Principles of Sailing

or

"Main sheets, spinnakers and belaying pins ahoy!"

Paul Pounds

12 March 2013

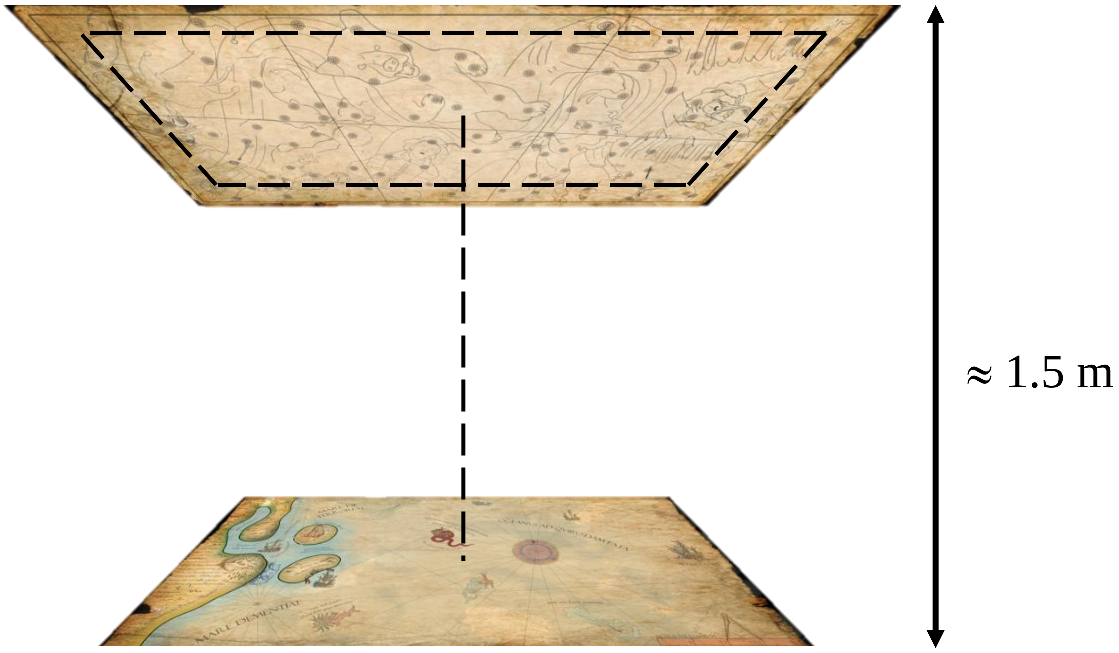
University of Queensland

But first…

Some house keeping

House keeping

- Tank specifications are now updated on Blackboard and the class website



  – ETA of tank: still end of March

Calendar at a glance

You are here →

Week	Dates	Lecture	Reviews	Demos	Assessment submissions
1	25/2 – 1/3	Introduction			
2	4/3 – 8/3	Principles of Mechatronic Systems design			
3	11/3 – 15/3	Principles of Sailing			Design brief
4	18/3 – 22/3	By request	Progress review 1		
5	25/3 -29/3	By request			
Break	1/4 – 5/4				
6	8/4 – 12/4	By request	Progress seminar		
7	15/4 – 19/4	By request		25% demo	
8	22/4 – 26/4	By request			
9	29/4 – 3/5	By request	Progress review	50% demo	
10	6/5 – 10/5				
11	13/5 – 17/5			75% demo	Preliminary report
12	20/5 – 24/5				
13	27/5 – 31/5	Closing lecture		Final testing	Final report and addendum

← OMG!

FAQ Roundup

- **Our group member hasn't gotten in touch with us!**
  - Have you emailed them? If not, email me and I'll help you track them down.
- **What is the wavelength/part number of the LEDs?**
  - Uhhhh…. White visible light. I *could* theoretically find the part number, but seriously I'm not going to go digging to find it and it won't really help you. The LED radiation pattern has a 70 deg spread.
- **Will the room lights be on/off?**
  - There is no room – the testing area is outdoors. However, there will be complete cover overhead, so you (hopefully) won't have to compete with the Cursed Daystar.
- **Can we use a Raspberry Pi?**
  - Yes. I won't respect you in the morning, but yes.

FAQ Roundup

- **Can we use an onboard camera?**
  - Sure. You can't use an *offboard* camera, but onboard is totally ok.
- **What do we have to do with the design brief?**
  - Show you have understood the design problem. Tell me what part of the project you are undertaking and how it fits with the team's approach. Highlight the key technical problems. Most of all, convince me that you have actually thought about the problem.

    Better yet – read the Blackboard assessment description!
- **Is there a marking rubric available?**
  - Yup. Read the Blackboard page.

Design brief design brief

- The objective of the design brief is to **convince** the client that the student has **understood the problem**, its **scope**, and its **requirements** and has **developed insights** into how the problem may be addressed. The student must provide a **description of the aspects** of the project he or she will be working on, a <u>**succinct analysis**</u> of the **key design challenges** of these aspects of the problem, the **proposed approach** to be undertaken in resolving them, and how the student's proposed solution **relates to other subsystems** within the project. Students will be assessed on the **thoroughness and insight** demonstrated in the brief. The design brief is to be <u>**no more than two A4 pages**</u>.

  Assignments are to be submitted through the Faculty of EAIT (Hawken Building 50) assignment chute and require an **assignment cover sheet**, available from https://student.eait.uq.edu.au/coversheets/

Functional requirements

- Convince me you understand:
  - The problem
  - Its scope
  - Its requirements (and constraints)
- Describe:
  - The aspects you are working on
  - Key challenges of your subtasks (with analysis)
  - Your proposed approach
  - How it relates to the approach of your team

Marking rubric

Design Brief – Individual Mark Sheet. **ENGG/METR** **Team number:**

Grade Band	Task description (20)		Problem Analysis (30)		Methodology (30)		Design Integration (20)	
Excellent (85-100%)	Clearly describes the student's part of the project – its scope and responsibilities. Tasks constitute a valuable, well-motivated and substantive contribution to developing a solution.	20 18	Problem broken down systematically. The technical challenges are highlighted and it is obvious how the design problems map to tasks. Well-considered specification provided.	30 27	A well justified, comprehensive breakdown of the approach to be taken. Tasks with resources and duration have been logically ordered and associated with logical milestones. Potential risks are reported where appropriate, with associated mitigation strategies.	30 27	Captures the most important design decisions and shows how the individual task integrates with the rest of the team. Part of a well-functioning design strategy.	20 18
Very Good (75-85%)	Sets out the work to be done, with some indication of scope or obligations. The student has an assigned task to undertake that will help the group.	16	Key challenges are recognised and described. Dependencies and prerequisites of major technical problems are discussed. A useful attempt at a specification is made.	24		24		16
Good (65-75%)	Broadly defined task description that maps to a major area of the project, but it less detailed about what is entailed or why that role was assigned.	14	Statement of the problem captures the essential challenges, and considers some interdependencies. Some analysis considered why these are challenging. Some performance specs.	21	A somewhat justified list of tasks with resources and duration has been ordered and assigned, with milestones. Risks are considered. Obvious thought has gone into assembling a solution plan.	21	Individual components are shown to work as part of a whole, with an indication of the interfaces between functional areas. Obvious communication in developing the solutions.	14
Satisfactory (50-65%)	Usable task and responsibility assignment provided. Unclear on boundaries or motivations.	12 10	Provides statement of what parts are difficult, without delving deeper into why. Little indication of thoughtful analysis. Expected performance requirements are minimal or missing.	18 15	A weakly justified list of tasks with resources and duration have been ordered and assigned, with illogical milestones. Some sense that thought was given the solution.	18 15	Functional breakdown across the project is awkward but each subsystem integrated usefully.	12 10
Poor (25-50%)	Some attempt made to provide task assignment and scope.	8 6	Simple restatement of the project challenges – limited insight into what makes the problem difficult.	12 9 6	An unjustified list of tasks with resources and duration has been ordered improperly. Denies apparent analytical consideration.	12 9 6	Collective design is haphazard and interfaces are nonexistant or illogical. Left hand has yet to meet right hand.	8 6
Very Poor (0-25%)	No attempt made at task scope	4 2 0	No attempt made at analysis	0	No attempt made at methodology	0	No attempt at integration	0

Group mark component: /100	**Comments:**
Penalties /Bonuses:	
Final mark: /100	**Marker's Signature:** **Date:**

