THE THIRTY-NINETH
UBC PHYSICS OLYMPICS
RULE BOOK

March 4, 2017

Financial sponsorship is provided by
Department of Curriculum and Pedagogy (Science Education Group)
Department of Physics and Astronomy

Version 2, 3 February 2017

General Rules

Each school, combination of schools, or (with permission) mini-school, may enter up to 15 students to compete in the 6 events in teams of up to 5. A school may request to have 2 teams, but each must have at least 4 students on the competition day, or they will be combined into one team. Events are designed so undersized teams are not penalized. Each event is run in 6 heats lasting about 1 hour each. There is a break for lunch (not provided, but the Student Nest building is across the street from the Hennings Building). Gold, Silver, and Bronze medals will be awarded to the members of the top teams in each event. Plaques will be awarded to the schools with the top 6 combined scores, and a traveling trophy will be awarded to the top school.

The combined score of a team is the sum of their decibel scores in the 6 events. The schools are ranked by their score in each event, and the decibel score for the event is $\mathrm{dB} = 10 \times \log_{10}(\mathrm{rank})$. Thus a first place ranking in an event is 0 dB, second is 3.01 dB, fifth is 6.99 dB, tenth is 10 dB, twentieth is 13.01 dB. The overall winner is the school with the lowest total decibel score.

Interpretation of Rules

Normal physics interpretations will be applied to all the terminology used in defining the challenges. Those solutions which, in the opinion of the event judges, do not comply with the spirit and intent of the rules will be disqualified from the event (and thus ranked last for the event). The ruling of the event judges is final.

Pre-Build Events

There are two events which require the teams to design and build devices before the event. Pre-built devices will be checked into a storage room until required for a heat. Modifications are not allowed after arrival, except for repairs of damage sustained in transit.

The pre-built events are intended to be learning experiences for the students, so we ask that team coaches resist the urge to overly involve themselves in the design and construction.

Winning solutions will typically push up against the limits of the rules, but violating the rules will result in disqualification. To avoid this disappointment, teams are encouraged to contact the Physics Olympics organizers for a preliminary evaluation about whether their design is within the rules. However, the ruling of the event judge about the legality of a pre-built device at the time of the competition is final, and overrides any preliminary evaluation.

Please direct inquiries about the rules to Prof. Thomas Mattison, preferably by email to
mattison@physics.ubc.ca or by telephone 604-822-9690, Monday-Friday 10 AM and 4 PM.

1. Elastomer-Powered Aircraft

Your goal is to build an aircraft that can achieve the longest flight duration powered by the energy stored in elastomers.

1. Flight and launch:
   a. Aircraft's flight must be powered by the energy stored in an elastomer.
   b. Aircraft must sustain an altitude of at least 10 cm above the floor or launch table (whichever is directly below the aircraft) for at least 2 seconds after the launch. Flights that do not meet these criteria will not score.
   c. The aircraft's flight time begins the moment the aircraft becomes airborne and ends when any part of the aircraft comes in contact with an obstacle, including the floor, ceiling, walls, chairs, person, etc.
   d. The aircraft must be launched from the designated launch table (the airfield) or by hand (as described in part 1.e) in the direction of the team's choice. There are two options for the designated launch table (the runway).
      i. The aircraft may be self-launching, such that no external devices (including external anchors) are used to achieve takeoff from the runway.
      ii. A launch-assist device may be used to help the aircraft become airborne from the runway. The device may be completely separate from the aircraft.
   e. The team may elect to hand-launch the aircraft instead of using the runway. A hand launch must be a simple toss by hand, and cannot be used in conjunction with a launch-assist device.
   f. The entire aircraft must remain intact throughout the launch and flight. No parts may be jettisoned (intentionally or unintentionally) during flight unless those parts remain physically attached to the aircraft throughout the duration of the flight. Jettisoning air from the aircraft, such as a source of propulsion, is permitted.
2. Elastomers:
   a. The term "elastomer" is intended to be inclusive of a wide variety of elastic materials, largely envisaged to be derived from natural and/or synthetic rubbers. Examples include rubber bands, balloons, and tubing (e.g., surgical).
   b. At least one elastomer must be incorporated into the design of the aircraft or into the design of the launch-assist device (if one is used).
   c. Multiple elastomers may be used in either the aircraft and/or in the launch-assist device (if used).
3. Materials and construction:
   a. The aircraft and launch-assist device (if used) must be constructed from basic materials that are readily available. Examples of allowed materials include wood; paper (including tissue paper and cardboard); plastic wrap; recyclable plastic containers; metal from recyclable containers; wire, including paper clips; straws; string; crafting beads and buttons; glue; tape; and elastomers.
   b. Aircraft components and structures may not be pre-manufactured.
      i. Components or structures that are from model aircrafts, including propellers, and structures that can be used as if it they were part of model aircrafts (e.g., a propeller for a boat) are not allowed.

