Matter: Phases, Forms and Forces

- **Matter: Phases, Forms, and Forces**
  - **Phases of Matter**
  - **Forms of Matter**
  - **Behavior of Atoms & Molecules**
  - **Pressure**
  - **Density**
  - **Weight, Density, Specific Gravity**
- **Fluid Pressure and Gravity**
  - **The law of fluid pressure**
  - **Fluid Pressure in the atmosphere**
- **Archimedes' Principle**
  - **Buoyancy**
  - **Archimedes' Principle**
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- **Pascal’s Principle**
- **Bernoulli’s Principle**

Matter: Phases – It is a messy spaghetti

Solids: Rigid; retain their shape unless distorted by forces. *Rock, Wood, Plastic, Iron,* H_2O=ICE

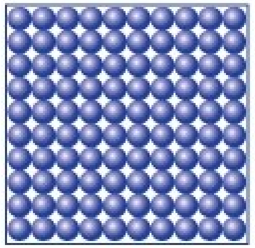
Liquids: Flow readily; conform to the shape of a container; have a well-defined boundary (surface); are not easily compressed. *Water, alcohol, gasoline, blood,* H_2O=Water

Gases: Flow readily; conform to the shape of a container; do not have a well-defined surface; can be compressed (squeezed into a smaller volume). *Air, carbon dioxide, helium, radon,* H_2O=Vapor

Plasma: Similar to Gas, **conducts electricity, interact strongly with magnetic field**, commonly exist at higher temperatures. *Neon, Vapor Lights, the Sun,* H_2O =No Plasma, only hydrogen plasma or oxygen plasma

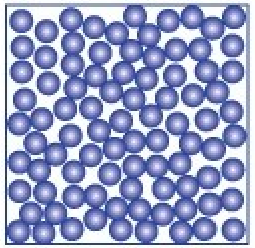
Behavior of Atoms & Molecules

Solids: Attractive forces between particles are very strong, the atoms or molecules are rigidly bound to their neighbors and can only vibrate



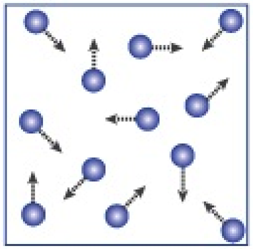
Solid

Liquids: The particles are bound together, though not rigidly, each atom or molecule can move about relative to each other but always in contact with atoms or molecules



Liquid

Gases: Attractive forces between particles are too weak to bind them together, atoms or molecules move freely with high speed and are widely separated; particles are in contact only briefly when they collide.

