PLANCKS 2017—Physics League Across Numerous Countries for Kick-Ass Students

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Abstract

PLANCKS is a theoretical team competition from physics students for physics students all around the world. It originates from the local version in the Netherlands, where it took place for the first time in 2014, and since then has spread through Europe, promoted by the International Association of Physics Students (IAPS). During national preliminaries teams had the opportunity to qualify for the final contest, which took place in 2017 in Graz, Austria. The entire organisation of this international competition is carried out by physics students on an honorary basis.

Keywords: competition, international student competition, IAPS, PLANCKS

(Some figures may appear in colour only in the online journal)

1. Organisation

PLANCKS is an annual international physics contest for bachelor’s and master’s students. The name is an acronym for ‘Physics League Across Numerous Countries for Kick-Ass Students’. It originates from the Netherlands where a national version of the competition, called PION (Project Interuniversitaire Olympiade Natuurkunde), already had been established [1]. Since 2014 the International Association of Physics Students (IAPS) [6] organizes PLANCKS as an international team competition, structured in two rounds. National committees of those countries where PLANCKS is already quite prominent organize preliminaries.
in which the best two or three teams qualify for the final round. Already these national competitions attract quite a lot of teams, as in Germany, where there are more than 20 participating teams in the so-called DOPPLERS preliminary PLANCKS round.

The venue of the final round alters every year and is determined by competitive application at the general assembly of the IAPS. Currently, whilst the approximately 10 preliminaries have a quite individual format, the finals follow a similar scheme. These take place in May or June, last for three to four days and start with an opening ceremony with highly qualified keynote speakers on the day of arrival. One day is usually dedicated to the competition and some cultural activities, whereas on the last day the results are announced and the winning teams are awarded.

The aim of PLANCKS is to bring young physicists together and to encourage scientific discussion amongst them. It acts as a possibility for getting to know other physics students from all over the world.

2. PLANCKS problems and competition

A typical PLANCKS challenge consists of 10 challenging theoretical problems from all areas of physics, such as astrophysics, electrodynamics, particle physics, special and general relativity, theoretical and quantum mechanics, statistical physics, thermodynamics, solid state physics, fusion physics, and so on.

The challenge is to solve those problems in a team without any tools like books or the help of a computing device. The usual working time for the final competition is four hours.

The set-up for the preliminaries may vary: in many cases fewer problems have to be treated in less time. Since the creation of sophisticated problems is not an easy task, national committees share their problems and have their preliminary competition on the same day, in so-called joint preliminaries.

The solutions of the teams are corrected immediately afterwards by PhD students or postdocs according to a correction scheme provided by the designers of the problems, who are usually professors from the respective universities.

3. PLANCKS 2017

One hundred and forty-four students from 19 countries qualified for and participated in the finals of the PLANCKS 2017 competition, which took place from 25 May to 29 May in Graz, Austria. With the competition attracting more and more students each year, there was a record 36 participating teams, mostly from European countries, in its fourth edition. Figure 1 shows a group picture of all participants and organizers just before the competition. The by far longest journey was made by the team NTU Singapore, which won a travel fund to compensate for their high travel expenses—the biggest hurdle for potential American and Asian teams to participate.

The finals were organized by many volunteers, local physics students with the financial support of the local student unions, universities, and the European Physical Society (EPS); participation fees covered board, local transport and lodging. The total budget amounted to approximately 35,000 €. The opening ceremony of the finals of PLANCKS 2017 started with three interesting talks, about the Higgs boson (Victoria Martin, University of Edinburgh, United Kingdom), gravitational waves (Reinhard Prix, Max Planck Institute for Gravitational Physics, Germany) and magnetic skyrmions (Karin Everschor-Sitte, Johannes Gutenberg University Mainz, Germany).

The four-hour competition on the next day was followed by a scientific discussion where the students had the chance to discuss their solutions with the professors who designed the problems. Interesting discourse then transformed into a barbecue party with a local live band,
On the third day, after breakfast, the winners were announced and certified. Team Aplanckados from Spain reached first place and was rewarded a prize money of €2,109.14. The scores of the best five teams are listed in table 1; the total results can be found online [5].

Afterwards the teams could explore Graz on an organised city tour and challenge their physical trivial knowledge in a pub quiz. The optional fourth day started with lab tours of the physics facilities at both universities in Graz and continued with a trip to the famous chocolate factory in South Styria, including a visit to a nice restaurant in the countryside.

The problems of the final PLANCKS competition 2017 are listed in table 2 and can be found online [2]. The distribution of reached points is visualized in figure 2 in a boxplot.

