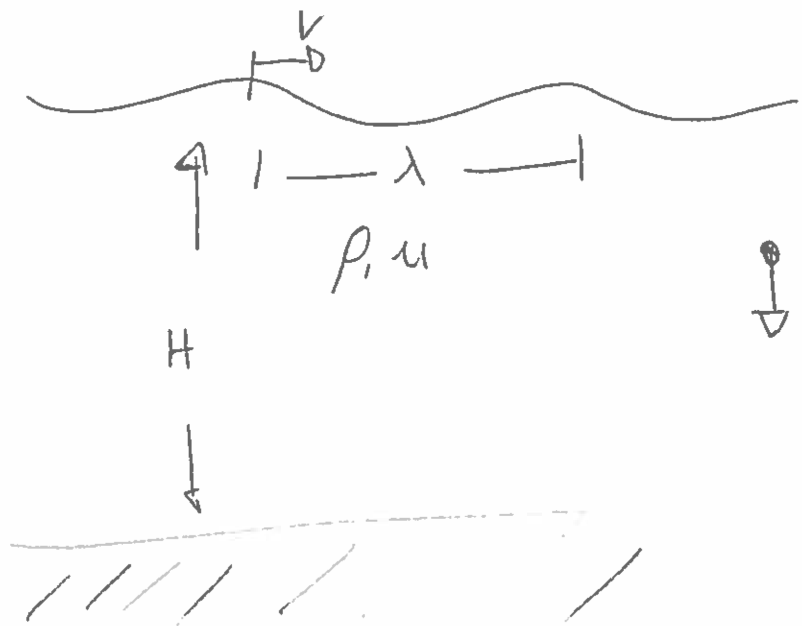
#1



Waves depend on λ, H, g, ρ, μ

Assume: 1) Since water is deep, at some point we reach a limit where H doesn't matter.

2) Since ocean waves propagate over 100–1000 miles viscosity does little

$V\left[\frac{L}{T}\right]$	$g\left[\frac{L}{T^2}\right]$	$\lambda\,[L]$	$\rho\left[\frac{M}{L^3}\right]$	Eliminate
$V\left[\frac{L}{T}\right]$	$g\left[\frac{L}{T^2}\right]$	$\lambda\,[L]$	—	M
$\frac{V^2}{g}\,[L]$	—	$\lambda\,[L]$	—	T
$\frac{V^2}{g\lambda}$	—	—	—	L

$$\frac{V^2}{g\lambda} = \text{Const} \qquad \boxed{V \sim \sqrt{g\lambda}}$$

#2

$r\,[L]$	$t\,[T]$	$E\left[\frac{ML^2}{T^2}\right]$	$\rho\left[\frac{M}{L^3}\right]$	eliminate
$r\,[L]$	$t\,[T]$	$\frac{E}{\rho}\left[\frac{L^5}{T^2}\right]$	—	M
$r\,[L]$	—	$\frac{Et^2}{\rho}\,[L^5]$	—	T
$\frac{\rho r^5}{Et^2}$	-	-	-	L

so $\boxed{\dfrac{\rho r^5}{Et^2} = \text{Constant}}$

#3

$F\left[\frac{ML}{T^2}\right]$	$u\left[\frac{L}{T}\right]$	$D\,[L]$	$\rho\left[\frac{M}{L^3}\right]$	$\mu\left[\frac{M}{LT}\right]$	eliminate
$\frac{F}{\rho}\left[\frac{L^4}{T^2}\right]$	$u\left[\frac{L}{T}\right]$	$D\,[L]$	$\frac{\rho}{\mu}\left[\frac{T}{L^2}\right]$	—	M
$\frac{F}{\rho u^2}\,[L^2]$	$\frac{\rho u}{\mu}\left[\frac{1}{L}\right]$	$D\,[L]$	—	—	T
$\frac{F}{\rho u^2 D^2}$	$\frac{\rho u D}{\mu}$	—	—	-	L

So

$$\boxed{\frac{F}{\rho u^2 D^2} = f\left(\frac{\rho u D}{\mu}\right)}$$

where $\frac{\rho u D}{\mu} \equiv$ Reynolds #

Limit #1 ρ matters, μ doesn't

$F\left[\frac{ML}{T^2}\right]$	$u\left[\frac{L}{T}\right]$	$D[L]$	$\rho\left[\frac{M}{L^3}\right]$	eliminate
$\frac{F}{\rho}\left[\frac{L^4}{T^2}\right]$	$u\left[\frac{L}{T}\right]$	$D[L]$	—	M
$\frac{F}{\rho u^2}\left[L^2\right]$	—	$D[L]$	—	T
$\frac{F}{\rho u^2 D^2}$	—	—	—	L

$$\boxed{\frac{F}{\rho u^2 D^2} = \text{Constant}}$$

Limit #2 μ matters, ρ doesn't

$F\left[\frac{ML}{T^2}\right]$	$U\left[\frac{L}{T}\right]$	$D[L]$	$\mu\left[\frac{M}{LT}\right]$	eliminate
$\frac{F}{\mu}\left[\frac{L^2}{T}\right]$	$U\left[\frac{L}{T}\right]$	$D[L]$	—	M
$\frac{F}{\mu U}[L]$	—	$D[L]$	—	T
$\frac{F}{\mu U D}$	—	—	—	L

