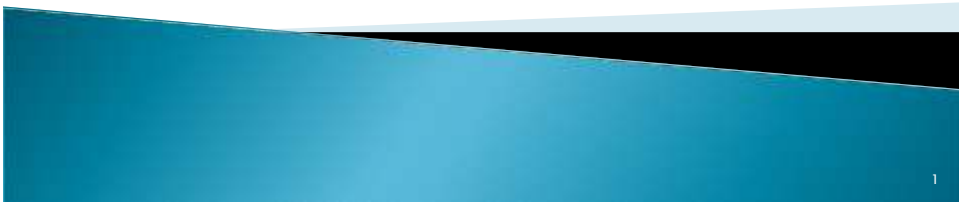


Chapter 10: Fluids

AP Physics B



Rank the densities



Rank the densities

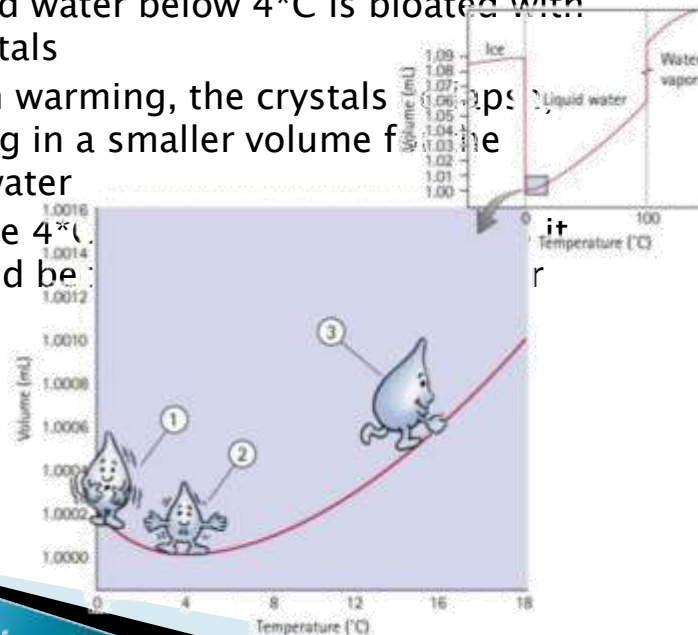
Substance	ρ (kg/m ³)
Hydrogen	0.0899
Helium	0.179
Steam (100°C)	0.598
Air	1.29
Oxygen	1.43
Carbon dioxide	1.98
Ethanol	0.806×10^3
Ice	0.917×10^3
Fresh water (4°C)	1.00×10^3
Sea water (15°C)	1.025×10^3
Iron	7.86×10^3
Mercury	13.6×10^3
Gold	19.3×10^3

*All densities are measured at 0°C and 1 atm unless otherwise noted.

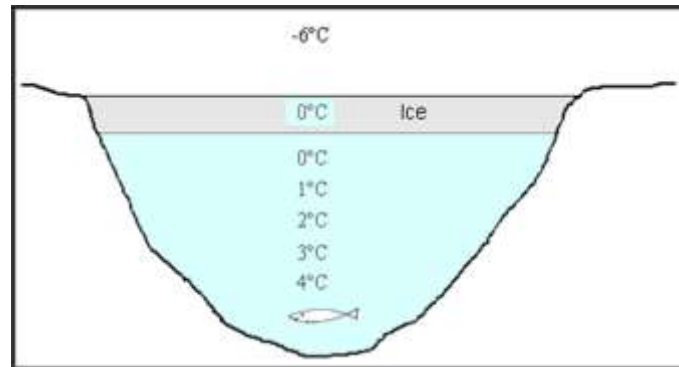
3

6.7 Expansion of Water

- ▶ 1) Liquid water below 4°C is bloated with ice crystals
- ▶ 2) Upon warming, the crystals melt, resulting in a smaller volume for the liquid water
- ▶ 3) Above 4°C, water expands as it is heated by thermal motion



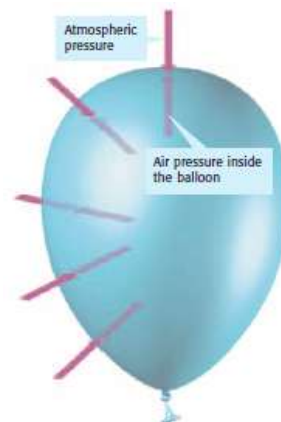
6.7 Expansion of Water



- ▶ What was the precise temperature at the bottom of Lake Michigan on New Year's Eve in 1901?

