

What Makes it Stay Up?

Principles of Flight

Physical Laws

- Make flight possible
- Make flight more difficult
- Are both predictable and changeable

The Nature of Air

Aircraft “Swim” in Air

- Air is a fluid
- The science of aerodynamics grew out of the already well-developed field of hydrodynamics
- The word “propeller” is borrowed directly from marine engineering
- Early aerodynamics relied heavily on well-understood principles concerning the physics of water – some translate well, some not so much....

Characteristics of Fluids

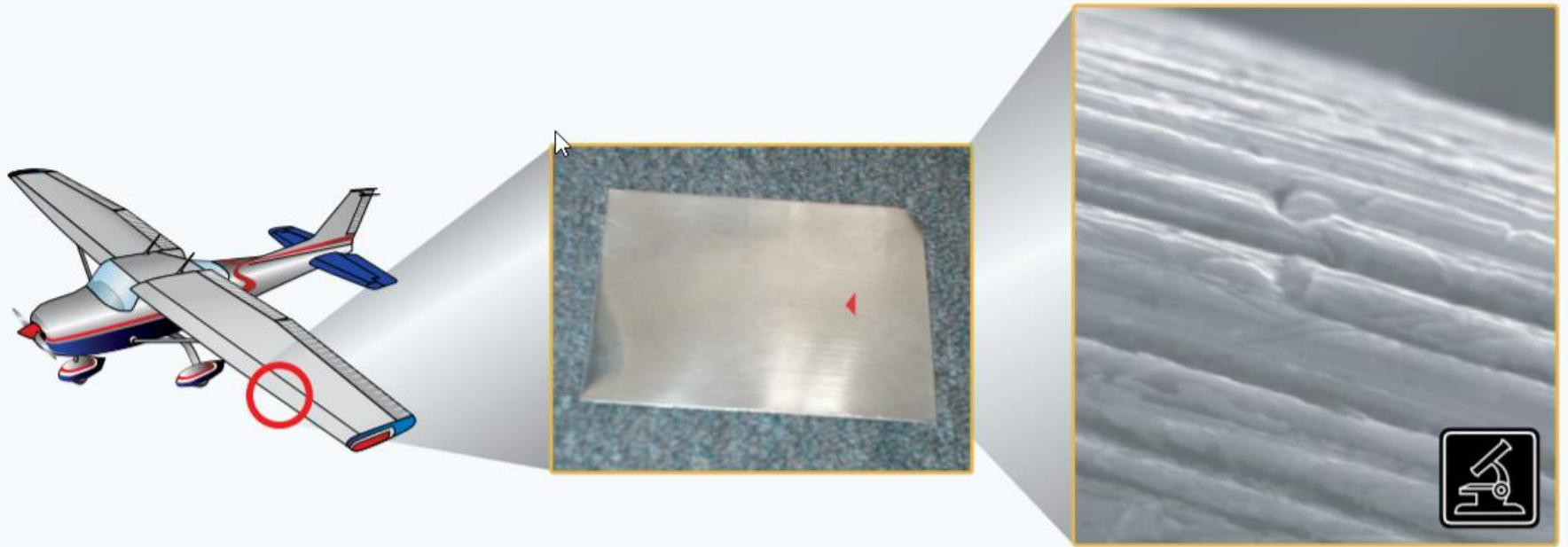
- They take on the shape of their containers
- If they resist “deformation” it is only slightly
- The resistance of a fluid to deformation is called “viscosity”
- Fluids flow
- The difference between water and air is that air is less dense. But air **does have** density, and that density changes. Changes in air density affect all aspects of flight

Viscosity

- Is the property of a fluid that causes it to resist flowing
- Oil is highly viscous, water less so. Air is less viscous still
- Viscosity is caused by the fluid's constituent molecules 'sticking' to each other

