THE FORTY-FIRST UBC PHYSICS OLYMPICS RULE BOOK

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Department of Curriculum and Pedagogy (Science Education Group)
Department of Physics and Astronomy

Version 3, 21 February 2019

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 students. 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 travelling 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. For each event, schools are ranked by their event score, and the corresponding decibel score for that event is given by $\mathrm{dB} = 10\log_{10}(\mathrm{rank})$. 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, and 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 that, 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 pre-build events, for which teams are required to design and build devices before the start of the pre-build events and to use the devices during those events. Pre-built devices will be checked into a storage room until required for a heat. Modifications are not allowed after arrival, except to repair damage sustained in transit.

The pre-build events are intended to be learning experiences for the students, so we ask that team coaches do not overly involve themselves in the device design and construction.

We strongly encourage creativity, 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 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. Aaron Boley, preferably by email to acboley@phas.ubc.ca or by telephone 604-822-3853, Monday-Friday 10 AM to 4 PM.

Pre-build 1: Rube Goldberg Machine

Preliminary rules published January 15, 2019
Event judge: Dr. Aaron Boley (acboley@phas.ubc.ca)

Your objective is to design, build, and use a Rube Goldberg machine to place a sugar cube into a coffee cup. The team that earns the most points will win.

Summary: A Rube Goldberg device is a machine that completes a simple task in an extraordinarily complicated way. In this pre-build event, teams are asked to create and run a machine that takes as many steps as possible using as many of the allowed step categories as possible to place a sugar cube into a coffee cup. There are additional tasks that can be completed to earn extra points. Teams will only have 10 minutes to set up and run their device, so this must be taken into account when designing the machine.

1. Machine construction
    a. The machine may be built out of any non-hazardous materials. Any machine that represents a hazard to the operator or bystanders will be disqualified. Contact the judges should you have any concern about a material.
    b. The machine may incorporate pre-manufactured objects.
    c. Only one battery or a single battery pack may be included and used by the machine, if desired, and must consist of the following: standard AAA, AA, C, D, or 9V. Other battery types can only be used with written prior approval from the event judge.
        i. No external power sources may be used to drive an action of the machine, whether in part or in entirety, or to set up the machine. See also Section (3) Part (a) Paragraph (v).
    d. The machine must fit entirely on a flat table provided by the judges. The table has a width of 76 cm and a length of 152 cm. The machine's length and width must fit within these dimensions. The machine may not extend more than 1 metre above the top of the table.
        i. Teams may include a base for their machine. The base must fit within the maximum allowed size.
        ii. The machine and its components must remain entirely within the length, width, and height limits. Unintended release of material outside of the allowed volume will be evaluated at the discretion of the judges.
2. Tasks
    a. There is one primary task and two optional tasks.
    b. The primary task is to place one sugar cube into an empty coffee cup.
        i. The cup should be equivalent to a small coffee cup, such as a "tall" from Starbucks or a small or medium from Tim Hortons.
        ii. The primary task must be attempted for the team to earn points.
        iii. The primary task should be completed as close to 60 seconds as possible. If the machine takes longer than 80 seconds to complete the primary task, then the team forfeits completion of the primary task.
        iv. The sugar cube must start completely outside of the coffee cup.

c. The optional tasks are to make a distinct sound and to turn on a light. These are referred to as the sound and light tasks, respectively. The sound and light tasks may be completed in any order, but the first optional task must be completed as close to 20 seconds as possible and must occur between 15 and 25 seconds, inclusive, after the start of the machine. The second optional task must be completed as close to 40 seconds as possible and must occur between 35 and 45 seconds, inclusive, after the start of the machine. The same optional task cannot be completed twice. If the sound task is elected to occur at 20 seconds, then the light task must occur at 40 seconds. If the light task is elected to occur at 20 seconds, then the sound task must occur at 40 seconds.
d. The sound task is completed by making a distinct sound as close to the elected time (20 or 40 seconds) as possible. The sound must be specifically identified before the machine starts and must be easily recognized by the judges. Likewise, the sound should be separate from the other actions of the machine. For example, a rattling sound that occurs due to a ball rolling on a track will not be counted.
e. The light task is completed by turning on a light as close to the elected time (20 or 40 seconds) as possible. The light need not remain on for the rest of the machine's run, but should be clearly visible to the judges when it first turns on.
f. The machine is started using a single action by a team member (e.g., turning a knob, flipping a switch, knocking over a domino, etc.). After this action, no team member may touch the device except to restart in accordance with Section (3) Part (a) Paragraph (vii) Subparagraph (5).