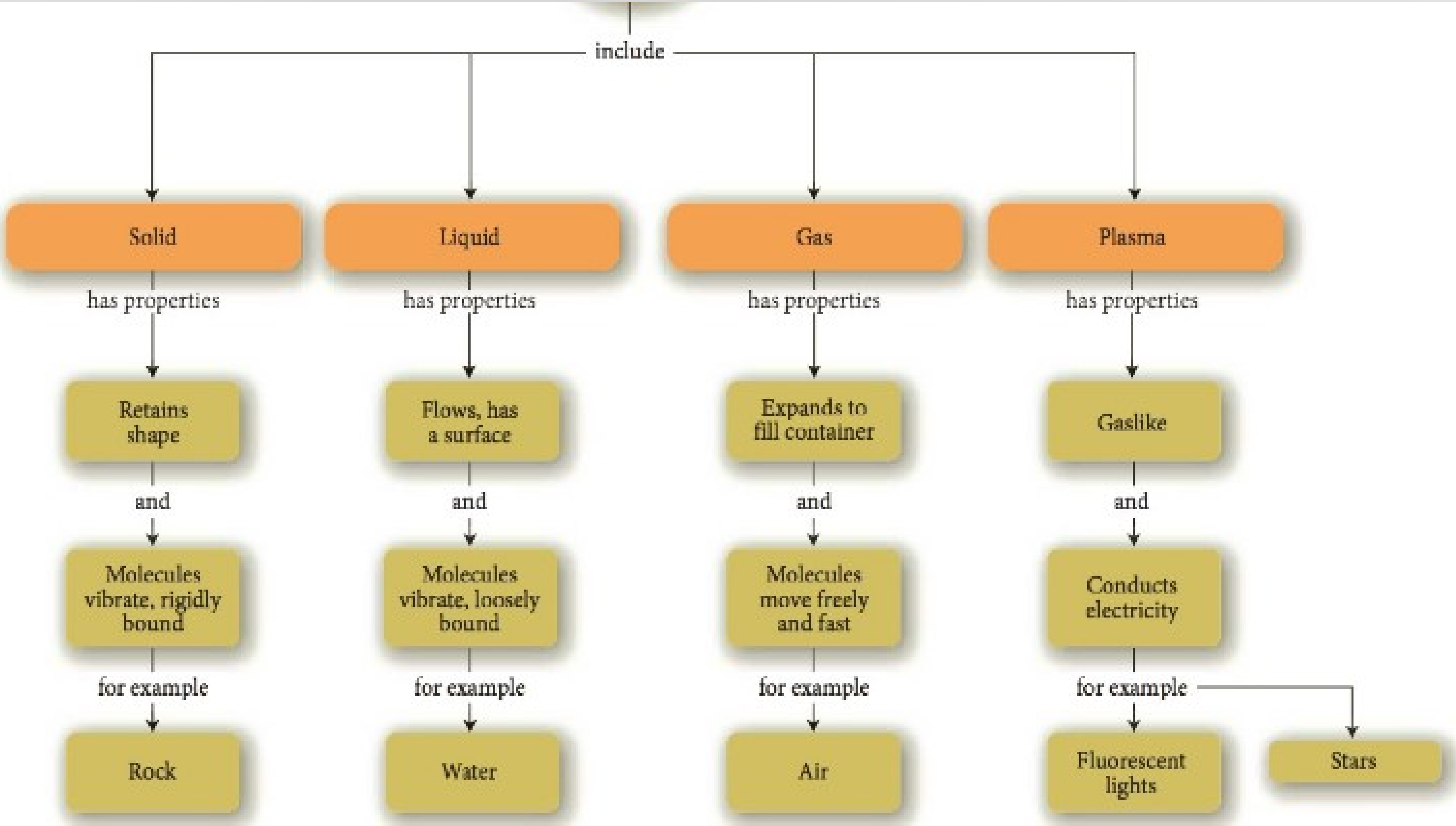


Gas

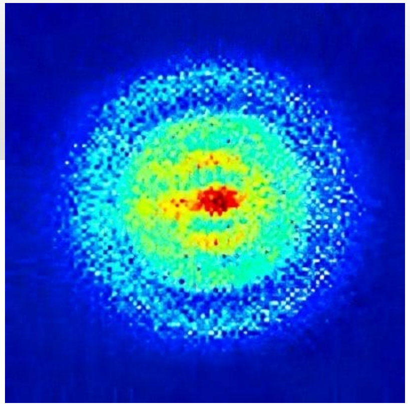
Liquids: molecules vibrates / Gas: Free mean path. Absolute 0 Kelvin no motion

0 Kelvin = -460 F = -273 C

It is just a mess - But we will fix it



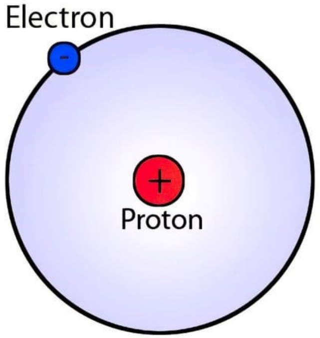
Elements -



Atoms (118 elements) Only 90 Exist Naturally.

