Competitions for secondary physics students

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PHYSICS OLYMPICS

The official logo of the Physics Olympics, designed by Dr. Robert Lillich of Newark, Delaware.

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The Physics Olympics is a series of competitive events for teams and individuals, organized like a track meet but involving contests based on physics. At the Indiana University of Pennsylvania we ran such an Olympics for high school students during the spring of 1975 and again in February 1976.

During the summer of 1974 high school physics teachers met on the IUP campus to discuss programs that could be conducted from IUP to support high school physics. Funds were obtained from the National Science Foundation for a pilot series of programs. The teachers active in these discussions were participants of the 1974 NSF-supported program for Project Physics Implementation, and a group of participants from our similar 1973 program. These past-participants had been invited back to the IUP campus to attend a one-week mini-course on the topic "Physics and Music." Altogether, some 70 physics teachers helped to plan the Physics Olympics. While both groups were concerned with the recognition and encouragement of talented students, they also saw the need for a motivating program for physics students of any ability level.

We decided to offer some form of competition for school teams and individuals organized along the lines of a track meet. A series of events would be conducted, each linked to physics and physical principles, but designed to be enjoyable or interesting for competitors and spectators. Ideas for possible events were "borrowed" widely from the imagination and memories of the teacher group and the staff at IUP. The Physics Olympics that emerged was thus a loosely-related series of events. The basic unit of competition was the school team, composed of four to eight students. Each team competed in six required events plus two additional events chosen by the team. Additionally, individual competitors in each event were allowed, as well as pentathlon entrants in a series of five events designed to determine the "best rounded" physics student.

The events of the Physics Olympics were organized loosely around six areas of competition. These were:

1. Knowledge in physics
2. Numerical estimation of physical quantities
3. Events involving the design and construction of apparatus
4. Events involving linear motion
5. Events involving trajectories
6. Events associated with art or music

These categories were neither exhaustive nor mutually exclusive. In all,

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fourteen separate events were conducted during the first competition.

This competition was announced to former program participants and then to all secondary schools in Pennsylvania. Notices were also sent to several groups of physics teachers from nearby states. Eventual registration for 1975 grew to 58 teams and 127 individual entrants representing 5 states. At the suggestion of Marshall Mattson, physics teacher at Adrian, Michigan, a preliminary competition was organized for teams from Michigan and Western Ohio. The winners of this competition then came to IUP for the final competition conducted in April 1975. In contrast, the 1976 competition was held too early in the year at IUP to allow prior regional competition, but two were conducted after the IUP event.

It became clear quite early that some schools were becoming rather deeply involved in the spirit of the competition. Many were conducting local eliminations to determine the students who would make up their strongest possible team. One school conducted such eliminations after school every night for a full month before the registration deadline. Another school conducted a sales campaign of tomato plants to outfit their teams in uniforms for the competition — they then arrived complete with a pep band and cheerleaders.

On the IUP campus, we did our best to cycle up an event worthy of these preparations. Over a thousand hours of faculty and student time was involved in preparing for and conducting the competitions. An official logo was produced and affixed to all communications as well as campus direction markers, event site signboards, and road signs. Tie-on vests for officials were imprinted with the logo and color-coded for different functions with brilliant fluorescent stripes. Fourteen categories of officials were identified by photographically produced badges. In addition to a 24-page book of rules, a separate 17-page book of competition instructions was sent to all registrants. On the day of the competition, the series of engraved plaques to be presented to winners were prominently displayed along with several hundred golden imprinted medallions mounted on gold, blue and red neckbands. All of this, except the plaques, was produced on campus at a minimal dollar expense. However, the effort expended for our first competition generally represented a one time effort which did not have to be repeated for our 1976 competition. Thus, the Physics Olympics was conducted in the standard mock-heroic spirit of a typical championship athletic event.

The separate events offered during our competition have been:

Fermi Question Competition

A Fermi question is a quantitative question requiring the rational estimation of several parameters and a subsequent calculation of the desired answer. Perhaps the best known of these was posed when Fermi casually asked, "How many piano tuners are there in New York City?" Questions used in the competition included, "What is the horsepower developed by a mosquito in flight?" and "What is the mass, in grams, of the rubber worn off the tire of a standard size Chevrolet in one kilometer of travel?" Individuals or teams were allowed eight minutes to answer as many of 20 questions as they could. Judges awarded points based on a fixed schedule of five points for the correct order of magnitude and fewer points for a one-or two-power error depending on the complexity of the estimates needed. Some questions require a "direct hit" for any points to be awarded.