3. Scoring
    a. The final score will be determined through a combination of steps, step categories, task completions, and restart penalties (deductions), if any.
        i. A step is a single, coherent motion (action) that advances the machine toward its primary task. The step must be clearly visible to the judges. Steps toward the secondary tasks are not scored unless they also advance the machine toward the primary task.
        ii. Other than for the purpose of completing secondary tasks, branching is not allowed, i.e., initiating two separate sequences of steps that advance the machine toward the primary task.
        iii. Each step must be performed by a functionally independent unit. For example, if two items are tied or chained together, then their motion will be treated as one, even if there is slack initially in the system. If a grouping of material is released as part of a step, e.g., a powder, sand, water droplets, a clump of ball bearings, etc., then the motion of the group of material is counted as a single step, even if the release is not instantaneous.
        iv. A self-contained device (e.g., a motor or a gearbox) is treated as a single unit, and the individual motion of its components will not be treated as individual steps.
        v. A microcontroller may be used in the machine, if desired, but it may only be used to complete a single step and must comply with all other rules.
        vi. All steps must be placed into a step category according to the type of action that describes the step. With the exception of the dominos

category, if a step can plausibly be assigned to more than one category, then the team has the option of selecting any one of the plausible categories. The categories are:

1. dominos
    a. Any group of objects that advance the machine by a rapid succession of falling and colliding (i.e., mimic the classic domino function). All domino motion can only have this category.
2. kinetic
3. gravity
4. springs/elastics
5. hydraulics
6. pneumatics
7. chemical
8. electrical/magnetic (no battery)
9. electrical (with battery)

vii. The total score is determined using the following formula:

$$\text{Score} = \sum_i^9 \log_2(1 + \text{Nsteps}_i) + 9\, f_{20} + 9\, f_{40} + 27\, f_{60} - Deductions$$

1. Nsteps_i is the total number of steps in the i^{th} category
2. The terms f_{20} and f_{40} are factors that depend on time. Here, $f_{20} = 1/\Delta t_{20}$ if the first optional task is completed between 15 and 25 seconds after the start of the machine and 0 otherwise. The factor Δt_{20} is the time difference between 20 seconds and the time when the first optional task is completed, also in seconds after the start of the machine. The difference is rounded to the nearest second, and cannot be less than 1 second. The factor f_{40} is similar, but referenced to 40 seconds for the second optional task and set to zero if the second optional task is not completed between 35 and 45 seconds after the start of the machine. The final term, f_{60}, is also similar, but referenced to 60 seconds after the start of the machine. This term is zero if time exceeds 80 seconds.
3. Time begins at the start of the first step and ends when the sugar cube comes to rest inside the coffee cup.
4. Judges will keep track of the machine's run time using stopwatches. Judges will record times for each task, and the times from each judge will be averaged together for scoring.
5. If the machine stops at any time, it may be restarted from the point of failure. However, each restart adds 2 points to the *Deductions* and results in a loss of the failed step in the score. All restarts must also be done as soon as a machine failure is recognized. If there is more than a 3 second delay in restarting the machine, then time may be stopped until the machine is restarted.

viii. In the event of a tie, the team that completes the primary task closest to 60 seconds, without going under, will win. If there is still a tie, the team with the greatest number of steps across all step categories will win.

4. Scoring Sheet and Check-in
    a. Upon registering for the day, each team must check in their device and their scoring sheet (see Appendix A of the rule book) or the team will not be allowed to compete.
        i. Teams that wish to submit their scoring sheet for inspection before the event day may submit a preliminary sheet to the head judge by email 1 week before the event.
    b. On the scoring sheet, each team must detail the action network and place each action in an appropriate category. The actions and their categories must be approved by the judges before the event. See the scoring sheet for further details.
5. Total event time
    a. Each team has 10 minutes to set up and run their machine to complete the primary task. Teams that are unable able to complete the primary task within this time will be disqualified.
6. Compliance with the rules
    a. Judges have the final decision on determining whether a device is compliant with these rules.
    b. Should the team need clarification of a rule during device construction, the team is strongly recommended to send an inquiry to the head judge prior to the competition.

