

Theoretical and Experimental Problems of the International Physics Olympiad – Requirements and Priorities.

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Abstract:

The International Physics Olympiad (IPhO) brings together the top high school physics students from over 80 countries and challenges them to complete both a theoretical and experimental exam. The host country for the IPhO has the responsibility for creating the exam questions. The quality of these exam questions set the high bar for defining the problem solving skills of high school students. In an effort to evaluate the characteristics and quality of Olympiad problems, a survey of IPhO team leaders from participating nations was conducted in 2010. The survey provides insights into which attributes of Olympiad problems are most highly valued. These results can be used by future host countries as guidelines in constructing their Olympiad exam.

Article:

IPhO – An analysis of past Olympiad Problems

The International Physics Olympiad (IPhO)

The mission of the International Physics Olympiad (IPhO) can be culled from the introduction to the statutes: “In recognition of the growing significance of physics in all fields of science and technology, and in the general education of young people, and with the aim of enhancing the development of international contacts in the field of school education in physics, an annual physics competition has been organized for secondary school students. The competition is called the International Physics Olympiad and is a competition between individuals.”

As anyone attending the past Olympiads, as a student, leader or observer, can attest, the IPhO is unique in welcoming high school students to the physics community, and challenging all students to learn more physics. The Olympiad is a scientific, social and cultural event that has a theoretical exam and an experimental exam as its major focus.

Every year, the Olympiad moves to another host country. The original 1967 Olympiad had only five countries in Europe participating. Over 90 countries from every continent participated in recent Olympiads. Given this wide participation, a single country will now probably have only one opportunity to host an Olympiad in anyone’s given lifetime. Host countries have an opportunity for the “best and brightest” high school physics students to visit their country and they devote many resources to insuring that the cultural, scientific and social activities leave all participants with warm memories of their visits.

- The host country is also responsible for creating the examination problems for that year. The host country has some guidance in the development of the theory and experimental problems. All problems must subscribe to the statutes of the Olympiad. These include :The theoretical examination shall consist of three theoretical problems and shall be of five hours total duration.
- The experimental examination shall consist of one or two problems and shall be of five hours total duration.
- The theoretical problems should involve at least four areas of physics taught at secondary school level, (see Syllabus). Secondary school students should be able to solve the competition problems with standard high school mathematics and without extensive numerical calculation.
- The total number of marks awarded for the theoretical examination shall be 30 and for the experimental examination 20. The competition organizer shall determine how the marks are allocated within the examinations.
- The standard of problems should attempt to ensure that approximately half the students obtain over half marks.
- The extensive use of the calculus (differentiation and integration) and the use of complex numbers or solving differential equations should not be required to solve the theoretical and practical problems.
- Questions may contain concepts and phenomena not contained in the Syllabus but sufficient information must be given in the questions so that candidates without previous knowledge of these topics would not be at a disadvantage.
- Sophisticated practical equipment likely to be unfamiliar to the candidates should not dominate a problem. If such devices are used then careful instructions must be given to the candidates.
- The original texts of the problems have to be set in the SI units.

In addition, there are other unstipulated but assumed rules:

- The text of the problem is short enough to be translated within the time constraints of the leaders;
- The problem can be graded across multiple languages;
- The problem can be graded within 48 hours of the exam;
- The problem is not identical to past Olympiad problems.

Although every host country strives to create problems that are creative and challenging given these constraints, each has a differing level of success as evidenced by the scores on problems and on the opinions of the leaders. It is important to realize that the leaders are familiar with many, if not all, past Olympiad problems. The leaders in many instances are also involved in either their individual country's selection exams and/or the training of the Olympiad team. Their opinions reflect this familiarity and experience.

Judging the quality of an Olympiad problem.

In 2009 we sent an email to all the leaders (two from each participating country) asking to choose the best 3 theoretical and best 3 experimental problems from all past Olympiads. Unfortunately only the leaders from 10 countries responded.

We found out that almost all the theoretical problems with some modeling (we did not have many in our history) were chosen as best. Most chosen experimental problems had something “to figure out” rather than following a given procedure.

The choices were probably “skewed” towards more recent problems since there are very few leaders who have been participating for more than 10 years. The list of problems, which obtained more than 2 “votes”, is in table 1. (The actual problems can be found on the official IPhO web site.)