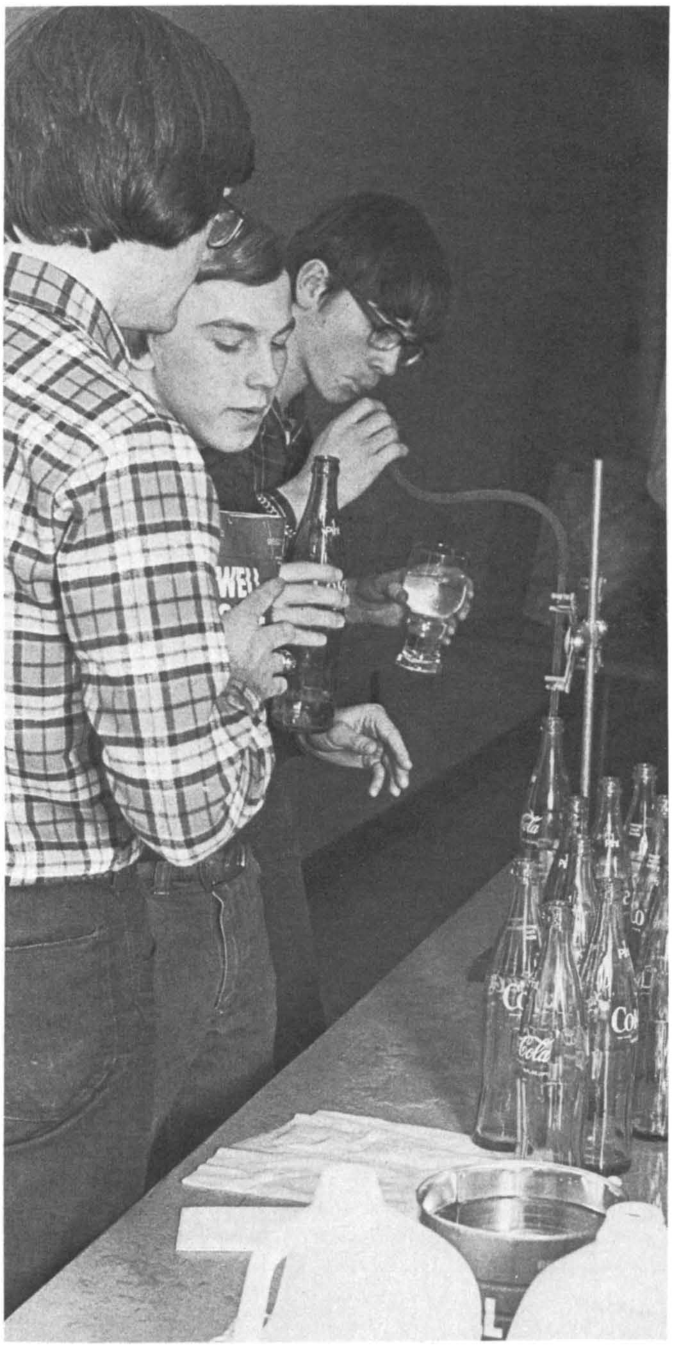


Fig. 1. A competitor "blows" a bottle to judge the note. Teams generated an 18 note standard scale including sharps and flats from high C to G below middle C.

Rock-Skipping Contest

Competitors were required to skip a rock across a lake surface with performance judged on distance achieved, number of skips and the aesthetics of the trajectory.

Paper Airplane Contest

Competitors launched paper airplanes of their own design in separate trials for distance, time of flight, and accuracy. (In the 1976 competition, the accuracy round was dropped.)

Slow Bicycle Race

Competitors rode a bicycle over a 1.2 m wide by 20 m long course both up-slope and down-slope trying for the greatest elapsed time. Bicycle "tireprints" under load were required to conform to maximum width and area requirements, and minimal wheel diameter and seat heights were specified. At all times the bicycle was required to have perceptible forward motion and its wheels could not touch the side marking lines.

