



**guidebook**2020



**fyziklani**2020



# Dear participants of Fyziklani 2020

I am pleased to welcome you to Fyziklani! It is fascinating how fast the last year went by. I don't mean it just as a phrase; we, organisers, would not have minded a few more weeks of preparations. We had many new ideas, but we had to shelve a lot of them for next year. After all, Fyziklani is primarily about fun and taking joy in physics and in that regard, I firmly believe there won't be any scarcity!

The most important part of Fyziklani is the problems which you will attempt to solve. As always, we tried to bring you interesting problems that are enjoyable to solve, not just some boring exercises from your average physics textbook. You can also amuse yourselves by reading about the origin of each task.

The main aim of Fyziklani is to allow all fans of physics – not only from Czechia and Slovakia, but from other countries as well – to meet up, compete and gain new friends with similar interests. I know that during the competition, there is not much time for this. That too was one of the reasons why we've prepared a rich programme for you after the end of the competition. We're very glad that your interest in Fyziklani is growing every year!

Dear participants, I firmly believe that you will like Fyziklani this year. If you do, don't forget to register for the competition next year! And if you don't want to wait that long, don't hesitate to join us at other events organized by FYKOS. I am sure you will not regret it! :)

Last but not least, I want to thank all the organisers who helped prepare Fyziklani 2020 and thus allowed it to happen.

I wish you a lot of luck and fun, not only when solving the problems, but during all of Fyziklani 2020!



Daniel Dupkala  
Leader of Fyziklani

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# Timetable of the competition

09:00 – 09:45	<b>Team registration</b> Expected arrival of teams to the competition and their registration.
10:00 – 10:25	<b>Opening ceremony</b>
10:30 – 13:30	<b>Competition</b> Competition lasts 3 hours.
13:45 – 14:30	<b>Announcement of results</b> Awards ceremony.

## TOP HOTEL Praha

Fyziklani 2020 will be held in TOP Hotel Prague, Blažimská 1781/4, 149 00 Prague 4.

Welcome to TOP HOTEL Prague, the biggest congress hotel in Europe.

TOP HOTEL Prague\*\*\*\* is unique in its wide range of offered services. The hotel has 5 congress halls, 16 lounges with a total capacity of 5000 seats with a possibility of various organization. The hotel can offer accommodation in more than 800 rooms and suites. There are also 5 luxurious restaurants located in TOP HOTEL Prague, serving both Czech and international cuisine.

During the whole competition, there will be an open buffet and a cloakroom available in the hotel.

There will also be space designated for the teachers.

## Accessibility

### From the airport to the hotel

From the airport, take bus no 119 in the direction „Nádraží Veleslavín“, and ride to the final stop.

Next, take the subway (Metro A) in the direction of „Skalka/Depo Hostivař“, get off at station „Muzeum“ and change to subway „C“-line, take a train in direction „Háje“, get off at station Chodov, and exit the subway station.

Then, you can either take the bus no 115 in the direction „Městský archiv“ from platform D and get off at the stop “Městský archiv”, which is situated in front of Top Hotel or you can use our special bus line that will be in place on Friday. Our busses (labelled ”Fyziklani“) from Chodov to the hotel are free. For the other busses, you will need a ticket.

## Night transport

Take extra care if you arrive between midnight and 5:00 AM as subway operations are interrupted and buses and trams run on a night schedule.

## Other tips

The easiest way to get to the hotel from city centre is to use subway line C (red line, goes through Hlavní nádraží (main train station) in Háje direction – get off at stop Chodov. Then hop on a city bus no. 115 (direction Městský archiv) and get off at stop Městský archiv (3 stops).

After midnight, you can use the night city bus no. 905, going via stops Troja, Hlavní nádraží or I. P. Pavlova (where you can transfer from one night bus to another) and get off at stop Chodovec, then it is around 10 minutes walk to the hotel.

You can **check-in** after 14:00, on the next day you have to leave your room, take all your belongings, and **check-out** before 11:00. You can store your luggage in the cloakroom.

## Useful contacts

Name	Function	Phone Number
Daniel Dupkala	Leader of Fyziklani	+421 915 506 689
Daniela Pittnerová	Leader of FYKOS	+421 915 248 034
Kateřina Charvátová	communication with the teams (accommodation, registration)	+420 775 152 896

For problems concerning accommodation or registration (delays, problems with travel) contact Kateřina Charvátová.

