Pre-build 1: “Rocket” Car
Event judge: Dr. Andrzej Kotlicki (kotlicki@phas.ubc.ca)

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, which includes 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. Chemical, electrical, and any other energy sources are prohibited.
   - **d)** Size of the car should be no more than 50cm x 50cm x 50cm at all times. Propellant once expelled may leave this volume.
   - **e)** The overall mass of the machine (car + propellant) can not exceed 2 kg.
   - f) 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). 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 *Prep 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. The distance between the target and the car will be measured from the measuring point described in Section 1, paragraph (f).
   - b) Teams will have a total of 5 minutes to complete the task, which includes setup in the “Prep area” (Section 2).
   - c) Each team may have up to two attempts. All attempts must fit within the 5 minute time allocation. If a second attempt is elected, the second attempt will be used for the final score, i.e., not the best of the two attempts.

d) The car must be placed with its measuring point on the centre of the startling 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) Event judge have the final decision in determining whether or not a 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.

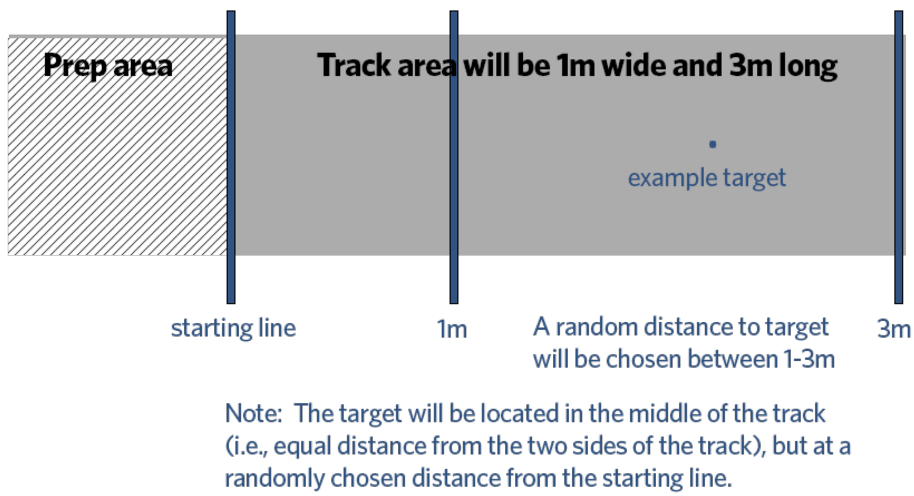

Figure 1

Pre-build 2: Vacuum Pump
Event judge: Valery Milner (vmilner@phas.ubc.ca)

1. **Objective.**
   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 *Test Procedure and Scoring* section below for more information).

2. **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 <u>5" (15 cm) long and have an inner diameter of 0.25" (6.3 mm)</u>, so as to slide onto a standard barb connector pictured in **Figure 1** 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) The device must not include a commercially available air pump as one of its parts (e.g. an aquarium pump).

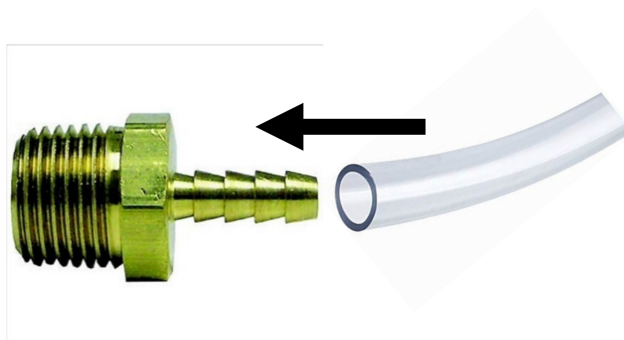

Figure 1. Brass barb connector for attaching a plastic PVC tube with 0.25" inner diameter. https://www.homedepot.ca/product/sioux-chief-1-4-inch-barb-adapter-brass-x-1-4-inch-fip-lead-free/1001002211

   B. Size.

Except for the connection tube (see above), the whole pump must not exceed 50 cm in width, depth, and 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 2.B and 2.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 2**) 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 2.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 2. Allowed 9 volt batteries: standard Duracell or Energizer only. Not more than two batteries per vacuum pump is allowed.

