THE FORTY-SECOND
UBC PHYSICS OLYMPICS
RULEBOOK

March 7, 2020

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

Version 1.1, 10 February 2020

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 with a number of food outlets is located across the street from the Hennings Building, where the Physics Olympics will take place). 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 Physics Olympics 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-build 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 Theresa Liao (Communications Coordinator, UBC Physics & Astronomy) by email to communications@phas.ubc.ca.

Pre-build 1: "Rocket" Car

Preliminary rules published January 27, 2020
Event judge: Dr. Andrzej Kotlicki (kotlicki@phas.ubc.ca)

GOAL: Your objective is to design, build, and run a car that uses only rocket action to propel itself a designated distance as accurately as possible, i.e., the car must achieve its motion by ejecting mass (propellant). The team with the lowest score will win.

1) **Car construction**
   a) The car and its propellant may only be built out of non-hazardous materials. Any machine, including its propellant, that represents a hazard to the operator or bystanders will be disqualified. Contact the event judge should you have any concerns about a material or the construction of the car or its propellant.
   b) The machine must be designed and built by the team. Pre-manufactured cars will be disqualified. Device components that are pre-manufactured may be used.
   c) The machine can only use gravitational or elastic energy sources to expel the propellant and all the other functionality. Chemical, electrical, and any other energy sources are prohibited.
   d) The propellant must be solid.
   e) The size of the car should be no more than 50cm x 50cm x 50cm at all times. Propellant once expelled may leave this volume.
   f) The overall mass of the machine (car + propellant) must not exceed 2 kg.
   g) The car must have an unambiguous measuring point (such as a boom) at the front of the car, which will be used for initial car placement on the starting line and for measuring the car's proximity to the target (see *Section 2: Track*). The measuring point cannot be more than 2.5 cm from the floor. The measuring point must be identified to the event judge prior to a team's attempt.

2) **Track:**
   a) The track area is shown in Figure 1. A randomly selected target distance will be chosen for each team. The target will be along the track's centre line, and the randomly chosen distance will be constrained to be between 1 m and 3 m from the starting line.
   b) There will be a wall behind the "Preparation area" of the track to aid in stopping the propellant.

3) **Task**
   a) The primary task is to get as close as possible to a target distance, which is randomly chosen as described in *Section 2: Track*. The distance between the target and the car will be measured from the measuring point described in *Section 1: Car construction*, paragraph (f).

b) Teams will have a total of 5 minutes to complete the task, which includes setup in the "Preparation area" (*Section 2: Track*).
c) Each team may have up to two attempts. All attempts must fit within the 5-minute time allocation. If a second attempt is chosen, the second attempt will be used for the final score, i.e., **not** the best one of the two attempts.
d) The car must be placed with its measuring point on the centre of the starting line (Section 2).
e) At no point may the car leave the ground.
f) Only rocket action may propel the car forward.

4) **Scoring**
  a) A team's score will be the distance between the measuring point and the target, measured to the nearest mm.
  b) In the case of a tie, the machine with the lowest overall mass (car + initial propellant) will be ranked higher.

5) **Compliance with the rules**
  a) The event judge will have the final decision in determining whether or not your machine is compliant with these rules.
  b) Should the team need clarification of a rule during machine construction, the team is strongly recommended to send an inquiry to the event judge prior to the competition.