Each atom is not an indivisible element

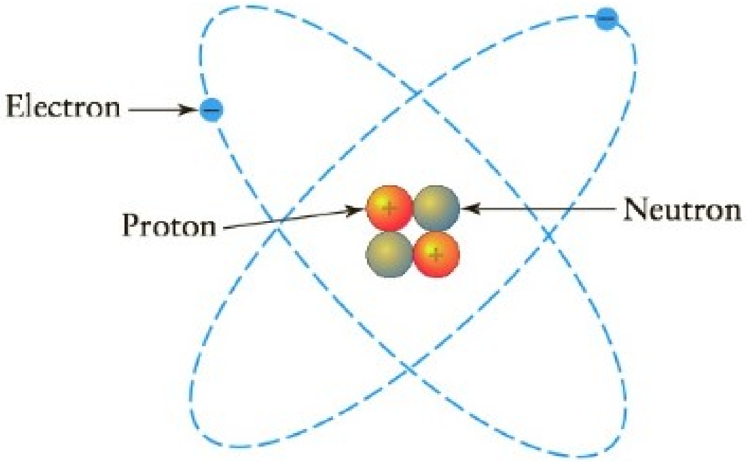
Each atom has 1 very dense Nucleus & 1 or many Electrons



Electrons (Surround the Nucleus)

Nucleus (is composed of Protons & Neutrons)

Protons & Neutrons are composes of Quarks



Protons & Electrons have equal but opposite charge which attract each other this leads the electron to orbit with a centripetal force

Practice – Matter & Phases

a) Describe the 4 phases of matter?

b) Why gases compress?

Atomic # Number -

Each Atom has an unique identifier (the number of protons)

Pure Form of Elements

i.e. Hydrogen H_2, Oxygen O_2, Helium He

Chemical Compounds are common substances such as salt, water, alcohol. Chemical Compounds are made of **Molecules**.

Molecules is made of unique combination of 2 or more atoms held together by electric forces - electrons.

Water = H_2O

Carbon Monoxide = CO

Carbon Dioxide = CO_2

Salt = NaCl

Element	Symbol	Atomic Number
Hydrogen	H	1
Helium	He	2
Carbon	C	6
Nitrogen	N	7
Oxygen	O	8
Neon	Ne	10
Sodium	Na	11
Aluminum	Al	13
Silicon	Si	14
Chlorine	Cl	17
Calcium	Ca	20
Iron	Fe	26
Nickel	Ni	28
Copper	Cu	29
Zinc	Zn	30
Silver	Ag	47
Gold	Au	79
Mercury	Hg	80
Lead	Pb	82
Uranium	U	92

Practice – Matter & Phases

a) List 5 elements that exist in Pure form?
b) Define the internal structure of an Atom?
c) What is the atomic number?
d) What is the difference between a mixture and a compound?

Behavior of Atoms & Molecules

Prior chapters all the objects we dealt with are Solids – Necessary assumption to manage forces, newtons law, motion and matter

Pressure: Force per unit area when the force act **perpendicular** to a surface. The perpendicular component of a force on a surface divided by the area of the surface.

$$p = \frac{F_{\perp}}{A} \left(\frac{N}{m^2}\right)$$

Pressure is the ratio of the force divided by the area. It is proportional to the force and inverse proportional to the area.

Keeping the area constant, a bigger forces results in more pressure.

Keeping the force constant, a bigger area reduces the pressure, a smaller area increases the pressure

Units: SI N/m^2 , Pascal ($1Pa = N/m^2$), PSI (lb/in^2), (lb/ft^2),in.Hg .

Practice - Pressure

Claudia is standing on the floor her weight is (150lb). The area of each shoe in contact with the floor is ($30in^2$)

a) What is the pressure on the floor in IP?

b) What happens if the Claudia stands on only 1 foot?

c) What happens if she puts on high heels and steps on 1 foot with the heel dimension 0.5in by 0.5in?

Practice - Pressure

In the exam I might ask you to find the pressure on the feet of elephant, then compare the result to Dali elephant with factious feet of a mosquito.

