Design for the Ocean Environment

Some Major Considerations

- Hydrostatic pressure
- Heat dissipation in housings
- Waves
- Forces on bodies in steady flow

- *But don't forget:*

  wind and rain, corrosion, biofouling, material fatigue, creep, chemical breakdown, human safety, regulations, etc.

	Young's Modulus, Pascals	Ultimate Strength, Pascals	Coefficient of thermal conductivity, W m / m^2 °K	Density, kg/m^3
Steel	200e9	550e6	4400	8000
Aluminum	70e9	480e6	22000	2700
Titanium	100e9	1400e6	1500	4900
Glass	70e9	<35000e6 (compression!)	100	2600
ABS Plastic	1.3e9	34e6	LOW	~1100
Mineral oil		-	17	~900
Water	2.3e9	-	60	1000

Wave Fields

Definition:

SeaState	Height (ft)	Period (s)	Wind (knots)
2	1	7	9
3	3	8	14
4	6	9	19
5	11	10	24
6	16	12	37
7	25	15	51

Wave height $H_{1/3}$
Significant wave: Average of one-third highest waves

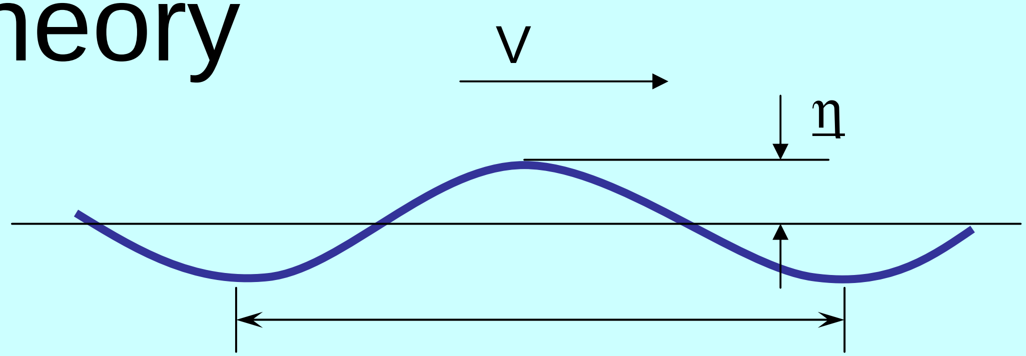
Distribution:

30% of world oceans are at	0-1m height
41%	1-2m
17%	2-3m
6%	3-4m
2%	4-5m

Wave fields depend on storms, fetch, topography

Linear Wave Theory

(deepwater)



Wave elevation:

$\eta = \underline{\eta}$ **cos(** ω **t – k x)** where

$\underline{\eta}$ is amplitude

ω is frequency in rad/s : period $T = 2\pi/\omega$

k is wavenumber in rad/m : wavelength $\lambda = 2\pi/k$

Dispersion Relation: $\mathbf{k = \omega^2 / g}$

Wave speed: $\mathbf{V = g / \omega}$

Particle velocities: $\mathbf{u = k \underline{\eta} V e^{-kz} \cos (\omega t - k x)}$

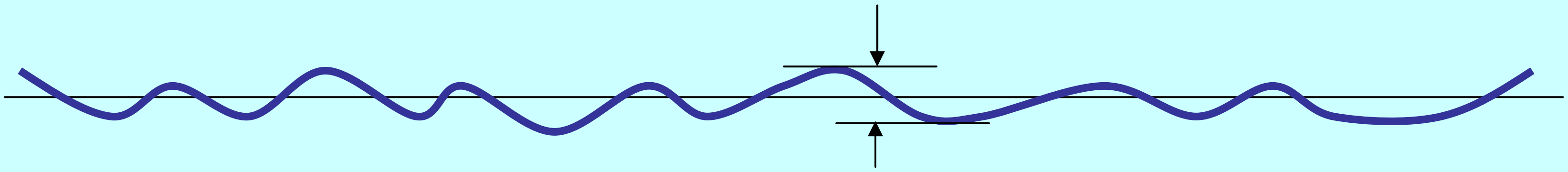
$\mathbf{w = k \underline{\eta} V e^{-kz} \sin (\omega t - k x)}$ where z is depth

Fluctuating pressure: $\mathbf{p = \rho \underline{\eta} g e^{-kz} \cos (\omega t - k x)}$

Statistics of Extreme Waves

- Average of one-third highest waves is significant wave height H_{sig} or $H_{1/3} = 2\,\underline{\eta}_{1/3}$
- An observer will usually report $H_{1/3}$
- $H_{1/10} = 1.27 * H_{sig}$
- Expected maxima:

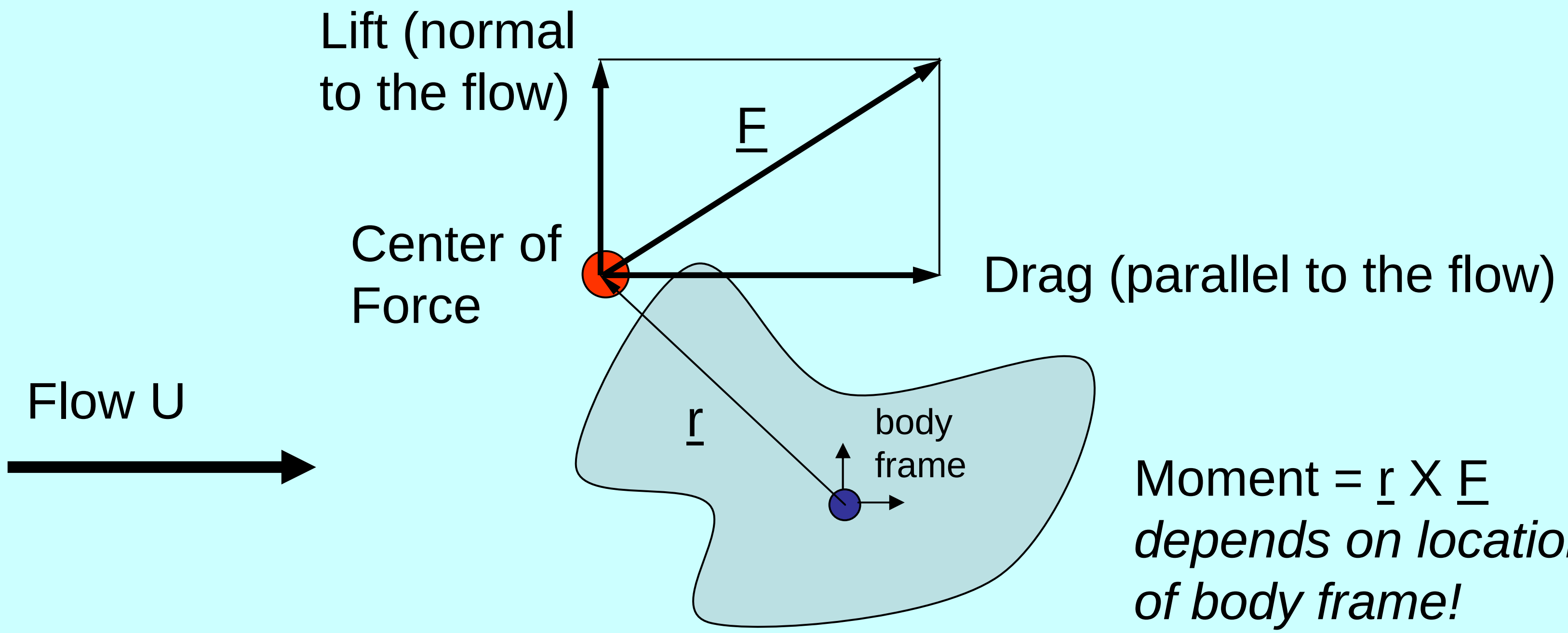
Expected maxima:	$N = 100$;	$1.62 * H_{1/3}$
	$N = 1000$;	$1.92 * H_{1/3}$
	$N = 10000$;	$2.22 * H_{1/3}$



Forces in steady flow

- Streamlined vs. Bluff Bodies
  - Bluff: Cylinders, blocks, higher drag, lower lift, large-scale separation and wake
  - Streamlined: airplanes and ship hulls, Lower drag but higher lift, avoids separation to minimize wake
  - Tradeoff in Directional Stability of the body:
    - A fully streamlined fuselage/fairing is unstable.
    - Drag aft adds stability, e.g., a bullet
    - Wings aft add stability, e.g., fins, stabilizers
    - Wings forward decrease stability, but improve maneuverability.
- Turbulent vs. Laminar flow
- High- vs. low-speed flow

Concept of Drag, Lift, Moment (2D)

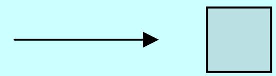
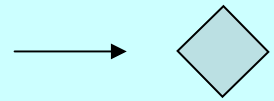
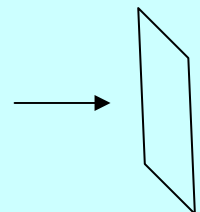
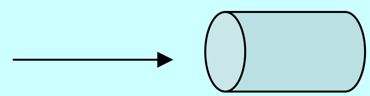


Moment = $\underline{r} \times \underline{F}$
depends on location of body frame!

Typical nondimensionalization:

Drag = $\frac{1}{2} \rho U^2 A C_d$, where A is (typically) frontal area or wetted area
Lift = $\frac{1}{2} \rho U^2 A C_l$, where A is usually a planform area
Moment = $\frac{1}{2} \rho U^2 D L^2 C_m$, where L is characteristic body length, and D is characteristic width (or diameter)

Typical Drag Coefficients (frontal area)

- Square cylinder section  2.0
- Diamond cylinder section  1.6
- Thin rect. plate AR=1 1.1
- AR=20 1.5
- AR>>1 2.0 
- Circular cylinder section 1.1
- Circular cylinder end on  1.0
- 1920 Automobile 0.9
- Volkswagon Bus 0.42
- Modern Automobile < 0.3
- MIT Solar Car?

Potter & Foss (1982)

Recommended References

- Fluid-Dynamic Lift. S.F. Hoerner, 1975, Hoerner Fluid Dynamics, Bakersfield, CA.
- Principles of Naval Architecture, Volume III (Motions in Waves and Controllability), E.V. Lewis, ed., 1989, SNAME, Jersey City, NJ.
- Fluid Mechanics, M.C. Potter and J.F. Foss, 1982, Great Lakes Press, Okemo, MI.
- Theory of Flight, R. von Mises, 1945, Dover, New York.
- http://naca.larc.nasa.gov/: NACA reports on bodies and surfaces