Extreme Floodwaters!

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Texas 2015
Arizona 2010
Estes Park 2013
Overarching Concepts

• Utilize images or video to explore environmental consequences of drag forces
• Integrate estimation exercises
• Use these ideas in concert with simple laboratory or field exercise to solidify conceptual understanding of these topics
**Activity 1: Physics and Environmental Detective work!**

Simplifying assumptions:

1) Assumed to be totally immersed but the buoyant forces, differential flow speed, and Bernoulli-like lift forces acting on the rock are ignored.

2) Assumed spherical but flat-bottomed $\rightarrow$ rolling behavior can be ignored.

Activity 1: Physics and Environmental Detective work!

Quadratic Force Law $|F_d| = \frac{1}{2} A \rho_w C_D |\vec{V}|^2$,

$F_d$ is the resistive force,

$A$ is the cross sectional area of the object

$\rho_w$ is the fluid density

$C_D$ is the dimensionless drag coefficient

$V$ is the relative velocity of the fluid

$\mu g = \frac{1}{2} \pi r^2 \rho_w C_D |\vec{V}|^2$,

$\mu = \frac{1}{2}$ for wet rock on rock

$g = 9.8 \text{ m/s}^2$

$r \approx 2.5 \text{ m}$

This results in an approximate weight for the rock of about 200 tons! (in reality it is over 400 tons)
Activity 2

Quadratic Force Law
\[ F_d = \frac{1}{2} A \rho_w C_D |\dot{V}|^2, \]

\( F_d \) is the resistive force,

\( A \) is the cross sectional area of the wheels (2x) or (4x)?

\( \rho_w \) is the fluid density

\( C_D \) is the dimensionless drag coefficient

\( V \) is the relative velocity of the fluid

Tire (assumed totally air) \( \rho_t \sim 1 \text{ kg/m}^3 \)

Water, \( \rho_w \sim 1000 \text{ kg/m}^3 \)

\( C_D \sim \frac{1}{2}, \)

\( \mu = 0.2 \) for wet tire on rock

\( g = 9.8 \text{ m/s}^2 \)

Tire radius (17 inch) \( r \sim 0.22 \text{ m} \)

Subaru Forester Weight 3300 lbs or about 14,700 Newtons

\[ F_f = |\mu g| = |F_d| \]

\[ \mu g = (2 \text{ or } 4) \frac{1}{2} \pi r^2 \rho_w C_D |\dot{V}|^2, \]

\[ V = \sqrt{\frac{\mu g}{\pi r^2 \rho_w C_D}} \]

Buoyancy reduces this speed by about 5%. Also, if you drive a Smart Car the speed would be about 4mph!
Drag Force Labs and Activities

Activities
- Displaced Boulders
- Pedestrian Safety
- Passenger Vehicles Safety
- Floating Houses

Experimental Laboratories
- Fishing
- Floating Fruit
- Marbles
- Styrofoam Models

Drag Force Comprehension
To Stoke’s Law or Not to Stoke’s Law

A “Simple” Test

• Stoke’s Law \( |\vec{F}_s| = 6\pi \eta r |\vec{V}| \),
  - \( F_s \) is the resistive force,
  - \( \eta \) is the viscosity of the fluid,
  - \( r \) is the object radius,
  - \( V \) is the velocity of the object
    relative to the fluid

• Quadratic Force Law \( |\vec{F}_d| = \frac{1}{2} A \rho_w C_D |\vec{V}|^2 \),
  - \( F_d \) is the resistive force,
  - \( A \) is the cross sectional area of the object
  - \( \rho_w \) is the fluid density
  - \( C_D \) is the dimensionless drag coefficient
  - \( \vec{V} \) is the relative velocity of the fluid

• The Test!
\[
\frac{|\vec{F}_d|}{|\vec{F}_s|} = \frac{\frac{1}{2} A \rho_w C_D |\vec{V}|^2}{6\pi \eta r |\vec{V}|} = 1 \Rightarrow |\vec{V}_C| = \frac{6\pi \eta r}{\frac{1}{2} A \rho_w C_D}
\]