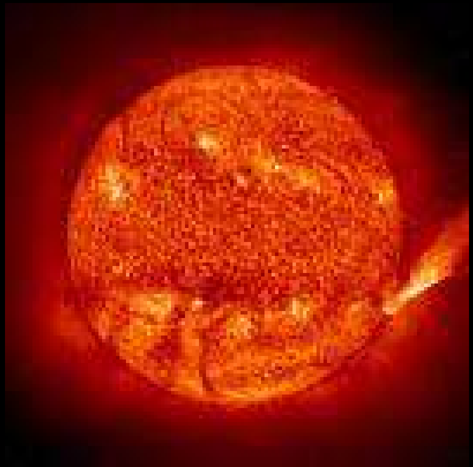
S-55

List and describe the four states of matter.



Fluids

AP Physics

Chapter 10

Fluids

10.1 States of Matter

10.1 States of Matter

Solid – fixed shape, fixed size

Liquid – shape of container, fixed size

Gas – shape of container, volume of container

Fluids – have the ability to flow (liquids and gases)

Fluids

10.2 Density and Specific Gravity

10.2 Density and Specific Gravity

Density – mass per unit volume

$$\rho = \frac{m}{V}$$

Mass in kilograms

Volume in m^3

Density of pure water is $1000 kg/m^3$

Salt water is $1025 kg/m^3$

10.2 Density and Specific Gravity

Specific Gravity – the ratio of the density of the substance to the density of water at 4^oC.

Water is 1 (no unit)

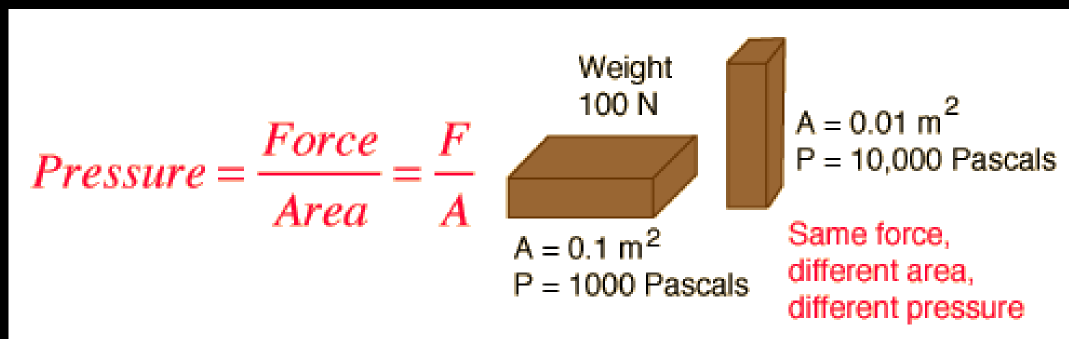
Salt water would be 1.025

Fluids

10.3 Pressure in Fluids

10.3 Pressure in Fluids

Pressure depends on the Force and the area that the force is spread over.



Measured in pascals (Pa – N/m^2)

$$P = \frac{F}{A}$$

10.3 Pressure in Fluids

Low pressure

Force is body weight – large surface area

High pressure

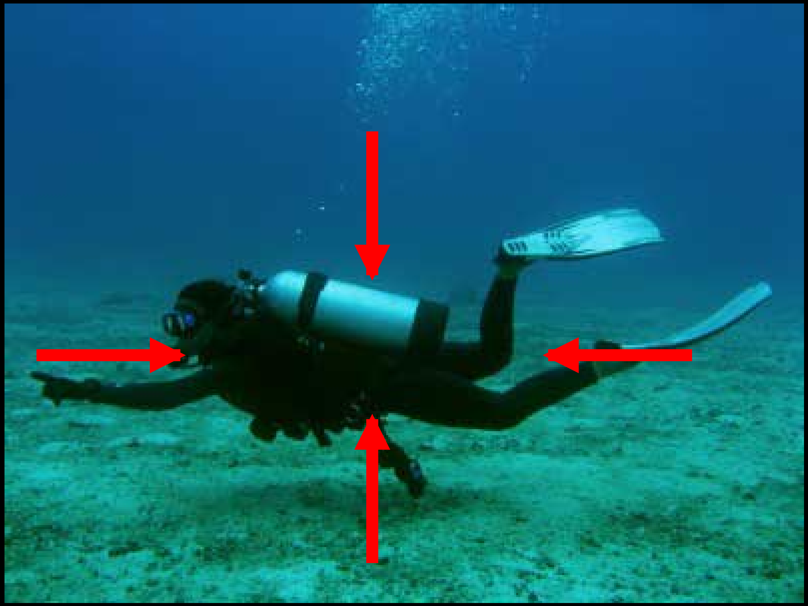
Force is body weight – small surface area