Quiz Show Program

Teams were given a time limit to accumulate points by answering as many factual questions in physics as they could. During 1975 each team was questioned independently. In the 1976 competition individual members of teams responded in writing.

Egg-Dropping Competition

In 1975, competitors were required to launch a packaged egg to a qualifying altitude of 8 m or more and return it unbroken. In the 1976 competition this event was truly an egg-dropping competition where eggs and containers were dropped from a height of 11 m onto a hard surface. The winning team was the one which managed to accomplish this drop in the least time without breaking the egg by removing as much of the effect of air resistance as possible.

Kite-Flying Contest

Competitors flew kites of their own fabrication attempting the greatest average rate of climb during a two-minute measurement interval.

I. U. P. Physics Olympics Quiz Show 1976

Sample questions from four categories:

I. Who	Give the name of the person who is primarily associated with or is responsible for the following theories and/or ideas in physics: Uncertainty Principle
II. What	Give the units in the mks system used to measure the following: Angular or rotational velocity
III. Substances	What relatively well known material is noted for each of the following properties? Highest index of refraction
IV. Queries	How does increasing the area of a capacitor's plates change its capacitance?

Water Balloon Launch

Using a football goalpost and surgical tubing as a slingshot, competing teams tried to attain the greatest accuracy in launching water-filled balloons at targets on the 30; 50-and 70-yard markers of a football field.

Fig. 2. Some teams produced tones by striking the bottle. Here a voice-trained student holds a note while her teammates adjust the pitch of a bottle. Following tuning, each team played a required musical piece for the judges and one of their own choice. The required piece (either "Daisey, Daisey," or "Dixie") generally required the synchronized playing of two to four competitors.

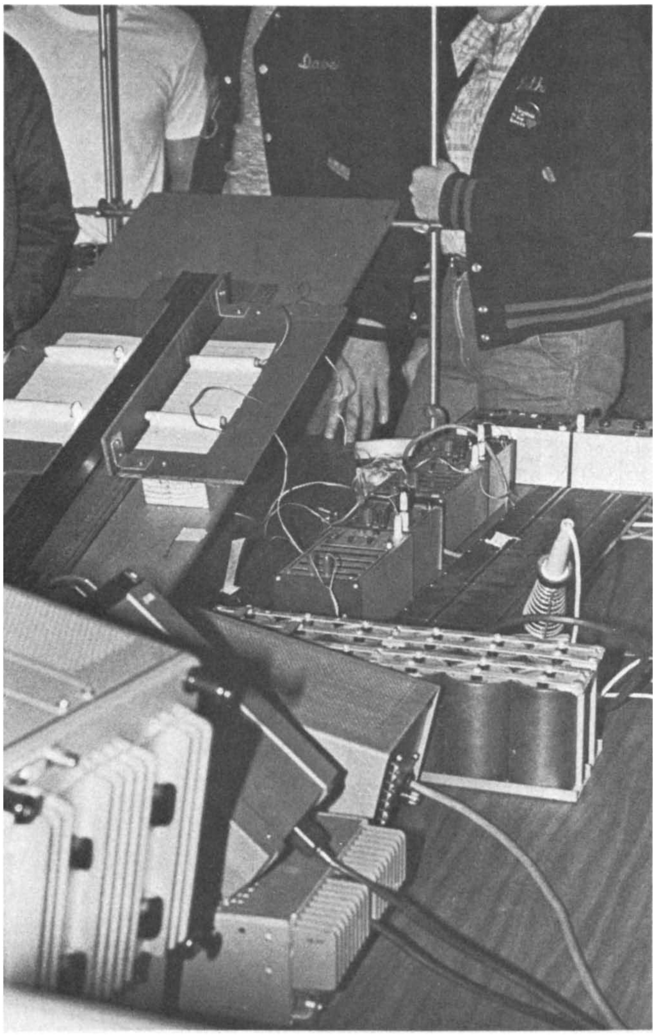


Fig. 3. Electronics assembly for producing the power burst to slot cars. Cars received a 0.30 second burst of power delivered at a nonstandard voltage and constant during the power surge. Capacitor banks shown helped smooth fluctuations which were monitored on an oscilloscope. If a variation greater than 0.1 V occurred, the run could be repeated without penalty. The nonstandard voltage insured students would have to modify cars to be in serious contention.