7.1 Fluids and Pressure

- ▶ Atmospheric pressure – pressure caused by weight of the atmosphere
 - $101,300\text{ N} \sim 101\text{ kPa}$ at sea level
- ▶ Why don't you implode?
 - The fluids in your body exert pressure.



6

7.1 Atmospheric Pressure

Explode or implode?



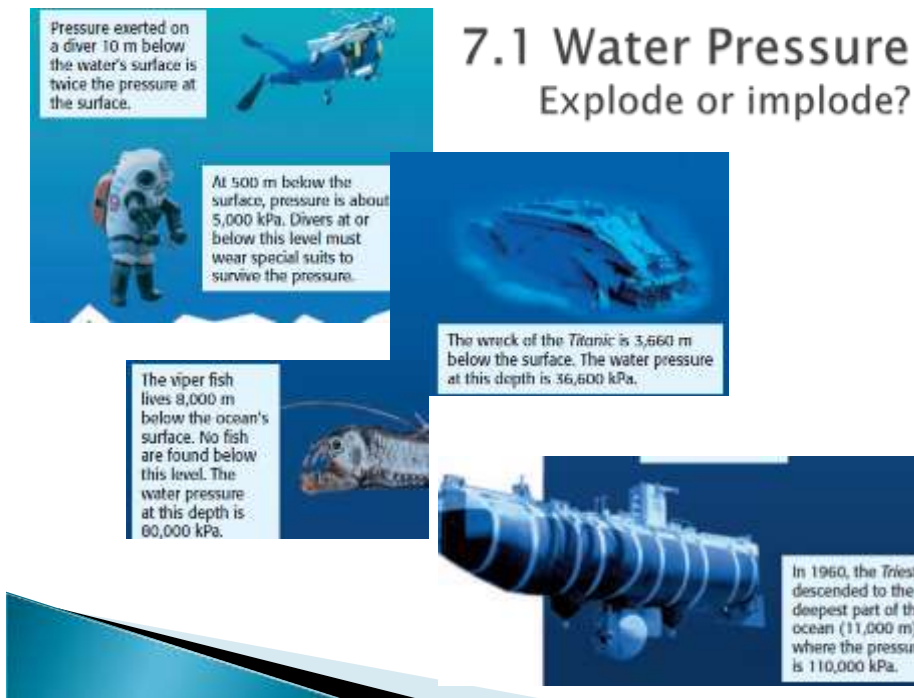
At 150,000 m above sea level, atmospheric pressure is almost 0 Pa. Humans cannot travel this high without protection. The space shuttle travels past this point on its way into orbit.

The atmospheric pressure at 12,000 m is about 20 kPa. Airplane cabins must be pressurized for passenger safety.

At the top of Mount Everest (8,847 m above sea level), atmospheric pressure is about a third of that at sea level.

Atmospheric pressure at La Paz, Bolivia (the world's highest capital city, at 4,000 m), is about 51 kPa.

At sea level (0 m), the full pressure of the atmosphere—101 kPa—is exerted on you.



7.1 Water Pressure

Explode or implode?

Pressure exerted on a diver 10 m below the water's surface is twice the pressure at the surface.

At 500 m below the surface, pressure is about 5,000 kPa. Divers at or below this level must wear special suits to survive the pressure.

The viper fish lives 8,000 m below the ocean's surface. No fish are found below this level. The water pressure at this depth is 80,000 kPa.

The wreck of the *Titanic* is 3,660 m below the surface. The water pressure at this depth is 36,600 kPa.

In 1960, the *Trieste* descended to the deepest part of the ocean (11,000 m), where the pressure is 110,000 kPa.

7.1 Fluids and Pressure

▶ Pressure Difference: Fluids flow from high/low to high/low pressure

▶ Everyday examples:

- How does a dropper work?
- How does a straw work?
- How do your lungs inhale air?