Pressure

Pressure is not limited to force of a solid object over a solid object.

Other forms of pressure include thermal, fluids etc …

i.e. the speed of gas molecules are highly influenced by temperature. Higher temperature equals higher speed & higher pressure. As such the pressure x volume of a gas inside an object is held constant.

When the temperature of a given quantity of gas is kept constant, however, the pressure *p* is related to the volume *V* as shown.

$$pV = \text{constant}$$

If the pressure is doubled, the volume is halved. This relationship is referred to as *Boyle's law*.

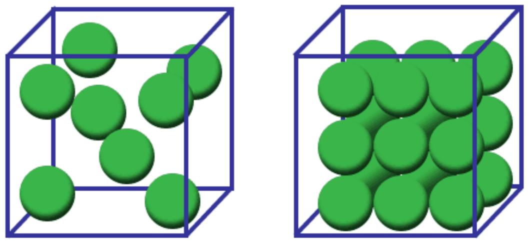
$$p_1V_1 = p_2V_2$$

Units: SI N/m^2 , Pascal ($1Pa = N/m^2$), PSI (lb/in^2), (lb/ft^2),in.Hg .

Density

Mass Density: The mass per unit volume of substance. The mass of a quantity of a substance divided by the volume it occupies

$$D = \frac{m}{V} \left(\frac{kg}{m^3}\right)$$



Pressure & density are a different presentation of force & mass respectively.

Pressure is a measure of the intensity & concentration of force.

Density is a measure of the intensity & concentration of mass.

Notation: we use capital D for Density and keep small d for distance.

To calculate the mass density of a substance, we measure or calculate its mass then divide by its volume – that simple!

Units: SI kg/m^3 , (g/m^3), slug per cubic

Space - Quantization

A good tool to calculate pressure among other things, we must know how to quantize ***Space***:

1D = Length / 2D = Surface Area / 3D = Volume.

Must know the difference between surface and volume and their respective units. Must know how to calculate the surface and volume of common objects:

- Volume of Box = L x W x H (Length*Width*Height)
- Volume of Cylinder = $\pi R^2 \times H$ (it is the surface area of circle * height)
- Volume of Sphere = $4/3 \pi R^3$

Practice with Cheat-Sheet

Units: SI kg/m^3 , (g/m^3), slug per cubic foot.

Practice - Pressure

Using the given dimensions, find the volume of the following objects:

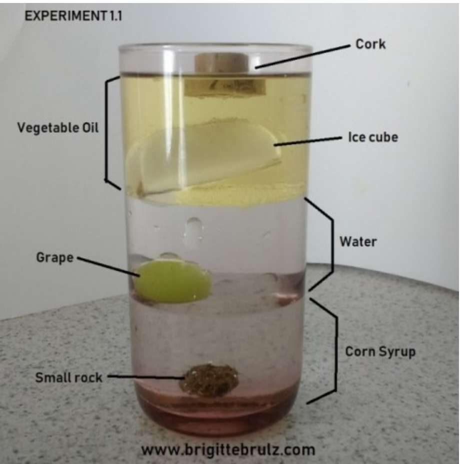
1. Box: L = 1 m, W = 3 m, H = 0.5 m
2. Barrel: The diameter = 23in, the Height = 34in
3.
    - Basket Ball, size 7 (diameter, 29.5in = 0.75 m)
    - Hydrogen Atom (1.06×10^{-10} m)
    - Proton (0.84×10^{-15} m)
    - The sun (1.38×10^{9} m)
    - Human cell (7.5 microns)