10.3 Pressure in Fluids

Pressure in a fluid

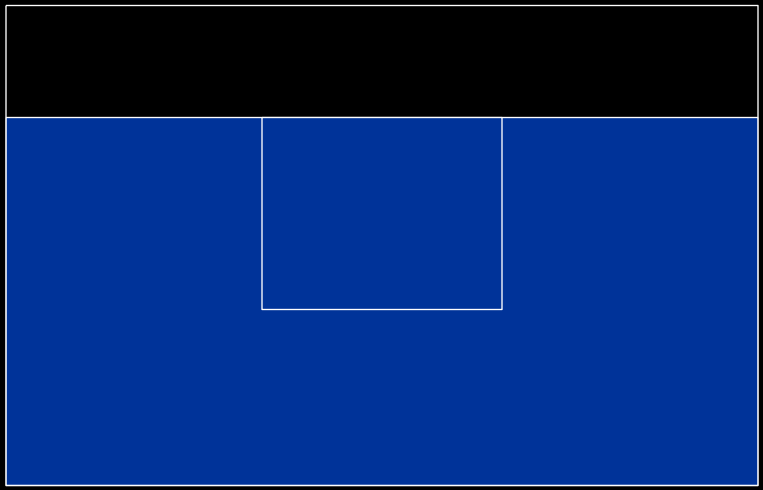
Pressure is equal on all sides

If not – object would accelerate



10.3 Pressure in Fluids

Pressure depends on depth in a fluid



If we pick a cube of the fluid

For the bottom of the cube

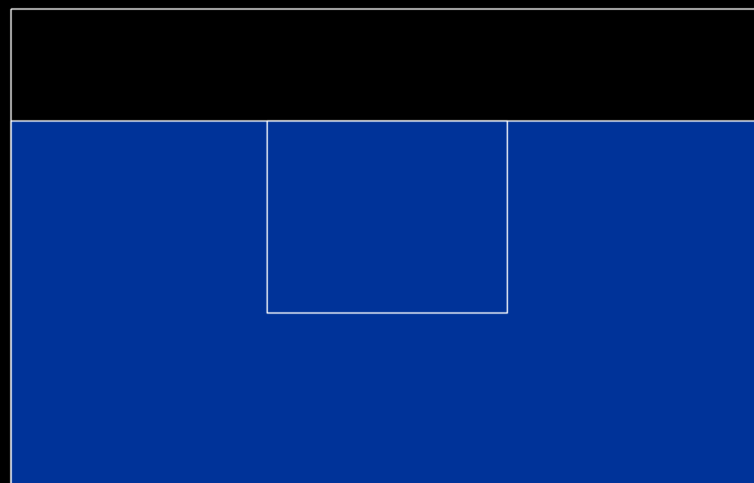
$$F = mg$$

$$m = \rho V$$

$$F = \rho V g$$

10.3 Pressure in Fluids

Pressure depends on depth in a fluid



$$F = mg$$
$$m = \rho V$$
$$F = \rho V g$$

Volume is A x height (y) so

$$F = \rho A y g$$

Now in the Pressure equation

$$P = \frac{F}{A} = \frac{\rho A y g}{A} = \rho g y$$

Fluids

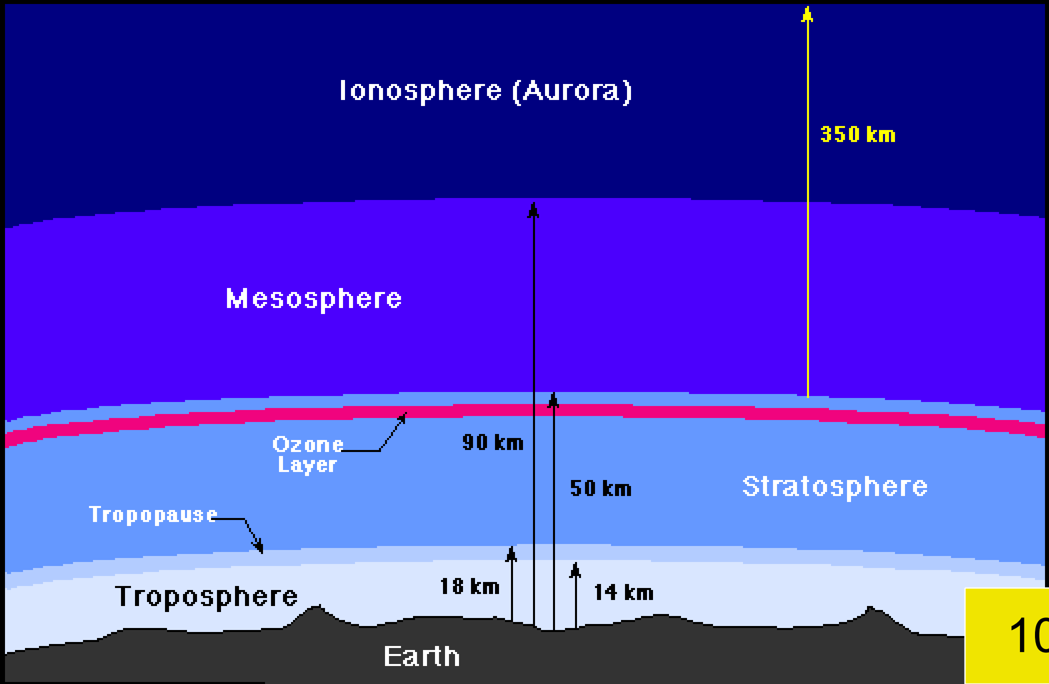
10.4 Atmospheric Pressure and Gauge Pressure

10.4 Atmospheric Pressure and Gauge Pressure

Air pressure – we are at the bottom of a pool of air

99% is in the first 30 km

But extends out to beyond geosynchronous orbit (36500 km)



10.4 Atmospheric Pressure and Gauge Pressure

Pressure also varies with weather (high and low pressures)

$$1atm = 101300Pa = 101.3kPa$$

10.4 Atmospheric Pressure and Gauge Pressure

How does a person suck drink up a straw?

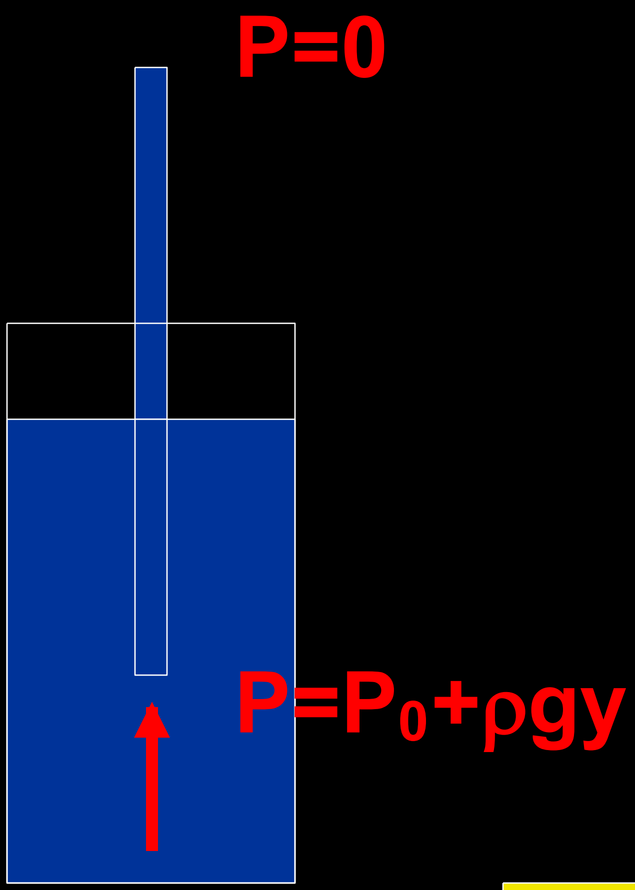
Pressure at the top is reduced

What is the pressure at the bottom?