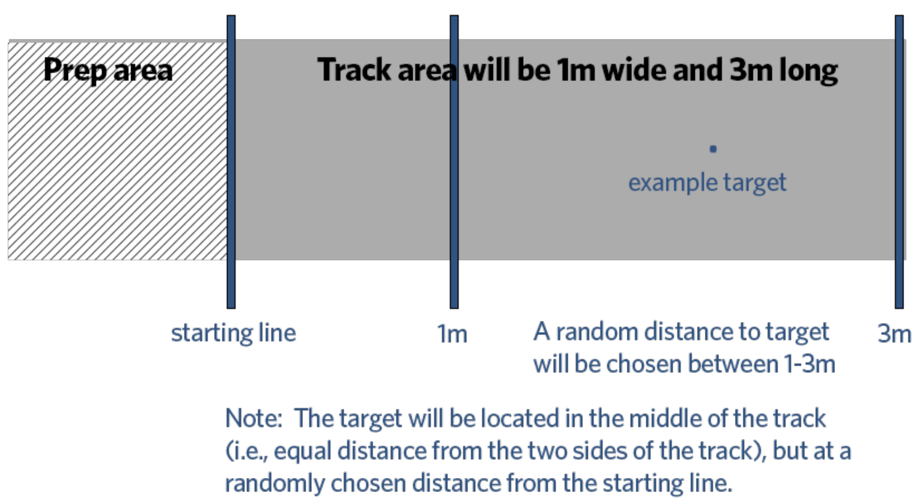

Figure 1. Pre-build event 1: "Rocket" Car set-up

Pre-build 2: Vacuum Pump

Preliminary rules published January 23, 2020
Event judge: Dr. Valery Milner (vmilner@phas.ubc.ca)

GOAL: Your objective is to build a device, hereafter referred to as the "vacuum pump", capable of removing air from, and thus lowering the air pressure in a test container provided by the judges. By design, the container will have a small leak – a hole with a diameter of about 1 mm. Your vacuum pump is expected to produce a continuous pumping action, which will achieve and maintain as low a pressure as possible in the leaky container (see *Section 3: Test Procedure and Scoring* section below for more information).

1) **Device.**
   The vacuum pump has to be built so as to include the following features and to satisfy the following constraints.

   A. General construction.
   a) The pumping action, i.e. lowering the air pressure in the test container, must be accomplished solely via removing air from the container through a single pumping channel. No material should enter the test container during the pumping process.
   b) The pump must feature a single flexible plastic tube, which will be connected to the output port of the test container, and through which the air will be pumped out of that container. The tube must be ~5" (~12.5 cm) long and have an inner diameter of 0.25" (6.3 mm), so as to slide onto a standard barb connector pictured in **Figure 2** below.
   c) The pump must have a single activation switch, such as an electrical switch or a mechanical release lever, which triggers the pumping mechanism.
   d) The device must not include a pre-pumped, i.e. a low-pressure, chamber.
   e) e) The device must not include a commercially available air pump as one of its parts (e.g. an aquarium pump or a bicycle pump). Assembling a pump from a purchased kit, or from parts which were manufactured to be assembled into a pump, is not allowed. However, replicating a known pump design using parts, which were not intended to be assembled into a specific vacuum pump, is permitted.

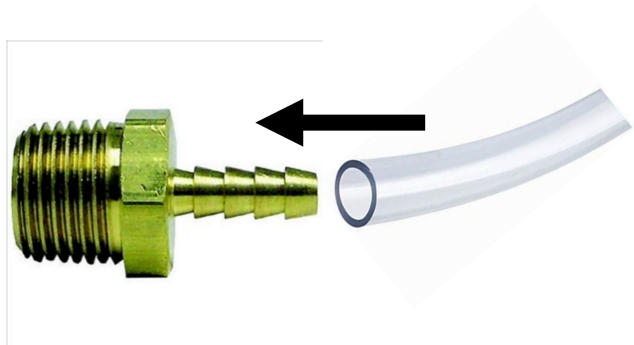

Figure 2. Brass barb connector for attaching a plastic PVC tube with 0.25” inner diameter. https://www.homedepot.ca/product/sioux-chief-1-4-inch-barb-adapter-brass-x-1-4-inch-fip-lead-free/1001002211

B. *Size.*

Except for the connection tube (see above), the whole pump must not exceed 50 cm in width, depth, or height. This size limitation must be maintained throughout the whole time of operation, i.e. all moving parts must be contained within this volume. If anything is ejected from the main body of the pump during its operation (other than air!), the ejected parts must also be contained within the initial apparatus volume.