Friction

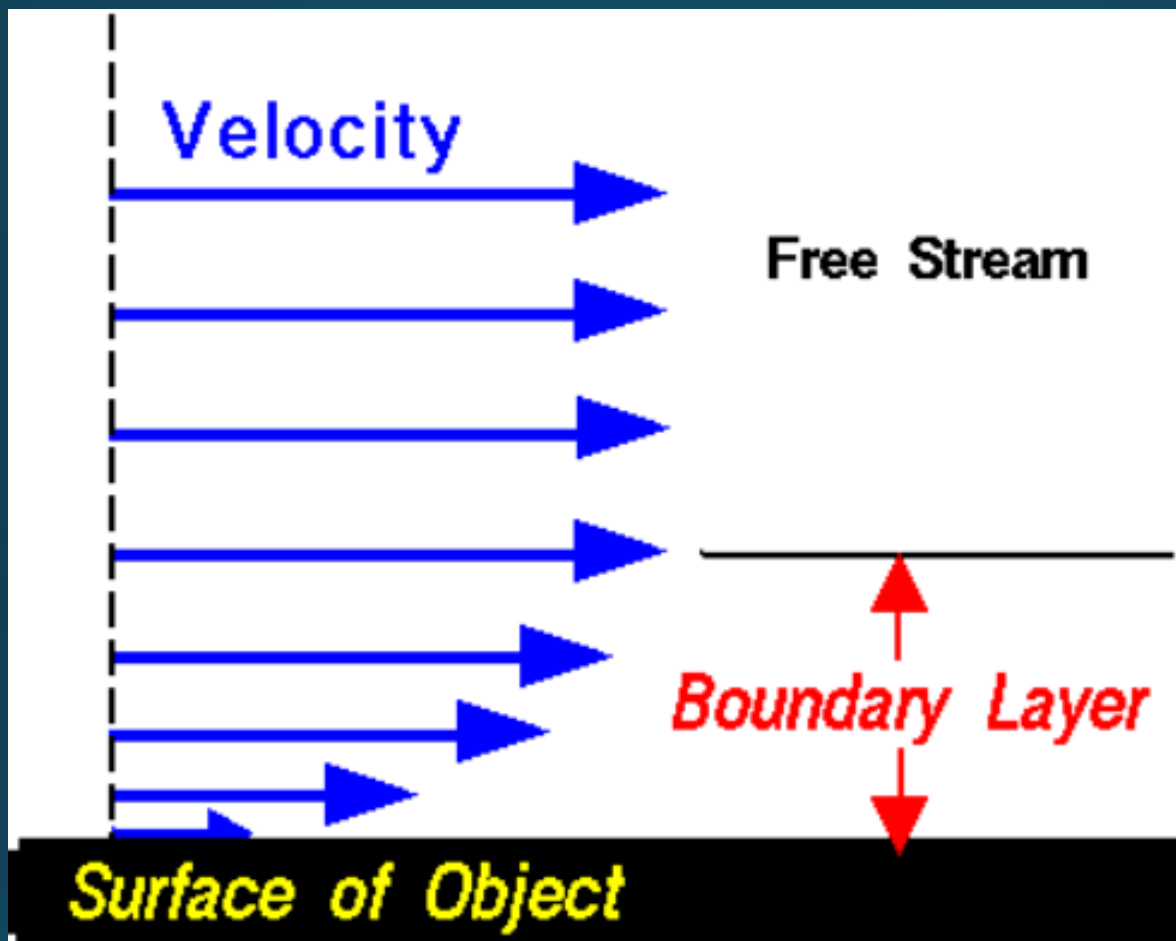
- Viscosity is the tendency of a fluid to stick to itself. Friction, on the other hand, is the tendency of a fluid to 'stick' to another surface
- When an aircraft moves through the air, all its surfaces create friction with the air