Since $$P = \frac{F}{A}$$

Then $$F = PA$$

Area at the top and bottom are the same so net force up



10.4 Atmospheric Pressure and Gauge Pressure

Nothing in physics ever sucks

Pressure is reduced at one end

Gauge Pressure – beyond atmospheric pressure

Absolute pressure

$$P = P_A + P_G$$

Fluids

10.5 Pascal’s Principle

10.5 Pascal's Principle

Pascal's principle – if an external pressure is applied to a confined fluid, the pressure at every point within the fluid increases by that amount.

$$P_{out} = P_{in}$$

$$\frac{F_{out}}{A_{out}} = \frac{F_{in}}{A_{in}}$$

$$\frac{F_{out}}{F_{in}} = \frac{A_{out}}{A_{in}}$$

Pascal Applet

This is called the mechanical advantage

10.5 Pascal's Principle

S-57

After eating too many crackers Polly got a little thirsty. If she can reduce the pressure inside

0 Pa,

v would

sume standard air pressure

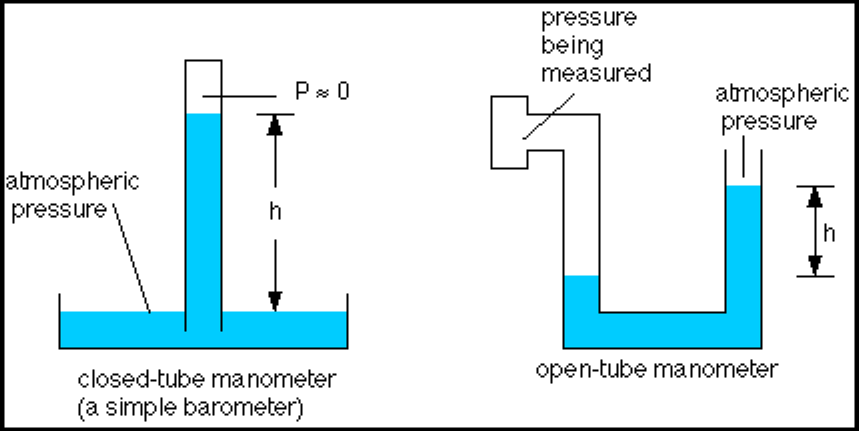
the water)

Fluids

10.7 Barometer

10.6 Barometer

How does a manometer work?



Closed tube

$$P = \rho g \Delta h$$

Open tube

$$P = P_0 + \rho g \Delta h$$

10.6 Barmometer

Aneroid barometer

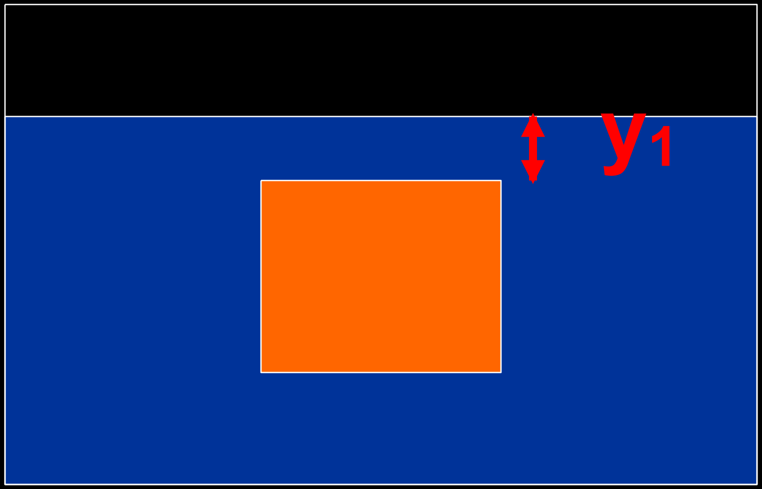
Push Me

Fluids

10.7 Buoyancy and Archimedes’ Principle

10.7 Buoyancy and Archimedes' Principle

Buoyancy – the upward force on an object due to differences in pressure

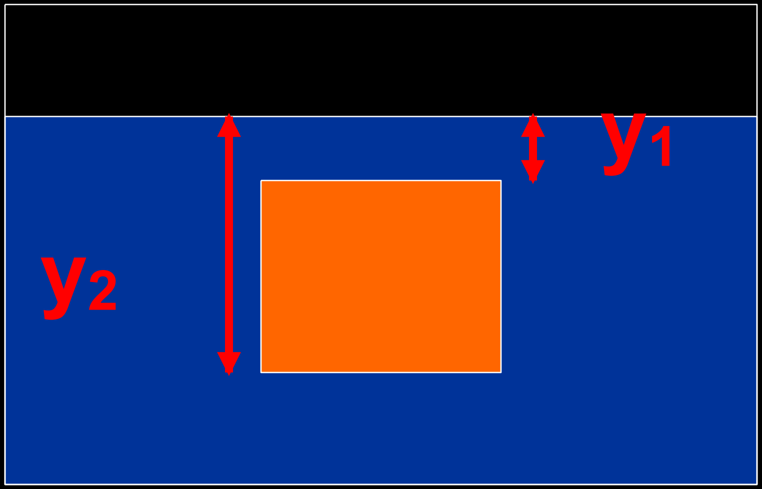


Pressure on the top of the box is

$$P = \rho g y_1 = \frac{F_T}{A}$$

10.7 Buoyancy and Archimedes' Principle

Buoyancy – the upward force on an object due difference is pressure



$$\rho g A y_1 = F_T$$

$$\rho g A y_2 = F_B$$

Pressure on the bottom of the box is

Solve both for F

Net force is the

$$P = \rho g y_2 = \frac{F_B}{A}$$

10.7 Buoyancy and Archimedes' Principle

Net Force (sum of forces)

$$B = F_B - F_T$$

$$B = \rho g A y_2 - \rho g A y_1$$

Simplified

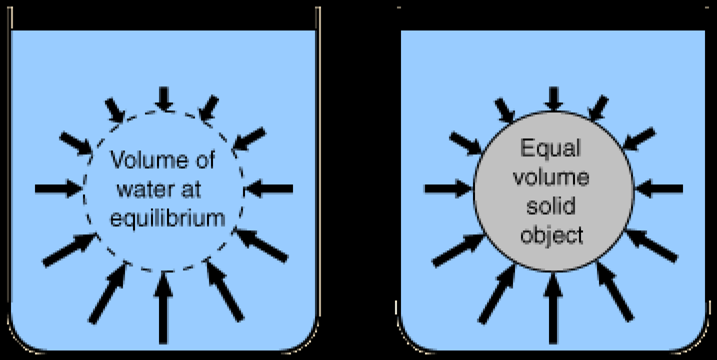
$$B = \rho g A (y_2 - y_1)$$

What is A x Δy?