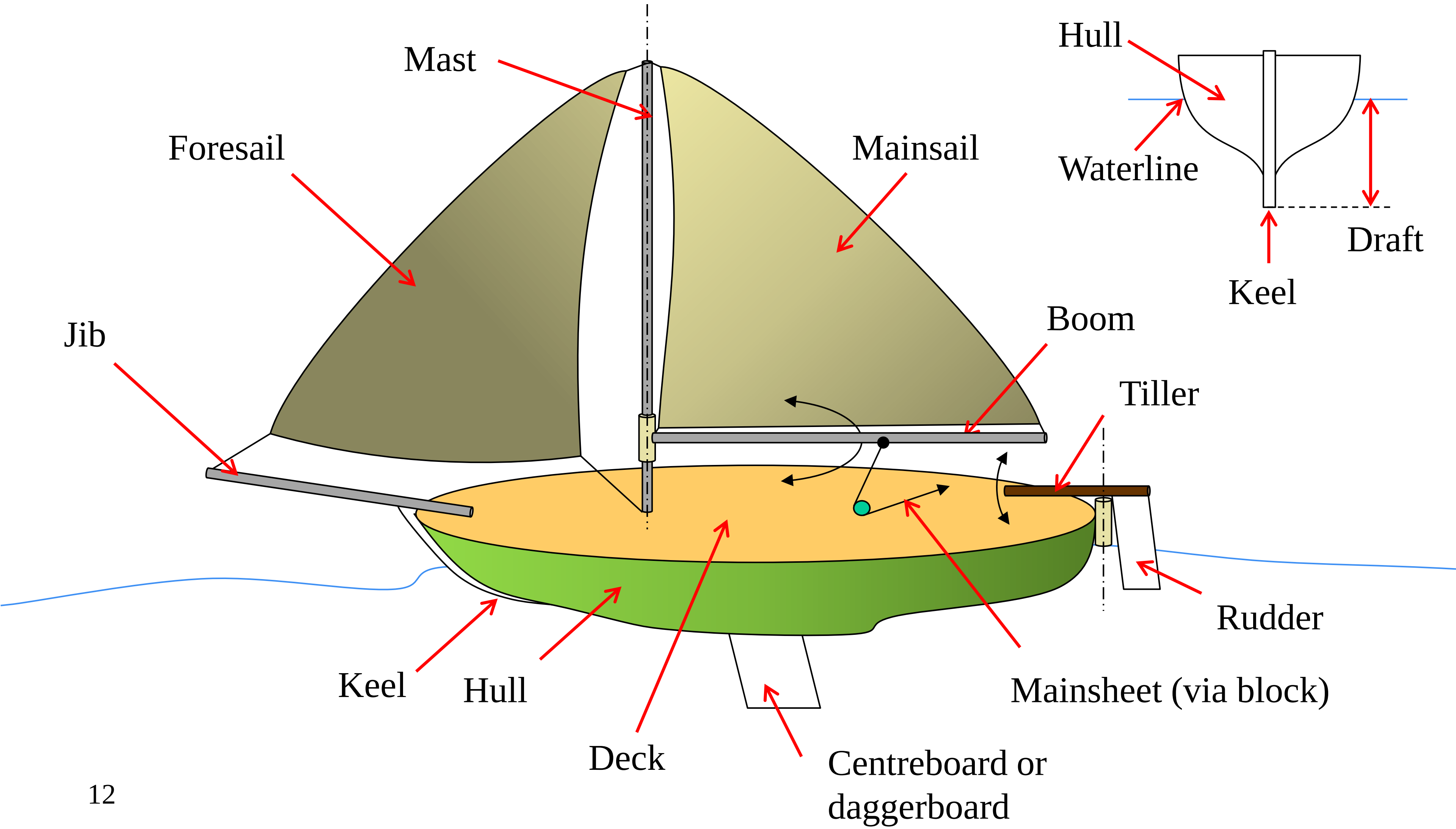
Aaarrrr.

On to the sailing!

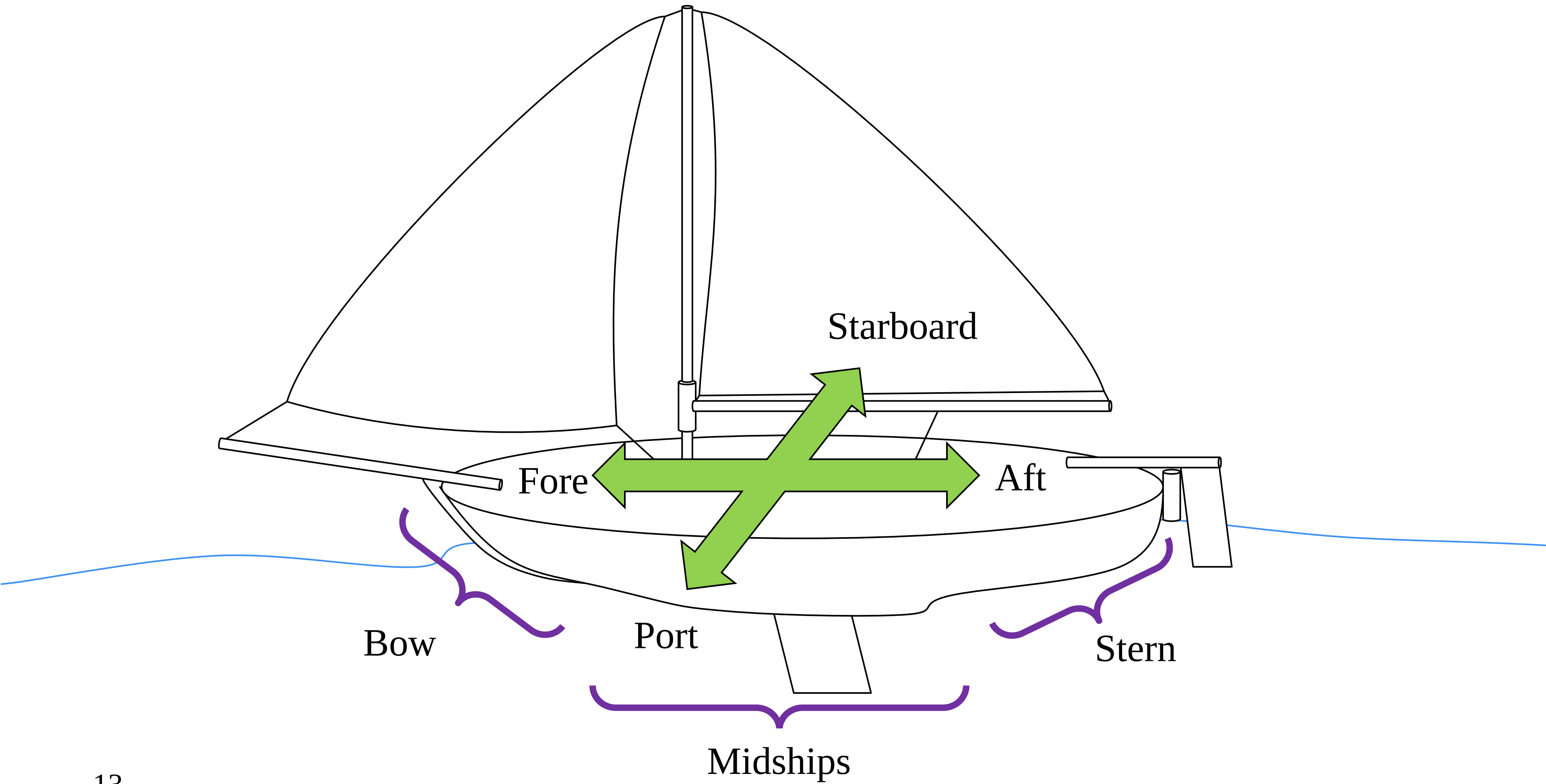
Sailing – what is it?

- The process of using the wind to propel a floating vessel by way of a foil called a sail
  - Force interaction of two discrete fluid dynamics systems gives rise to controllable propulsion
- Sailing requires no fossil fuels
- Sailing has unlimited range
- Sailing produces no carbon emissions
- Sailing is also very fun!