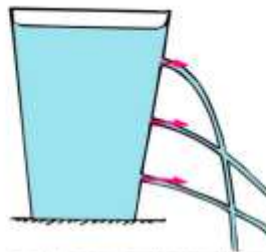
- Why are tornadoes like vacuum cleaners?



9

7.1 Fluids and Pressure

▶ Question: Why does pressure increase with depth?



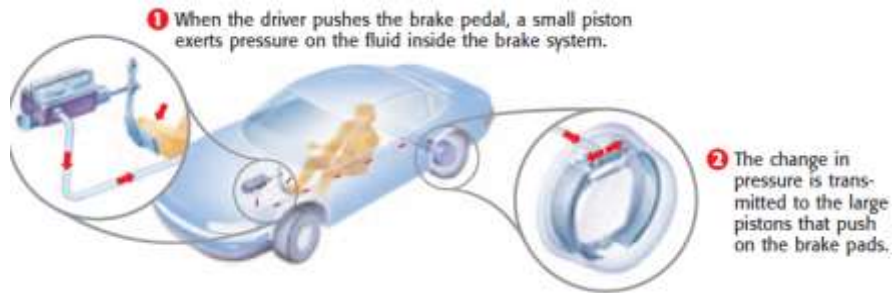
If there is a hole in the container's surface then liquid will initially flow out perpendicular to the surface (gravity eventually causes path of flow to curve)

at greater depths...net force & pressure are greater...velocity of escaping liquid is greater (note: longer velocity vectors)

10

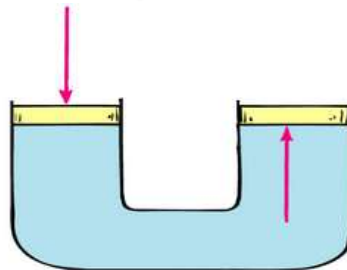
7.3 Pascal's Principle

- ▶ For an enclosed fluid, change in pressure in 1 place = change in pressure everywhere.



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Pascal's Principle

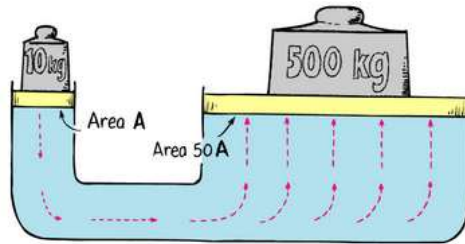


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Pressures are equal. Since the areas are equal then the forces exerted on the areas are equal as well.

12

Pascal's Principle



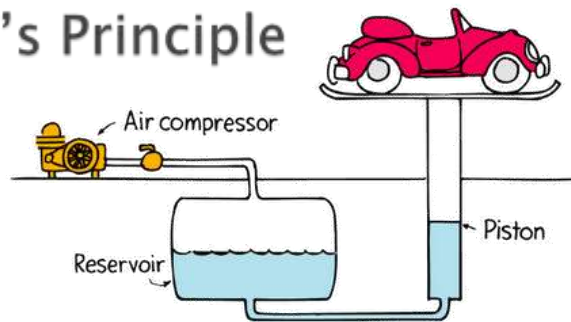
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The pressures ($P = F/A$) are equal. If the diameters of the pistons are different then the forces exerted on them will be different as well. If area of second piston is 50 times greater, then the force exerted will be 50 times greater. Note: the force needed to lift a 500kg mass is equal to its weight ($w = mg$).

$\frac{F_1}{A_1} = \frac{F_2}{A_2}$ a small force exerted over a small area will result in
a large force exerted over a large area

13

Pascal's Principle



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Air compressor puts pressure on a large surface area of fluid in underground reservoir tank. The pressure exerted on reservoir fluid is equal to pressure the fluid will exert on smaller surface area piston.

Pressure = force / area

Since both Pressures are equal and the areas are different, then the forces should be different (in a reciprocal fashion) as well to yield equal pressures.