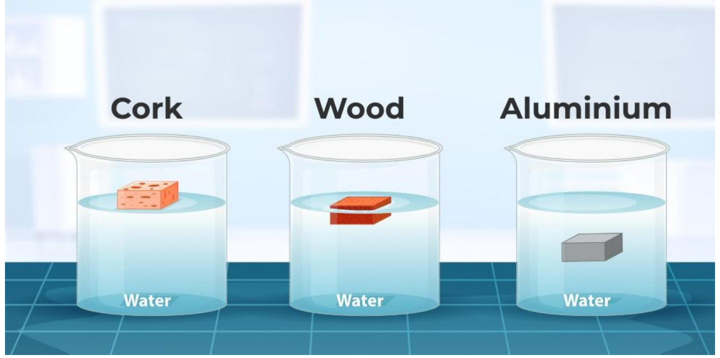
Density

Mass Density: The mass per unit volume of substance. The mass of a quantity of a substance divided by the volume it occupies

Density is very useful for forensic science from medical, to criminal investigation, archeology.

It is very important when evaluating the rate at which blood flows in human artery relative to factors such as the diameter of the artery.





Units: SI kg/m^3 , (g/m^3), slug per cubic

Density

Density of common materials, P140 of text book.

Note For all practical purposes, Densities are considered to be stable. (Do not change over time)

However, gases densities change with temperature. So gas densities are measured under given “ambient” standardized temperatures and pressures.

Substance	Type*	Mass Density, D (kg/m^3)	Weight Density, D_w (lb/ft^3)	Specific Gravity
Solids				
Styrofoam	m	37	2.3	0.037
Juniper wood	m	560	35	0.56
Ice	c	917	57.2	0.917
Ebony wood	m	1,200	75	1.2
Concrete	m	2,500	156	2.5
Aluminum	e	2,700	168	2.7
Granite	m	2,700	168	2.7
Diamond	e	3,400	210	3.4
Iron	e	7,860	490	7.86
Brass	m	8,500	530	8.5
Nickel	e	8,900	555	8.9
Copper	e	8,930	557	8.93
Silver	e	10,500	655	10.5
Lead	e	11,340	708	11.34
Uranium	e	19,000	1,190	19
Gold	e	19,300	1,200	19.3
Liquids				
Gasoline	m	680	42	0.68
Ethyl alcohol	c	791	49	0.791
Water (pure)	c	1,000	62.4	1.00
Seawater	m	1,030	64.3	1.03
Antifreeze	m	1,100	67	1.1
Sulfuric acid	c	1,830	114	1.83
Mercury	e	13,600	849	13.6

Weight Density & Specific Gravity

Weight Density: The **weight force** per unit volume of a substance. The weight of a quantity of a substance divided by the volume it occupies

$$D_W = \frac{W}{V}$$

Sometimes it is more convenient to use weight force density as opposed to mass density. In particular for British physics. Most of the time we will use Mass Density and occasionally we use Weight Density. Note the unit has changed from kg/m^3 , N/m^3

Specific Gravity: The ratio of the density of a substance to that of water.

$$SG = \rho = \frac{D_{Substance}}{D_{Water}}$$

For instance, the specific gravity of Diamond is 3.4 and the specific gravity of Gasoline is 0.68 see density table for more information – though SG is already on the table, SG is easy to measure

Units: SI N/m^3 , (lb/ft^3), (lb/in^3).

Summary Mass Density, Weight Density & Specific Gravity

Mass Density	$D = \frac{m}{V}$	kg/m^3, $(slug/ft^3)$
Weight Density	$D_w = \frac{W}{V}$	N/m^3, (lb/ft^3), (lb/in^3)
Specific gravity	$SG = \rho = \frac{D_{Substance}}{D_{Water}}$	No Units!