Leading edge of wing under 1,500x magnification

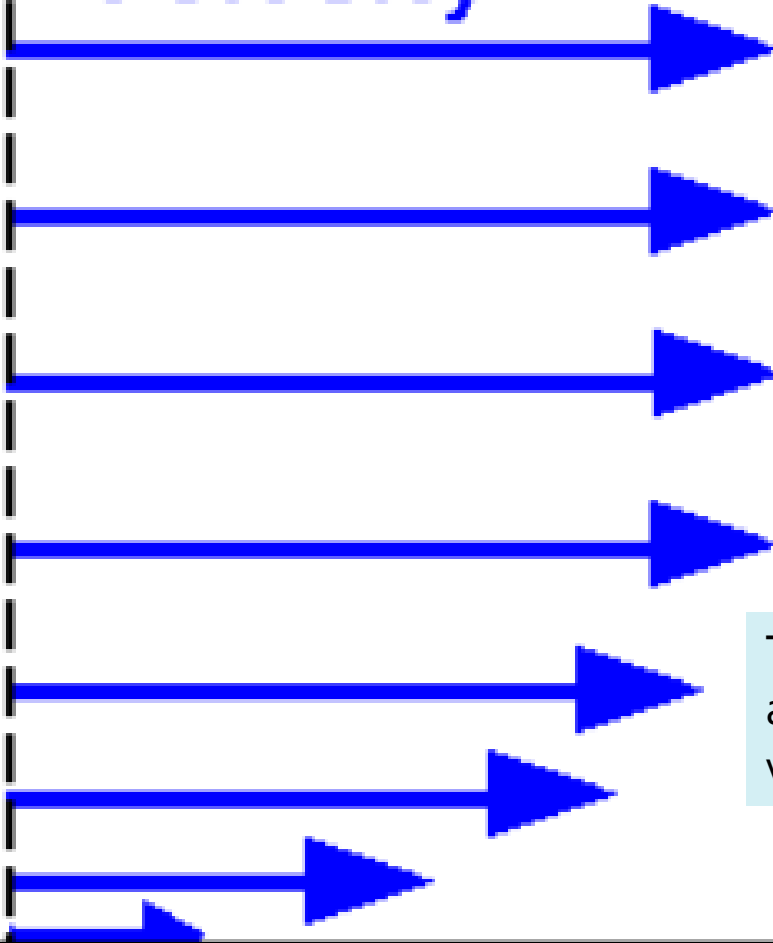
Even a surface that looks and feels completely smooth has rough texture at a microscopic level

Aircraft designers attempt to create aerodynamically efficient shapes that reduce friction, but it can never be completely eliminated



- Molecules of air close to the wing surface adhere and move very slowly
- This is called the boundary layer

Velocity



Free Stream

The layers of air above that are slowed because of viscosity

ayer

Surface of Object

The molecules of air in contact with the wing surface are almost motionless due to friction

Structure of the Atmosphere

Atmospheric Gases

- ❖ Nitrogen : 78%
- ❖ Oxygen: 21%
- ❖ Trace gases (mainly argon and carbon dioxide): 1%

These fractions refer to dry air and are more or less constant across the surface of the earth and regardless of altitude.