        ii. Basic pre-manufactured shapes, such as wooden circles, squares, etc., or pre-manufactured items, such as elastomers, paper clips, straws, string, etc., may be used.

    c. 3D printing is not allowed.
    d. The aircraft must be constructed by the team. Aircraft that consist entirely of a pre-manufactured item, e.g., a balloon, will be disqualified.
    e. An object that relies solely on drag to remain airborne (e.g., a simple parachute) will not be viewed as an aircraft and will be disqualified.
    f. All aircraft must be heavier than air.
    g. The launch-assist device (if used) does not need to use an elastomer (provided part 2.b is met). However, the launch-assist device may not be battery powered or use an external electrical power source.

4. Event time:
    a. Each team will have 3 minutes to prepare, launch, and fly their aircraft (including any winding).
5. Dimensions:
    a. The aircraft and launch-assist device (if used) must fit in a box with dimensions not to exceed 90 x 90 x 90 cm^3.
    b. Flights will take place in the Hebb theatre. The dimensions of the launch table are 105 cm by 240 cm. There are rows of desks and chairs in front, to the side, and behind the launch table. See Figures 1 and 2 for the launch table's position in the Hebb theatre and the relative layout. The desk rows curve around the front podium area. The front wall is about 13.5 metres from the launch table, and the side walls are about 8.5 metres from the launch table, converging toward the front. The Hebb ceiling is complicated. Directly over the launch table, there is 5.8 metre clearance. A few metres to the left or right, the clearance decreases to 4.4 metres. Toward the walls, clearance is reduced to 2.8 metres, stepping down to 2 metres in some spots.
6. Tools:
    a. During each team's event time (part 4.a), tools can only be used to store energy in an elastomer for use in the aircraft or in the launch-assist device (if used) before the flight of the aircraft.
    b. Power tools will not be allowed during the event time except as follows: Powered drills may be used for winding rubber bands. Electric rubber band winders may also be used.
    c. Hand tools, such as manual drills or manual rubber band winders, may be used during the event time.
7. Scoring:
    a. Teams will be awarded 1 point for every second of flight time, rounded to the nearest second. Flights will only be scored if they achieve the minimum altitude and time requirement (1.b)
    b. Aircraft that are self-launching and meet the minimum flight requirement will be awarded an extra 10 points.
    c. Aircraft that use a launch device and meet the minimum flight requirement will be awarded an extra 5 points.
    d. A hand toss does not earn extra points.

    e. Aircraft with the same scores will be ranked according to weight, heaviest to lightest (heaviest wins). The launch-assist device (if used) will not be included in the weight. All weigh-ins will be done prior to launch.

8. Attempts:
    a. Each team will be allowed three attempts, provided those attempts can all be completed within the 3 minute event time. All attempts must be with the same aircraft.
    b. Any aircraft that is designed to be self-launched or to be launched with a launch-assist device may be launched by hand should the intended launch option fail. This option can only be used if the aircraft itself uses at least one elastomer for sustaining flight.
    c. The highest-scoring attempt will be used for the final score.
9. Repairs:
    a. Repairs may be made at the event should there be damage to the aircraft during transit.
    b. Repairs for special circumstances will be evaluated on a case-by-case basis.
10. Staging:
    a. Upon a team's arrival to Physics Olympics, teams must place their aircraft into the storage area.
    b. Just prior to a team's heat, the aircraft may be retrieved by the team and taken to the Hebb theatre.
    c. Weigh-in will take place just prior to a team's flight.
11. Tips:
    a. Keep it simple, at least at first! Get something that works, then worry about making improvements.
    b. Think light thoughts. Heavier aircraft need more lift, which quickly becomes challenging. While we will use weight to break ties, do not worry about making the aircraft heavier until you know you have something that is competitive.
    c. You will need multiple test flights until you get something that works. Think of this as an experiment. The first flight will likely not be a complete success, if at all! Note how the aircraft flies, and then determine what can be done to make it better. Unless you think you need a completely different approach, only make small changes at a time.
    d. Keep it balanced. Note the flight characteristics of your aircraft. Is it stable in flight? Where is the centre of gravity? Where is the centre of lift? Does it have multiple lifting sources? Do they all need to work in the same way?
    e. Mind the torque. You do not need to use something with a propeller; but if you do, remember that the propeller is a gyroscope that will affect the flight of the aircraft. Depending on the design, this may or may not be an issue. It could even be turned into a feature.
    f. Airplanes are awesome (and welcome), but you don't have to make an airplane. You should feel free to try different designs. Not everything needs to be a propeller-driven, fixed-wing aircraft. Launch-assist devices open up many possibilities.
    g. Cambered wings work very well, but barn doors can fly, too. Take a look at the concept of "angle of attack". If you think you can get a cambered airfoil to work,

