

General Instructions: Theoretical Examination

The theory exam lasts 5 hours and is worth a total of 30 points.

The beginning and the end of the examination will be indicated by your Invigilator. You must not open the envelopes or document folders containing the problems before the Invigilator indicates the beginning of the competition. There will be announcements every hour indicating the elapsed time, 15 minutes before the end, and at the end of the examination.

During the exam:

- Use only the pen provided. You may use pencil to draft your figures/schemes/graphs, but please trace the outlines of the final version with the pen to ensure the best contrast as your work will be scanned.
- Dedicated answer sheets (marked A) are provided for writing the final answers. The blank working sheets (marked W) are provided for detailed solutions. Be sure to indicate the question numbers in your solutions and always use the working sheets that belong to the problem you are currently working on (check the problem number in the header). If you have written something on any sheet that you do not want to be graded, cross it out. Only use the front side of every page and do not write anything outside the border.
- If you need more blank sheets, please ask your Invigilator. Write your country and student codes (copy that information from your working sheets) as well as question and page numbers in the header of each provided extra sheet.
- In your answers, try to be as concise as possible: use equations, logical operators and sketches to illustrate your thoughts whenever possible. Avoid the use of long sentences.
- You may sometimes be able to solve later parts of a problem without having solved the previous ones.
- You will be recorded during the whole examination. You are not allowed to leave your working place without permission. If you need to go to the toilet or need other assistance (extra sheets or pen, more water or snacks), please draw the attention of your Invigilator.

At the end of the exam:

- You must stop writing immediately as soon as the end of the exam is announced.
- For every problem, sort the corresponding sheets in the following order: cover sheet at the top, questions (Q), answer sheets (A) and finally working sheets (W), including any empty or extra sheets at the bottom.
- Put all the sheets belonging to one problem into the same envelope or document folder, but leave these General Instructions sheets (G) on your table outside of any envelop or document folder. You are not allowed to take any sheet of paper out of the examination area.
- When your Invigilator allows, you may leave the examination area. You can keep the IPhO pens, pencils, pencil sharpeners, erasers, rulers, protractors and calculators.

Physical Constants

Below is the list of physical constants you might use in your solution in addition to the quantities given in the problem text.

Physical constant	Notation	Numerical value
Speed of light in vacuum	c	299 792 458 m/s
Vacuum permeability (magnetic constant)	μ_0	$4\pi \cdot 10^{-7} \text{ N/A}^2$; [1 N/A ² = 1 Vs/Am]
Vacuum permittivity (electric constant)	ϵ_0	$8.8541878128(13) \cdot 10^{-12} \text{ F/m}$; [1 F/m = 1 As/Vm]
Elementary charge	e	$1.602176634 \cdot 10^{-19} \text{ C}$; [1 C = 1 A · s]
Electron rest mass	m_e	$9.1093837015(28) \cdot 10^{-31} \text{ kg}$
Proton rest mass	m_p	$1.67262192369(51) \cdot 10^{-27} \text{ kg}$
Neutron rest mass	m_n	$1.67492749804(95) \cdot 10^{-27} \text{ kg}$
Atomic mass unit	m_{amu}	$1.66053906660(50) \cdot 10^{-27} \text{ kg}$
Gravitational constant	G	$6.67430(15) \cdot 10^{-11} \text{ m}^3/(\text{kg} \cdot \text{s}^2)$
Avogadro constant	N_A	$6.02214076 \cdot 10^{23} \text{ mol}^{-1}$
Molar gas constant	R	$8.31446261815324 \dots \text{ J}/(\text{K} \cdot \text{mol})$
Boltzmann constant	k_B	$1.380649 \cdot 10^{-23} \text{ J/K}$
Stefan–Boltzmann constant	σ	$5.670374419 \dots \cdot 10^{-8} \text{ W}/(\text{m}^2 \cdot \text{K}^4)$
Planck constant	h	$6.62607015 \cdot 10^{-34} \text{ J} \cdot \text{s}$
Reduced Planck constant	$\hbar = h/(2\pi)$	$1.0545718176 \dots \cdot 10^{-34} \text{ J} \cdot \text{s}$