Atmospheric Pressure

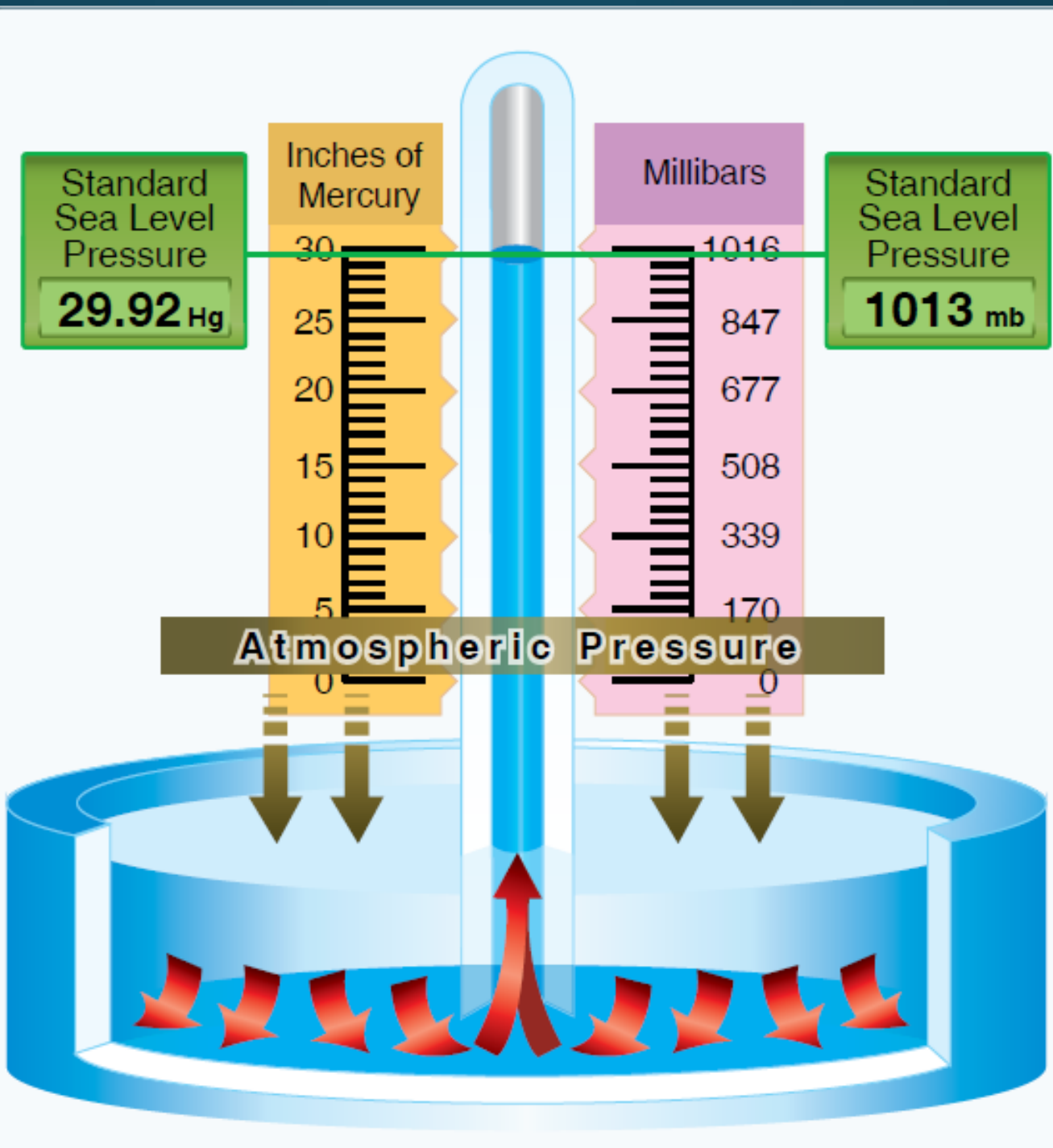
- Air is light, but not weightless. It possesses mass in proportion to the number of molecules of its constituent elements
- The weight of the column of air above a spot on the earth is **air pressure**

Why Do Pilots Care about Air Pressure?

- Air pressure affects how airplanes behave
- Air pressure affects how we measure altitude

Pressure and Altitude

- Altitude, in concept, is vertical distance above some point or level used as a reference
- In aviation, the measurement of altitude(s) is intimately connected with the prevailing atmospheric pressure, and its relation to 'standard' pressure