go for it! However, this is not necessarily critical. It completely depends on the design of the aircraft as a whole.

h. For those electing to use a propeller in the design, there are a few things to consider.
    i. It is not that hard to make your own, although it will require some experimentation.
    ii. You can make a very good and durable propeller using a paperclip (for the drive), a coffee straw (for the driveshaft), a small dowel with small hole drilled into it (makes a hub for the drive), and cutouts from a plastic container (propeller blades when attached to the hub). Use a few beads as buffers here and there. This is only one possible option. Take a look online to see many examples. Mind the angles at which you set the blades.

i. Experiment with different elastic bands and/or combining elastic bands together in different ways. A reasonable test for any aircraft before any flight is to see how long a particular elastic band (alone or in combination) can supply power.

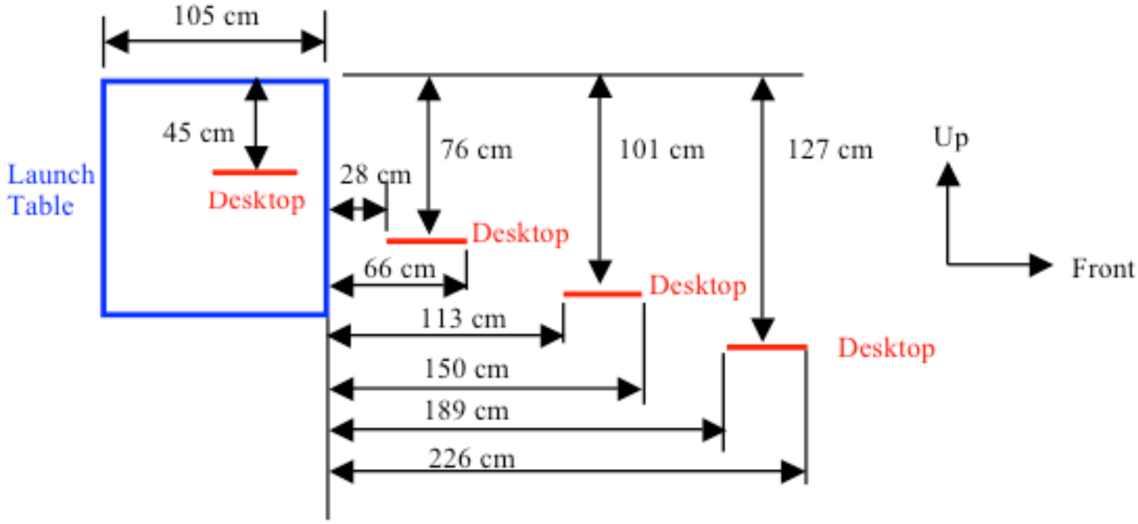

Figure 1: Side View of Launch Table and Desktops

Figure 2: View of Launch Table from Front of Aerodrome

2. Coin Sorting Device

Your goal is to construct a passive device to sort Canadian coins, US coins, and wooden disks. The device may not use any sources of energy other than the gravitational potential energy of the tokens. Commercial coin sorters or parts from them may not be used.

Use of magnets is permitted, except as a source of energy.

Your device may not alter the tokens in any way, including leaving any liquid residue on them.