In case of other major problems, call the first two contacts in the table.

You can also contact us by email at [fyziklani@fykos.cz](mailto:fyziklani@fykos.cz).

# Patronage

Besides the main organizers and the sponsors, there are some important public figures and the capital city Prague, who significantly contributed and offered their patronage to the competition. We would like to thank them here.

**Capital city Prague** (Prague) is a historical city in the heart of Europe. It's the capital city of the Czech Republic, formerly Czechoslovakia, and it was the residential city of kings Rudolf II and Charles IV. Prague is the main tourist destination in the Czech Republic and home to one of the most famous ZOOs in the world. Thanks to the patronage of Prague, you will be able to enjoy a banquet in the mayor's residence.

The patronage was taken over by the mayor of Prague **MUDr. Zdeněk Hřib** who studied general medicine at the Third Faculty of Medicine at Charles University. During his studies, he completed an internship in Taiwan. He is the director of a public service company Institution for applied research, education and management in health care. He is the author of many articles in professional and lay press. However, he also supports entertainment events, such as the recent Comic-Con Prague. On the other hand, he is active on the political scene as a member of the Czech Pirate Party.

The member of Chamber of Deputies of the Czech Republic **Mgr. et Mgr. Jakub Michálek** is the next patron. He graduated from Johannes Kepler Grammar School and studied at the Faculty of Mathematics and Physics and the Faculty of Law at the Charles University. Therefore, he has experience and knowledge of both law and theoretical physics. He is interested in Czech opera and constitutional law. During his studies of physics, he was an organiser of FYKOS. He is also a member of the Czech Pirate Party and Chairman of its parliamentary group.



Zdeněk Hřib



Jakub Michálek

# Weekend programme after Fyziklání

The programme on Saturday and Sunday begins at 9:30 a.m. in the buildings of MFF UK at Ke Karlovu 3, 5.

The main group is scheduled to leave TOP HOTEL at 8:20 am on both days.

If you are not staying in TOP HOTEL, we will meet at 9:15 a.m. at Ke Karlovu 5.

## Friday 14. 2.

19:00 – 23:00	Banquet Banquet at the City Mayor's Residency Registration required due to limited capacity. Dress code: business casual.
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## Saturday 15. 2.

09:30 – 10:45	1. set of physics lectures Superfluidity and quantized vortices Detekce gravitačních vln – Divy ve Vesmíru a zázraky v laboratoři – only in Czech
11:00 – 12:15	2. set of physics lectures From falling apples to merging black holes Budiž světlo! – only in Czech
12:30 – 14:15	Lunch break The main group will go to the Shopping mall Palladium – Náměstí Republiky
14:30 – 17:30	Old town sightseeing The most significant sights of the old town. National technical museum Alternative option to sightseeing (50 CZK/2 EUR)
18:00 – 20:00	Prague's planetarium Excursion and lecture in the planetarium (70 CZK/3 EUR) Štefánik's observatory Only in Czech
20:00 – 20:00	Return to TOP HOTEL

## Sunday 16. 2.

09:30 – 11:30	Excursions at MFF UK Excursions at Faculty of Mathematics and Physics at Ke Karlovu
11:30 – 12:30	Ending of the weekend after Fyziklání

## Lectures

### Superfluidity and quantized vortices (EN)

prof. Mgr. Jakub Čížek, Ph.D.

The lecture provides a brief insight into interesting physical phenomena related to Bose-Einstein condensation and occurring at very low temperatures. In particular, the lecture is focused on the behaviour of cryogenic liquids, fluid dynamics of liquid helium, super-

fluidity, superconductivity and quantum turbulence. A unique feature of these processes is that the quantum mechanism is demonstrated on a macroscopic scale.

### From falling apples to merging black holes

RNDr. Robert Švarc, Ph.D.

The talk gives a basic overview of the main ideas of Einstein's general relativity and its applications in current astrophysics and cosmology. We try to explain remarkable advantages of the geometric description of gravity in terms of spacetime curvature together with its essential astrophysical predictions which have successfully passed various sophisticated experimental tests during the last century.