The parts of a vessel

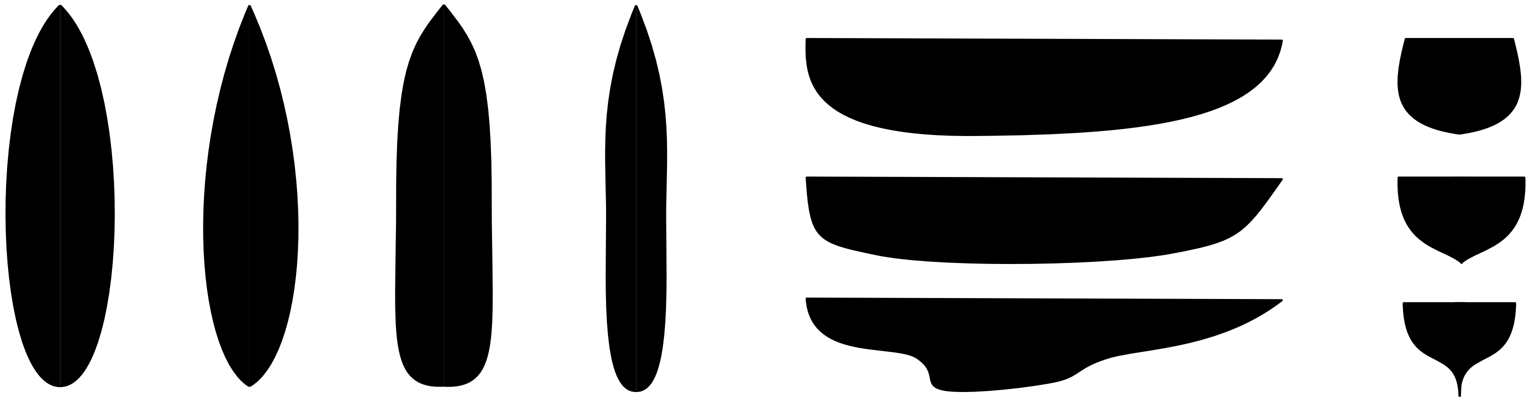


The parts of a vessel



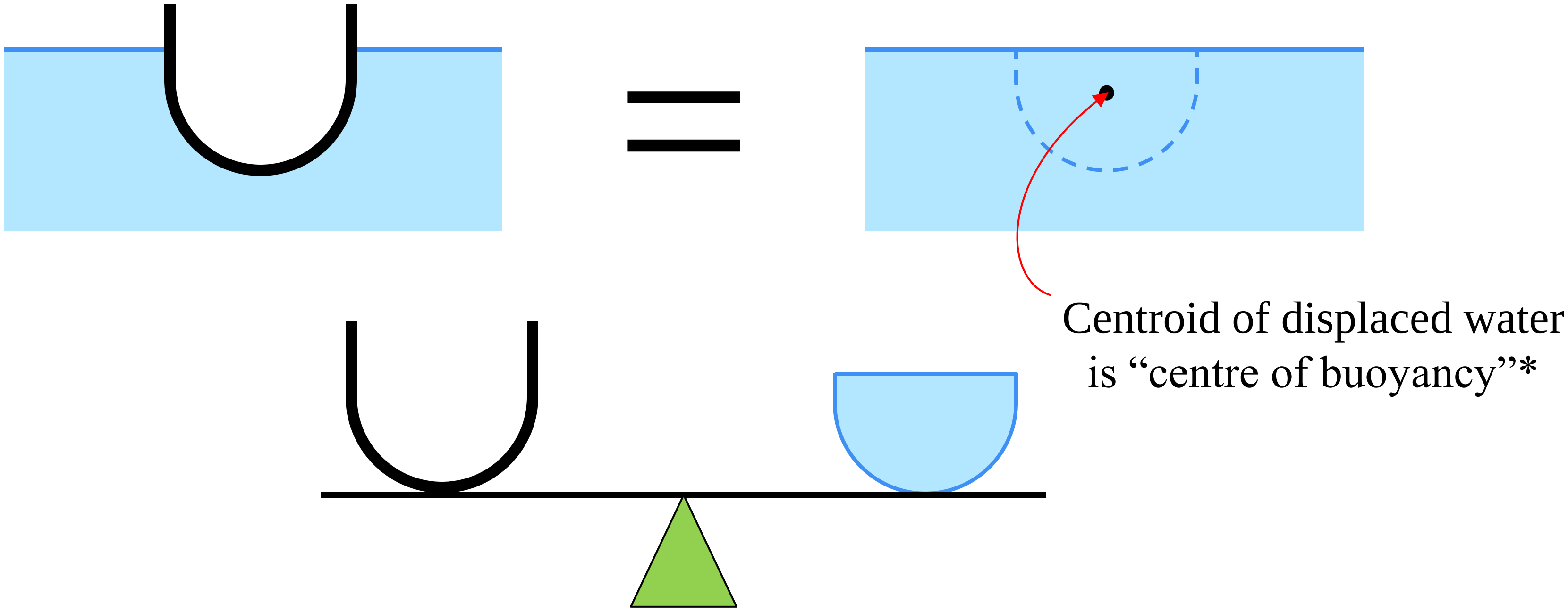
Hulls

- Hydrodynamic shapes
  - Provide volume to carry passengers and cargo
  - Push through the water cleanly
  - Provide pitch and roll stability
  - Provide buoyancy



Buoyancy

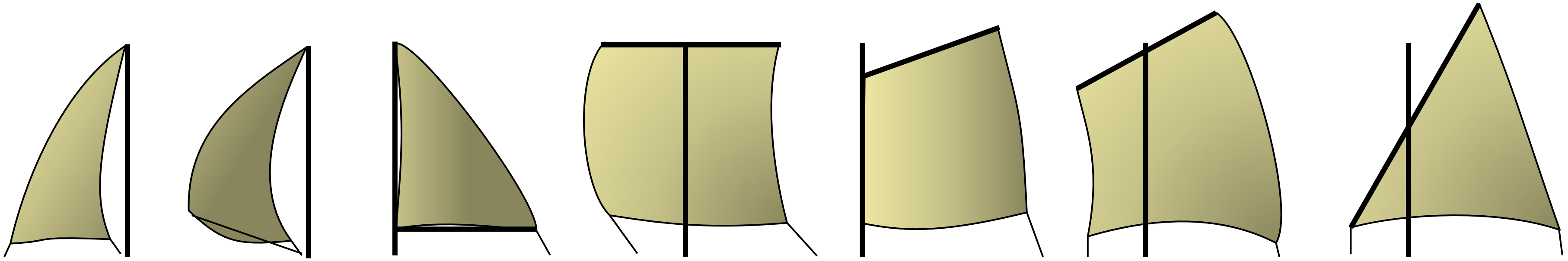
- Principle of displacement:
  - A body floats in the water at a depth that exactly displaces its mass in water



*see also 'metacentric height'

Sails

- A sail is fabric given shape by the wind that generates force from dynamic air pressure
- Sails come in many forms that each work slightly differently to produce propulsion

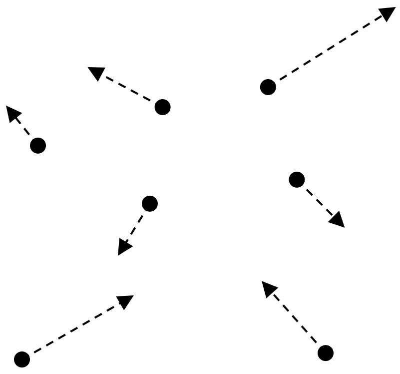


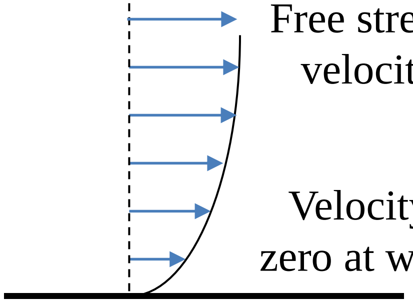
But first…

A quick detour into fluid mechanics

Some thoughts about fluids

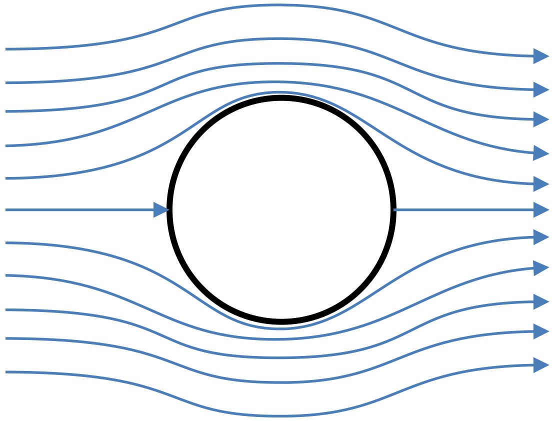
- Unsurprisingly, air and water are both fluids
  - Fluids are composed of many tiny particles
- Common false assumptions:
  - Fluids are incompressible
  - Fluids are inviscid
  - Fluids have negligible mass





Boundary conditions

- Consider a shape in an on-coming flow:
  - The flow adheres to the surface of the shape

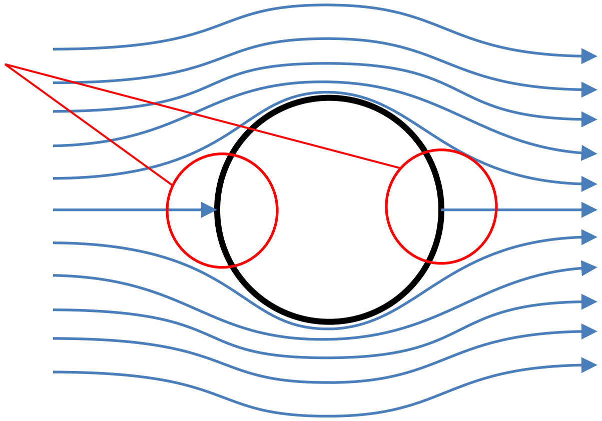


Blue lines are streamlines; locally tangent to velocity field

Boundary conditions

- Consider a shape in an on-coming flow:
  - The flow adheres to the surface of the shape

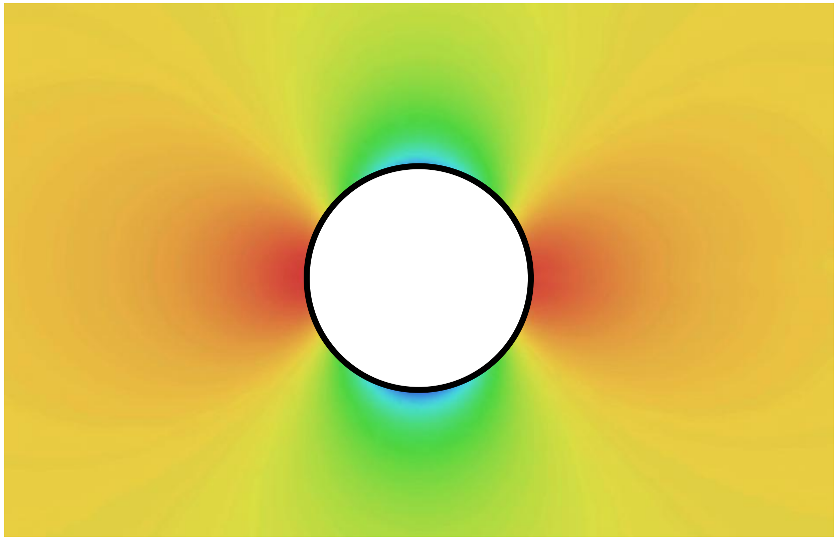
Stagnation points



Blue lines are streamlines; locally tangent to velocity field

Boundary conditions

- Pressure increases where flow 'bunches up', Decreases where flow 'spreads out'