Bridge-Building Contest

From a specified amount of balsa wood sheeting, students designed and constructed bridges to withstand the greatest load on the center of the span. Bridges were required to pass a 10-cm cube under the span without touching and have at least 40-cm of clearance between supports at the base.

Gravitational "500"

Competitors attempted to have a car of the "Hot Wheels" type complete a complex course in the least elapsed time.

Slot Car Acceleration Contest

Competitors attempted to have a slot car display the greatest possible acceleration from a standing start using a specified, but definitely non-standard voltage power supply provided.

Bottle Music Contest

Given a matched set of empty bottles and water, the team had to tune a musical scale and perform both a required musical piece given them at the competition and an exhibition composition of their own choice.

Two Meter Band Contest

Competitors were required to construct instruments of their own design and play both a required musical piece and an additional exhibition composition of their own choice. The use of commercial components was carefully defined to not preclude electronic instruments. All varieties of instruments were encouraged.

Instant Poster Contest

Each team was supplied with a full range of paraphernalia for the production of posters and a workroom. They then were given a topic — for example, "The conservation of momentum," and were given 20 minutes to brainstorm and produce the best poster on the topic.

Results

As might be anticipated, each year problems arose during the day of competition. In 1975 the weather was clear but quite cold and gusty. Many light kites were torn to shreds by the gusts, while others broke guide lines. Waves on the lake made it difficult to follow rock trajectories for judging. During the afternoon the water balloon launching apparatus had repeated problems and the back-up system would not meet the specifications of the original. Most serious, several events lagged behind schedule and began to interrupt the scheduling of other events. However, students and teachers reacted quite well to most adversities. The 1976 competition had fewer problems.

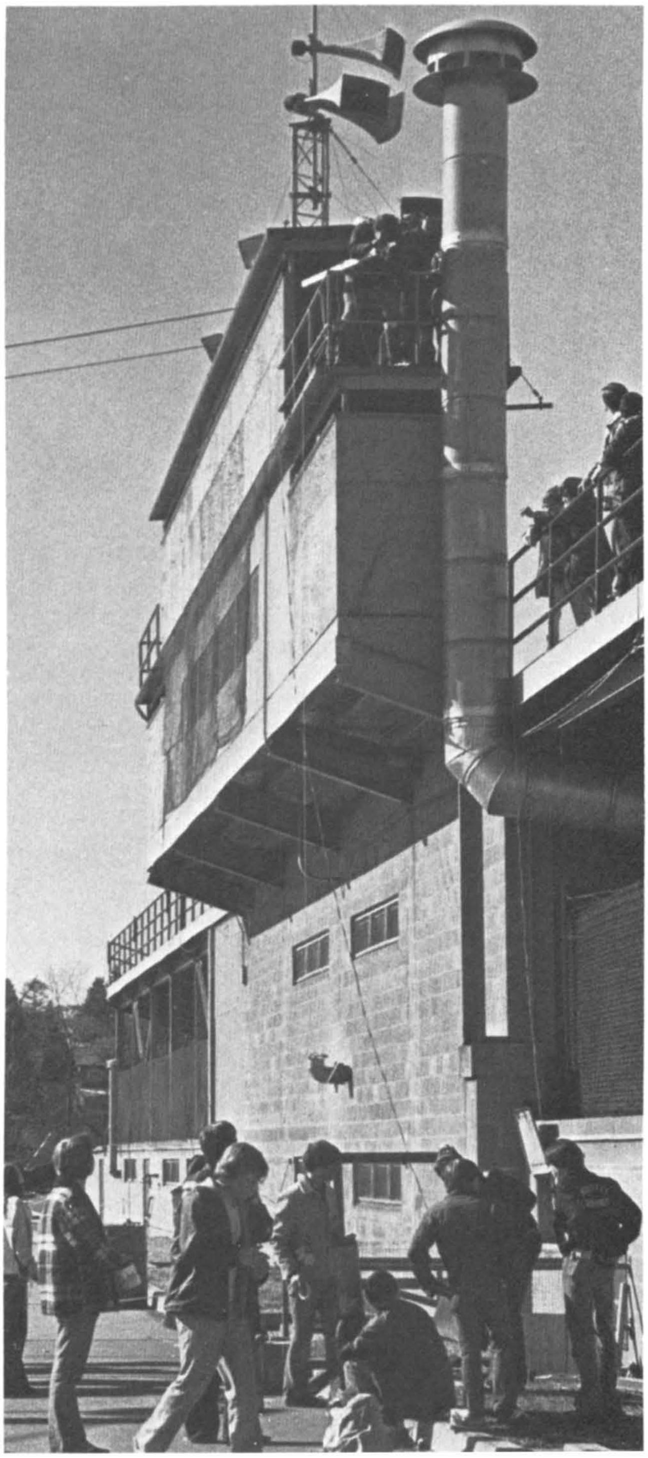
Humorous incidents occurred during most events. On several occasions teams launched water balloons with a torque on the apparatus holding the balloon which then rotated during the contraction of the tubing and did not release the balloon at the end of the stroke, but flung it back at the launching team on the return stroke where it broke, spraying the team with droplets of water and kicked-up dirt. This invariably pleased the crowd more than the competing team. Well-practiced teams had no difficulty in landing three consecutive shots within a few meters of a target almost 80 m distant.