Your device must have a slot with dimensions 35 mm by 3 mm through which the 25 tokens will be inserted. The tokens will be the following, in random order:

- 2 small wooden disks (22 mm diameter, 1.5 mm thick)
- 2 larger wooden disks (33.5 mm diameter, 1.5 mm thick)
- 3 US nickels
- 3 US dimes
- 3 US quarters
- 3 Canadian nickels
- 3 Canadian dimes
- 3 Canadian quarters
- 3 Canadian “Loonie” dollars

Your device must separate the tokens into 9 appropriately labeled compartments corresponding to value or size and nationality or material.

There is a maximum score of 50 points:

- You will receive 2 points for each wooden disk that comes to rest in the correct size “wood” bin.
- You will receive 2 points for a coin that comes to rest in the bin with the correct value and correct nationality.
- You will receive 1 point for a coin that comes to rest in a bin with the correct value but wrong nationality.

In the event of a tie, the winner will be the device that weighs the least.

A judge will gently insert one token into your device through the slot approximately every 2 seconds. You may ask us to stop inserting tokens if a token stops within the device outside of the sorting bins. You may remove the stopped token(s), which will be set aside, and we will then continue to insert the remaining tokens.

Once all 25 tokens have been inserted, you will be allowed additional attempts to get a better score within the 5 minute time limit.

Wooden disks for testing may be found at arts & crafts stores, e.g. Michael’s.

Figure 3: Wooden disks at Michael's arts & crafts store

3. Balance Lab

A laboratory-based event involving balance and centre of mass. Heats (except the last) will be closed to all persons except the participants.

4. Faraday Lab

A laboratory-based event involving Faraday's Law of Induction. Heats (except the last) will be closed to all persons except the participants.

5. Quizzics!

Team members will work together to answer questions about physics and astronomy. Questions may involve mechanics, waves, electricity and magnetism, optics, fluids, "modern" physics, famous scientists, or the history of science. Some questions may involve short calculations. Use of cellphones or other wireless devices will result in disqualification.

All teams will participate in the preliminary Quizzics! heats. Questions are in multiple-choice format and each team will answer using an electronic "clicker." Consultation between team members is allowed. The same questions will be used in each preliminary heat, so these heats (except the last) are closed to all except the participants.

The teams with the highest scores in the preliminary heats will meet in the public round of Final Quizzics! using a buzzer system. Each question will be answered by the first team to buzz. The correct answer (indicated by holding up a letter card) is worth 1 points, an incorrect answer (or failing to hold up a card within 5 seconds) loses 2 points, for the first question. For the second question, a correct answer is worth 2 points, and an incorrect answer loses 3 points. For question N, a correct answer is worth N points, and an incorrect answer loses N+1 points. The winner is the team with the maximum number of Final Quizzics points.

6. Fermi Questions

The great twentieth century physicist Enrico Fermi was famous for being able to estimate anything to within a factor of ten. Examples of "Fermi Questions" are:

- What is the total mass of the students competing in the Physics Olympics today?
- How many litres of gasoline are consumed in Greater Vancouver each year?
- How many molecules of air are there in this room?

For more examples, look on the web. These were taken from
http://www.physics.uwo.ca/science_olympics/events/puzzles/fermi_questions.html

Answering a Fermi question in physics requires common sense understanding, knowing the order of magnitude of key constants of nature and physical parameters, and the ability to do approximate calculations quickly.

Your team will be given a number of Fermi Questions to answer using only pencil and paper and your own knowledge. No notes, tables, or books are allowed. No calculators, computers, tablets, cellphones, or other wireless devices are allowed. Since there will be a substantial number of questions to answer and only a limited time to answer them, speed and teamwork will be important. Your written answers will be graded for accuracy appropriate to the questions. Your answers must include appropriate units, in the SI (MKS) system. The same questions will be used in each heat, so these heats (except the last) are closed to all except the participants.

Many physicists pride themselves on knowing various constants of nature and physical parameters to at least one decimal place. Parameters that may be needed, to this accuracy, include but are not limited to:

the speed of light
Planck's constant
Boltzmann's constant
Avogadro's number
the mass of the electron
the mass of the proton
the charge of the electron
the constant in Coulomb's Law
the constant in Newton's Law of Gravity
the acceleration of gravity on Earth
the radius of the Earth
the distance to the Sun