Standard Sea Level Pressure
29.92 Hg

Inches of Mercury
30
25
20
15
10
5
0

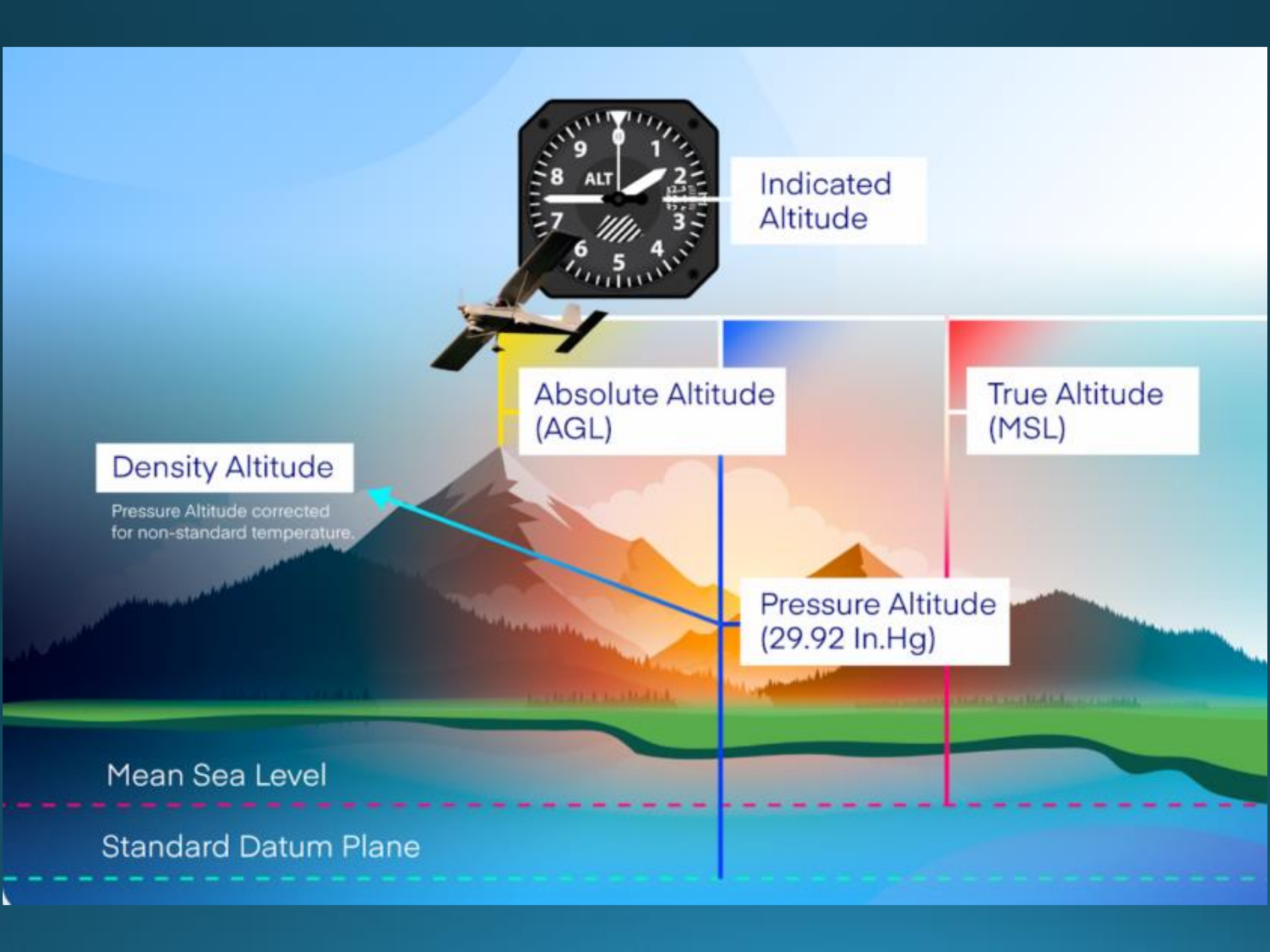
Millibars
1016
847
677
508
339
170
0

Standard Sea Level Pressure
1013 mb

Atmospheric Pressure

Aviation Altitudes

- TRUE altitude: the vertical distance above mean sea level
- PRESSURE altitude: the altitude you would have to be at for pressure to be standard
- INDICATED altitude: the altitude reported on the altimeter when it is correctly adjusted for standard conditions (air pressure and temperature)
- DENSITY altitude: PRESSURE altitude corrected for non-standard temperature



Indicated
Altitude

Absolute Altitude
(AGL)

True Altitude
(MSL)

Density Altitude

Pressure Altitude corrected for non-standard temperature.