$$B = \rho V g$$

10.7 Buoyancy and Archimedes' Principle

Archimedes' principle – the buoyant force on an object immersed in a fluid is equal to the weight of the fluid displaced by the object



Since the water ball is supported by the forces

The ball must experience the same forces as the displaced water

10.7 Buoyancy and Archimedes' Principle

Example: When a crown of mass 14.7 kg is submerged in water, an accurate scale reads only 13.4 kg. Is the crown made of gold? (ρ=19300 kg/m^3)

If W_A is t

Weight c

Using the

$$- B$$

$$\rho_g Vg$$

$$\frac{(14.7)(1000)}{(14.7-13.4)} = 11300\,\frac{kg}{m^3}$$

$$W - W_A = \rho_{H_2O} Vg$$

$$\frac{W \rho_{H_2O}}{W - W_A} = \rho_g$$

S-58

A girl dives into the fine pond below. It turns out that it is 25 m deep, and she goes all the way to the bottom.

A. What would be the gauge pressure at that point?

B. What would be the absolute p assuming that the air is at s pressure.

C. What is the force on her, if h area is 0.65 m^2?

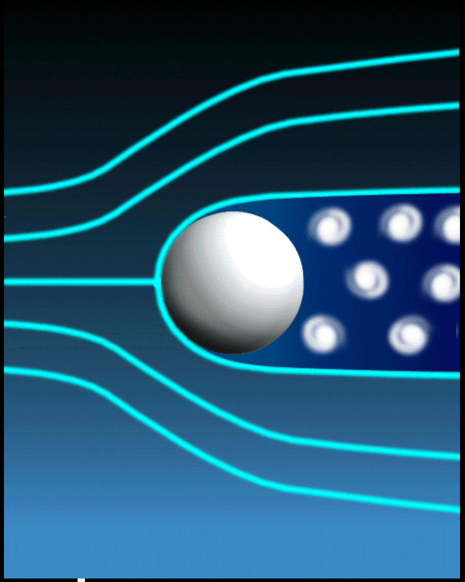
Fluids

10.8 Fluids in Motion: Equation of Continuity

10.8 Fluids in Motion: Equation of Continuity

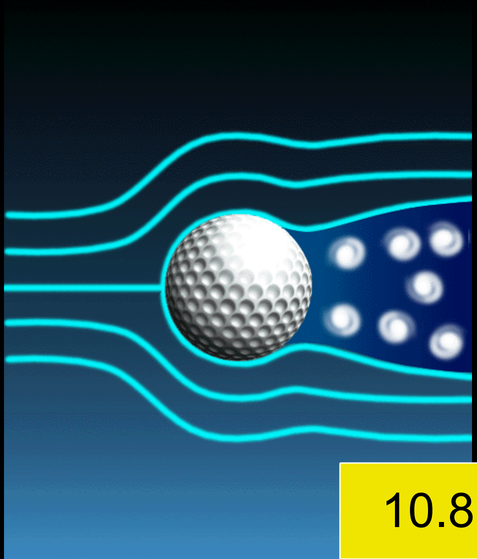
Fluid Dynamics – fluids in motion

Laminar Flow – smooth



Turbulent Flow – erratic, eddy current

We’ll deal with Laminar flow

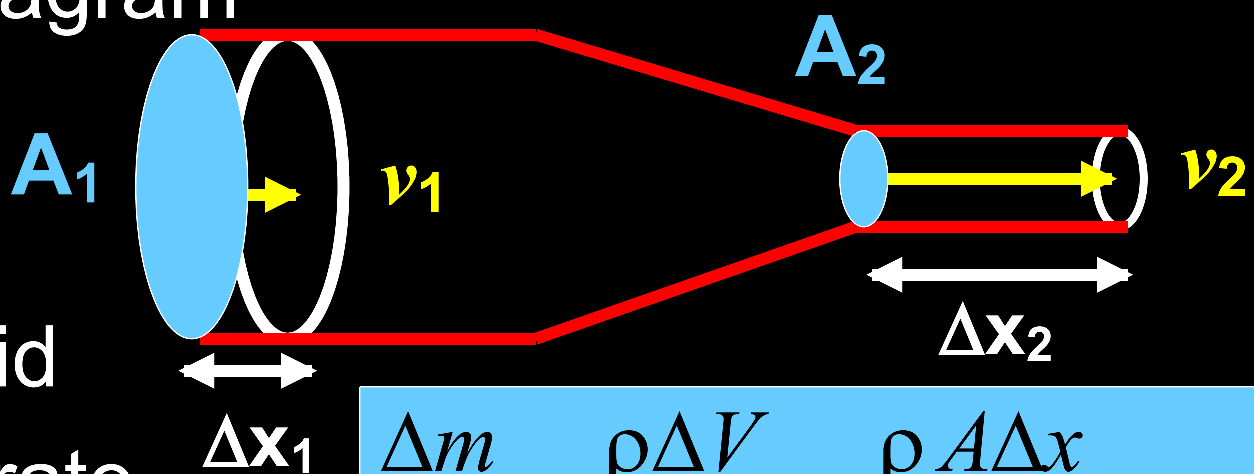


10.8 Fluids in Motion: Equation of Continuity

Equation of Continuity

Mass flow rate – mass per unit time $\frac{\Delta m}{\Delta t}$

Using the diagram



Since no fluid is lost, flow rate must remain constant

$$\frac{\Delta m}{\Delta t} = \frac{\rho \Delta V}{\Delta t} = \frac{\rho A \Delta x}{\Delta t} = \rho A v$$