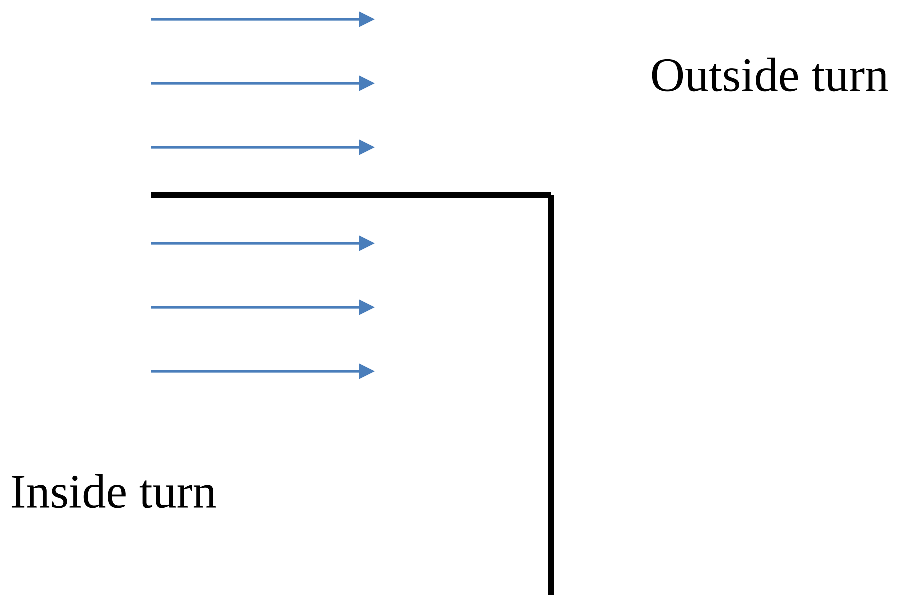


Colours represent pressure field

Red = high pressure, green = low pressure

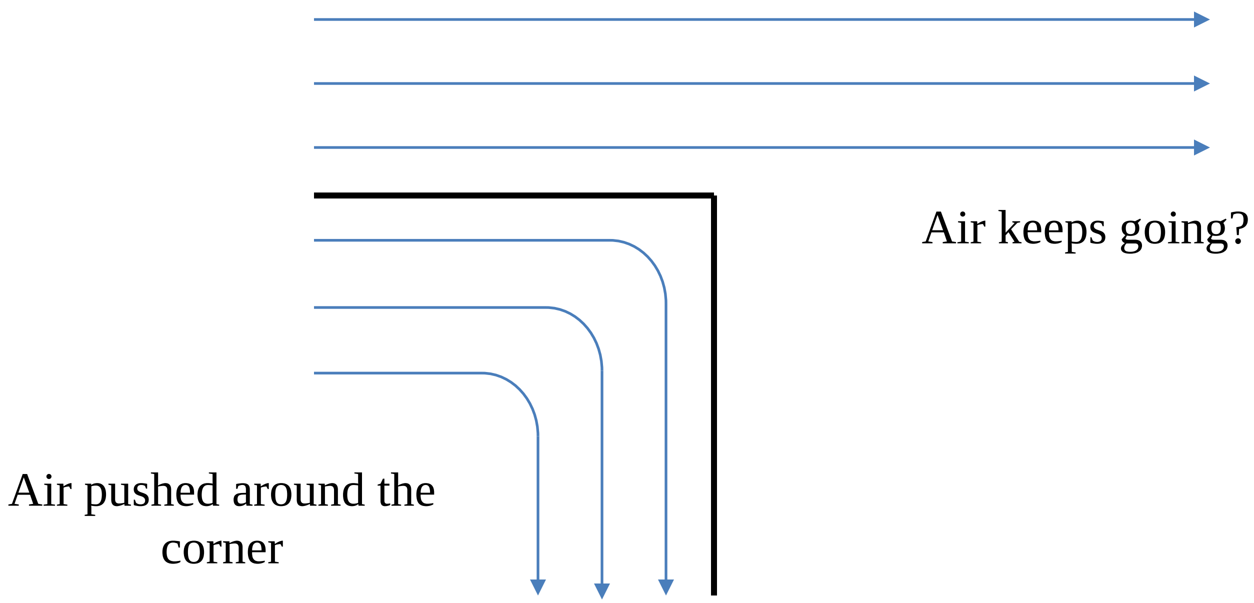
Some intuition

- Consider fluid encountering a corner



Some intuition

- The fluid must follow the surface contour, to satisfy the boundary condition



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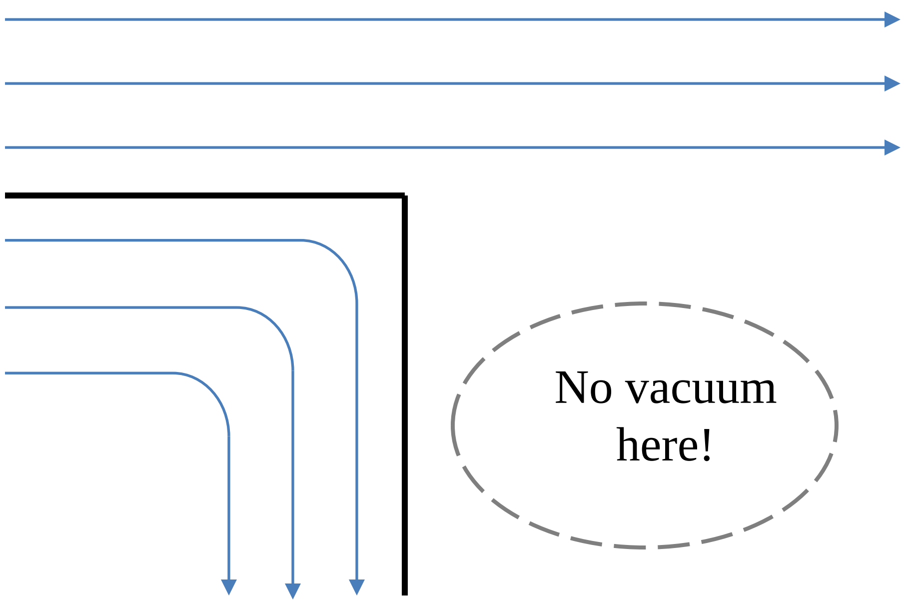
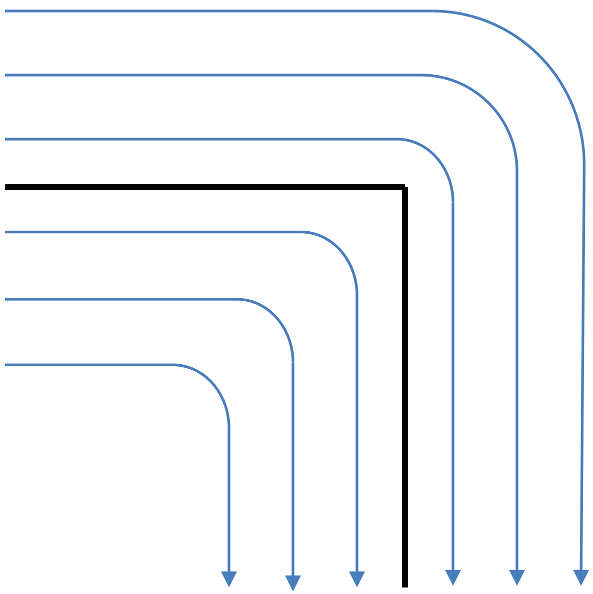


An intuitive idea

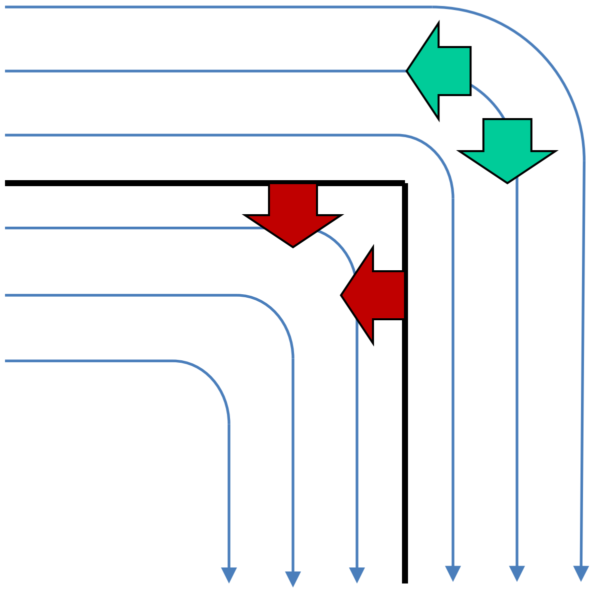
- The fluid must follow the surface contour, to satisfy the boundary condition