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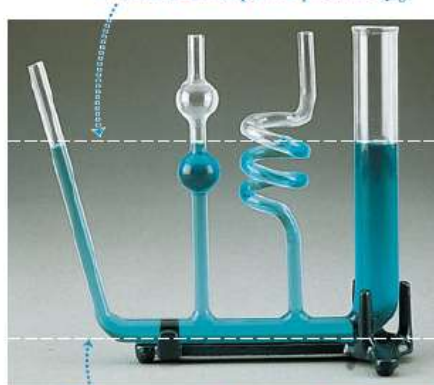
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pressure of liquid is same at any given depth below surface regardless of shape of container



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The pressure at the top of each liquid column is atmospheric pressure, p_0 .

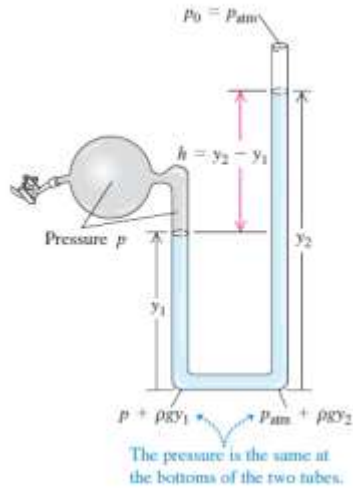


The pressure at the bottom of each liquid column has the same value p .

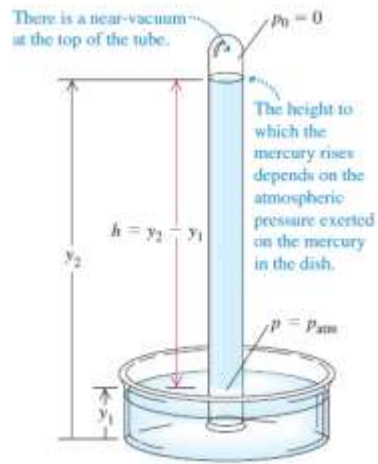
The difference between p and p_0 is ρgh , where h is the distance from the top to the bottom of the liquid column. Hence all columns have the same height.



(a) Open-tube manometer



(b) Mercury barometer

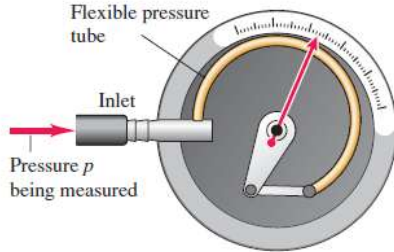


mmHg? And Water?



(a)

Changes in the inlet pressure cause the tube to coil or uncoil, which moves the pointer.



(b)

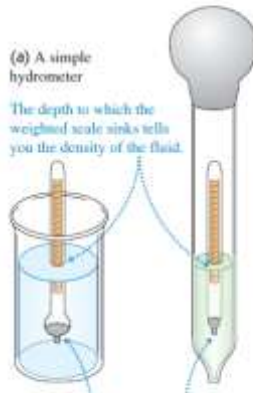


12.12 Measuring the density of a fluid.

(b) Using a hydrometer to measure the density of battery acid or antifreeze.

(a) A simple hydrometer

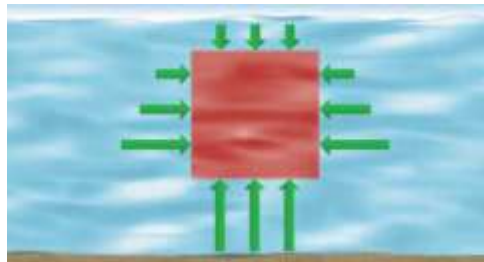
The depth to which the weighted scale sinks tells you the density of the fluid.



The weight at the bottom makes the scale float upright.

7.2 Buoyant Force

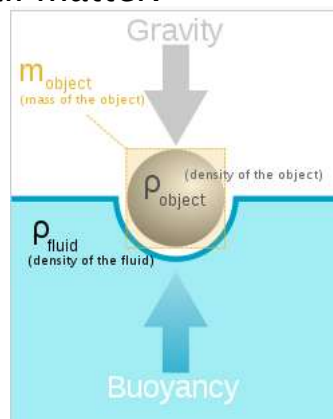
- ▶ There is more pressure below than above