Table 1. The best five teams of the final PLANCKS competition 2017 in Graz.

| Ranking | Team name          | Country     | Total points |
|---------|--------------------|-------------|--------------|
| 1st place | Aplanckados       | Spain       | 61.0         |
| 2nd place | Je bent een koning | The Netherlands | 60.0       |
| 3rd place | Maxwell’s demons  | Hungary     | 55.5         |
| 4th place | Take it Ising     | Germany     | 55.0         |
| 5th place | Team Awesome      | The Netherlands | 54.5       |

Table 2. List of all 10 problems in the final of the PLANCKS 2017 competition combined with the average number of reached points.

| Problems PLANCKS 2017                  | Average points |
|---------------------------------------|----------------|
| 1. Laser ionization                   | 1.2            |
| 2. Generalised 1D Brownian motion     | 6.6            |
| 3. Particle physics                   | 2.9            |
| 4. Nuclear/neutron physics            | 5.3            |
| 5. Solid state physics                | 3.3            |
| 6. Two accelerating locomotives       | 2.7            |
| connected by a tin-can telephone      |                |
| 7. Carnot cycle with van-der-Waals gas| 6.1            |
| 8. Crystal geometry                   | 4.4            |
| 9. Spin qubits                        | 1.9            |
| 10. Tribute to Joseph Ritter von Fraunhofer | 5.2        |

‘The Phy-sicks’. On the third day, after breakfast, the winners were announced and certified. Team Aplanckados from Spain reached first place and was rewarded a prize money of $2\cdot10^{37}$, $\approx 2,109.14. The scores of the best five teams are listed in table 1; the total results can be found online [5].

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including the median (red line), first and third quartile (lower and upper bound of the box) and minimal and maximal reached points.

The following is an example of one of 2017 competition’s problems.

**Spin qubits**

**Hint:** This problem should not be addressed by brute force. It is very useful to take into account spin rotation invariance.

In particular, when combining two systems described by angular momenta $\vec{J}_1$ and $\vec{J}_2$, then one can choose a basis of eigenvectors of $\vec{J}_1^2$ and $\vec{J}_2^2$, where $\vec{J} = \vec{J}_1 + \vec{J}_2$ is the total angular momentum operator. Also think how $\vec{J}_2$ is related to the scalar product $\vec{J}_1 \cdot \vec{J}_2$.

Consider a qubit set-up consisting of four spin-$\frac{1}{2}$ particles in a square arrangement (see figure 3). We work in units with $\hbar = 1$.

The Hamiltonian of the system is

$$H = \frac{1}{2} \sum_{i,j} J_{ij} \overrightarrow{S}_i \cdot \overrightarrow{S}_j,$$  

(1)

where

$$\overrightarrow{S}_j = (S_{jx}, S_{jy}, S_{jz})$$  

(2)

denotes the three components of the quantum mechanical spin operator of particle $j$ ($j = 1, 2, 3, 4$), and the dot ‘.’ denotes the scalar product over these components. The coupling constants $J_{ij}$ can have the values $J_A$ or $J_B$ according to the figure.

**Consider first the case** $J_A < 0$, $J_B < 0$

(1, 1 point) Determine the energy and degeneracy of the ground state of Hamiltonian equation (1).

The system is prepared at $t = 0$ in a state consisting of all spins oriented in the $x$ direction. At the same time a magnetic field, described by the Hamiltonian
is applied in the $z$ direction.

(2, 1 point) How long does it take for the system to go back to the state with all spins oriented in the $x$ direction?

(3, 2 point) Determine the time dependence of the magnetisation $M^x$ in the $x$ direction, where

$$M^\alpha \equiv \langle S^\alpha_i \rangle, \quad S^\alpha_{tot} \equiv \sum_{i=1}^{4} S^\alpha_i \quad \alpha = x, y, z,$$

and the expectation value $\langle \cdots \rangle$ is taken with respect to the above-mentioned time-dependent state.

We now go back to the Hamiltonian equation (1) (without magnetic field (equation (3))

(4, 1 point) For the case $J_A = J_B$, determine all eigenvalues of $H$ as well as their degeneracies.

(5, 2 point) Consider now the case $\Delta J \equiv J_B - J_A \neq 0$, but $\Delta J$ small enough (We always consider $\Delta J$ small enough such that there are neither level crossings nor accidental degeneracies.). Determine again all eigenvalues of equation (1) as well as their degeneracies.

From now on we consider the case $J_A > 0, J_B > 0$ and $\Delta J \neq 0$

(6, 1 point) Consider again the action of a magnetic field, equation (3). Determine the magnetic susceptibility

$$\chi \equiv \frac{d M^z}{dB} \bigg|_{B=0},$$

where the expectation value in equation (4) is carried out with respect to the ground state of $H + H_B$.

(7, 2 point) Consider now $\Delta J > 0$ and a magnetic field applied to the first spin only, described by the Hamiltonian
Determine the local susceptibility

\[ \chi_{\text{loc}} = \frac{d m^z}{db} \bigg|_{b=0}, \]

where

\[ m^z = \langle S^z_z \rangle \]

and the expectation value is evaluated with respect to the ground state of \( H + H_{\text{loc}} \) (no \( H_B \)).

4. Outlook

The fifth edition of PLANCKS will take place from 11 May to 13 May 2018, in Zagreb, Croatia \[3]\]; the sixth edition will take place from 17 May to 20 May 2019, in Odense, Denmark \[4]\). The hope for the future is to attract more students from all over the world and also to receive more financial support on a permanent basis to allow for more teams to participate. The challenges of the future are to create permanent structures that facilitate the annual re-establishment of the Organising Committee and the maintenance of contacts with national organisers.

PLANCKS is an unique experience for both the organising and participating students. It fosters international exchange, team work in solving physics problems or organizing international events, and cultivates a critical scientific discussion. The format especially promotes scientific collaboration, which is the key for a successful scientific career.

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