$\therefore$ at least some fluid must turn the corner

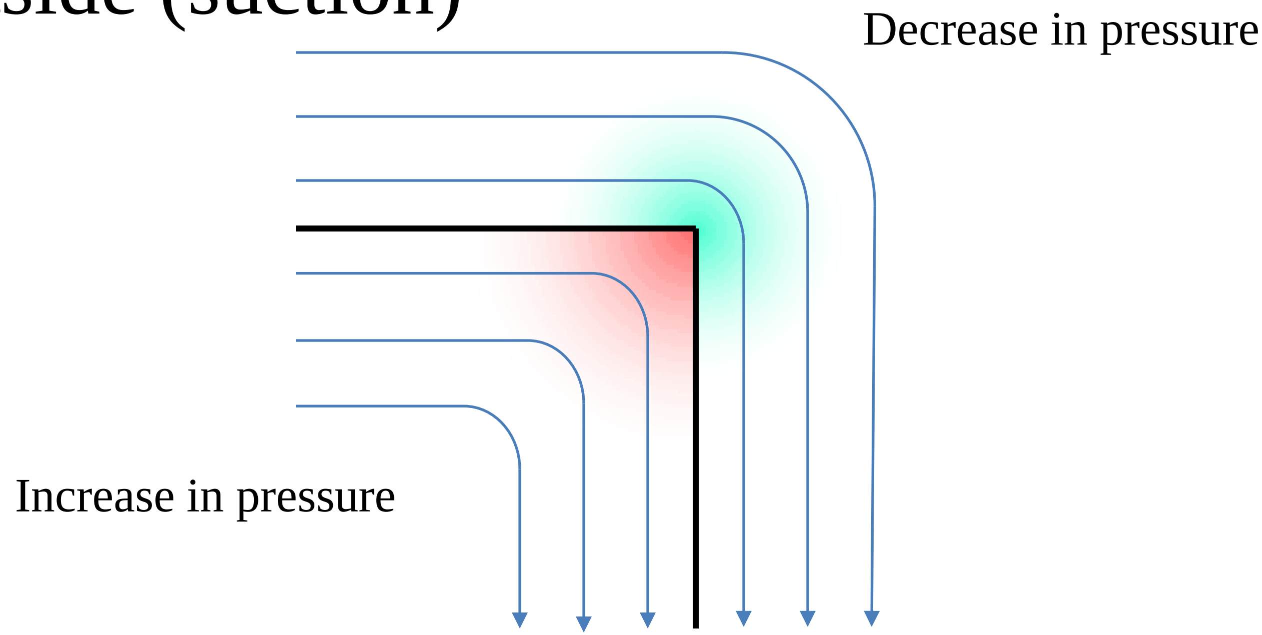
Some intuition

- Some force must act to decelerate the fluid horizontally and accelerate it vertically



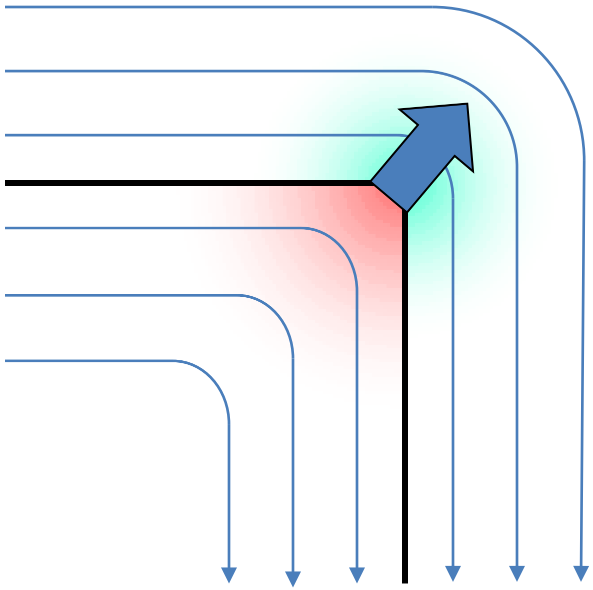
An intuitive idea

- This takes the form of increased pressure inside the corner and decreased pressure outside (suction)



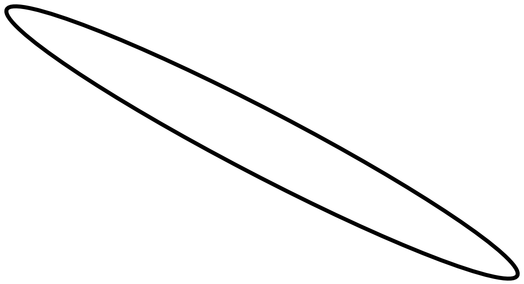
An intuitive idea

- A corresponding force acts on the corner
  - Ie. Newton's third law



Slightly more complicated

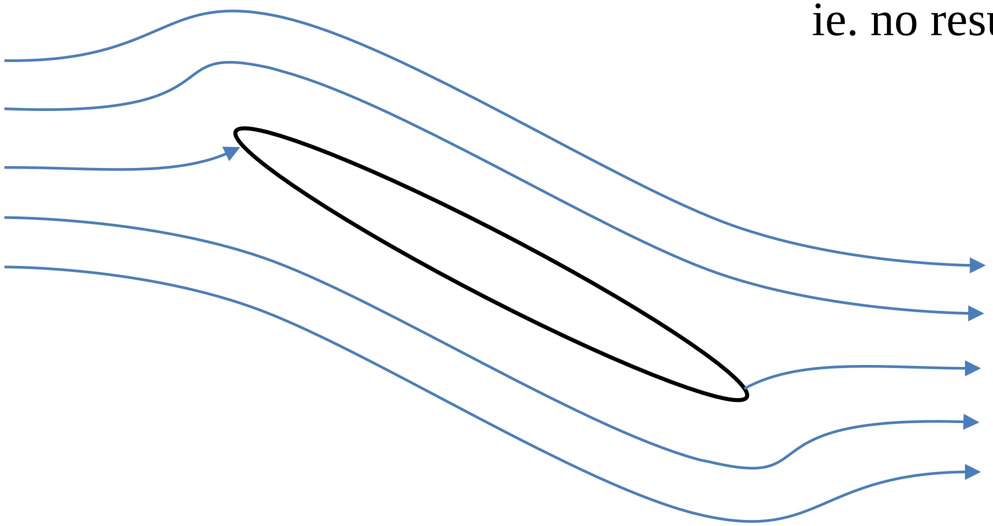
- Now consider a symmetric body in a flow