21

7.2 Buoyant Force

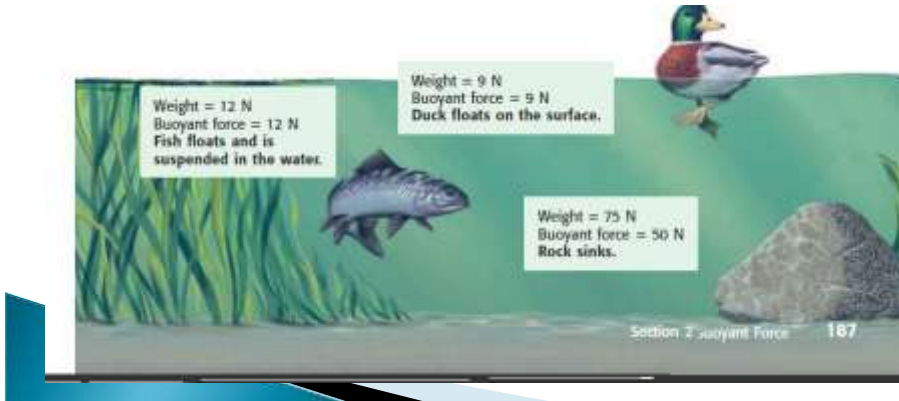
- ▶ Buoyant force = upward force that fluids exert on all matter.



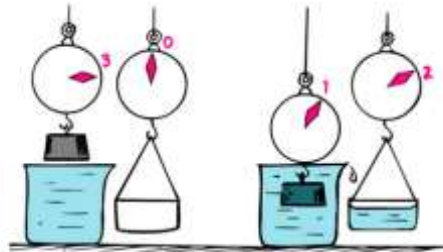
22

7.2 Buoyant Force

- ▶ Archimedes' Principle:
The buoyant force = weight of displaced fluid
- ▶ The weight of the object does not matter!



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Apparent weight: object appears to have less weight because buoyant force is acting upward on object. Buoyant force is equal to weight of volume of fluid displaced.

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7.2 Buoyant Force

- ▶ Math

- You need a force of 15 N to lift an object that is underwater. The object displaces 2 L of water

What is the weight of the object?



25

7.2 Buoyant Force

- ▶ Floating, sinking, and density.

- When the object is more/less dense than the fluid, the object will sink/float.

- ▶ Density =

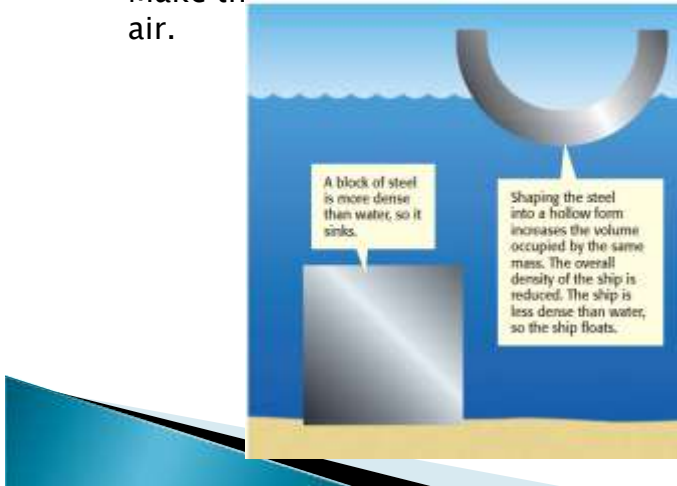
mass/volume



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7.2 Buoyant Force

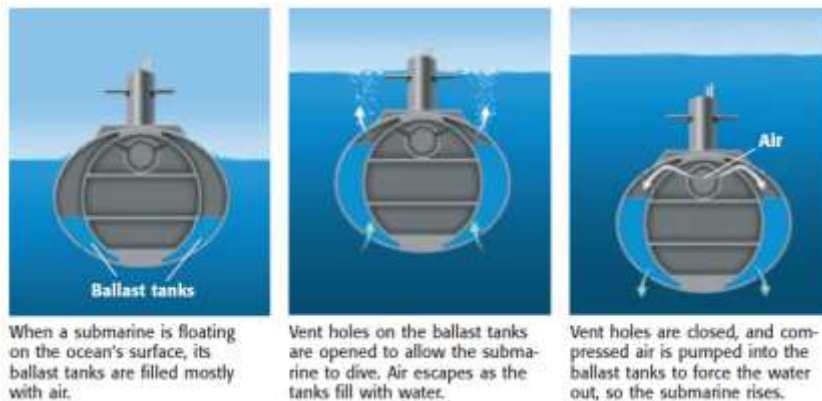
- ▶ Changing overall density.
 - Make the density less by filling up more space with air.