C. *Weight.*

There are no weight limitations. However, in the event of a tie, the lightest pump will win.

D. *Energy sources.*

The pump can be powered by any number and combination of only the following sources of energy.

a) Gravitational: hanging, falling or swinging weights are allowed as long as the constraints on the overall size and weight, described in *Sections 1.B and 1.C*, are satisfied.
b) Elastic: any combination of elastic bands, springs and bent/twisted objects is allowed.
c) Electrical: any combination of not more than two standard 9V batteries from either Duracell or Energizer (**Figure 3**) is allowed. No other makes or types will be allowed, even if rated for 9 volts.
d) Gyroscopic: powering the pump by a spinning gyro is allowed as long as the gyro is spun either by hand or by the electrical power described above in *Section 1.D.c.* No external electrical devices (e.g., a power drill) will be allowed for spinning a gyro.

No other types of energy sources are allowed (e.g., no chemical reactions, thermal sources such as hot or cold bodies, compressed gases or liquids).

Figure 3. Allowed 9-volt batteries: standard Duracell or Energizer only. Not more than two batteries per vacuum pump is allowed.

2) **Test setup.**
The performance of your pre-built vacuum pump will be tested by means of a setup schematically shown in **Figure 4**.

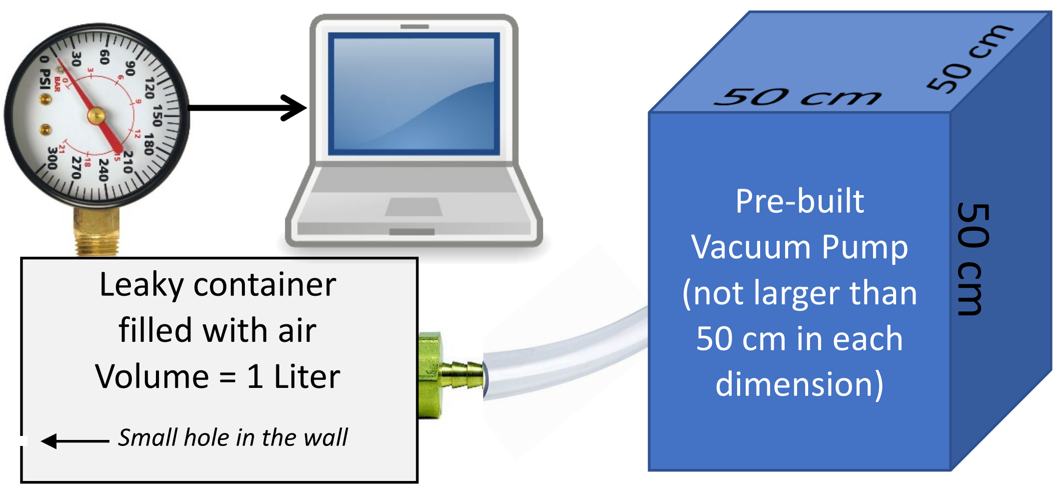

Figure 4. Scheme of a setup for testing the performance of a pre-built vacuum pump. Note: the analog gauge is for illustrative purposes only; the actual pressure will be measured by an electronic pressure gauge connected to a computer.

A. *Test container.*
The test setup consists of a 1 Liter container. The container is initially open to atmosphere and is therefore filled with ambient air at room temperature and atmospheric pressure. A hole with a diameter of about 1 mm is drilled in the wall of the container to produce a small leak.

B. *Vacuum connection.*

To test your pre-built device, it will be connected to the test container through a standard brass 0.25” barb connector shown in **Figure 2**. The part can be purchased at Home Depot (https://www.homedepot.ca/product/sioux-chief-1-4-inch-barb-adapter-brass-x-1-4-inch-fip-lead-free/1001002211). The team is responsible for making sure that a flexible plastic tube on their device will make an air tight connection with a brass barb.

C. *Measuring device.*
The test container will be equipped with an electronic pressure gauge connected to a computer.

3) Test procedure and scoring.