The rock-skipping contest was found to be a complex event to arrange and judge. (The rules alone ran over three pages long.) During the 1975 competition the winds and currents on the lake were very unfavorable and the light plastic floats used as course markers were dragged as much as 15 m out of position even though each was anchored by a concrete block. Contrary to our expectations, none of the competitors became sufficiently involved to fall out of the throwing pit and into the lake during the competition, but some did manage shots which all of the judges lost in the waves. Due to the dependency of this event on favorable weather conditions it was dropped from our 1976 program.

The Fermi question competition produced highly unpredictable results during 1975. Several otherwise well-prepared teams did poorly in the event and vice versa. (After one session we did suggest to a student that if

Fig. 4. Egg-Dropping Contest — Loading the egg into the drop container. At 15 to 20 m of drop height, limiting velocity problems begin to influence most designs unless very heavy containers are allowed. 1977 rules limit the container to several egg-masses and egg-lengths and a drop height of 10 m.

Fig. 5. Egg-Dropping Contest — The drop location chosen was the platform on the press box of the football field, affording access to electricity at both ends of the drop as well as a secure position for the upper crew.



offered a chance to buy a tire that shed 10^4 g of rubber per km he should resist the temptation.) By 1976, the concept of rapid estimation of reasonably bizarre quantities seemed to have acquired a new stature at some schools. With only 20 questions having a sliding point value (typically 5-3-1) based on accuracy of estimate, a perfect score is 100 points. Two teams exceeded two-thirds of the available points within the eight minute time limit and 15 teams accumulated points in this event toward the team title.

In the original running of the egg-drop, the altitude attained in the launch phase was used to determine winners. Since we had not excluded rockets in the rules, we were obliged to admit them. Thus, rocket launch systems were admitted to competition provided they were entirely hand fabricated except for the rocket engines which were required to be commercial models. Generally, the rocket systems performed quite well and outclassed other systems. One rocket did illustrate design problems, since, when fired, the engine drove through the retaining wall, through the egg, through the parachute recovery apparatus, out the nosecone and to considerable altitude leaving a smouldering pile of debris on the launch pad, including the semicooked, scrambled egg. The only original system to seriously challenge the rocket system was an ingenious arrangement of helium-filled balloons designed to lift the egg to altitude whereupon a timer would detonate all but one balloon which served as a braking system for the egg. Unfortunately, this system depended on reasonably good weather and an operating timer to recover the egg. Neither managed to work out and when last seen the balloon assembly had drifted several miles and was crossing the ridge enclosing the valley of the competition site.

Appropriately, individuals and teams displaying the most creative input and practice did much better than more casual competitors.

Each year the winning entry in the bridge-building contest held a full size waste paper basket filled with sand (78 lbs) hung from the center of the span. The 1975 bridge would have supported much more weight, bearing purely vertically, but a thin lateral brace gave way making a sideways collapse likely, and ending the testing. As an indication of the increased seriousness of the competition, 16 of the bridges entered in 1976 exceeded the load record of the third place bridge in 1975.