27

7.2 Buoyant Force

- ▶ Changing density by changing mass.



28

7.2 Buoyant Force

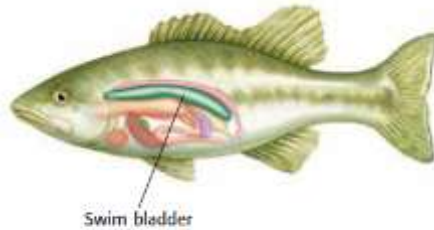


Figure 6 Most bony fishes have an organ called a swim bladder that allows them to adjust their overall density.



29

From Archimedes
Buoyant force and density?



30

7.3 Fluids and Motion

- ▶ <http://www.youtube.com/watch?v=WDGNcmEOjs4>
- ▶ http://www.youtube.com/watch?v=yvz_pS3pZ8s&feature=related
- ▶ <http://www.youtube.com/watch?v=fgHvC55AKig&feature=related>



31

7.3 Fluids and Motion

- ▶ What happened?
- ▶ Bernoulli's Principle: The faster the fluid moves, the less pressure there is.
 - Think of a running crowd.



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7.3 Bernoulli's Principle

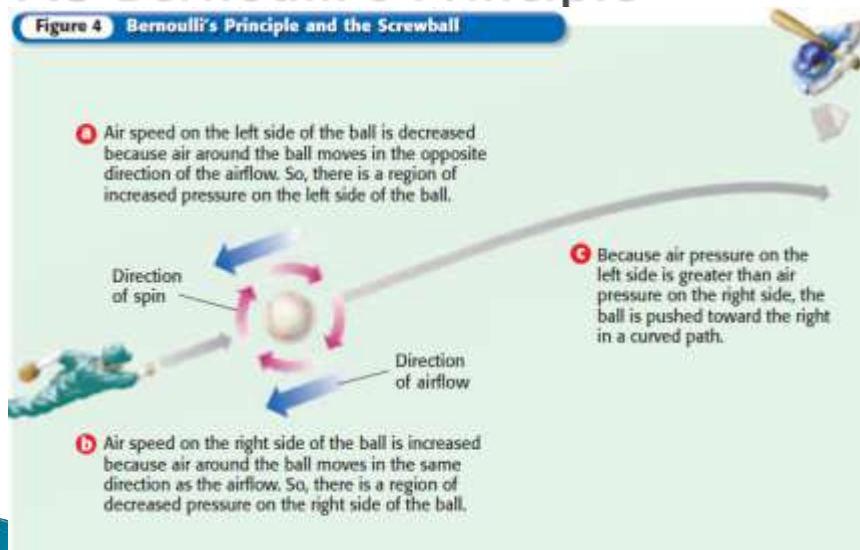
- ▶ Explain this



33

7.3 Bernoulli's Principle

Figure 4 Bernoulli's Principle and the Screwball



34

7.3 Bernoulli in Flight

WEIGHT

LIFT:
 -Pressure difference
 -Newton's 3rd Law

a Airplane wings are made so that the air speed above the wing is greater than the air speed below the wing.

b According to Bernoulli's principle, a difference in air speed means a difference in pressure. The result is an upward force that contributes to lift.

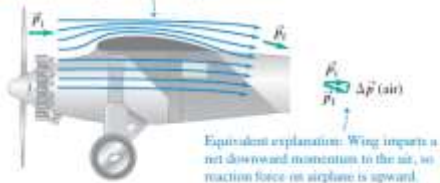
c Another feature of wing design is that the shape of the wing forces the air downward. So, the air pushes the wing upward.