## Programme descriptions

### Old town sightseeing

Saturday 14:30 – 17:30

We will visit several historical places as well as places connected with physics.

### National technical museum

Alternative programme to sightseeing

The museum, opened in 1908, shows the development of many technical fields and industry in the Czech Republic. There are 15 permanent expositions covering all sorts of technology like transportation or television studio.

### Prague's planetarium

Saturday 18:00 – 20:00

We will attend a screening of a programme about the night sky.

### Štefánik's observatory

Alternative programme to Prague's planetarium

Only in Czech

### MFF UK – The faculty of Mathematics and Physics

Sunday 9:30 – 12:30

We will visit several laboratories at MFF UK.

- Transmission electron microscope lab (TEM) – works with an electron beam that penetrates the observed sample.
- Raman spectroscopy lab (RS) – uses inelastic scattering of light to determine composition of a substance
- OptoSpintronics lab (OSP) – A field of electronics that uses the properties of electrons called spin.
- Two-dimensional electronic spectroscopy lab (TDES) – spectroscopy examines materials based on how they interact with electromagnetic waves.
- Optoelectronics and magneto optics technological lab preparing monocrystals of semiconductors CdTe and (CdZn)Te (OMTPM).
- Experiments in low-temperature physics (ELTP)

# Organisers

**Daniel Dupkala** (Leader of Fyziklani)

MFF UK student of master's in physics and math education

**Daniela Pittnerová** (Leader of FYKOS)

MFF UK student of physics

**Štěpán Stenclák** (IT of Fyziklani)

MFF UK student of informatics

**Michal Červeňák** (IT of Fyziklani)

FJFI ČVUT student. Works at the Institute of plasma physics of The Academy of Sciences of the Czech Republic

**Jozef Lipták** (Tasks manager)

MFF UK student of physics

**Sára Belejová** (Public relations)

MFF UK student of physics

**Kateřina Charvátová** (Public relations)

MFF UK student of physics

**Marcel Vasiľák** (PR and weekend program)

MFF UK student of physics

**Ivan Hudák** (Weekend program)

MFF UK student of physics

**Karel Kolář** (Senior consultant)

Has finished a Ph.D. in physics education on MFF UK

**Martin Vaněk** (PR)

MFF UK student of physics

**Participated in the preparation of problems, reviews, and translations:**

Jáchym Bártík, Matěj Coufal, Katarína Častulíková, Daniel Dupkala, Jindřich Jelínek, Róbert Jurčo, Šimon Knoška, Karel Kolář, Josef Lipták, Štěpán Marek, Matěj Mezera, Šimon Pajger, Daniela Pittnerová, Kačka Rosická, Matěj Rzechulka, Jakub Šafin, Martin Vaněk

# FYKOS.cz

Organisers of the competition work under FYKOS (Internet Physics Competition), which is open to all high school students with interest in physics. We send eight new problems to contestants six times a year. They have about a month to solve these problems and submit their solutions, which we mark and send back with comments. Everyone can participate, so do not hesitate!

Best of the contestants can attend week-long camps in spring and autumn. These camps are focused on physics lectures, but also include plenty of games and leisure activities. Along with Fyziklani, FYKOS organises an online version of this competition – Fyziklani Online, which is held every year in late November, Day with Experimental Physics and Week with Applied Physics.

## Faculty of Mathematics and Physics, Charles University

FYKOS and Fyziklani 2020 are under the auspices of The Faculty of Mathematics and Physics at Charles University (MFF UK). You can find more information at [mff.cuni.cz/en](http://mff.cuni.cz/en).

The Charles University is the oldest university in central and eastern Europe and it is the best-ranked university in said region. (e.g. in the Academic Ranking of World Universities). It was founded in the year 1348 by Charles IV. The MFF UK was founded in 1952.

## The Ministry of Education, Youth and Sports of the Czech Republic

The Ministry of Education, Youth and Sports of the Czech Republic (MEYS) supports Fyziklání 2020 through the programme Support of Competitions and Shows in Subject Education. Thanks to this support, the competition is listed in the list of competitions maintained by MEYS. Category A of the competition participates in the development programme Excellence of High Schools.