$$A_1 v_1 = A_2 v_2$$

Practice

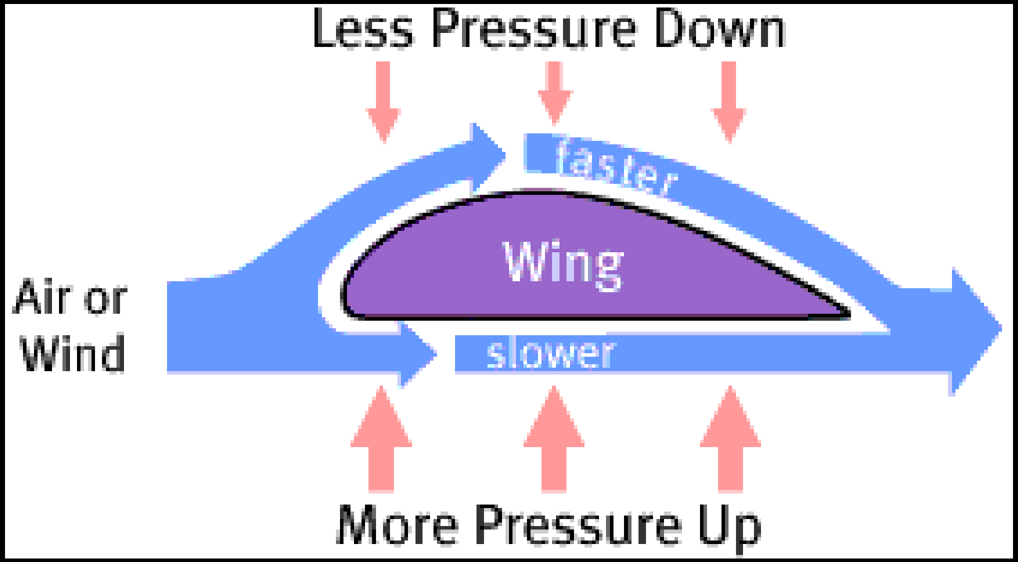
The image below is of a water cannon designed to repel pirates. If the water enters through the bottom valve with a volume flow rate of 125 kg/s and the nozzle steps the volume down from a diameter of 10 cm to a diameter of 0.25 cm, v
the water leaving the g

Fluids

10.9 Bernoulli's Equation

10.9 Bernoulli's Equation

Bernoulli's principle – where the velocity of a fluid is high, the pressure is low, and where the velocity is low, the pressure is high



We will assume

1. Lamnar flow
2. Constant flow
3. Low viscosity
4. Incompressible fluid

S-59

Larry the 255 kg hippo is napping in the water. If 2/3 of his body is under water, what is his density?

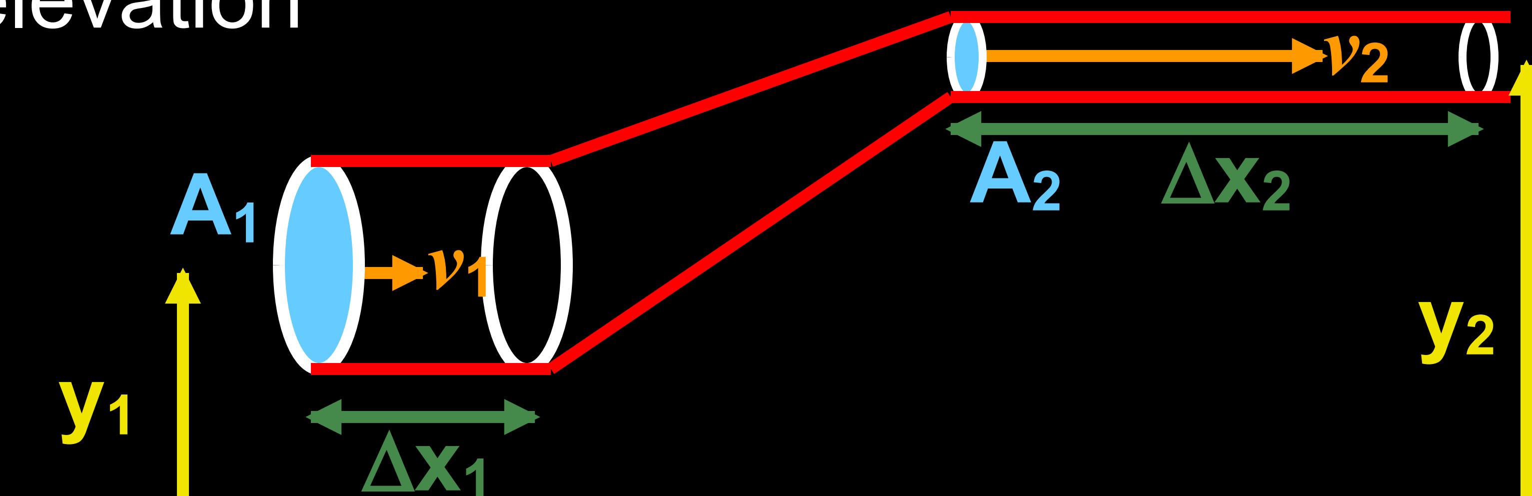
S-60

A real hotel in Turkey is built under water. If the windows are 12m under water, what is the force on each square meter of glass that makes up the windows? How much less would the pre as alcohol (spe

