Beatrice is talking about the fields around house A | aukarnayo |
| Anabelle is talking about a horse near her house | hus |
| Beatrice is talking about the forests near house A | aukarna |
| Beatrice is talking about a tractor she is sitting in | tus |

**A and B go fishing at the dock.**

| | |
|---|---|
| Beatrice talks about all the fish she hopes to catch | hukash |
| Beatrice refers to a fish she caught on her fishing rod | tus |
| Anabelle refers to Beatrice’s boat near the docks | hukarna |
| Anabelle mentions a fish she sees in the water | hus |
| Beatrice talks about a fishing rod back at her house | aus |
| Beatrice talks about a bridge downstream | eikarna |

| | |
|---|---|
| Anabelle mentions a different fishing spot upstream | eizna |
| Anabelle mentions Mount Lashka | aighs |
| Beatrice recalls a goat on the path to Lashka | aighzna |
| Anabelle talks about the mountains surrounding Lashka | aighznayo |

Today, Anabelle and Beatrice decided to go treasure hunting at Mount Lashka. They took a boat down the river, hiked for an hour and sat down near the waterfall. **Decide what demonstrative term should be used for each object / place that Anabelle and Beatrice are talking about.**

1. Anabelle sees a chicken on the other side of the waterfall
2. Beatrice sees a goat on a hill across the valley
3. Beatrice talks about a faraway castle behind the mountains
4. Anabelle mentions the mountain flowers under her feet
5. Anabelle mentions glaciers visible from the path
6. Beatrice discusses other distant lands to see after Lashka
7. Anabelle mentions her house
8. Beatrice refers to trees that were left near the boat
9. Beatrice refers to the tractor near her house
10. Anabelle finds a coin on the side of the path

**Hint:**

Consider how the demonstrative word changes depending on where Anabelle and Beatrice are located with respect to each other, their environment, etc.

**Solution:**

Here is how Anabelle and Beatrice use demonstratives. To build her demonstrative, Anabelle first describes how far an object is located from <u>her location</u> specifically. This is why Anabelle and Beatrice describe the same objects differently on the phone, but not when they're together. Anabelle would describe a place as:

*tu*: right where she is
*hu*: close to where she is
*ei*: not too far away
*au*: in a defined, faraway place
*aigh*: extremely far away

In addition, Anabelle would add *-s* (*-z-* in the middle of a word) when talking about a specific, countable object (a cat, a tractor, a river dock) or *-kash* (*-kar-* in the middle of a word) when talking about something more broad (the fields, the desert, an abstract location or an unknown number of things).

Here's the trickiest part of the demonstrative: sometimes, it's important for Anabelle to specify an object's location not only compared to where she is right now, but also compared to <u>the area</u> where that object is found. For example: when Anabelle mentions a cat near Beatrice's house, the cat is far from Anabelle (*au-*) but immediately near House B, so it stays as *aus*. Meanwhile, a lake would be a bit further but still near House B (not depicted, sorry!) and would therefore take the demonstrative *au-z-<u>na</u>* (or *au-kar-<u>na</u>* when talking about the trees *near* the house). Finally, *au-kar-<u>nayo</u>* can be used to refer to something that's not only far from Anabelle, but is also far from the house (such as the vast fields surrounding Beatrice's house).

This problem is largely up to interpretation — students who interpreted the logic behind *-s/-kash/-na/-nayo* slightly differently received up to 4 points if their demonstratives were consistent with their explanation (such variation would also be expected in real life). Here are some recommended demonstrative terms:

| | | | | |
|---|---|---|---|---|
| 1. eis | 2. aus | 3. aighs | 4. tukash | 5. aukash |
| 6. aighkarnayo | 7. aukash | 8. aukarna | 9. auzna | 10. hus |

## 10 points:

The following problem asks you to design a catapult using **only** printer paper, scotch tape, paper clips and / or rubber bands. The catapult must be able to propel an object between 10 and 20 grams (such as: a battery, a ball of foil, etc) through the air in one direction. Only clear scotch tape is allowed (no duct, electrical, or masking tape). Please submit the following items:

1. A **link to a video** of your catapult in action completing the longest desired projectile travel length. Please upload your video to Google Drive, YouTube (unlisted) or Dropbox and copy-paste the link as part of your PDF submission. Make sure that the link is shared with 'everyone' so that graders can watch the video.
2. A **1-2 page writeup** explaining the catapult and documenting evidence pertaining to: a) the weight of the projectile, b) the distance travelled, c) the fact that only permitted materials are used in the design. Please include at least one drawing of your design in the writeup.