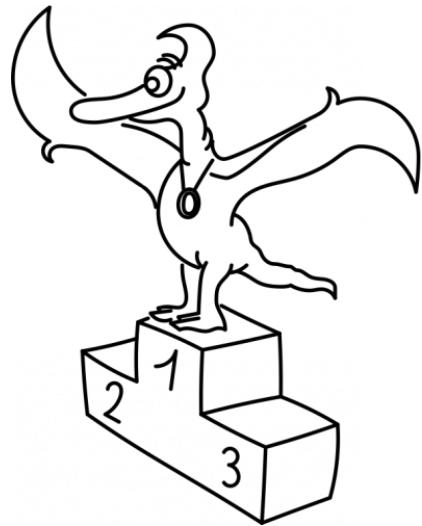
MEYS is responsible for public administration in education, for developing educational, youth and sport policies and international cooperation in these fields.

## IAPS – International Association of Physics Students

FYKOS is a local group of the international organisation IAPS. IAPS is an association of physics students and student societies from around the globe, working to promote peaceful collaborations amongst them.



IAPS runs an annual International Conference for Physics Students (ICPS), an annual physics competition PLANCKS, visits to global research institutions, summer schools, exchange programmes, outreach activities, and multinational meetings all over the world. FYKOS regularly participates in IAPS School Day.



# Sponsors

## Allocacoc

Everyone hates tangled cables and a mess of extension cords. Now there is a solution - PowerCube - an elegant hub and a great gadget not only on the road. It's a cube, which provides sockets and USB ports on the faces. Allocacoc company gave us 10 PowerCube Original USB.



## Bohemsca

"With these lemonades, you can experience nature in the city." Thanks to the natural ingredients, these lemonades are suitable for vegans, celiacs and everybody who loves real taste. The real taste is enhanced by a pinch of cane sugar. Bohemsca company took care of the hydration needs of all contestants.



## Doller

To win Fyziklání, to run a marathon, to write a book – whatever is your dream, Doller will be your best friend on that road. It is a motivation diary, with which you can start whenever you want – it's undated. As Doller likes to support interesting events, they decided to support Fyziklání by donating 15 Doller diaries.

D O L L E R

## Escape Point

"Intelligent entertainment" – an escape game that makes you think. Escape point provides 6 unique games with adjustable difficulty. Three teams will receive a voucher for a game of their choice.



## Garko

The best teams will win a medal from this company, which gave us a 30% discount.



## Havlík

Not too thin, not too thick, just perfect. These are iconic Havlík breadsticks. While the classic cheese and salt breadsticks are an integral part of bars, pubs, coffee shops, and wine bars mainly in Moravia, Havlík makes many other flavours of breadsticks such as onion, garlic or piquant. Havlik company gave us 200 packs of their breadsticks.



## Hobžovy Strážnické brambůrky (Hobža's crisps)

"We are not chips, we are crisps, crisps from Moravia" – family company taking pride in quality and taste, making sure the crisps really taste the way they should. Hobza's brothers gave us 10 boxes of the crisps and they believe they come in handy during the competition.



## IVECO BUS



IVECO BUS is a company working on the development and production of public transport vehicles. Its goal is to make public transport safe, effective, comfortable, and environmentally friendly. The company gave us a financial donation.

## Jumppark Zličín

A huge complex full of the trampolines, inflatable attractions and a climbing wall? That's Jumppark Zličín. You can't find a better place for fooling around, relaxing or enjoying a fun time with friends. Jumppark Zličín gave us 15 free entries to their trampoline paradise.



## The Kingdom of Railways

The Kingdom of Railways is a model railway in the ratio 1:87, which represents the railway system of the Czech Republic. They donated 15 free entries for individuals and 3 vouchers for a school class.



## LEU Brain Stimulator

LEU Brain Stimulator is a funny and gripping game with a huge pedagogical value for all from 4 to 104 years. It consists of 960 different 2D and 3D tasks in ten different levels, so it provides entertainment and stimulates the brain in different ways. This company donated us three board games for the development and training of your brain.



## Mindok

Mindok is a publisher of moderns board games for children and adults. In their wide range of products, you can find a lot of educational, family, and cooperative games. The Mindok company donated 15 board games, for example, Ninja karty, Jak jako jak? or Master of Orion.



