Hack My Infrastructure

Genre

Bands will find a gravel-sized rock in a laboratory flume, with no direction home – Like a Rolling Stone! The rock's dimensions and characteristics aren't a complete unknown, but bands will develop a rigorous set of open-channel hydraulic calculations and attempt to roll the stone using minimal flume discharge.

Artists

Like a Rolling Stone bands can include up to five members.

Instruments

Bands should bring the following:

- a laptop computer equipped with a spreadsheet software (e.g. Microsoft Excel)
- a stopwatch or a cell phone with a stopwatch

Competition organizers will provide a balance and ruler for measurements.

Bands should develop a calculation spreadsheet prior to the competition. The calculation spreadsheet will display the following plots:

- discharge (cm^3/s) per rock facial area (cm^2)
- discharge (cm^3/s) per coefficient of friction (μ, unitless)

Bands should prepare a report prior to the competition. The report will include the following components:

- the calculation spreadsheet
- detailed explanations of the calculations in the calculation spreadsheet
- identification and description of all potential forces acting on the rock
- identification and explanation of any assumptions made in the calculations

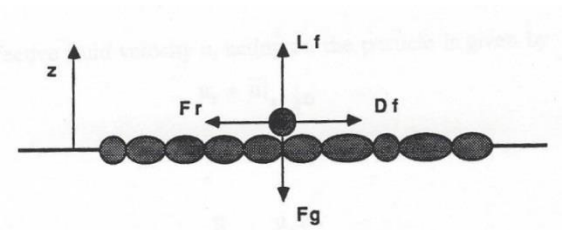

Figure 1 - Free Body Diagram

Bands should use the following background information to develop their calculations:

- The rock will be subject to the four forces in Figure 1: drag (D_f), frictional resistance (F_r), lift (L_f), and submerged gravity (F_g). The rock will lie on a smooth flume bottom, not the rocks in Figure 1. The arrow z in Figure 1 depicts the upward direction in the flow field from the flume bottom.
- <u>Assume that lift (L_f) is negligible.</u>
- <u>Assume that drag (D_f) dominates during the initiation of motion.</u> Calculate drag using the equation:

$$D_f = C_d \rho A_f \left(\frac{V^2}{2}\right)$$

where:

C_d	=	drag coefficient (unitless)
ρ	=	fluid mass density (g/cm^3)
A_f	=	facial area (against the flow field, cm^2)
V	=	fluid velocity (through the flume cross-section, cm/s)

- C_d values from literature range from 1.2 for a circular cylinder to 1.8 for a plate oriented fully perpendicular to the flow field, and assume fully rough, turbulent flow. Select one or more C_d values which best accommodate the potential shape of the rock.
- Frictional resistance (F_r) and submerged gravity (F_g) will also act during the initiation of motion. The frictional resistance is a function of the submerged gravity ($F_r = \mu F_g$). Estimate the coefficient of friction (μ) using the empirical equation:

$$\mu = 0.0027 + 0.00047 A_b$$

where:

μ	=	coefficient of friction (unitless)
A_b	=	basal contact area (against the flume bottom, cm^2)

- The flume is 7.5 cm wide and has a downward slope (S) of 0.0082 m/m.
- Assume the water temperature is 12°C and the water unit weight is 9800 N/m^3.
- Assume the rock's specific gravity (G_s) is 2.65.
- Assume uniform flow through the flume cross-section.
- Carry out decimal places to ten-thousandths (10^{-4}) or more; magnitudes will be very small.
- Rocks will be gravel-sized.
- Calculations should be rigorous. Calculations should be accurate for rocks within the gravel-sized range, regardless of the specific dimensions; therefore, specific dimensions will not be provided.

Tracks

Bands will be assigned timeslots the day of the competition. Bands will select a gravel-sized rock and use the provided balance and ruler to measure the rock's mass (m), length (L), width (W), and depth (D). The rock will not be a perfect rectangular prism, so bands will estimate a volume adjustment factor ($\forall_a$) by either "eyeballing it" or using some other rudimentary method.

Figure 2 – Laboratory Flume Photographs

Testing

Bands will estimate the discharge (cm^3/s) required to move the rock and write the estimate on a provided sheet. Competition organizers will turn on the flume pump. Bands will operate the laboratory flume (Figure 2) and the weigh tank. Example operation is shown is shown here. The following procedure is strongly recommended:

1. Turn the ball valve (Figure 2, middle) to the lowest setting.
2. Once low velocity flow has developed, set the rock at the 8-ft mark (Figure 2, right).
3. Very slowly turn the ball valve counter-clockwise, in increments, to adjust the flow. Between each increment, wait 15 seconds to let flow reach equilibrium before proceeding.
4. Stop turning the ball valve when the rock begins to slide, roll, or saltate. Use the provided ruler to measure the flow depth (y).

5. A 68-kg set of weights will be pre-placed on the control arm (Figure 2, left). The weight tank plug valve will be open, and the control arm will be down. Ready a stopwatch and a 15-kg weight and use the black knob to close the plug valve.
6. At the exact moment the control arm rises, start the stopwatch and set the 15-kg weight on the control arm.
7. At the exact moment the control arm rises again, stop the stopwatch, open the plug valve, remove the 15-kg weight.
8. Repeat Steps 5, 6, and 7 until you have recorded three measurements. Compute discharge using the equation:

$$Q = \frac{15\ \mathrm{kg}}{t\gamma}$$

where:

Q	=	discharge (m^3/s)
t	=	recorded time (s)
γ	=	0.001 kg/cm^3

Report Score - 65% of Total Score
Judges will score reports for appearance and presentation (15 points), clarity of explanations, identifications, and descriptions (30 points), and technical accuracy (20 points).

Laboratory Score – 35% of Total Score
Judges will compare estimated discharges with measured discharges and score as follows:

- ≤5.0% deviation - 35 points
- 5.1%-10.0% deviation - 30 points
- 10.1%-15.0% deviation - 25 points
- 15.1%-20.0% deviation - 20 points
- 20.1%-25.0% deviation - 15 points
- 25.1%-30.0% deviation - 10 points
- 30.1%-35.0% deviation - 5 points
- ≥35.1% deviation - 0 points

Notes

Direct any RFIs to conference organizers. This section will be updated to include RFI responses.