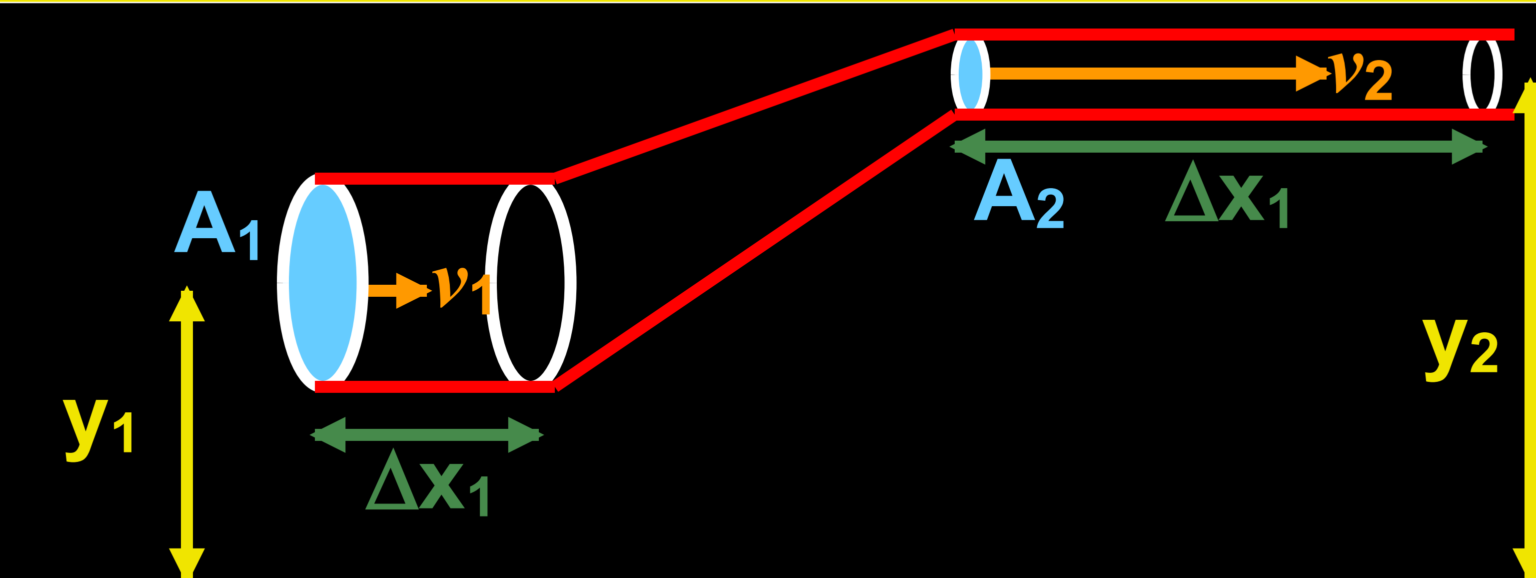
10.9 Bernoulli's Equation

Let us assume a tube with fluid flow

The diameter changes, and it also changes elevation



10.9 Bernoulli's Equation



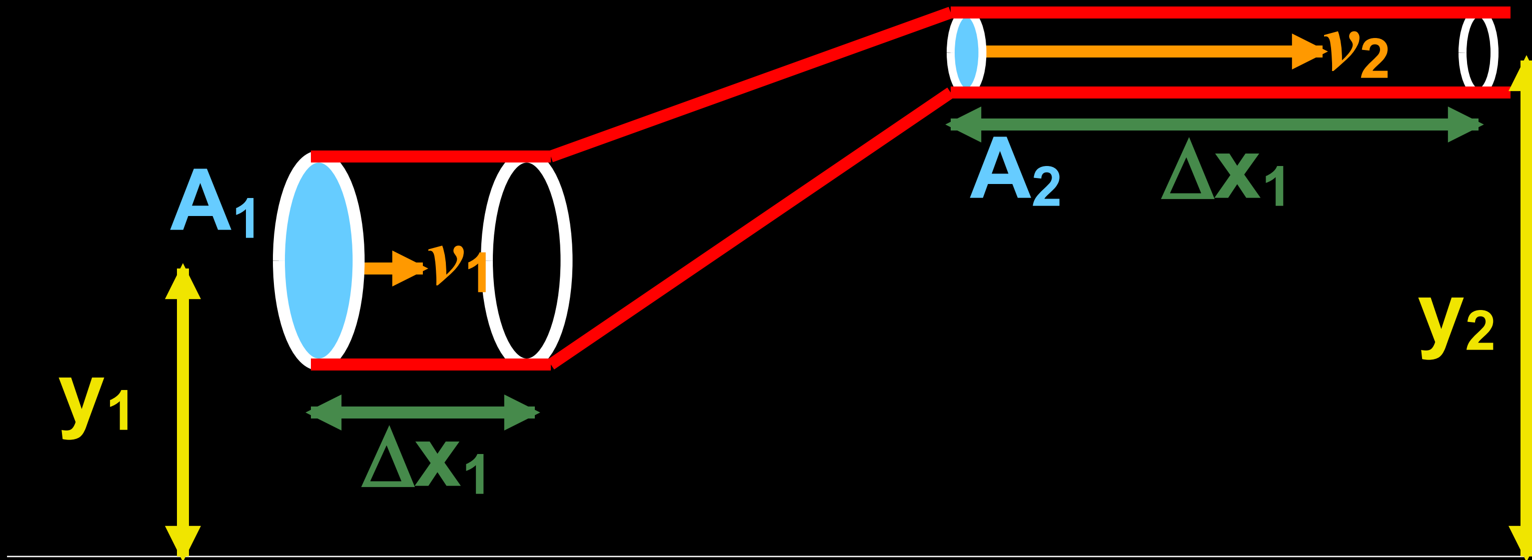
Work done at point one (by fluid before point 1)

$$W_1 = F\Delta x = P_1 A_1 \Delta x_1$$

At point 2

$$W_2 = -P_2 A_2 \Delta x_2$$

10.9 Bernoulli's Equation



Work is also done lifting the water

$$W_3 = -mg\Delta y$$

$$W_1 = P_1 A_1 \Delta x_1$$

$$W_2 = -P_2 A_2 \Delta x_2$$

10.9 Bernoulli's Equation

Other works cancel out

$$W_1 = P_1 A_1 \Delta x_1$$

$$\tfrac{1}{2}\rho v_2^2 - \tfrac{1}{2}\rho v_1^2 = P_1 - P_2 - \rho g y_2 + \rho g y_1$$

Substitute for mass

$$W_3 = -mg\Delta y$$

$$P_0 + \tfrac{1}{2}\rho v_0^2 + \rho g y_0 = P + \tfrac{1}{2}\rho v^2 + \rho g y$$

Since mass stays constant, so must the volume

$$A_1 \Delta x_1 = A_2 \Delta x_2$$

10.9 Bernoulli's Equation

This is Bernoulli's Equations

$$P_0 + \tfrac{1}{2}\rho v_0^2 + \rho g y_0 = P + \tfrac{1}{2}\rho v^2 + \rho g y$$