## Razer

The Razer company produces accessories for gamers. Their logo perfectly describes the company philosophy "For Gamers, By Gamers." They believe, that there are many enthusiastic gamers among the participants of Fyziklaní. Thanks to Razer, every member of the winning team in every category will receive a Razer Huntsman TE keyboard with the BT Keycap Upgrade Set with the total value of 160 USD.



## **Skittles**

Fruit chewy candy – Taste The Rainbow. Lime, grapes or strawberry? It is up to you, which flavour will be your favourite! Wm. Wrigley Jr. Company donated 1000 packets of Skittles.



## **Vida!**

Amusing science park stretching over 6000 m<sup>2</sup> at the Brno Exhibition Centre. All exhibits are interactive, and they will (almost) literally absorb you. At the moment, an interactive exhibition connecting video game technology with art – Digitálium – is taking place at Vida! Vida! donated 15 free tickets for you and your teacher.



## **iQLANDIA**

A modern science centre, where the young and the mature alike can take joy in science. In ten exhibitions, there are over 400 interactive exhibits from various areas of science and technology, such as iQPLAN-ETARIUM, where you can watch screenings of films with themes from the Earth and the Cosmos. iQLANDIA donated 15 free tickets to the 4-story high science centre.



## Brief rules

- The competition lasts for 3 hours.
- At any instance, every team should have 7 tasks accessible. Solutions of the tasks should be written on the paper containing the problem statement and delivered to the judges.
- If the solution is correct, the team earns points and gets a new task straight away. So, every team always has 7 problems to solve.
- If the solution is incorrect, the team gets the task back and can try again.
- The problems are awarded points based on the attempts needed to solve the problem, in the following way: a single attempt – 5 points, two attempts – 3 points, three attempts – 2 points, and four or more attempts – 1 point.
- It is not possible to exchange a task for a new one. The only way to get a new task is to solve another one correctly.
- In an exceptional case, a judge can ask how the team found the solution.
- Solutions are accepted in standard form, i.e. with correct units. Fractions should be simplified. You can use constants like  $\pi$  and round correctly.
- Use of any written or printed material is permitted. Electronic devices, except calculators, are strictly forbidden.

## Complete rules of Fyziklani

### Participation in the competition

- If a team wants to participate, it must register through [fyziklani.org](http://fyziklani.org).
- By registering for the competition, each team agrees to follow the Rules of Conduct and these Competition Rules and confirms they have made themselves acquainted with them.
- A team consists of 1-5 members.
- Members of the team must all be members of a school equivalent to high school (pre-university education) or lower.
- A team must consist of members belonging to at most two schools.
- Students of a single school can compete at most in four distinct teams. In the case of unfilled places or other similar conditions, the organisers reserve the right to make an exception to this rule.

- The name of a team can't spread political or religious views, can't be rude or insulting, or be in any other way inappropriate. The main organiser has a right to change the name of such a team, to censor it or to disqualify the team completely.
- By registering in the competition, you agree with publishing the results of your team in the form of basic information (your name, surname, category, school and points) in the results table on the website, handbooks and yearbooks of FYKOS.

## Designation into categories

- The competition is run with three categories, to which teams are assigned based on the following algorithm.
- Students studying in a year equivalent to the high school freshman year (1st of 4 before beginning university education) are assigned a coefficient 0, students in sophomore year (2/4) coefficient 1, students in junior year (3/4) coefficient 2, etc.
- The coefficient of a team is calculated as the arithmetic mean of the coefficients of individual members (they are added together and divided by the number of members).
- The team is assigned the lowest category whose conditions it satisfies:
  - category A: team coefficient  $\leq 4$ ,
  - category B: team coefficient  $\leq 3$  and at most two members have a coefficient 4,
  - category C: team coefficient  $\leq 2$ , no member has a coefficient 4 and at most two members have a coefficient 3.
- A team can compete in category A even if the team coefficient assigns it to a lower category if they choose to do so during the registration.
- Organisers reserve the right to move a team back to the lower category or conversely move a team to category A if the need arises. The team will be notified of such a change at least a day before the competition begins.
- All categories share the same set of problems.
- Each category of the competition is announced in a separate list of results.