So $\boxed{\frac{F}{\mu U D} \equiv \text{constant}}$

Summary

$$\frac{F}{\rho U^2 D^2} = f(Re) \qquad Re \equiv \frac{\rho U D}{\mu}$$

Inertia

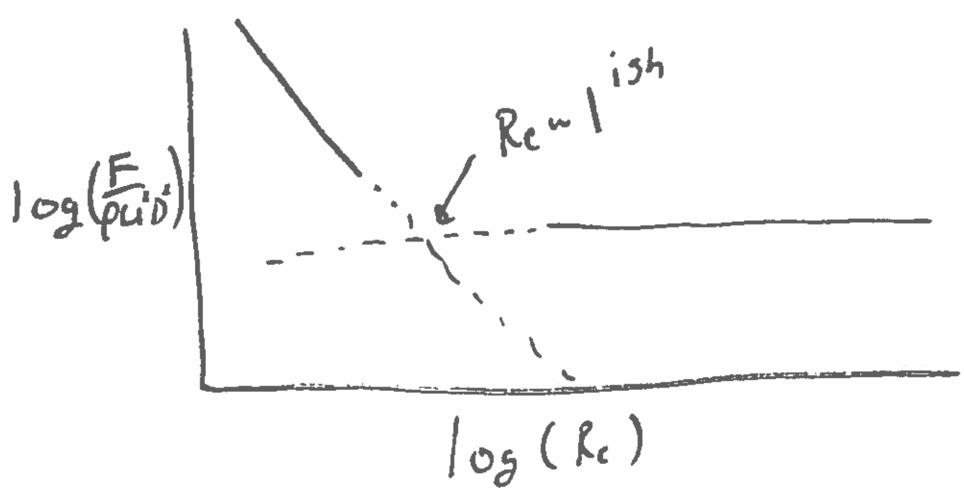
$$\frac{F}{\rho U^2 D^2} = \text{Constant}$$

Viscous

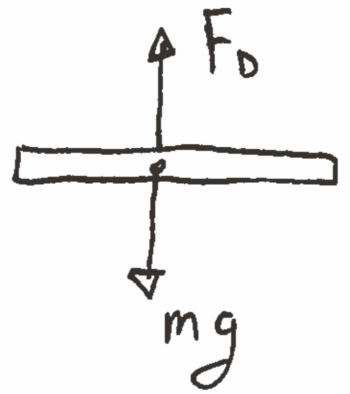
$$\frac{F}{U \mu D} = \text{Constant}$$

-or-

$$\frac{F}{\rho U^2 D^2} = \frac{C \mu U D}{\rho U^2 D^2} = \frac{C \mu}{\rho U D} = \frac{C}{Re}$$



#4



when falling at terminal Velocity

$$F_{DRAG} = mg$$

mass of Card : $m = \rho_{Card}\, t\, L^2$

Drag Force : $F_D = C \rho_{Air}\, U^2 L^2$ (Assume Inertia limit for Drag)

So

$$g \rho_c t \cancel{L^2} = C \rho_A U^2 \cancel{L^2}$$

$$\boxed{U^2 = \frac{\rho_{Card}\, t\, g}{C \rho_{Air}}}$$

terminal Velocity does not depend on size of Card.

#5

$Q\left[\frac{L^3}{T}\right]$	$D[L]$	$\frac{\Delta P}{\ell}\left[\frac{M}{L^2T^2}\right]$	$\mu\left[\frac{M}{LT}\right]$	remove
$Q\left[L^3/T\right]$	$D[L]$	$\frac{\Delta P}{\mu\ell}\left[\frac{1}{LT}\right]$	—	M
$\frac{Q}{D^3}\left[\frac{1}{T}\right]$	—	$\frac{\Delta P D}{\ell\mu}\left[\frac{1}{T}\right]$	—	L
$\frac{Q\mu\ell}{D^4\Delta P}$	—	—	—	T

$$\frac{Q\mu\ell}{D^4\Delta P} = \text{Constant}$$

- or -

$$Q = \text{Constant}\ \frac{\Delta P D^4}{\mu\ell}$$

Double diameter and volumetric flow goes up by a factor of 16.

Confirms experiment