Slightly more complicated

- It would be reasonable to expect the flow pattern to be symmetric

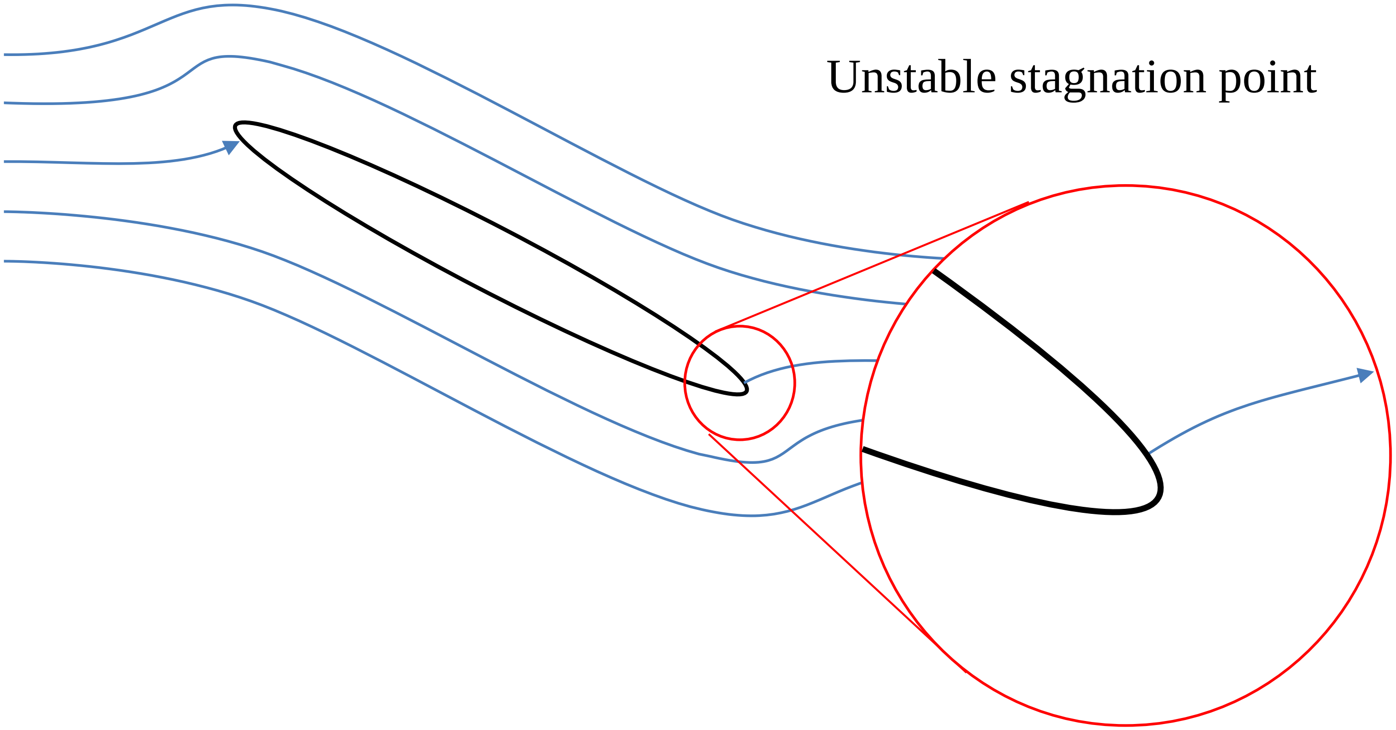
ie. no resultant force



This is true only in the (aphysical) inviscid flow case

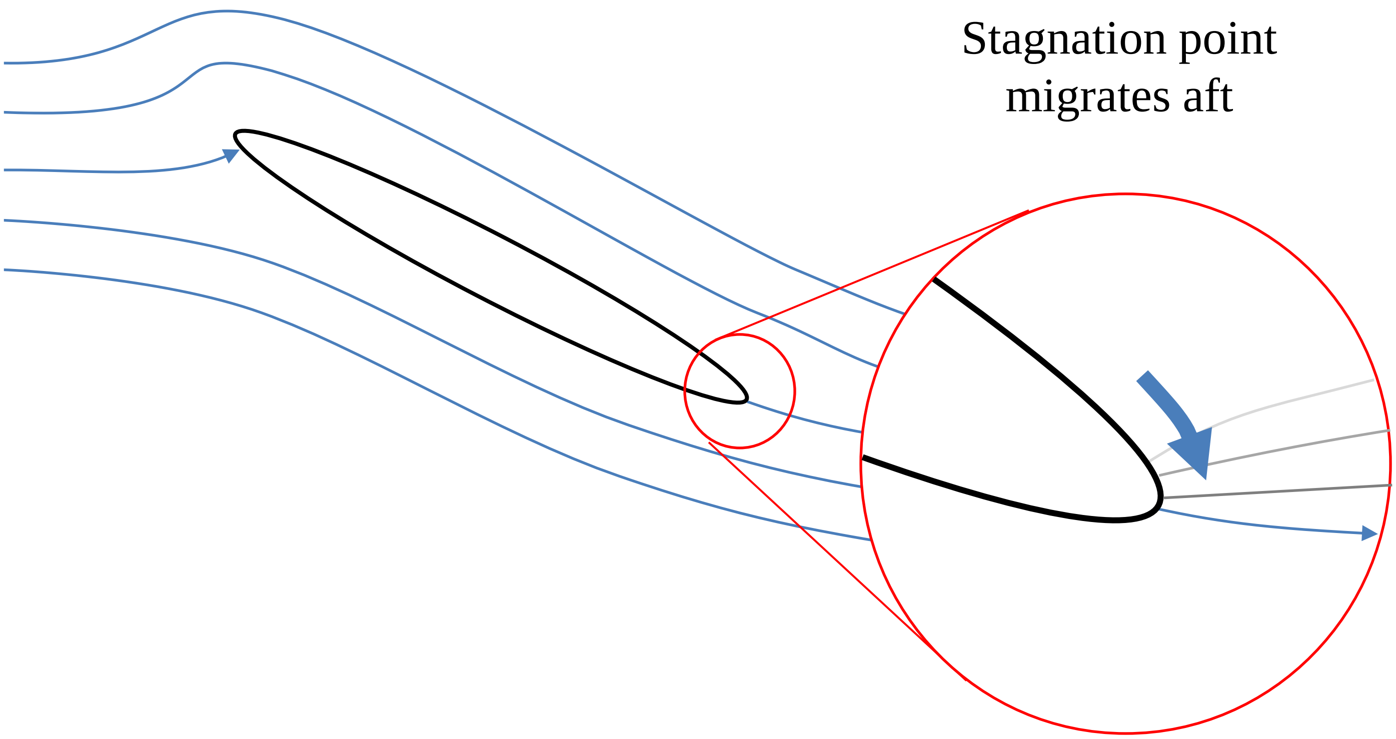
Slightly more complicated

- In reality, viscosity in the flow removes energy along the boundary layer



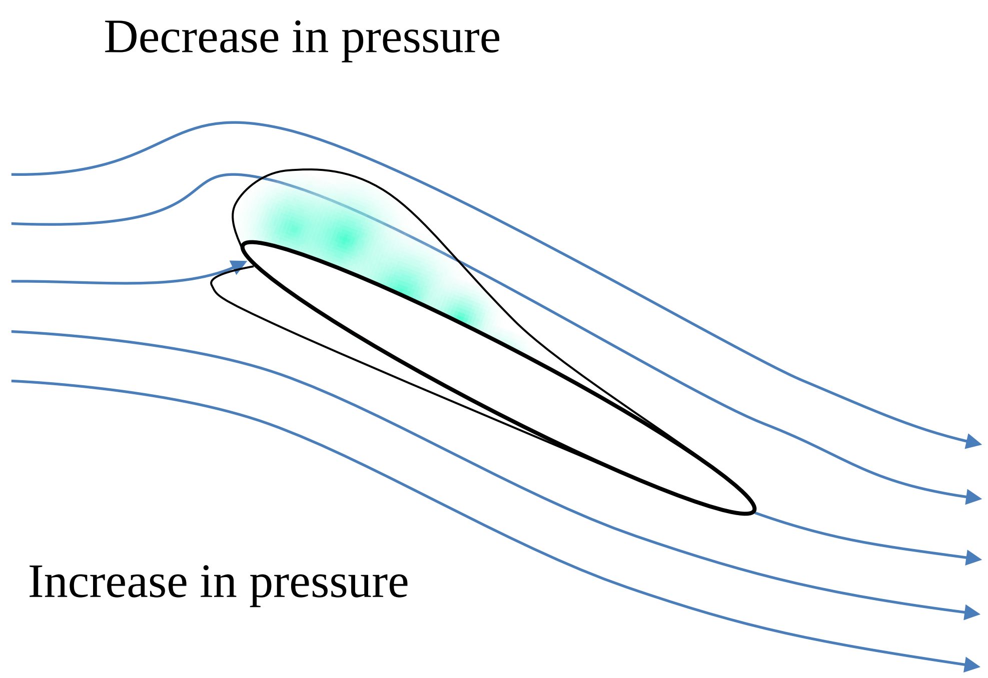
Slightly more complicated

- The rear stagnation point shifts to the trailing edge (the Kutta condition)



Slightly more complicated

- This is the basic idea behind wing lift



Slightly more complicated

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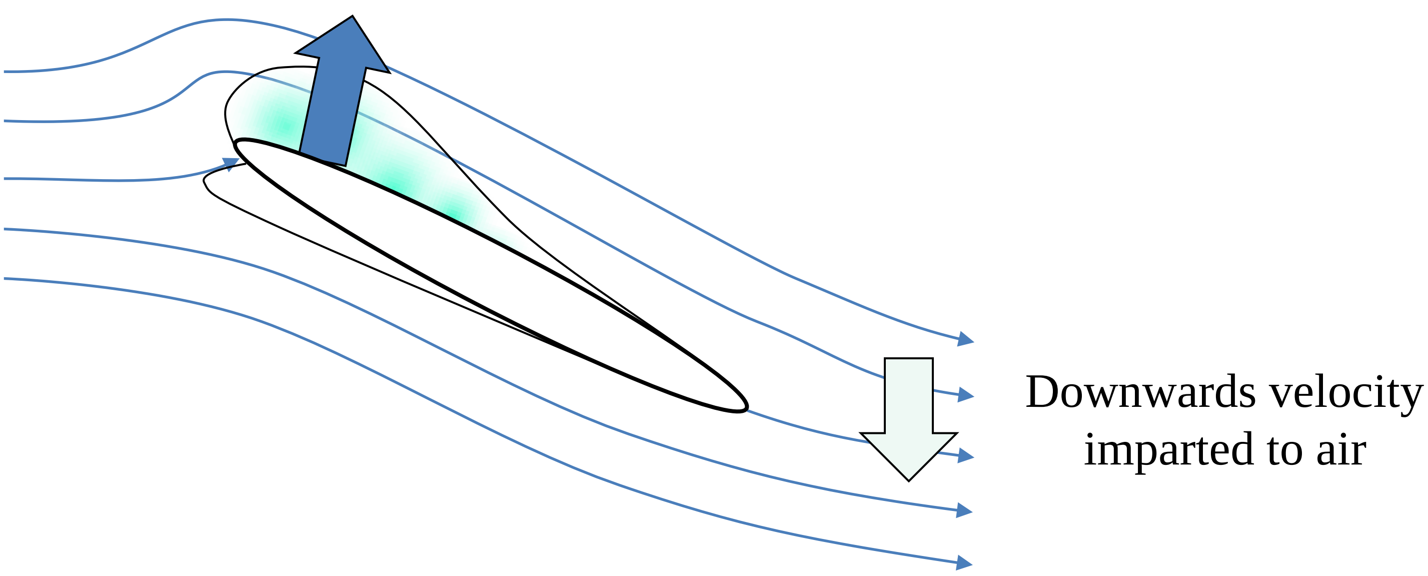


Note: You may also hear reference to "airfoil circulation", "vortex theory," "potential flows", and element or momentum methods. All are valid ways of describing the mechanics of wings

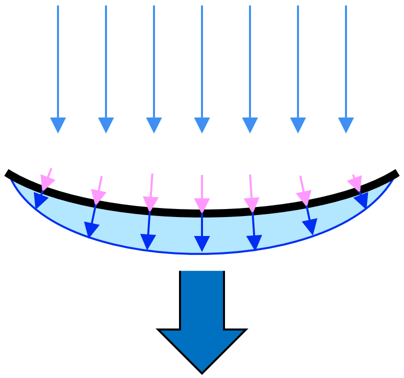
Right…

Back to sailing

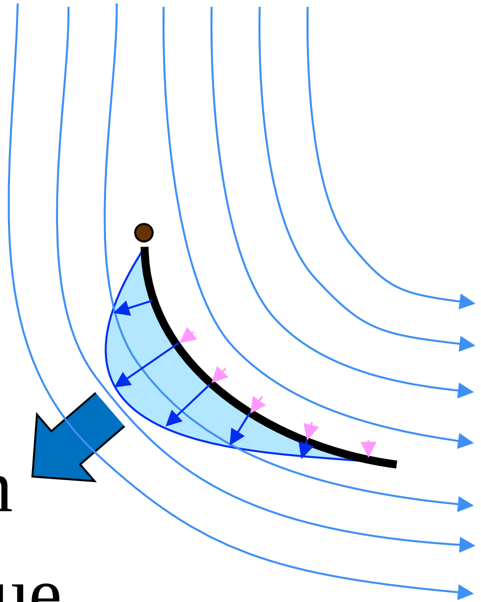
How sails work

Two main approaches:

- Parachute
  - Uses drag to drive downwind
  - Force proportional to sail area



- Wind-inflated ram-air parafoil
  - Curvature of air over the airfoil generates lift
  - Sail force acts some distance from the mast; resultant windward torque

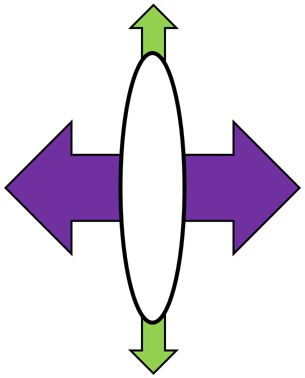


How hulls work

- Streamlined hulls create a preferential low-drag direction of travel
  - Can be thought of as an 'inclined plane' for changing direction of motion given force

Very low longitudinal drag force

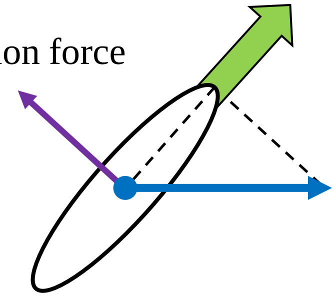
Very high lateral drag force



Resultant motion

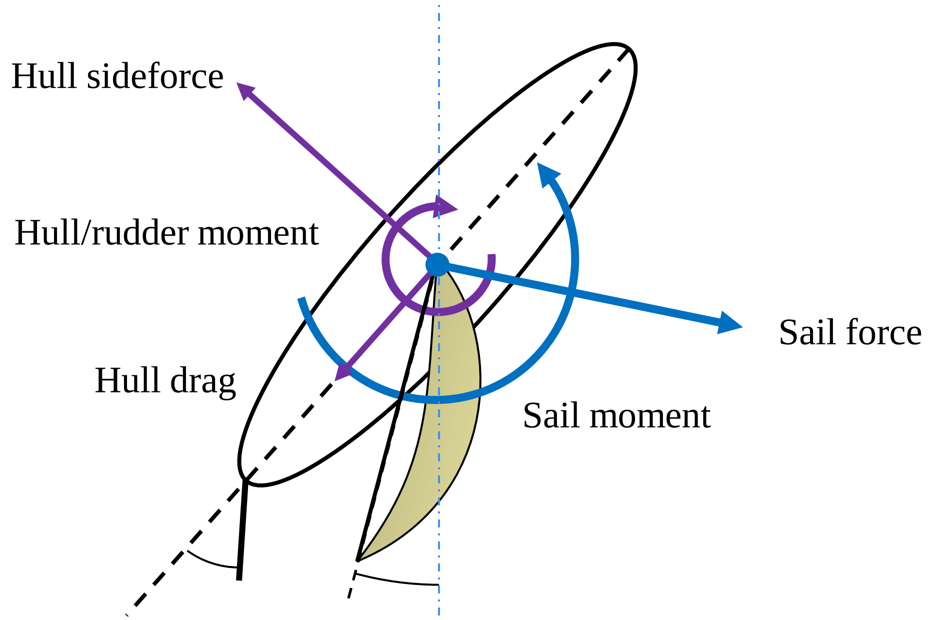
Hull reaction force

Applied sail force



Sailing trim

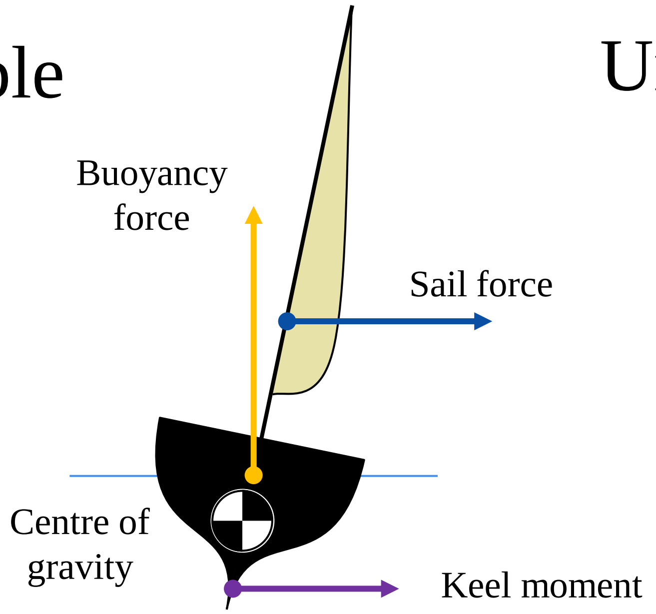
- When on course and forces/torques balance, the vessel is said to be "in trim"
  - Trim sail force by changing sail angle of attack
  - Trim rudder moment by turning the tiller



Lateral moment balance

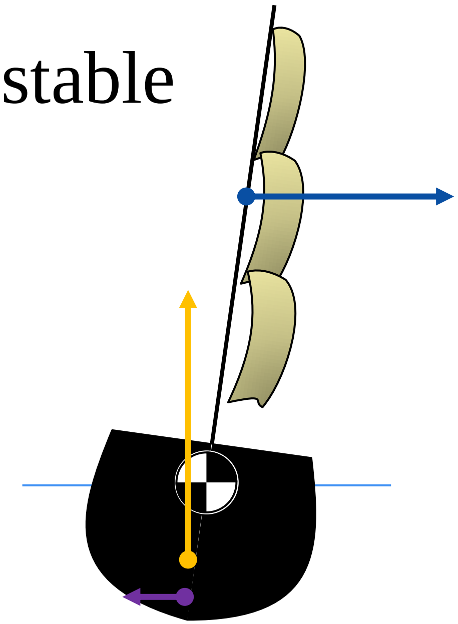
- Sail force is applied above the hull CoG
  - High sail forces can tip poorly designed vessels

Stable



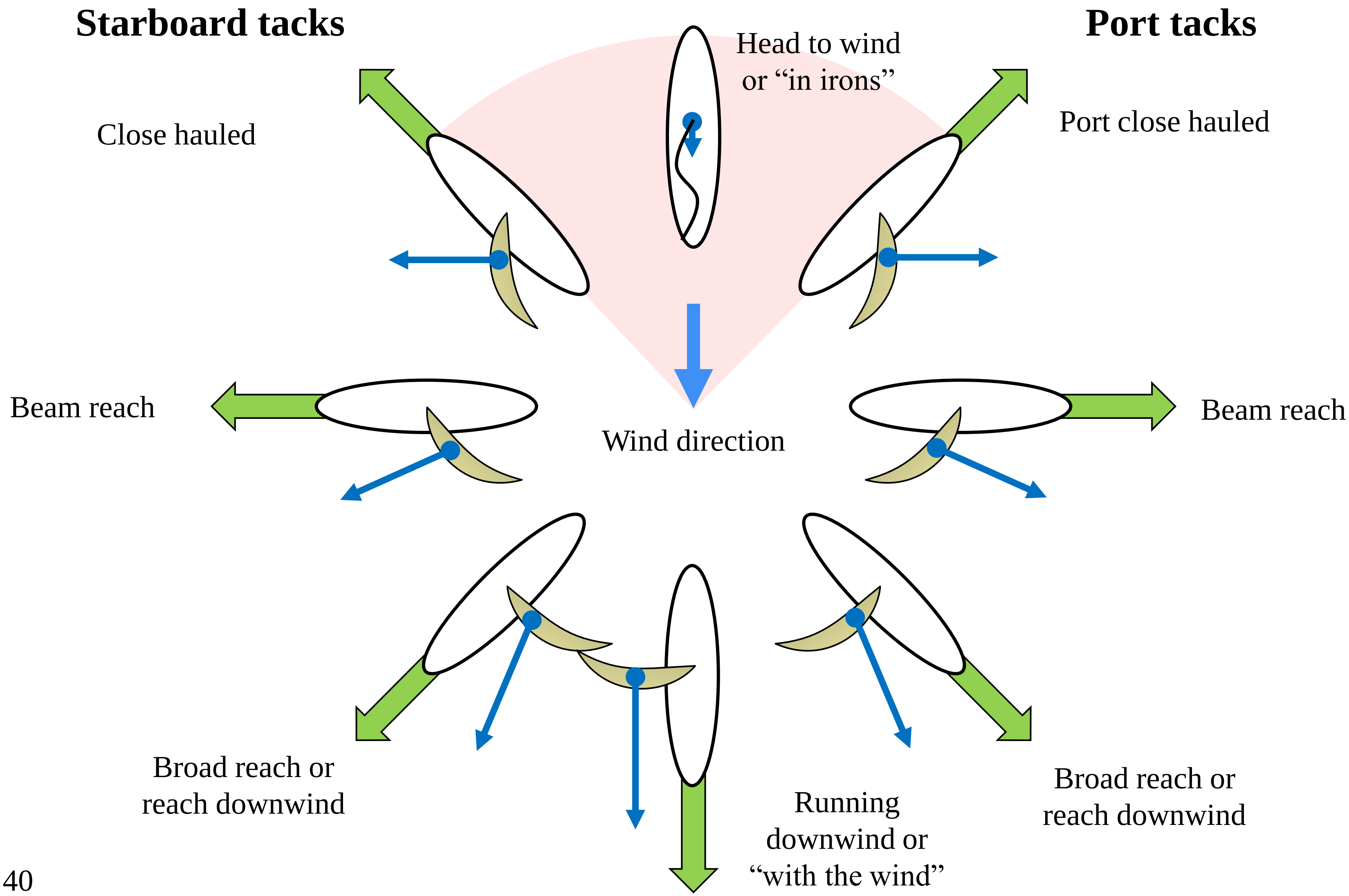
Low sail centre of pressure
Centre of buoyancy above CoG
Deep keel with fin or centreboard

