Leaky Bucket Lab
Laboratory Experiences in Mathematical Biology

Lab Setup: Students cut an aperture of \(a \approx 0.25 \text{ cm}^2\) and inscribe horizontal marks every centimeter above. Bucket is filled to twelve cm above the hole while the hole is covered with duct tape; students remove the tape and measure the bucket's drainage, recording the time for changing levels.

Materials

The following materials are needed (for each group of 3-4 students):

- 1-2 quart translucent or clear plastic jugs such as those containing milk, soda or juice for use as leaky buckets
- Scalpels or X-ACTO knives for cutting apertures and removing burrs (a drill with bits is useful for circular holes, but not recommended)
- Stopwatch
- Ruler with at least millimeter scale
- Graduated cylinders or kitchen measuring cups for measuring metric volumes
- Access to tap water
- Plastic dishwashing tub to capture drained water if a large sink is not available

Note that it is not available for groups of students to develop and offset their own procedures, if a procedure with a fitter is standing past to get things rolling, we provide the following procedure (based on using a 1/2 gallon milk jug):

1. Divide into groups of 3-4. Each group will need at least one person to manage the stopwatch (Timer), spot fluid levels (Spotter) and record data (Recorder).
2. Set up the bucket. Where the jug begins to have regular horizontal cross sections (2-4 cm above base for a standard US plastic half gallon milk jug) cut a horizontal slit 1-2 mm tall and 1-2 cm wide, being careful that the top and bottom of the slit are parallel to the base of the jug. Every cm vertically from the bottom of the slit horizontal marks, up to between 10 and 15 cm above the bottom of the slit, are marked. Fluid levels are observed at these marks and the drainage time is recorded.
3. Measure the bucket's volume if it is not a standard half gallon milk jug. Students may be able to measure the cross sectional volume directly, adding a known volume to the bucket and measuring by a volumetric method.
4. a) Fill the bucket to the desired initial height (12 or 13 cm are used in this paper), as measured by the bottom of the fluid meniscus. The aperture will need to be covered either with a piece of clear tape or a convenient finger. If using a finger be careful not to deform the container.
   b) Spotter removes tape and says, "Start!" Timer starts stopwatch.
   c) As fluid passes each vertical mark, Spotter calls "Mark!" and Timer gives the time of the split, which Recorder records next to the appropriate vertical level.
   d) Recorder records final emptying time. For a 1/2 gallon container with aperture of 0.25 cm\(^2\), filled to 12 cm above slit, this will be between 30 and 60 seconds.
5. Repeat the observation sequence at least three times for the same initial height of fluid to assess variability.

One of the bigger issues is determining when to stop; depending on the size and shape of both bucket and aperture the flow may transition from a free stream to an attached flow to a periodic dripping. Alternatively students should observe the drainage times, stopping the experiment when a bucket is in danger of drifting or when a stopping rule for the observation sequence is reached.

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