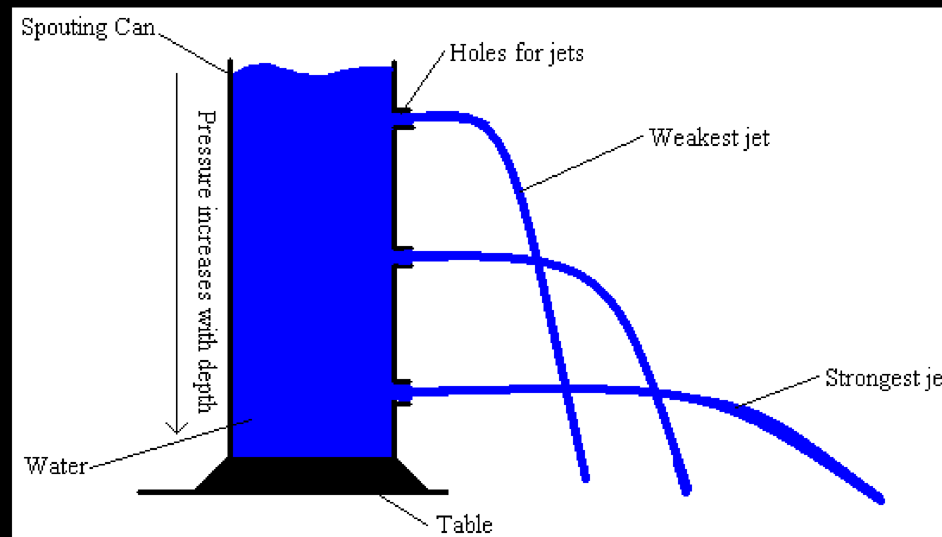
It is a statement of the law of conservation of energy

Fluids

10.10 Application of Bernoulli's Principle

10.10 Applications of Bernoulli's Principle

Velocity of a liquid flowing from a spigot or hole in a tank.



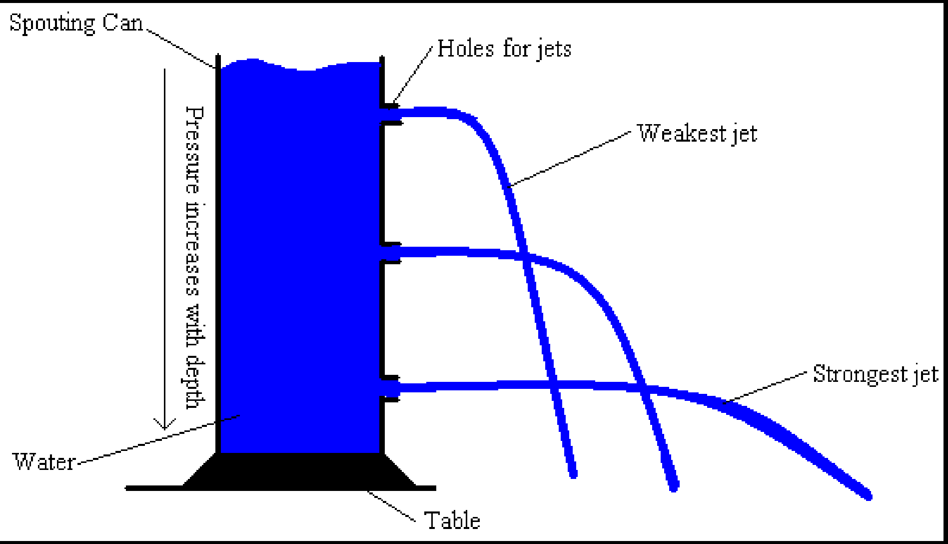
If we assume that the top has a much greater area than the bottom, v at the top is nearly 0

And both are open to the air so P is the same

$$\rho g y_0 = \frac{1}{2}\rho v^2 + \rho g y$$

10.10 Applications of Bernoulli's Principle

The density cancels out



Rewrite to solve for v

$$v = \sqrt{2g(y_2 - y_1)}$$

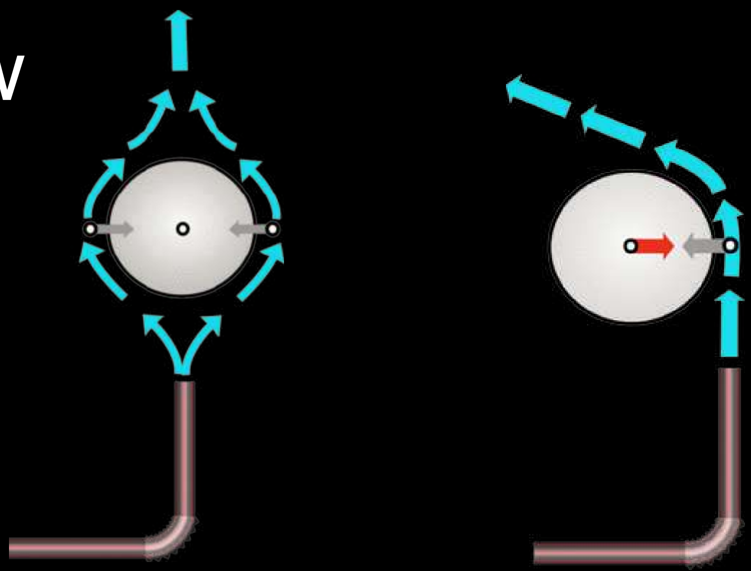
10.10 Applications of Bernoulli's Principle