A. *Connecting the pump.*
Upon bringing your pre-built vacuum pump to the stage, your team will connect the pump to the test setup using the flexible plastic tube (See *Section 1.A.b*). No additional bands or clamps will be allowed to tighten the seal. The onus is on the team to make sure that a press fit of a plastic tube on the barb connector provides sufficient sealing.

B. *Arming the pump.*
Arming the pump, e.g. by stretching a spring or adjusting an internal weight, should be done in front of the judge and take no longer than one minute.

C. *Starting the pump.*
When ready, the team will be asked to start the pump (ready/set/go) using a single switch on their device.

D. *Recording the pressure.*
As soon as the team starts their pump, the judges will begin recording the air pressure inside the test container by means of a pressure gauge interfaced with a computer. The recording will continue for 60 seconds, generating a plot of Pressure-vs-Time, *P(t)*, shown in two examples in **Figure 5** below.

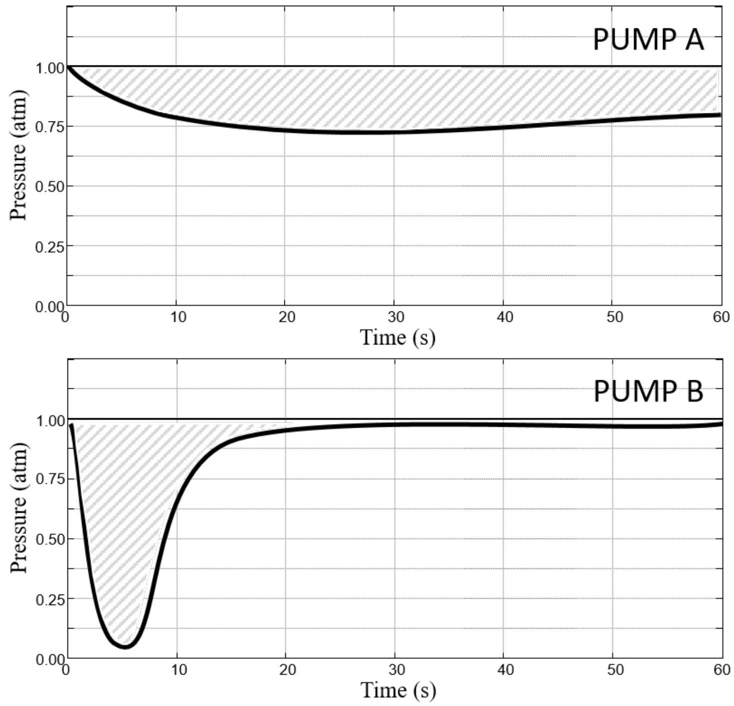

Figure 5. Examples of Pressure-vs-Time curves recorded with a pre-built pump.

E. *Scoring the performance.*

To assess the performance of your pump, the judges will calculate the area between the P(t) curve and a *P=1* atm baseline, as shown by dashed surfaces in Figure 5. <u>The bigger the area, the higher the score.</u>

NOTE: Your vacuum pump is expected to produce **a continuous pumping action** lowering the pressure in the test container and maintaining that pressure for as long as possible despite the existing leak. For instance, in the examples above, Pump A scores better than Pump B, because of the larger area above the corresponding *P(t)* curve, even though Pump B produces much lower intermittent pressure in the test container.

3. Centre of Mass Lab

A laboratory-based event involving the concepts of centre of mass and balance. Understanding of the following will be necessary to complete the lab: equilibrium of forces, center of mass of 1D and 2D objects, and concepts related to them. 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. Use of cellphones or other wireless devices will result in disqualification. Teams are encouraged to bring a calculator and a ruler.

4. Electrical Mystery Lab

A laboratory-based event involving electrical circuits. 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 Universal Gravitation
- the acceleration of gravity on Earth
- the radius of the Earth, and
- the distance from Earth to the Sun.

GOOD LUCK!