Unstable



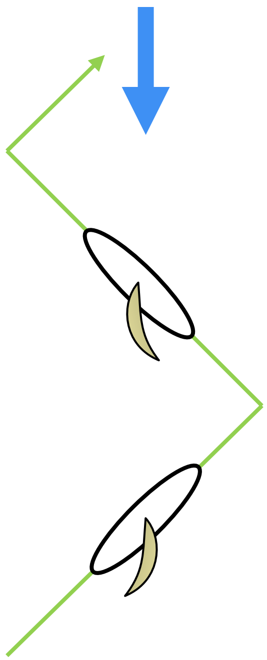
High sail centre of pressure
CoG above centre of buoyancy
Shallow keel, no centreboard

Points of sail



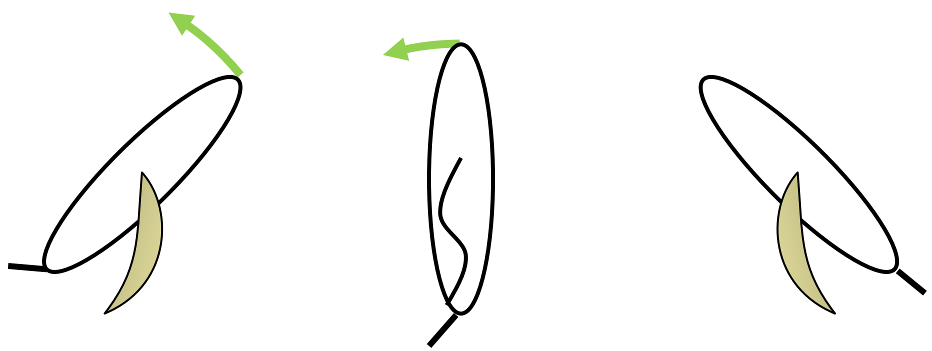
Beating

- Obviously a vessel cannot sail into the wind
  - Alternating port and starboard close hauled tacks allows cumulative upwind travel



Beating

Tacking or “Coming about”



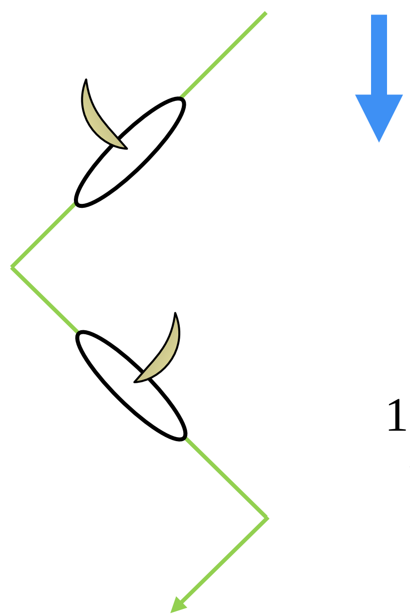
1. Initiate turn with rudder

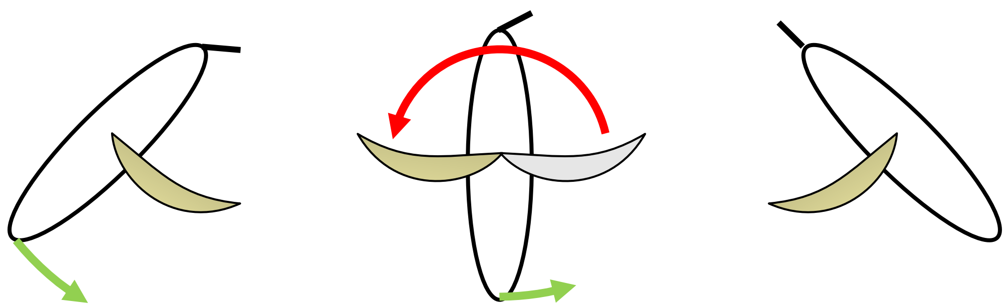
2. Momentum carries through turn into the wind (sail goes slack)

3. Straighten up on new tack

Gybing

- Gybing (or “jibing”) is changing tack from port to starboard (or vice versa) downwind
  - This can be a dangerous manoeuver if performed without planning and preparation!





1. Initiate turn with rudder

2. Boom swings across rapidly – everyone ducks!

3. Straighten up on new tack

Useful equations

- The lift, drag and pitching moment of an convex body in laminar flow is given by:

–

–

–

where , and are non-dimensionalised lift, drag and moment coefficients dependent on body geometry*, and is the density of air, is the wing area, and is wind velocity

*Data for airfoils can be found published online or found by experiment or CFD

Questions?

Abaft the beam
Abeam
Aground
Alee
Aloft
Amidships
Archboard
Astarboard
Athwartships
Avast
Aweigh
Backstays
Baggywrinkle
Bailer
Ballast
Barbette
Barca-longa
Barkentine
Barrelman
Batten
Beaching
Beam
Becalm
Belay
Belaying pin
Berth
Bilander
Bilge
Bimini top
Bimmy
Bitts

Bitter end
Block
Blue Peter
Boatswain
Bobstay
Bollard
Bonnet
Boom
Boom gallows
Boom vang
Boomkin
Bosun
Bottlescrew
Bottomry
Bow
Bower
Bowse
Bowsprit
Brace abox
Brail
Brass monkey
Breakwater
Bridge
Brig
Brigantine
Brightwork
Broach
Broadside
Brow
Buffer
Bulkhead

Bumboat
Bunting tosser
Buntline
Buoy
Burgee
Caboose
Capsize
Capstan
Caravel
Careen
Carrack
Carvel
Cat
Catamaran
Cathead
Catpaws
Centreboard
Chafing
Chine
Chock
Cleat
Clew
Clinkerbuilt
Coaming
Cockpit
Collier
Companionway
Conn
Convoy
Counterflood
Cowl

Coxswain
Crance
Crosstrees
Cuddy
Cunningham
Cunt splice
Cutter
Daggarboard
Davit
Davy Jones' Locker
Dayblink
Deadeye
Deadrise
Decks
Derrick
Devil seam
Dhow
Dinghy
Displacement
Disrate
Dodger
Dogwatch
Dory
Dreadnought
Drifter
Drogue
Dunnage
Embayed
Ensign
Eyesplice
Fairlead

Falkusa
Fantail
Fardage
Fathom
Felucca
Fid
Fife rail
Flank
Flotsam
Footloose
Forecastle
Forestays
Founder
Freeboard
Funnel
Furl
Futtocks
Gaff
Galleass
Galleon
Gam
Gangway
Garbling
Gash
Gennaker
Genoa
Gig
Gooseneck
Grapeshot
Graving dock
Gripe

Growler
Gunwale
Gybe
Halyard
Harbour
Hardtack
Hawsepiper
Head
Heave
Helm
Hitch
Holystone
Hulk
Inglefield clip
Ironclad
Jacklines
Jib
Jibboom
Jetty
Jetsam
Jigger-mast
Joggle
Kedge
Keel
Keelhaul
Ketch
Knighthead
Knot
Lagan
Lanyard
Lanboard

Lanteen
Launch
Lay
Lazaret
League
Leeboard
Leeward
Line astern
List
Lofting
Loggerhead
Lubber's hole
Luffing
Lumberhooker
Lugsail
Mae West
Mainsheet
Marconi rig
Marlinspike
Masthead
Matelot
Mess
Midships
Mizzenmast
Mole
Monkey's fist
Moor
Nipper
Nun
Oakum
Offing

Oilskines
Orlop deck
Outhaul
Overbear
Overhaul
Panting
Parley
Parbuckle
Parrel
Pinnace
Pintle
Pitchpole
Pontoon
Poop deck
Pooped
Port
Porthole
Press gang
Privateer
Prow
Puddening
Purser
Quarterdeck
Quayside
Rabbet
Ram
Ratlines
Razee
Reaching
Reduced cat
Reef-points

Reeve
Rigging
Rigol
Rip rap
Rode
Romper
Rowlock
Rummage sale
Sagging
Sampan
Scantlings
Schooner
Scow
Scud
Sudding
Scull
Scuppers
Seaboots
Seacock
Sextant
Shanghaied
Sheer
Sheet
Shift tides
Shoal
Short stay
Shrouds
Sidewheel
Skiff
Skipper
Skyscraper

Sloop
Slop chest
Slush
Smack
Sounding
Spanker-mast
Spinnaker
Spotting top
Splice
Spreader
Squat effect
Stanchion
Starboard
Staysail
Steerage
Steeve
Stern
Stopper knot
Strake
Studding-sails
Swigging
Tack
Tacking
Taffrail
Tailshaft
Thole
Thwart
Timoneer
Tingle
Tiller
Tompion

Topgallant
Trailboard
Tamp trade
Transom
Trice
Trim
Trimaran
Tumblehome
Turnbuckle
Turtling
Tye
Underway
Unship
Upbound
Vang
Wake
Waft
Wash
Waterline
Weatherly
Weigh anchor
Whelkie
Wherry
Whiskerstays
Whipstaff
Windage
Worm
Yacht
Yardarm
Yarr
Yawl

Tune-in next time for…

Sensor Fusion and Filtering

or

“Making sensors make sense”

Fun fact: The poop deck is not what you think it is.