Extreme Floodwaters!

Kenneth A Pestka II
Longwood University
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Texas 2015

Arizona 2010

Estes Park 2013

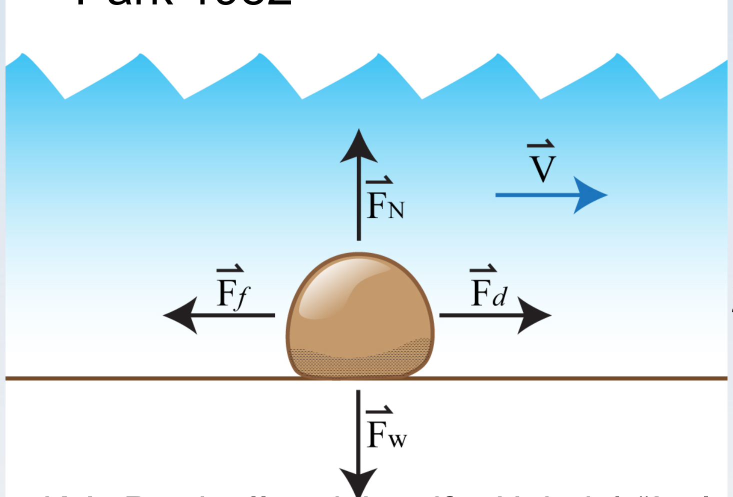
Overarching Concepts

- 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!

Alluvial Fan at Rocky Mountain National Park 1982

Alluvial Fan at Rocky Mountain National Park 2013



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* → rolling behavior can be ignored.

K.A. Pestka II and Jennifer Heindel, "An Interdisciplinary Approach to Drag Forces: Estimating Floodwater Speeds From Displaced Riverbed Boulders," *Phys. Teach.*, **53**, 272 (2015).

Alluvial Fan at Rocky Mountain National Park 1982

Activity 1:Physics and Environmental Detective work!

Alluvial Fan, Rocky Mountain National Park 1982

Quadratic Force Law $\left|\vec{F}_d\right| = \frac{1}{2} A \rho_W C_D \left|\vec{V}\right|^2$,

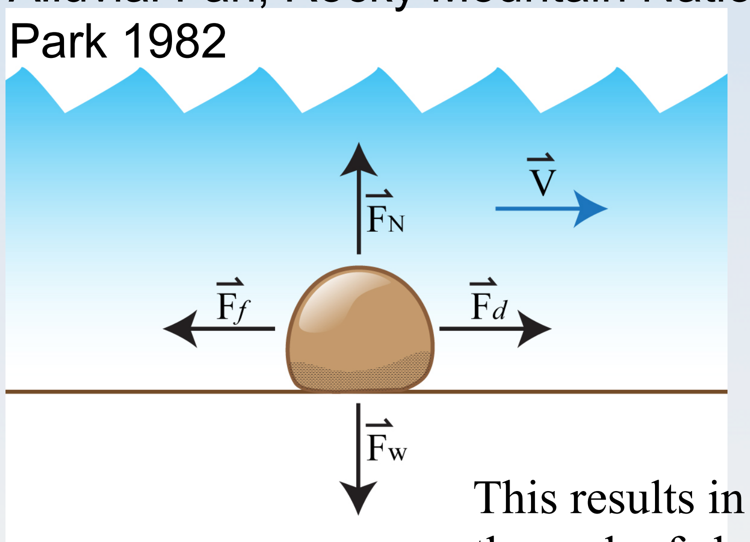
F_d is the resistive force,

A is the cross sectional area of the object

ρ_W is the fluid density

C_D is the dimensionless drag coefficient

V is the relative velocity of the fluid



$$\left|F_f\right| = \left|F_d\right| \Rightarrow \mu m g = \frac{1}{2}\pi r^2 \rho_W C_D \left|\vec{V}\right|^2,$$

$$\mu \rho_R \frac{4}{3}\pi r^3 g = \frac{1}{2}\pi r^2 \rho_W C_D \left|\vec{V}\right|^2$$

Granite, $\rho_R \sim 2700$ kg/m³
Water, $\rho_W \sim 1000$ kg/m³
$C_D \sim ½$,
μ= ½ for wet rock on rock
g=9.8 m/s²
r~2.5m

$$\Rightarrow V = \sqrt{\frac{8\mu\rho_R r g}{3\rho_W C_D}}.$$

V~13.3m/s or about 30mph

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

Physics and Environmental Detective work! Activity 2

Texas May 2015
youtube.com / Christina Geddes

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

F_d is the resistive force,

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

ρ_W is the fluid density

C_D is the dimensionless drag coefficient

V is the relative velocity of the fluid

Tire (assumed totally air) $\rho_T \sim 1$ kg/m^3
Water, $\rho_W \sim 1000$ kg/m^3
$C_D \sim$ ½,
μ= 0.2 for wet tire on rock
g=9.8 m/s^2
Tire radius (17 inch) r ~ 0.22 m
Subaru Forester Weight 3300 lbs or about 14,700 Newtons