Pre-build 2: Mechanical Timepiece

Preliminary rules published January 15, 2019
Event judge: Dr. Andrzej Kotlicki (kotlicki@phas.ubc.ca)

Your objective is to design, build, and use a mechanical timepiece to determine two successive time intervals as accurately as possible.

1) Timepiece construction
    a) The timepiece may be built out of any non-hazardous materials. Any clock that represents a hazard to the operator or bystanders will be disqualified. Contact the judges should you have any concerns about a material.
    b) The timepiece may incorporate pre-manufactured objects that are not themselves a timepiece or a part of a manufactured timepiece.
    c) The clock needs to fit within a 1 metre by 1 metre by 1 metre cube.
    d) The clock must be mechanical.
        i) Except the switches described in Section (1) part (e), no electrical parts or electrical power sources may be used in the clock.
        ii) Hydrodynamic and/or pneumatic components are allowed and will be considered to be mechanical for the purposes of this competition.
        iii) Magnets are allowed if used in a mechanical sense to hold or slow a part of the machine.

e) The clock must incorporate three mechanically-activated electrical switches that are visible to the judges for inspection (see Figure 1). Each switch must be connected to two clean electrical leads or wires, also accessible to the judges. The judges will connect the leads, using alligator clips, to two timers provided by the judges. Closing the first switch will start both timers. The second switch will stop the first timer, and the third switch will stop the second timer.
    i) Each switch must be able to withstand an electrical current of up to 0.5 A and have a resistance less than 500 Ω when closed and more than 10 GΩ when open.

2) Tasks
    a) The timepiece must be mechanically programmable to produce three distinct events.
        i) Events will be measured using three electric switches, as described in Section (1) part (e).
        ii) The first event is the closing of Switch 1, which will set the reference time by starting the two timers. This first switch can be activated at the team's discretion.
        iii) The second event is the closing of Switch 2. It must occur at a time t_2 after the first event. The value of t_2 will be given to the team by the judges at the start of the team's attempt. The value will be determined randomly, but will be constrained to be between 10 and 20 seconds. The time $t_2$will be given to the nearest tenth of a second.
        iv) The third event is the closing of Switch 3. It must occur at time $t_3$after the first event. As with the second event, the value of t_3 will be determined randomly, but will be constrained to be between 60 and 90 seconds. The time $t_3$will be given to the nearest tenth of a second.
        v) Manually starting the device is allowed using a single motion, which may include triggering the first switch. The team may not interact with the machine after it is started. For any given attempt, the machine may only be started once.

3) Scoring
    a) The team with the lowest score will win.
    b) The total score *TS* is determined by the following formula, in which capital *T* corresponds to the measured event time and little *t* is the time given to the team by the judges:
        i) $TS = |T_2 - t_2| + |T_3 - t_3|$

4) Each team has a run time of 5 minutes to complete their attempts, including setup. Teams that cannot program their timepiece and run it within that time will be disqualified.
    a) Multiple attempts
        i) Two attempts are allowed. All attempts must fit within the five-minute run time. A new set of event times (t_2 and t_3) will be given if a second attempt is elected by the team.
        ii) If a second attempt is elected, then the team's score will be based on the outcome of the second attempt (not the best of the two attempts).
5) Compliance with the rules
    a) The event Judge have the final decision on determining whether a device is compliant with these rules.
    b) Should the team need clarification of a rule during device construction, the team is strongly recommended to place an inquiry to the head judge prior to the competition.

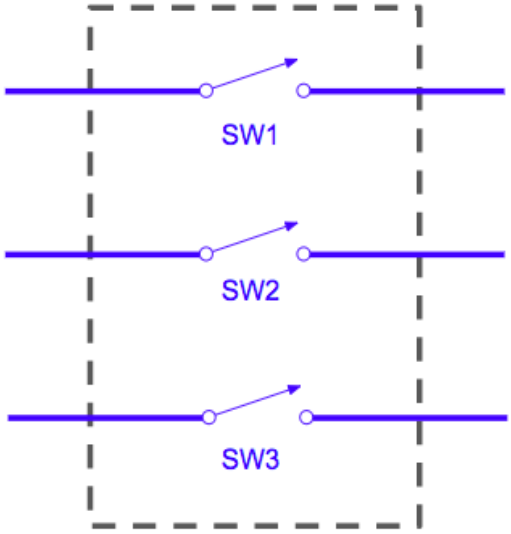

Figure 1: Schematic for the pre-build timepiece switches. The blue portion represents the three switches, each with two leads that must be incorporated into the timepiece design. The switches must be mechanically activated to accomplish the three events described in Section 2. The leads will be connected using alligator clips to a circuit with timers (provided by the judges). The closing of SW1 will start two timers. Closing SW2 will stop the first timer, and closing SW3 will stop the second timer. Switches should have low internal resistance, but must be less than 500Ω to ensure that the timers will be tripped. Each switch must be able to withstand a current up to 0.5 A.