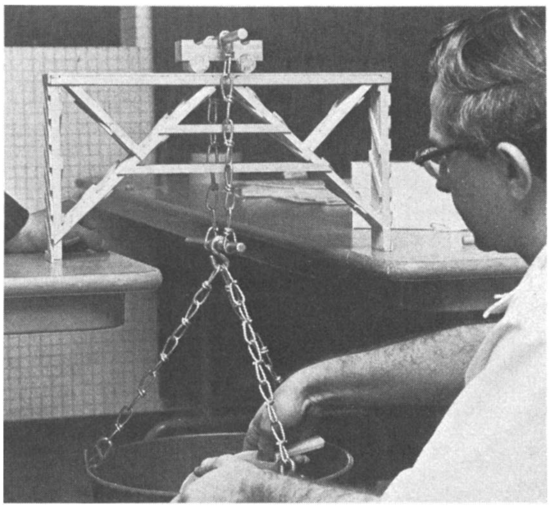


Fig. 6. Bridge Building Competition — The testing frame for bridges is shown. Force is applied through two 1.27-cm radius dowels on 6-cm centers. Sand is added to the hanging bucket until the first clear failure of any bridge member in the opinion of the judge. The weight is immediately removed so that students can retain their handiwork. David Ramsey was the judge.

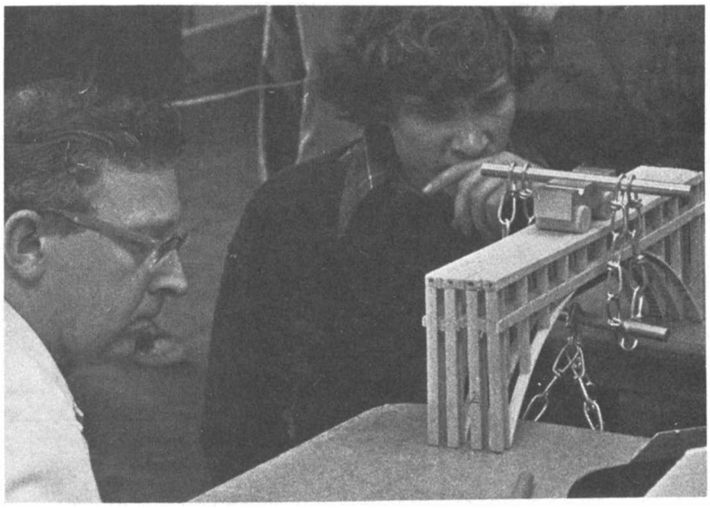


Fig. 7. Tension mounts as the bridge passes 100 times its own weight with no failure yet evident. The most minor indication of structural failures or any clear sound of failure ends the testing. Flexure is monitored with a laboratory cathetometer during testing and must remain within one centimeter. Tests are conducted by David Ramsey, Director of Shops for the IUP Division of Sciences.

Normally, testing is continued only until the failure of the first member of the bridge. The rules contain complete specifications for the testing jig to allow the design to concentrate bridge strength in critical areas. By testing until the first part fails and immediately removing the load, most students can retain their bridge in essentially intact condition. This procedure doesn't always work. One 1976 bridge gave no indication of impending failure before completely fragmenting into a spray of fine balsa fragments showering the testing area. (As an interesting aside to this competition, one teacher produced a set of over 30 photographs of the bridges entered showing the structural details of each. These photographs are being used as a classroom exercise with students, having them predict the relative strengths of the designs before the testing data is revealed to them.)

— It was fascinating to hear a Mozart trio performed by students using instruments they had fabricated themselves. The rectangular sounding boxes on the instruments produced limited sound intensity and less subtlety of tone than professional instruments but were clearly audible throughout a 160-seat auditorium. While each of the 1975 entries in this contest was admirable, the 1976 time schedule did not allow a lengthy student preparation time so this event was dropped.

Fig. 8. The array of bridge entries made a popular and attractive exhibit for students. One bridge survived an automobile trip across three states to arrive at the IUP competition. Thirty-one bridges were tested in the 1976 competition. A majority of them would have placed in the top group in 1975 although no entry beat the earlier record.

