THE THIRTY-FOURTH UBC PHYSICS OLYMPICS RULE BOOK

March 10, 2012

Financial sponsorship is provided by the Rex Boughton Memorial Fund

The UBC Physics Olympics is organized by the Department of Physics and Astronomy and the Department of Curriculum and Pedagogy (Science Education)

Version 4, 28 March 2012

General Rules

Each school may enter one team of students, which participates in all 6 events. A team may have a maximum of 10 registered students, of which at most 5 participate in a given event. Events are designed so undersized teams are not penalized. Each event is run in 6 heats lasting about 1 hour each, with up to 10 schools participating in each heat. There is a break for lunch (not provided, but the Student Union Building is across the street from 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 is 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 their 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.

1. Gravity Defying String Climber

The goal is to build a device to climb up a vertical string in the shortest amount of time, using only gravitational potential energy derived from the descent of a 0.2 kg weight.

The string is 0.6 mm diameter nylon monofilament fishing line (40 lb test, Red Wolf brand, purchased at Canadian Tire), under tension from a 2 kg weight. The starting point is 1.5 m from the floor, and the end point is 4.0 m from the floor. The start and end times will be measured electronically by light beams at the start and finish points. Your device must be able to block the 10 cm diameter light beams, even if it rotates as it climbs. See Figure 1.

The drive weight of 0.2 kg illustrated in Figure 2 will be supplied by the organizers. Your device may not utilize any source of energy other than the descent of this weight.

You will have 6 minutes to connect your device to the string, connect the 0.2 kg weight to your device, and attempt to climb the string one or more times. You will have 2 minutes to remove your device from the string, and remove the 0.2 kg weight from your device.

The organizers will release your device and the weight for each climb attempt. You may not touch your device or the weight during the climb attempt. The organizers will lower the string after each climb attempt to allow you to recover your device and prepare it for additional climb attempts.

Your score will be your fastest time to complete the climb. Devices that do not complete any climbs will be ranked below all those that complete the climb, ordered by their highest stopping point. You will be penalized by 10% if you cannot remove your device and the weight within the 2 minutes.

It is to your advantage to design your device so it may be quickly connected to and disconnected from the string. The 2 kg tension weight may be temporarily removed so that the string so may be threaded through your device if necessary, but a fishing sinker with diameter < 8 mm and length < 20 mm will remain on the string. It is to your advantage to design your device so the 0.2 kg weight may be quickly connected and disconnected.

It is to your advantage to design your device so it may be prepared quickly for additional climbs after the first attempt. If your device gets tangled to itself or to the climbing string, it is your responsibility to untangle it.

Your device may not damage the string or weight in any way. All parts of your device must remain within 25 cm radially of the string at all times. No parts of your device may contact any object other than the string after starting (except the 0.2 kg weight may contact the floor). All parts of your device including the weight must initially be below the starting point (1.5 m from the floor). The length of your device may not change during the climb, apart from the descent of the weight and its suspension.