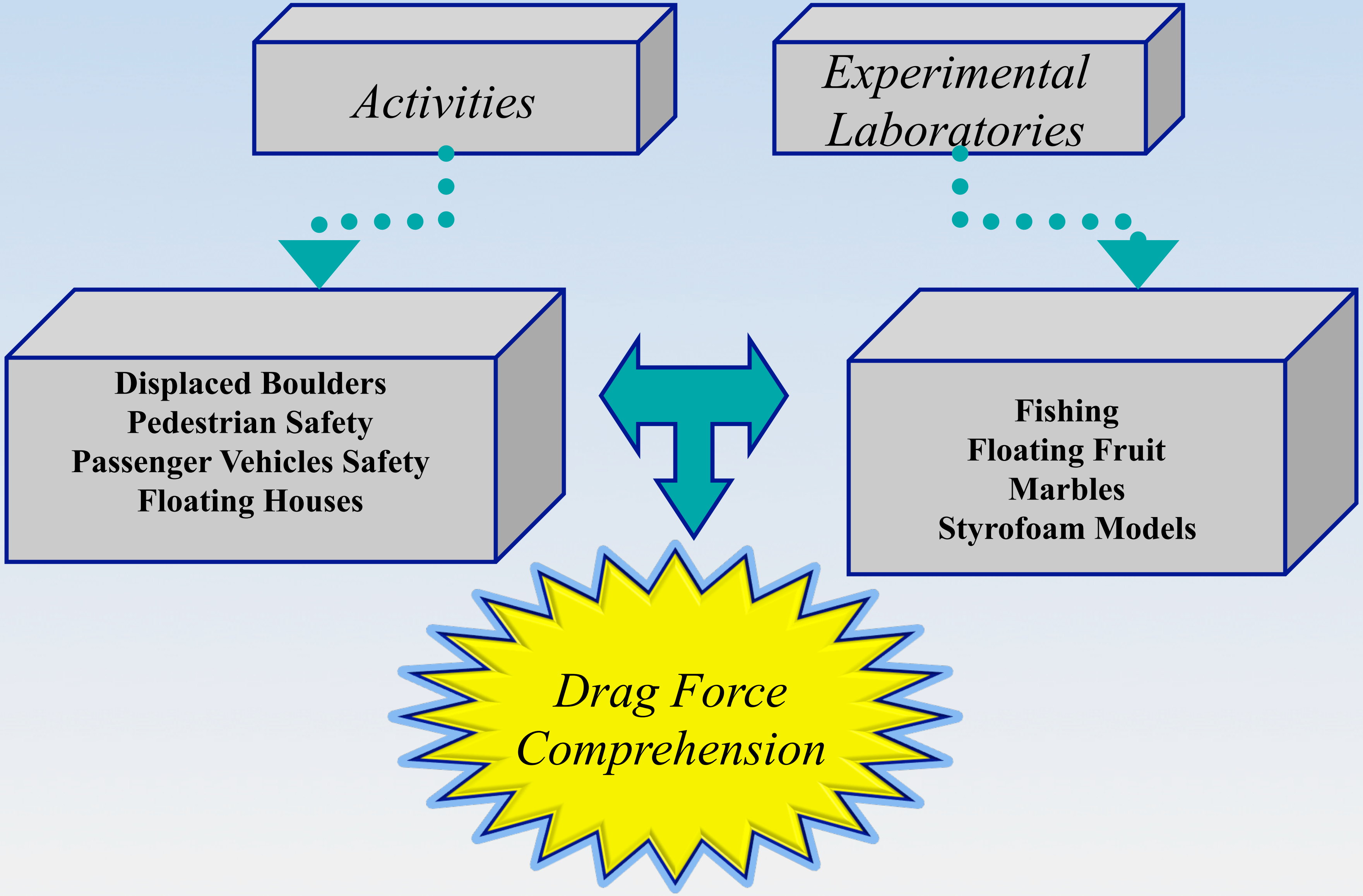
$$\left|F_f\right| = \left|F_d\right| \Rightarrow \mu m g = (2 \ \text{or} \ 4)\frac{1}{2}\pi r^2 \rho_W C_D \left|\vec{V}\right|^2,$$

$$V = \sqrt{\frac{\mu m g}{\pi r^2 \rho_W C_D}}$$ V~3m/s or about 6.7 mph

$$\Rightarrow V = \sqrt{\frac{\mu m g}{2\pi r^2 \rho_W C_D}}$$ V~2.2m/s or about 5 mph

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



To Stoke's Law or Not to Stoke's Law
A "Simple" Test

- Stoke's Law $\left|\vec{F}_s\right| = 6\pi\eta r\left|\vec{V}\right|$,
  - F_s is the resistive force, η 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 $\left|\vec{F}_d\right| = \frac{1}{2}A\rho_W C_D\left|\vec{V}\right|^2$,
  - F_d is the resistive force, A is the cross sectional area of the object
  - ρ_W is the fluid density C_D is the dimensionless drag coefficient
  - V is the relative velocity of the fluid
- The Test!

$$\frac{\left|\vec{F}_d\right|}{\left|\vec{F}_s\right|} = \frac{\frac{1}{2}A\rho_W C_D\left|\vec{V}\right|^2}{6\pi\eta r\left|\vec{V}\right|} = 1 \Rightarrow \left|\vec{V}_C\right| = \frac{6\pi\eta r}{\frac{1}{2}A\rho_W C_D}$$