## Arrival at the competition

- Teams are required to arrive on time. Organisers reserve the right to not allow late teams into the competition.
- Teams are required to register after their arrival and specify the details of the members of the team (years, schools, etc.). Teams are obliged to clarify any changes in their composition.

- Each team will obtain an envelope with the first seven problems. The team is forbidden to open this envelope until they are instructed to do so by the leader of the room in which they are competing.

## The competition system and awarding of points

- The competition lasts 3 hours.
- At the beginning of the competition, each team receives 7 problems, which they try to solve.
- If the team thinks it has arrived at the correct solution of a problem, they send one of the members to one of the examiners, who tells the member whether that solution is correct or incorrect. The designated member must present the paper with the problem with a solution clearly marked on the paper.
- The examiners have the right to request a team to describe the steps used to produce the solution.
- The presenting member selects the correct examiner based on the label on the problem sheet. The proper algorithm for this selection will be explained before the competition starts.
- If the solution is incorrect, the examiner marks this on the problem sheet and the presenting member returns to the team and continues solving this problem.
- If the solution is correct, the examiner marks the problem sheet with the number of points obtained and forwards the presenting member to the distributor, from whom the presenting member receives a new problem sheet.
- The problems are awarded points based on the attempts needed to solve the problem, in the following way: a single attempt – 5 points, two attempts – 3 points, three attempts – 2 points, and four or more attempts – 1 point.
- The aim of the team is to receive as many points as possible.
- During the competition, the up-to-date results of all teams are projected in all rooms. These are hidden 30 minutes before the competition finishes.
- If there is a serious issue discovered with one of the problems during the competition, organisers reserve the right to modify the problem or to remove the problem from the competition completely, excluding any right to compensation to any of the teams.
- During the competition, all the participants are allowed to communicate only with the members of their team or with the organisers. Any interaction with teachers, other teams, etc. is strictly forbidden.
- Teams are permitted to use any literature in printed, paper form. It is forbidden to use the Internet during the competition. Furthermore, teams are permitted to use calculators and writing or drafting supplies. The calculator mustn't allow access

to the Internet or any other form of communication (devices like mobile phones, tablets, laptops, smart watches and similar are hence strictly prohibited to be used as calculators).

- All supplies that the competitors use or have in their surroundings during the competition, can be requested to be disclosed to the organisers for a control.

## Conclusion of the competition and announcement of winners

- The end of the competition is announced by the lead organiser of the room, in which the team competes.
- After the announcement of the end of the competition, no team is allowed to send a member to the examiners. If a presenting member was standing in a queue to an examiner when the end was announced, the member is allowed to stay there and their solution will be examined, but they are forbidden to use any writing supplies.
- If the winning team, or any other awarded positions, can't be determined purely by the number of points obtained, the order will be decided on several criteria in the following order: higher average points awarded per submitted problem, higher number of problems awarded 5 points, higher number of problems awarded 3 points, lower team coefficient, earlier date and time of team registration and random draw.

## Breach of rules

- In the case of a substantial suspicion of a breach of the Competition Rules or the Rules of Conduct, the chief organiser has a right to perform extraordinary measures to confirm or rebut the suspicion and to prevent the continuation of disallowed conduct.
- If a team breaches some of the Competition Rules or the Rules of Conduct, the consequences to that team will be decided by the chief organiser or by a committee designated for this task by the chief organiser.
- In the case of a breach of rules of a lesser magnitude, the chief organiser or a committee designated for this task by the chief organiser can decide on the removal of a certain number of points of a team based on the severity of the breach.
- Organisers are allowed to disqualify a team which commits a severe breach of rules.
- In the case of an extremely severe breach of the Competition Rules or the Rules of Conduct, the Central Committee of the competition may decide on a ban on participation in the competition in the subsequent years or another punishment for the members of the team and/or for any of the schools they come from.
- Extremely severe breaches of rules involve especially any intentional attempt to obtain the problems or their solutions before the competition, their publication or dis-

closure to other participants of the competition. Any intentional attempts to impede the smooth running of the competition for the other participants or the organisers, or an attack on the competition server, are also understood as extremely severe breaches of rules.