Student performance will be curved based on the best / worst performing designs. Roughly 5 points will be awarded for a good writeup with no major design flaws, and roughly 5 points will be awarded for projectile performance. Students will be **disqualified** (0 points for performance) if they provide no evidence for the weight of the object or distance travelled. Good luck!

**Hint:**

Once the ball touches the ground for the first time, distance is **no longer counted**. You can measure distance by leaving evenly spaced marks of tape on the floor or by laying a meterstick along the direction in which the projectile travels.
If you're having trouble uploading your video onto the SigmaCamp website, upload your file to Google Drive or DropBox first, then **make sure to change the sharing settings of your video** so that everyone could view / edit the file, then post a link as part of your PDF submission.

**Solution:**

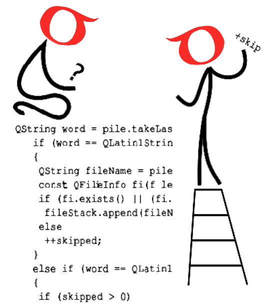
The Applied Science team would like to apologize to anyone whose submission got a point deduction for improper submission, especially when it comes to uploading video files — these instructions were only added as a hint after some designs were already submitted. Students whose videos didn't load correctly were scored more leniently for this reason: up to 2 points were awarded for performance.

Several students also counted distance travelled by the projectile after hitting the ground, resulting in a greater total distance. This 'rolling' distance was subtracted from the distance score, since only distance travelled through the air prior to touching the ground is considered towards the score.

In your grading comments, your elapsed length (in cm) was included as interpreted by the grader. For performance alone, considering no submission issues, the following scores were awarded:

- 5 points: over 400 cm (3 students)
- 4 points: under 400 cm (5 students)
- 3 points: under 200 cm (6 students)
- 2 points: under 100 cm (2 students)
- 1 point: under 50 cm (5 students)
- 0 points: no photo / video evidence of distance (6 students)

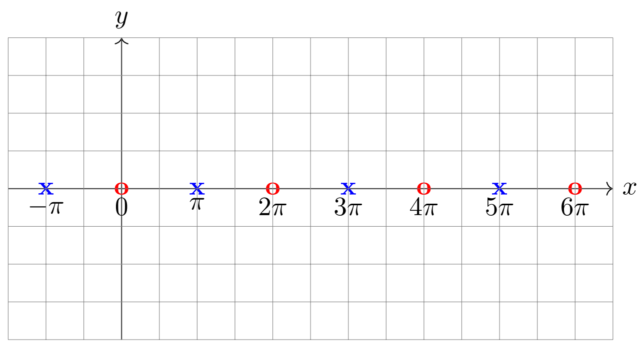
# Computer Science




## 5 points:

A Support Vector Machine (SVM) is a machine learning tool that classifies data by finding the best dividing line (or boundary) between different groups. They aim to keep this boundary as far as possible from all data points to ensure accurate separation.

Anar gives Tarika the following set of points of two classes (**x** and **o**) that he wants to separate with a straight line using a Support Vector Machine. This set of points extends infinitely along the $x$-axis.




Tarika tells Anar, "How do I separate these two classes with a single straight line? All the points of both classes lie on the same line!" Anar then tells Tarika that she can transform her data in a way that allows it to be separable by a straight line. What should Tarika do?

### Hint:

No hints this month.

### Solution:

There are several transformations that Tarika could apply, with the easiest being $f(x) = \cos(x)$. All points of class **o** will be transformed to have a $y$-coordinate of $y = 1$, and all points of class **x** will now have a y-coordinate of $y = -1$. The horizontal axis $y = 0$ can then be used to separate the two transformed classes.

## 10 points:

Hangman is a game in which a player tries to guess a hidden word by guessing each letter with a limited number of guesses. Implement your own variation of Hangman in Python or Java by using the following dataset of English words:

https://www.dropbox.com/scl/fi/joeoyuhc3iat7e8hlyiy4/words.txt?rlkey=bamyosttqp8wafh9zv8ogw3c0&e=1&dl=0

Include a PDF outlining your program's design, and explain your code structure thoroughly. Include your code either by pasting the code into your write-up or pasting a URL to your code on an external site (e.g. GitHub) in your write-up.

Be creative! Marks will be awarded for code structure, write-up structure and thoroughness, and the originality of your program.

**Hint:**

No hints this month.

**Solution:**

We received many amazing submissions this month! Below are some of the most creative submissions.

**Featured submission (Avitel Gaidukova):**

Hangman with a currency system. Solve math problems to get money to buy extra lives!

https://github.com/avitel99/POMJanuary2025

**Featured solution (Simon Lisansky):**

Aim and shoot at the letters you want to guess!

https://github.com/Lemur11/SigmaCamp-2025-POM-Code