Another case is if fluid is flowing horizontally

Speed is high where pressure is low

Speed is low where pressure is high

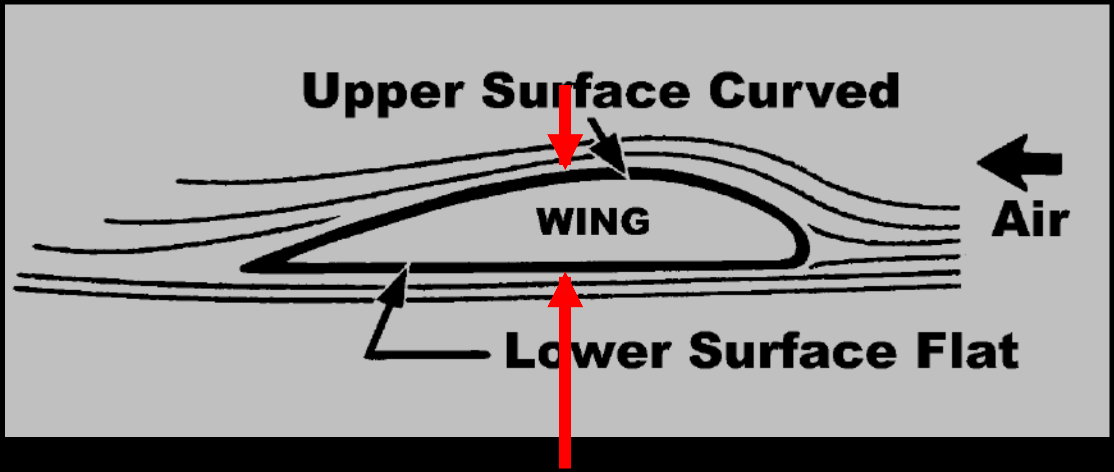
Ping pong ball in air flow



$$P_0 + \frac{1}{2}\rho v_0^2 = P + \frac{1}{2}\rho v^2$$

10.10 Applications of Bernoulli's Principle

Airplane Wings



Air flows faster over the top – pressure is lower

Net Force is upward

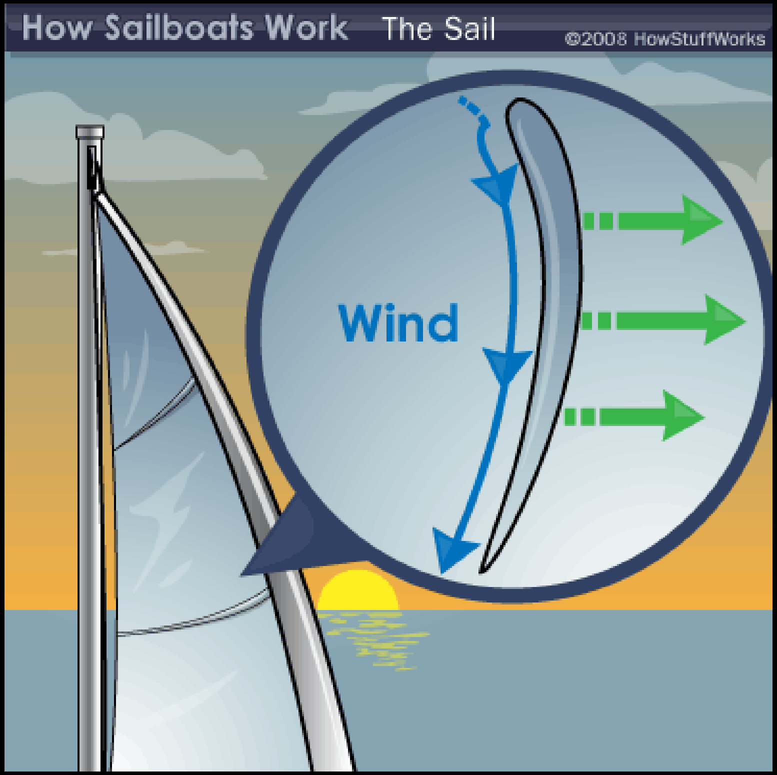
$$P_0 + \frac{1}{2}\rho v_0^2 = P + \frac{1}{2}\rho v^2$$

10.10 Applications of Bernoulli's Principle

Sailboat moving into the wind

Air travels farther and faster on the outside of the sail – lower pressure

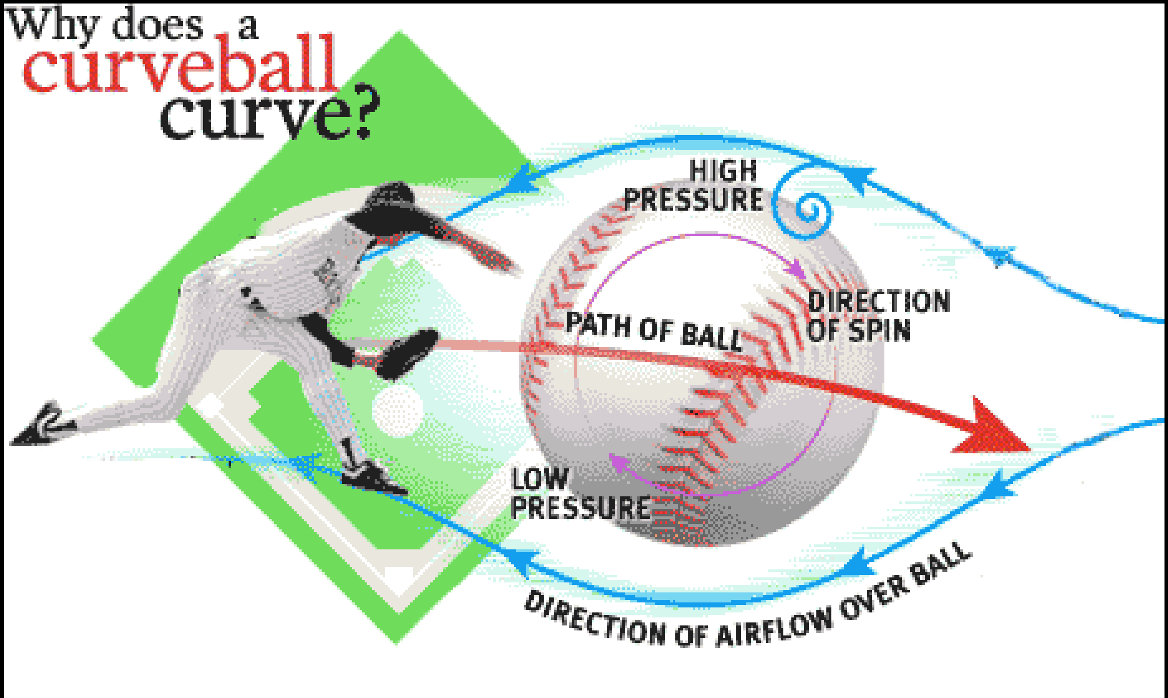
Net force is into the wind



$$P_0 + \frac{1}{2}\rho v_0^2 = P + \frac{1}{2}\rho v^2$$

10.10 Applications of Bernoulli's Principle

Curve ball
ball spins
curves toward
area of high
speed – low
pressure



$$P_0 + \frac{1}{2}\rho v_0^2 = P + \frac{1}{2}\rho v^2$$

S-61

A experimental plane with a wing surface area of 120 m^2, lifts off when it travels at 20 m/s. If the flow over the top of the wing is 2.17 times faster across the top of the wing than the bottom, what is the maximum take-off mass of the

S-62

The XB-70 Valkyrie was a prototype bomber built in the in 1964 and designed to cruise at Mach 3+. The takeoff weight of the plane was 243,045 kg, and it had an approximate wing surface area of 960 m^2. Each of six engine generated 133,600 N

upper wing surface w

of the lower win

long a runway wo

to take off?

S-63

Water is dribbling out of a tiny hole in this dam. The water is shooting out a distance of 16 m when it falls from a hole that is 6 m above the water surface. If the hole surface, and the hole m, what is the volum the lake?

S-62

Wet Cat!

Test Day!

Yah!

Blank