## Final remarks

- Organisers reserve the right to make minor changes in the rules before the start of the competition.
- Resolution of any potential conflicts or issues, not covered by these rules, is decided by the chief organiser or an organiser designated by them.
- A team has a right to appeal against a decision of the chief organiser, but no later than 14 days since the decision has been made. The appeal will be processed by the Central Committee of the competition, which will decide the case no later than 40 days after the appeal has been made.
- These rules have been ratified by the Central Committee of the competition Fyziklani on 18. 11. 2019.
- These rules replace the previous version and come into effect on 18. 11. 2019.

You can find the complete organisational regulations at:

<https://fyziklani.org/rules/organisational-regulations>.

Left empty for your notes



# List of constants

## Fundamental physics constants

speed of light in vacuum	$c$	$2.998 \cdot 10^8 \text{ m}\cdot\text{s}^{-1}$
permittivity of free space	$\epsilon_0$	$8.854 \cdot 10^{-12} \text{ F}\cdot\text{m}^{-1}$
permeability of free space	$\mu_0$	$1.257 \cdot 10^{-6} \text{ H}\cdot\text{m}^{-1}$
gravitational constant	$G$	$6.674 \cdot 10^{-11} \text{ m}^3\cdot\text{kg}^{-1}\cdot\text{s}^{-2}$
Planck constant	$h$	$6.626 \cdot 10^{-34} \text{ J}\cdot\text{s}$
Rydberg constant	$R_\infty$	$1.097 \cdot 10^7 \text{ m}^{-1}$
elementary charge	$e$	$1.602 \cdot 10^{-19} \text{ C}$
electron mass	$m_e$	$9.109 \cdot 10^{-31} \text{ kg}$
proton mass	$m_p$	$1.673 \cdot 10^{-27} \text{ kg}$
atomic mass unit	$u$	$1.661 \cdot 10^{-27} \text{ kg}$
Avogadro constant	$N_A$	$6.022 \cdot 10^{23} \text{ mol}^{-1}$
Boltzmann constant	$k_B$	$1.381 \cdot 10^{-23} \text{ J}\cdot\text{K}^{-1}$
molar gas constant	$R_m$	$8.314 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$
Stefan-Boltzmann constant	$\sigma$	$5.670 \cdot 10^{-8} \text{ W}\cdot\text{m}^{-2}\cdot\text{K}^{-4}$

## Astronomical constants

mass of Earth	$M_\oplus$	$5.974 \cdot 10^{24} \text{ kg}$
mass of Sun	$M_\odot$	$1.989 \cdot 10^{30} \text{ kg}$
equatorial radius of Earth	$R_\oplus$	$6.378 \cdot 10^6 \text{ m}$
equatorial radius of Sun	$R_\odot$	$6.957 \cdot 10^8 \text{ m}$
nominal solar luminosity	$L_\odot$	$3.828 \cdot 10^{26} \text{ W}$
astronomical unit	$au$	$149.6 \cdot 10^9 \text{ m}$
Hubble constant	$H_0$	$73 \text{ km}\cdot\text{s}^{-1}\cdot\text{Mpc}^{-1}$

## Other useful constants

gravity of Earth	$g$	$9.81 \text{ m}\cdot\text{s}^{-2}$
speed of sound in air	$c$	$343 \text{ m}\cdot\text{s}^{-1}$
normal pressure	$p_a$	$101.325 \text{ kPa}$
normal temperature	$t$	$20^\circ\text{C}$
Zero-point of Celsius scale	$0^\circ\text{C}$	$273.15 \text{ K}$

## Properties of water under normal conditions

specific latent heat of vaporisation	$l_v$	$2.26 \cdot 10^6 \text{ J}\cdot\text{kg}^{-1}$
specific latent heat of fusion	$l_t$	$3.34 \cdot 10^5 \text{ J}\cdot\text{kg}^{-1}$
heat capacity	$c$	$4184 \text{ J}\cdot\text{kg}^{-1}\cdot\text{K}^{-1}$
index of refraction	$n$	1.333
density	$\varrho$	$998 \text{ kg}\cdot\text{m}^{-3}$
dynamic viscosity	$\mu$	$1.005 \cdot 10^{-3} \text{ Pa}\cdot\text{s}$
surface tension	$\sigma$	$7.27 \cdot 10^{-2} \text{ N}\cdot\text{m}^{-1}$



# good luck

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