Pressure Altitude
(29.92 In.Hg)

Mean Sea Level

Standard Datum Plane

True Altitude

- This is the altitude you are really interested in as a pilot – measurements like field elevation, the height of obstacles, and the vertical dimensions of controlled airspace are all defined with respect to mean sea level
- But traditional aviation altimeters have no way to measure true altitude; they must estimate by measuring the weight of ambient air

Pressure Altitude

- Pressure altitude is the vertical distance a pressure sensing device – such as an altimeter – would believe you to be if conditions were “standard”
 - atmospheric pressure = 29.92” Hg
 - Temperature 59 ° F or 15 ° C
- You can obtain pressure altitude from an altimeter by adjusting its pressure window to 29.92” Hg and reading the resulting altitude

Density Altitude

- Pressure altitude refers to standard conditions, which are both air pressure (29.92" Hg) AND temperature (59°F) at sea level
- Both temperature and pressure decrease as elevation above sea level increases. The standard "lapse rate" is 1 inch of mercury per 1000 feet and 2°C/3.5°F per 1000 feet

Standard Atmosphere

Altitude (ft)	Pressure (Hg)	Temperature	
		(°C)	(°F)
0	29.92	15.0	59.0
1,000	28.86	13.0	55.4
2,000	27.82	11.0	51.9
3,000	26.82	9.1	48.3
4,000	25.84	7.1	44.7
5,000	24.89	5.1	41.2
6,000	23.98	3.1	37.6
7,000	23.09	1.1	34.0
8,000	22.22	-0.9	30.5
9,000	21.38	-2.8	26.9
10,000	20.57	-4.8	23.3
11,000	19.79	-6.8	19.8
12,000	19.02	-8.8	16.2
13,000	18.29	-10.8	12.6
14,000	17.57	-12.7	9.1
15,000	16.88	-14.7	5.5
16,000	16.21	-16.7	1.9
17,000	15.56	-18.7	-1.6
18,000	14.94	-20.7	-5.2
19,000	14.33	-22.6	-8.8
20,000	13.74	-24.6	-12.3

Density Altitude

- Density altitude is pressure altitude *corrected* for non-standard temperature
- It is not directly observable in the way pressure altitude can be observed
- It is calculated measure and is typically either read from a chart or calculated using a standard E6B
- It is often included as additional information on AWOS/METAR reports

How Does a Wing Fly?

Lift

- The force that overcomes gravity and allows an aircraft to fly is lift
- In a heavier-than-air craft, lift must be produced by manipulating the laws of the physics of motion
- Contrary to popular opinion, aircraft do not fly because you open the window and throw money out as fast as you can

Newton vs. Bernoulli ?



Newton's laws of motion in physics

LAW #1

A body at rest will remain at rest, and a body in motion will remain in motion unless it is acted upon by an external force.

LAW #2

The force acting on an object is equal to the mass of that object times its acceleration, $F = ma$.

LAW #3

For every action, there is an equal and opposite reaction.