3. Test setup.
The performance of your pre-built vacuum pump will be tested by means of a setup schematically shown in **Figure 3**.

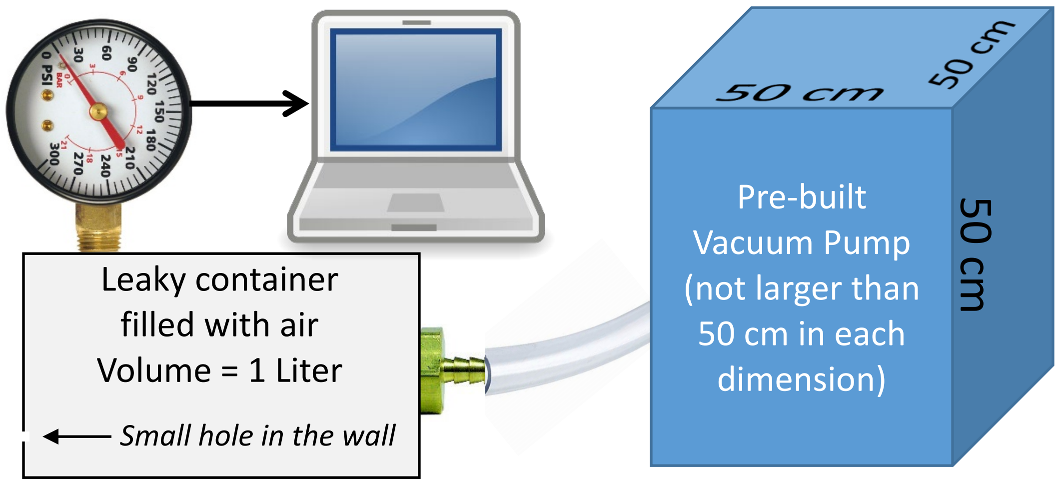

Figure 3. Scheme of a setup for testing the performance of a pre-built vacuum pump. Note: analog gauge is for illustrative purposes only.

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 1**. 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.

4. 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 2.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 4** below.

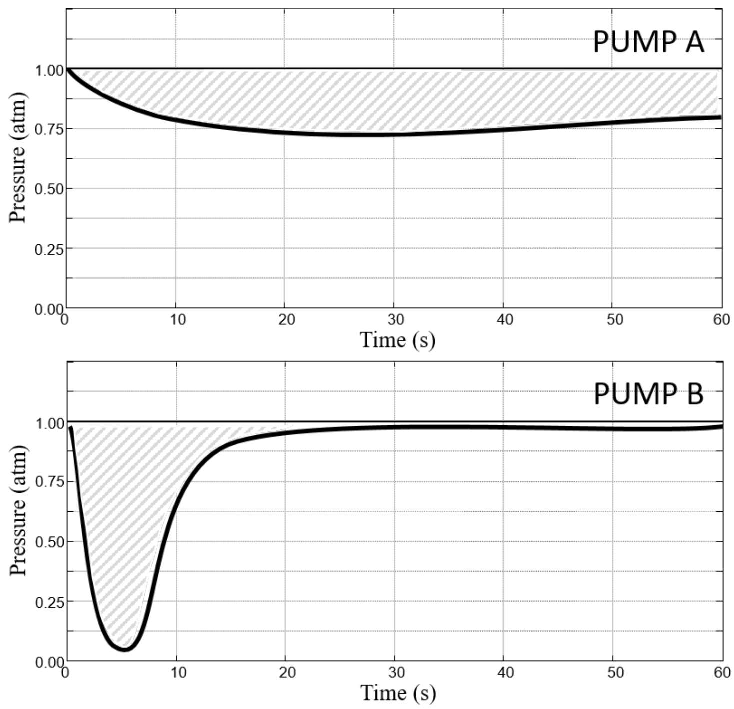

Figure 4. Examples of Pressure-vs-Time curves recorded with a pre-built pump.

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 4. The bigger the area, the higher the score.

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.