35

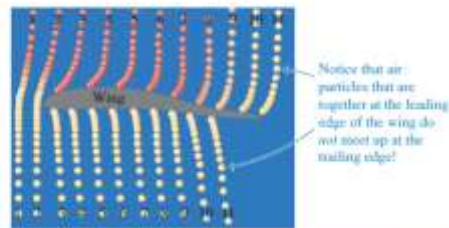
12.26 Flow around an airplane wing.

(a) Flow lines around an airplane wing

Flow lines are crowded together above the wing, so flow speed is higher there and pressure is lower.



(b) Computer simulation of air parcels flowing around a wing, showing that air moves much faster over the top than over the bottom.



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7.3 Bernoulli's Principle

- ▶ Do you think a fast or slow plane needs bigger wings? Why?

Figure 3 Increased Thrust Versus Increased Wing Size



The engine of this jet creates a large amount of thrust, so the wings don't have to be very big.



This glider has no engine and therefore no thrust. So, its wings must be large in order to maximize the amount of lift achieved.

37

7.3 Bernoulli's Principle

- ▶ Do you think a fast or slow plane needs bigger wings? Why?

The plane with more thrust (more force to go faster) has less pressure above wings, so it has more lift.

The slower plane has less pressure above wings, so it needs bigger wings for more lift.

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7.3 Bernoulli's Principle

- ▶ Why does a small bird need to flap more to fly? Why does a large bird flap less?



39

7.3 Bernoulli's Principle

- ▶ What are the flaps on an airplane wing for?



40

7.3 Fluids and Motion

▶ Review

1. What forces act on an airplane?
2. When an airplane is flying, how does the air pressure above a wing compare with that below the wing?
3. How is thrust related to the speed of an airplane?



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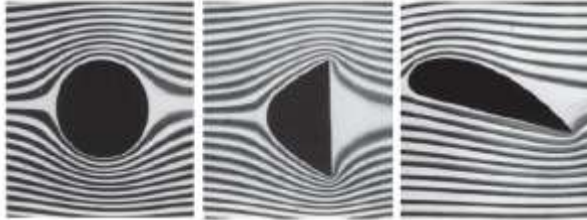
- ▶ http://w3.shorecrest.org/~Lisa_Peck/Physics/syllabus/phases/liquids/ch19liquid_images/ch19_images.htm
- ▶ <http://www.vivaphysics.com/animations.php?id=6>



42

Laminar Flow, Streamlines

12.19 Laminar flow around obstacles of different shapes.



12.20 The flow of smoke rising from these incense sticks is laminar up to a certain point, and then becomes turbulent.



43

Test Your Understanding of Section 12.4 A maintenance crew is working on a section of a three-lane highway, leaving only one lane open to traffic. The result is much slower traffic flow (a traffic jam). Do cars on a highway behave like (i) the molecules of an incompressible fluid or (ii) the molecules of a compressible fluid?



Test Your Understanding of Section 12.5 Which is the most accurate statement of Bernoulli's principle? (i) Fast-moving air causes lower pressure; (ii) lower pressure causes fast-moving air; (iii) both (i) and (ii) are equally accurate.



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Applications

1. Torricelli's Theorem



45

Applications

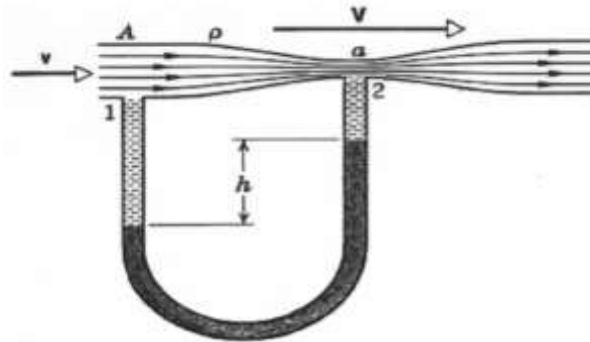
2. Perfume Atomizer



46

Applications

3. Venturi Meter



47

Applications

Why collide?



48

References

- ▶ http://www.hbcc.edu.sa/facpages/samaila/pt/PPA6_Lecture_Ch_10.pdf
- ▶ http://www.hbcc.edu.sa/facpages/samaila/pt/PPA6_Lecture_Ch_11.pdf
- ▶ All online!