Newton's laws of motion in physics

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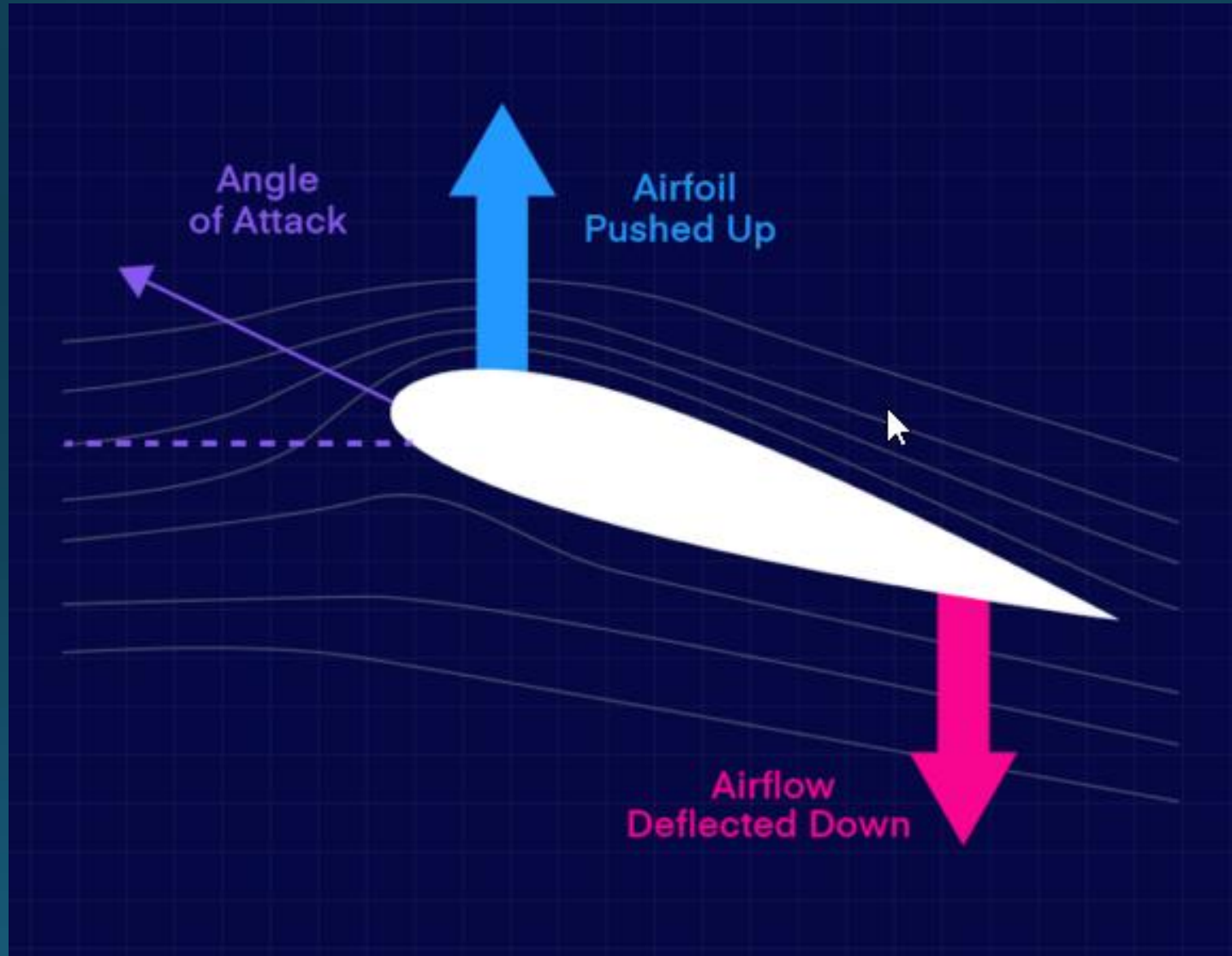
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LAW #3

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Newtonian Lift: Pushing Back



Bernoulli: Differential Pressure

- Bernoulli's insight was that air pressure varies with the velocity with which the air is moving: slower air is denser than faster air