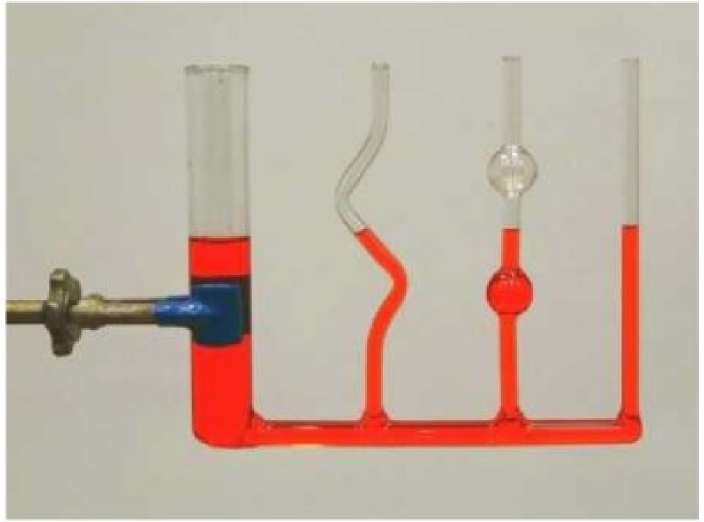
The table is very useful

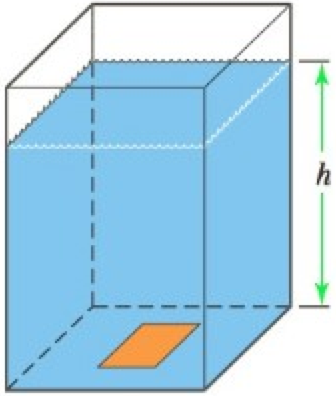
Fluid Pressure & Gravity

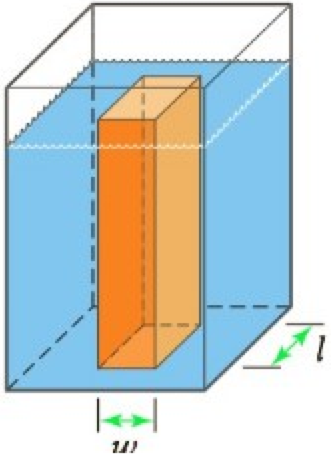
Fluid Pressure: The (gauge) pressure at any depth in a fluid at rest equals the weight of the fluid in column extending from that depth to the "top" of the fluid divided by the cross-sectional area of the column.

Fluid Pressure is still pressure, so the units are still the same.
The following pic, the pressure at the bottom is exactly the same.

$$p = \frac{F_{\perp}}{A} = \frac{W}{A} = \frac{weight\ of\ Liquid}{cross-sectioinal\ area}$$







Units: SI N/m^2 , Pascal ($1Pa = N/m^2$), PSI (lb/in^2), (lb/ft^2),in.Hg .

Fluid Pressure & Gravity

Fluid Pressure: In a liquid, the absolute pressure at a depth is greater than the pressure at the surface by an amount equal to the weight density of the liquid times the depth.

$p = D_w\,h = Dgh$

Does not matter the size of the area – the pressure depend on the Height and density – lets derive it.

$p = \frac{F}{A}$, what is F? $F = m * a$,

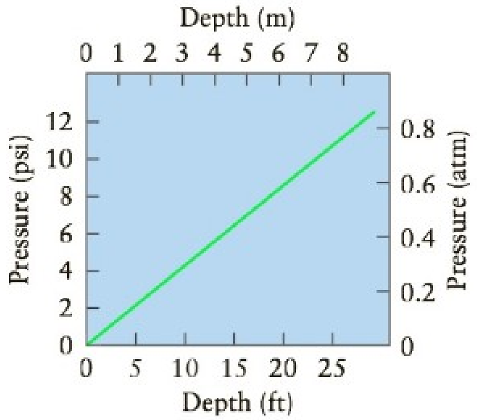
Now what is a? $a = g$ where $g = 9.8\ \frac{m}{s^2}$

How about m? from density $m = D * V$

Reorganizing $p = \frac{D*V*g}{A}$ voulme of a box $V = A * h$

Finally 2 equations:

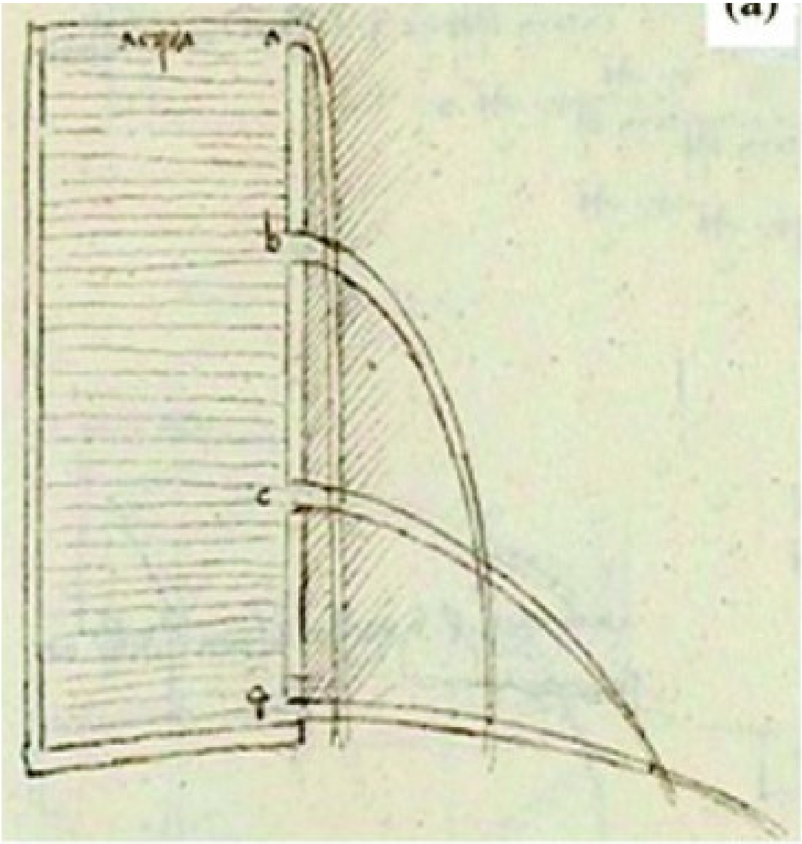
- Using Mass Density $p = Dgh$
- Using Weigh Density $p = D_w\ h$