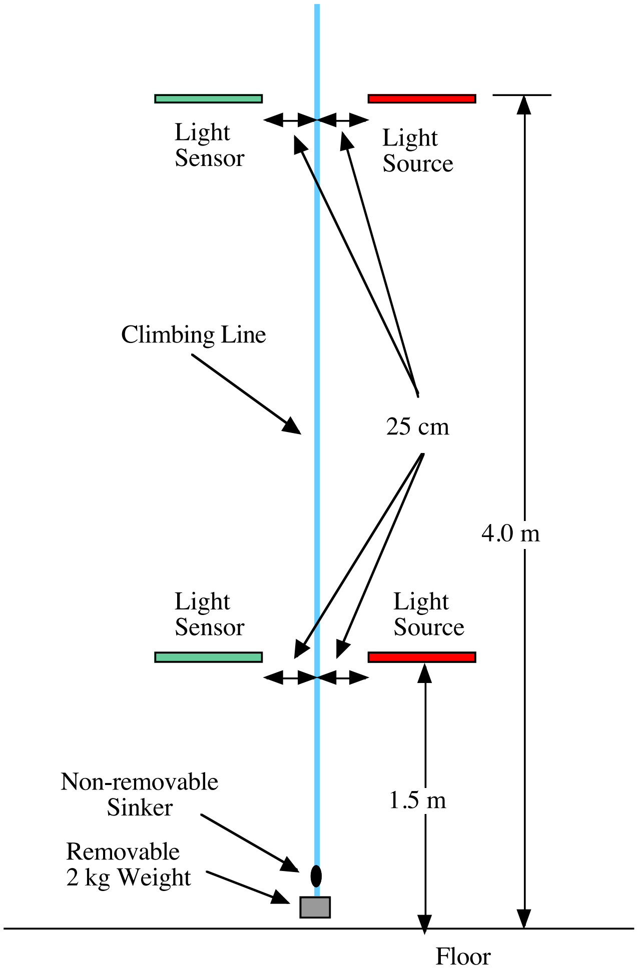

Figure 1: Gravity Defying String Climber Setup

Figure 2: 0.2 kg Weight

2. Styrofoam Xylophone Bar

The goal is to fabricate a xylophone bar from Styrofoam, with its first mode tuned as close as possible to “middle C” (C_4 , 261.626 Hz), and its second mode tuned as close as possible to C_6 (1046.50 Hz), with both frequencies as well-defined as possible.

A xylophone bar is shaped so that its lowest two vibrational resonance frequencies are two octaves apart (a factor of four in frequency). The density, stiffness, length, thickness, and thickness profile of the bar control the frequencies of the resonances. The bar is supported at approximately the ¼ points, where both resonances have small amplitudes (Figure 3). The properties of the bar and of the supports control the decay time of the sound, which determines how well-defined the frequencies are.

Construct your bar out of Styrofoam, and construct an open sound-box to suspend your bar, as illustrated in Figure 4. We recommend dense polystyrene foam at least 2 inches thick. Any materials may be used for the box and supports; cardboard and rubber bands are adequate.

You will need to measure the frequencies and re-shape the bar in an iterative procedure. Note that re-shaping the bar will typically change both frequencies. The effect on the two frequencies depends upon where the material is removed.

The free, open-source, multi-platform program Audacity (http://audacity.sourceforge.net/) can be used to acquire data from a microphone and perform a spectrum analysis. Other similar programs can also be used. There are many control parameters in such programs, which affect the quality of the analysis. The quality of the microphone is not critical, but we recommend putting your microphone inside the sound box.

A single tap near the end of the bar will create a sound wave containing both modes, as illustrated in Figure 5. A time window should be set to include the sound wave, and a frequency spectrum should be computed as shown in Figure 6. The frequencies of the resonance peaks should be noted. Then the bar should be re-shaped to move the resonance frequencies as close as possible to C_4 and C_6 .

A tap at the center of the bar will excite the first resonance more strongly than the second resonance. Using a single support at the center of the bar (so it damps the first resonance) and tapping near the zero-crossing of the first resonance shape will excite the second resonance with less excitation of the first resonance. See http://www.lafavre.us/FFT-mallet-position.htm . Note that your Styrofoam bar will have much more damping, so your peaks will be much broader.

Bring your bar, suspended in your sound-box, and your mallet to the Physics Olympics. We will put our microphone (13.5 mm diameter, 25 mm long) inside your sound-box. You will tap your bar once with your mallet, and we will perform a spectrum analysis within 50 Hz of C_4 and within 100 Hz of C_6 . You may decide whether to accept the results after examining them, or reject them and try another tap, up to a total of 3 taps. Your bar will be graded on the proximity of both resonances to C_4 (261.626 Hz) and C_6 (1046.50 Hz). If we cannot distinguish between two entries, the one with narrower peaks (full width at half max) will prevail.

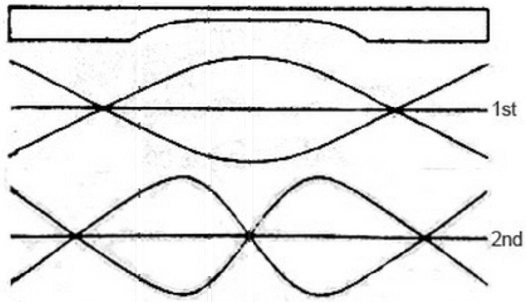

Figure 3: Side view of a Xylophone/Marimba bar showing the mode shapes of the first two resonances. From http://www.lafavre.us/FFT-mallet-position.htm

Figure 4: Styrofoam xylophone bar, suspended by rubber bands near the zero-crossings of the first resonance in a cardboard sound-box, and being struck near one end.