Pre-build Rule Amendments

Rube Goldberg Machine

- Section (3) Part (a) Paragraph (vii) Subparagraph (2) modified in Version 3 to allow the optional tasks to be completed in any order.
- Section (2) Part (c) modified in Version 3 to allow the optional tasks to be completed in any order.
- Section (2) Part (d) and (e) modified in Version 3 to allow the optional tasks to be completed in any order.
- Section (1) Part (c) modified in Version 2.
- Section (2) Part (f) added.
- Section (3) Part (a) Paragraph (v) added. The previous Paragraph (v) and subsequent paragraphs were all incremented accordingly.
- Section (3) Part (a) Paragraph (vii) Subparagraph (4) added. Old Subparagraph (4) is now called Subparagraph (5).
- Title of Section (5) changed.

Mechanical Timepiece

- Section (1) Part (d) Paragraph (iii) added.
- Section (2) Part (a) Paragraph (v) modified.

3. Fluid Lab

A laboratory-based event involving fluid flow and pressure. Understanding of the following will be necessary to complete the lab: hydrostatic pressure, buoyancy, flow rate, Bernoulli equation, and concepts related to them will be tested in this event. Heats (except the last) will be closed to all persons except the participants. No more than five participants per team will be allowed in the lab. A team will be allowed to use one smartphone (visible to the judges) as a timepiece. Use of cellphones or other wireless devices for other purposes will result in disqualification. Teams are encouraged to bring a calculator.

4. Planetary Astronomy Lab

A laboratory-based event involving exoplanet detection and characterization. Understanding of one or more of the following will be necessary to complete the lab: transits, radial velocity measurements, Kepler's laws, and flux laws. Heats (except the last) will be closed to all persons except the participants. No more than five participants per team will be allowed in the lab. A team will be allowed to use one smartphone (visible to the judges) as a timepiece. Use of cellphones or other wireless devices for other purposes will result in disqualification. Teams are encouraged to bring a calculator.

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 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. For the first question, the correct answer (indicated by holding up a letter card) is worth 1 point, while an incorrect answer (or failing to hold up a card within 5 seconds) loses 2 points. 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. **GOOD LUCK**

Appendix A: Scoring Sheet

School Name: _____

Use the table on the following page to lay out your machine's design and the corresponding scorable steps. Include a short description of each step to identify the steps to the judges. If a step is repeated *N* times in a row, then the team may write (X*N*) in the description. In the next column put the letter corresponding to the appropriate step category. Please leave the last column empty. If you have more steps than you can list on one page, print out multiple copies of Appendix B and label them with page numbers. After completing the list of steps, count the number in each category and record it in the table below. After that, take the sum and record it. A description of the sound and light must also be included if the sound and light tasks are attempted.

Category	Count	*(leave blank)*	Category	Count	*(leave blank)*
(**D**) Dominos			(**H**) Hydraulics		
(**K**) Kinetic			(**P**) Pneumatics		
(**G**) Gravity			(**C**) Chemical		
(**S**) Springs/Elastic			(**E**) Electric/Magnetic (no battery)		
(B) Electric (battery)					
Total Number of Steps:					

Please leave everything below this line blank.

t_1= _____
For $15 \leq t_1 \leq 25, f_{20} = 1/|20 - t_1|$, 0 otherwise.
9 f_{20}= _____

t_2= _____
For $35 \leq t_2 \leq 45, f_{40} = 1/|40 - t_2|$, 0 otherwise.
9 f_{40}= _____

t_3= _____
For $t_3 \leq 80$, $f_{60} = 1/|60 - t_3|$, 0 otherwise.
27 f_{60}= _____

$\Sigma_i{}^9 log_2(1 + Nsteps_i)$ =_____ $Deductions$ =_____

$$Score = \Sigma_i{}^9 log_2(1 + Nsteps_i) + 9\, f_{20} + 9\, f_{40} + 27\, f_{60} - Deductions$$

Score = _____

Appendix B: List of Steps

Page: _____

Description	Category	*(leave blank)*