Olympiad	Problem number	Year	
Theory			
	11	2	1982 oscillations of a coat hanger, very smart, no structure, simple to mark!, needs model
	35	1	2004 Disk jumping inside capacitor, structured,
	36	2	2005 Analysis of several experiments used in electric metrology
	40	3	2009 Calculation of the star parameters from first principles
Experiment			
	28	1	1997 Bimorph
	30	1	1999 Tortion pendulum
	32	1	2001 rotating liquid
	37	1	2006 Microwave interference
	38	1	2007 Energy gap in Semiconductor thin film
	40	1	2009 Wavelength of the laser diode

In an attempt to explore what criteria leaders think make a good Olympiad problem, we generated a list of 25 attributes for Olympiad problems that included both problem selection as well as grading aspects. During an International board meeting of the 41st IPhO in 2010, we asked leaders of participating countries to rank each of these as most important (1), important (2), little importance (3) or not important (4). There was a computer for each two leaders so there are common responses from the two leaders of each country. In order to rank the importance of each criteria, we multiplied the response value by the number of countries choosing that response, summed the results, and then sorted based on the sum. Those problem attributes which received the lowest sums were deemed the most important attributes.

Based on this survey, the rankings of attributes are shown in Table 2.

Question	very important	important	little importance	not important	Score
The problem rewards physical insights more than mathematical manipulations	43	29	0	0	101
The student has the possibility of receiving partial marks	43	24	4	1	107
Student creativity can be rewarded	38	31	3	0	109
The students achieve a physical insight as a result of solving the problem	29	36	7	0	122
A grade of 10 should require some special insights into the physics	26	27	17	1	135
The problem should be applied to a real situation.	13	43	16	0	147
The problem should allow all Olympiad students a chance of receiving at least 1 mark	31	18	10	13	149
The problem requires the student to justify the reasonableness of the solution that he or she has reached.	13	42	13	4	152
The problem spans more than one part of the syllabus	11	41	16	4	157
The problem requires the student to look at limiting cases	7	39	25	1	164
The problem requires the student to build a model	9	35	22	6	169
The problem require students to compare a theoretical model with an experimental result	7	36	25	4	170
The student is required to give an "order of magnitude" answer rather than a numerical answer	9	25	30	8	181
The problem requires the student to look at special cases	2	33	34	3	182
The problem require students to use dimensional analysis	5	23	39	4	184
The problem require students to use approximations	2	32	33	5	185
The problem should have at most 4 parts	15	18	19	20	188
The problem requires the use of symmetries	2	21	45	4	195
The problem has multiple solutions	4	17	37	13	201
The problem has a numerical value to be checked	2	17	36	17	212
The problem should have at least 4 parts	3	6	31	31	232
The problem should reflect the host country's culture or history.	3	3	36	30	237
The problem should be similar to textbook problems	3	8	22	39	241

The leaders agreed that the most important attribute of an Olympiad problem is that “the problem rewards physical insights more than mathematical manipulations.” We can all create a difficult physics problem that is only difficult because it requires the use of complicated trigonometric functions rather than new insights into physics. We can also make a problem time consuming by requiring extra mathematical calculations without introducing any new physics. The leaders seem to agree that math requirements without physics insights should be discouraged.

The leaders also agreed that “the problem should be applied to a real situation.” We know that students in our schools are more motivated when the physics topics are relevant to their lives. We don’t need to worry about student motivation with the select group of Olympiad students, but the leaders still placed a high value on ‘real situations.’ We can construct a problem that has a ball resting on a mass which is resting on another mass. One mass gets pulled to the right and the student can describe what happens to the ball on top and the mass below given coefficients of friction and other information. But, who cares and why would anyone want to solve this problem? Clearly during the Olympiad students have a very strong motivation to solve all the problems and win so it is in this sense that all the problems are relevant. But it would be nice for IPhO popularization and value to the larger physics education community to show that physics is relevant to real life.

The leaders also agreed that “the problem (should) require the student to justify the reasonableness for the solution that he or she has reached.” In our teaching, we are often confronted with students who never

check their answers. We know that our Olympiad students often do. We also now know that leaders think that this should be rewarded. In future Olympiad problems, whether this is formerly requested or assumed, it should be valued in the grading.

Future Olympiads

The construction of exam questions is often completed by a committee of the host country. The questions are then tested with professors, graduate students and undergraduates. Through a series of iterations and constant review of the questions with respect to the statutes, the problems are agreed upon and presented at the Olympiad.

The survey results are a first attempt to guide the creation of future Olympiad problems. The survey can be used as an additional checklist in order to judge the quality of new problems. The survey can also be used as a guide in selecting problems.

At future Olympiads, the host country could also show how their problems correlate with the attributes on this survey in the same way that they show how the problem spans the content areas on the syllabus.

Finally, this preliminary survey may serve as vehicle to further discuss the strengths and weaknesses of Olympiad problems.

The Olympiad problem sets are an international standard for what the highest achieving secondary school students are capable of solving. It would also be advantageous if they served as a model for defining what a quality physics problem should look like. In this way, the Olympiad problems can enhance physics education internationally for all students.