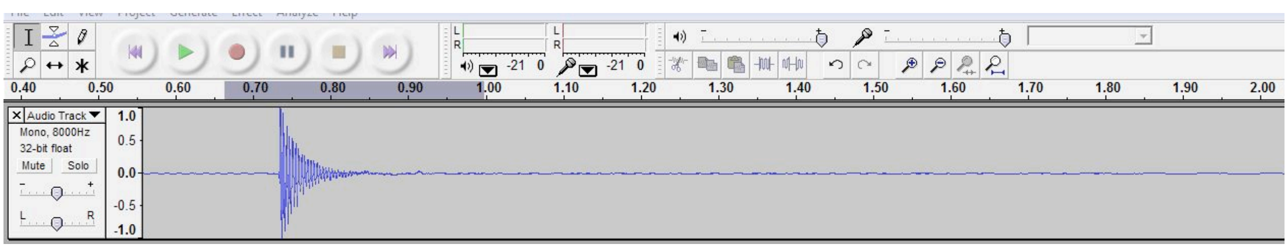

Figure 5: Sound wave from single tap near the end of the Syrofoam bar, recorded by Audacity.

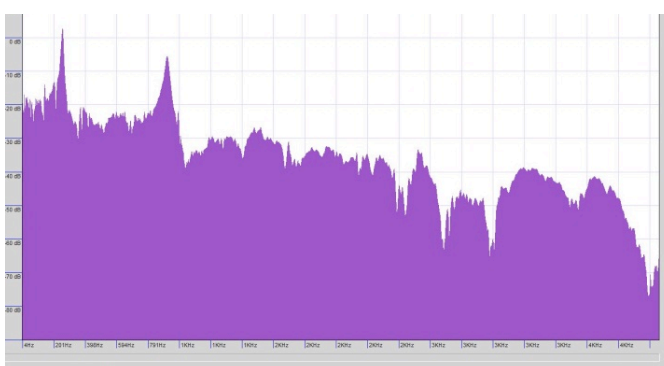

Figure 6: Audacity spectrum showing two resonance peaks.

3. Position, Velocity, and Acceleration

A laboratory-based event involving measurements of position, velocity, and acceleration
Heats will be closed to all persons except to the participants.

4. Electromagnetic Mystery Event

A laboratory-based event involving electricity and/or magnetism.
Heats 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 famous scientists, history of science, mechanics, waves, electricity and magnetism, fluids, and "modern" physics. Some questions may involve short calculations.

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. The first team to buzz must answer the question. An incorrect answer (or failing to answer within 30 seconds) loses 5 points, and allows the other teams a chance to buzz to answer the same question. A correct answer is worth 5 points, plus a chance to answer a bonus question for 10 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 calculators, computers, books, or notes 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 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

Addendum to Styrofoam Xylophone event

“Expanded” polystyrene (EPS) foam is made by expanding small beads of polystyrene foam. The beads are still visible in the final product, which is usually white.

“Extruded” polystrene (XPS) foam is made by extruding polystyrene foam into continuous sheets. It has no visible bead structure, and is often tinted blue or pink.

The XPS material is usually denser. The EPS material is somewhat easier to find, and cheaper. The bead structure of EPS has little impact on workability, if sharp tools are used.

Either material may be used for your xylophone bar. There does not appear to be a large difference between the two materials in the sound quality for a well-constructed bar. Differences in the design, the mounting, and the tap point appear to be more significant.

Addendum to Gravity Defying String Climber event

The rules state:

"No parts of your device may contact any object other than the string after starting (except the 0.2 kg weight may contact the floor)."

This prohibits designs that employ any parts that rest on the floor.

The rules also state:

"The length of your device may not change during the climb, apart from the descent of the weight and its suspension."

The length of the device includes all of its components. So all components of your device must climb the string. Designs that have a non-moving part clamped to the string below the start point are prohibited, since they would increase in length.