Fig. 9. The winner took 32 min to complete the course — at all times displaying forward motion and never touching the foul lines or losing balance. The 1977 rules substantially modify the event since this version has been "solved" by the students. Two entries were similar to the bicycle shown. This one is within 2 mm of the limits allowed the vehicle in the specifications.

— The top contender in the 1975 Slow Bicycle Race, using a bicycle modified within the detailed rules, took over five minutes to complete the two 20 m runs required always displaying forward motion within the narrow, inclined track. This was such an outstanding performance that we were totally unprepared for the 1976 winner's total time of 1957 sec, or over 32 min!

The students had welded flat steel bands to both front and rear wheels making certain they were 2 mm narrower than the rules allowed. The winning ride was painful to watch or judge, as the students had practiced slow riding until it was an art form. Barbell weights were worn around the student's calves to increase the inertia of the lower leg and eliminate erratic movements. Once finished, the student found it difficult to move under his own muscle power. The judges in this event also made a special award to another individual completing the course in 621 sec using a narrow tire 10-speed bicycle. Since this problem in optimization has apparently been mastered by the competitors, our 1977 rules will be modified to present new challenges to the students.

Evaluation

At the end of the 1974-1975 academic year a questionnaire was sent to all teachers participating in the various events and competitions conducted by IUP during the year. The Physics Olympics received a solid 4.45 rating on the grade scale used (A = 5.0) by the group of teachers that had participated. Of these, 47% recommended "definitely continue" and 41% "continue" on a five level recommendation scale with the remaining 12% having no recommendation. In August of 1975, the physics teachers voted unanimously to conduct another competition in 1976, and in 1976 the IUP Physics Department decided to continue the program for the future as a continuing service to secondary classrooms. The rules and events will be somewhat modified each year using the experience gained with each running of the Physics Olympics, but the general format will be the same. The 1975 winning schools were:

1. Greater Latrobe High School, Latrobe, Pennsylvania
2. Valley High School, New Kensington, Pennsylvania
3. Adrian High School, Adrian, Michigan

and the 1976 winners were:

1. Hampton High School, Allison Park, Pennsylvania
2. Cuyahoga Falls High School, Cuyahoga Falls, Ohio
3. Adrian High School, Adrian, Michigan

We feel that this program has contributed to secondary physics by increasing physics awareness in the participating schools. Approximately 200 event and team awards were made following the competition. In many cases, local newspapers carried the story. And, in several schools, for the first time the student body witnessed an award being given to physics students during the awards assembly in the school. Even if this doesn't change the context in which physics is viewed by students in these schools, the favorable reaction of teachers, students, parents and counselors involved in this program has made it worthwhile.

We have currently printed the detailed rules for our 1977 competition and will supply a copy to interested teachers. At this writing we know of seven individuals or groups who either are working on a regional competition or have indicated their intent to do so. These are:

1. Southern New Jersey — Delaware Area
   Alan Feldman, Willingsboro High School
   Willingsboro, New Jersey 08046 and
   Robert Lillich, Glasgow High School
   Newark, Delaware 19711
2. Philadelphia Archdiocese Schools
   Anthony Consentino
   North East Catholic High School
   Philadelphia, Pennsylvania 19124
3. Central Pennsylvania
   John Matsik, Hollidaysburg High School
   Hollidaysburg, Pennsylvania 16648
4. Western Pennsylvania
   James Mussolino, Valley High School
   New Kensington, Pennsylvania 15068
5. Rochester (New York) area
   Henry Metzler and/or Gerald Bucklin
   Greece-Olympia High School
   Rochester, New York 14615

Fig. 10. A water balloon being aimed for the 80 yard range. The photograph shows the attachment of the surgical tubing to the water balloon holder.

6. Southern Michigan
   Marshall Mattson, Adrian High School
   Adrian, Michigan 49221 and
   James Reid and/or Glen Deslich
   Lansing Sexton High School
   Lansing, Michigan 48900
7. Northern Ohio
   John Peduzzi
   John Marshall High School
   Cleveland, Ohio 44111

The rapid spreading of interest in this program would seem to indicate that it meets a perceived need of secondary physics. The more the basic idea is borrowed, consciously modified to suit local conditions and put into practice, the more certain this conclusion will become.

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