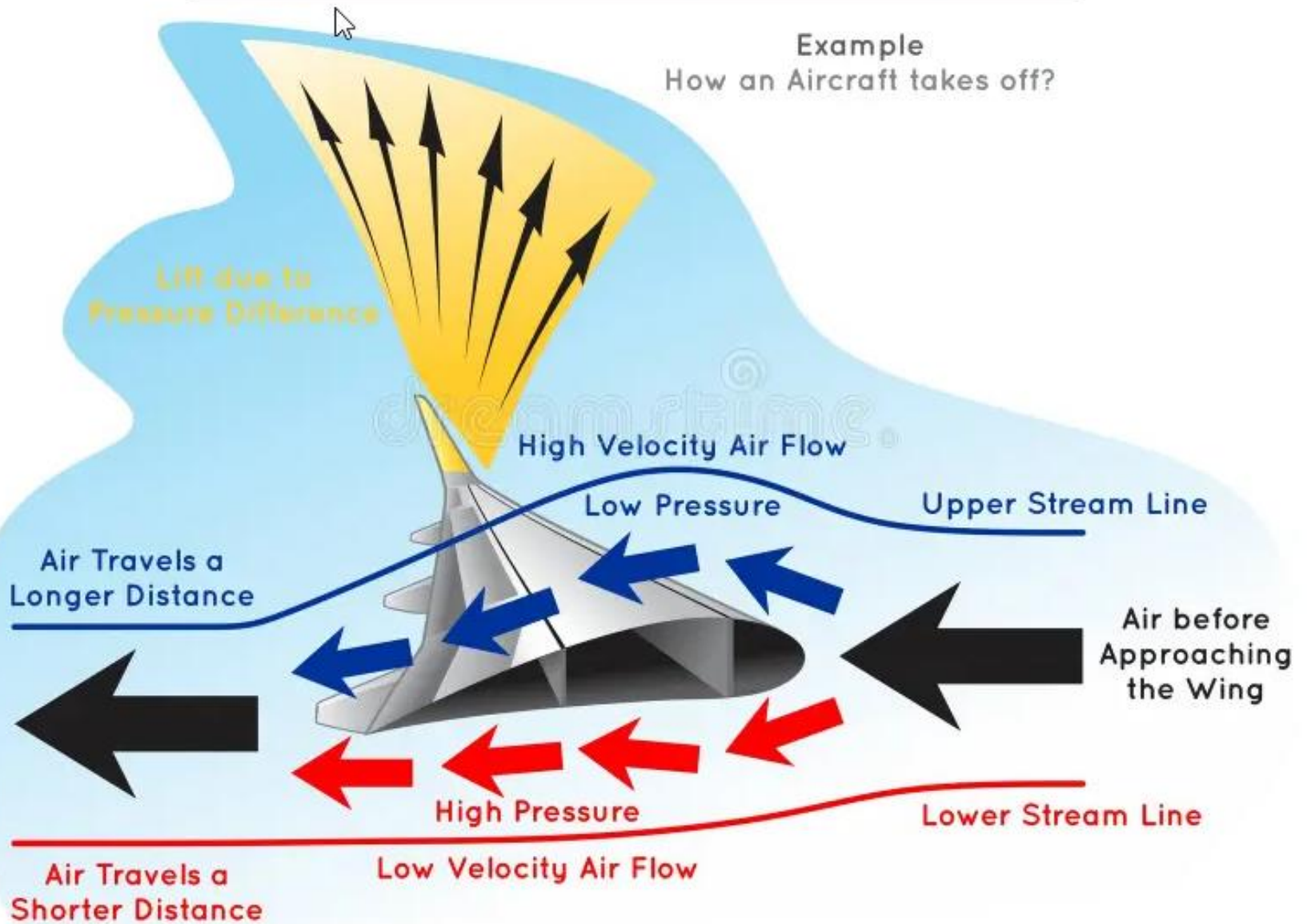
Bernoulli: Differential Pressure

- Faster air = lower pressure
- Airfoil shapes are constructed so that the air moving over the top of the wing is going faster.
- Lower pressure = lift

Bernoulli's Principle

The higher the flow velocity, the lower the pressure

Example
How an Aircraft takes off?





Newton AND Bernoulli



Both effects are at work when a wing develops lift, and the physics is extremely complex.

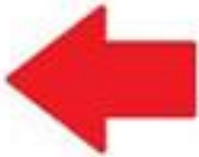
The FAA test question bank tends to emphasize Bernoulli, and understanding the concept of differential pressure will enable you to answer these questions correctly.

The Four Forces of Flight

DREAMS



FAA



MONEY



REALITY