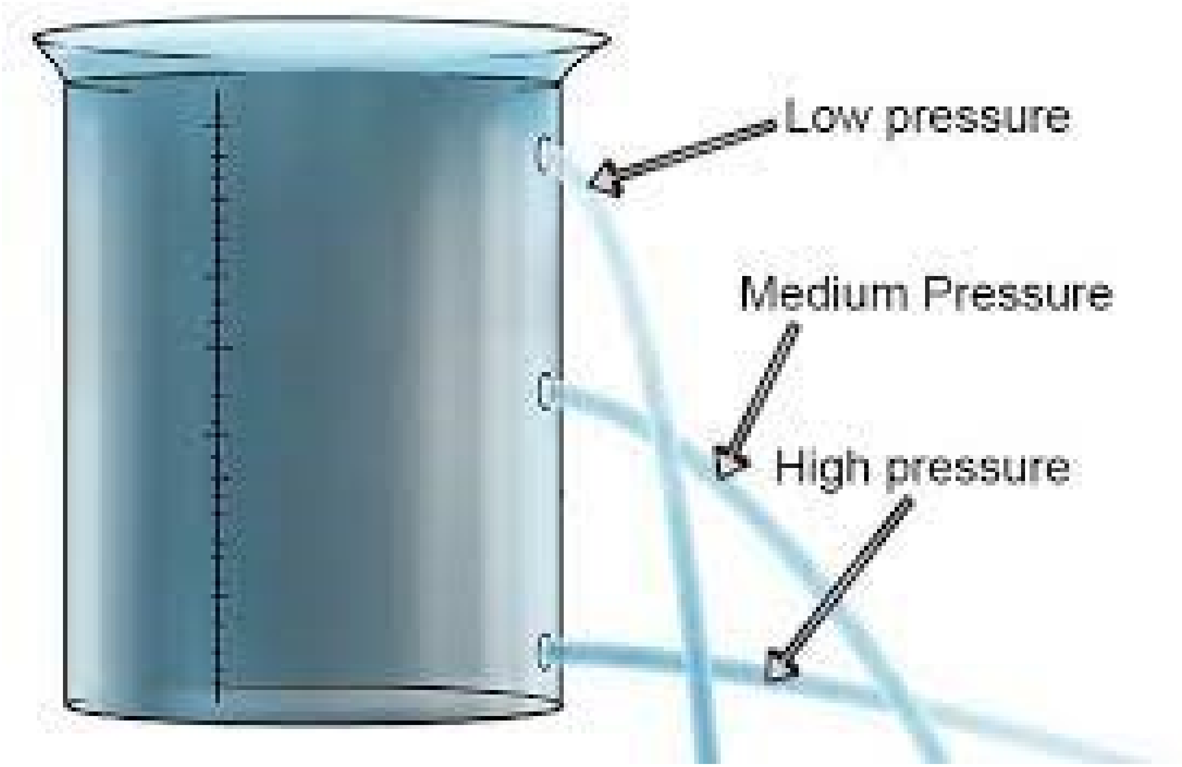


Units: SI N/m^2 , Pascal (1Pa = N/m^2), PSI (lb/in^2), (lb/ft^2),in.Hg .

Fluid Pressure & Gravity

Davinci, if we put a force gage or pressure gage. The measured force / pressure at the bottom is much higher than the top. A good confirmation is by looking at the jet.





Units: SI N/m^2 , Pascal (1Pa = N/m^2), PSI (lb/in^2), (lb/ft^2),in.Hg .

Practice - Pressure

- What is the “gauge” pressure at the bottom of a typical pool if you are down at 5ft from the top?
- What would be the pressure if we double the depth?
- What would be the pressure if you are in the ocean at a depth of 40ft, then at 47ft?

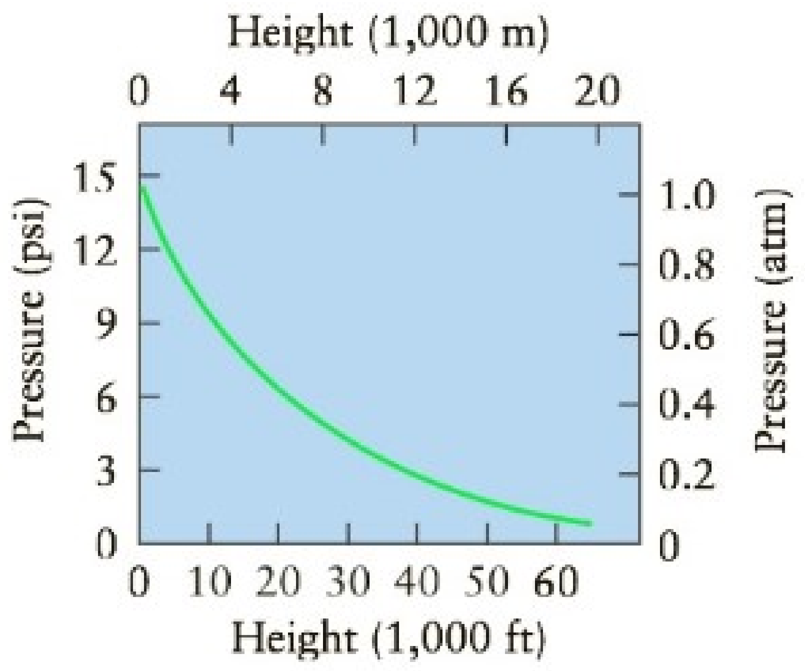
Fluid Pressure & Gravity

Be Careful, fluid might be a liquid or gas. The relation of air pressure to height is not linear.

Do you know that we carry air on top of us every day.

You are carrying less air on the top off a mountain than on sea level

Picture time!

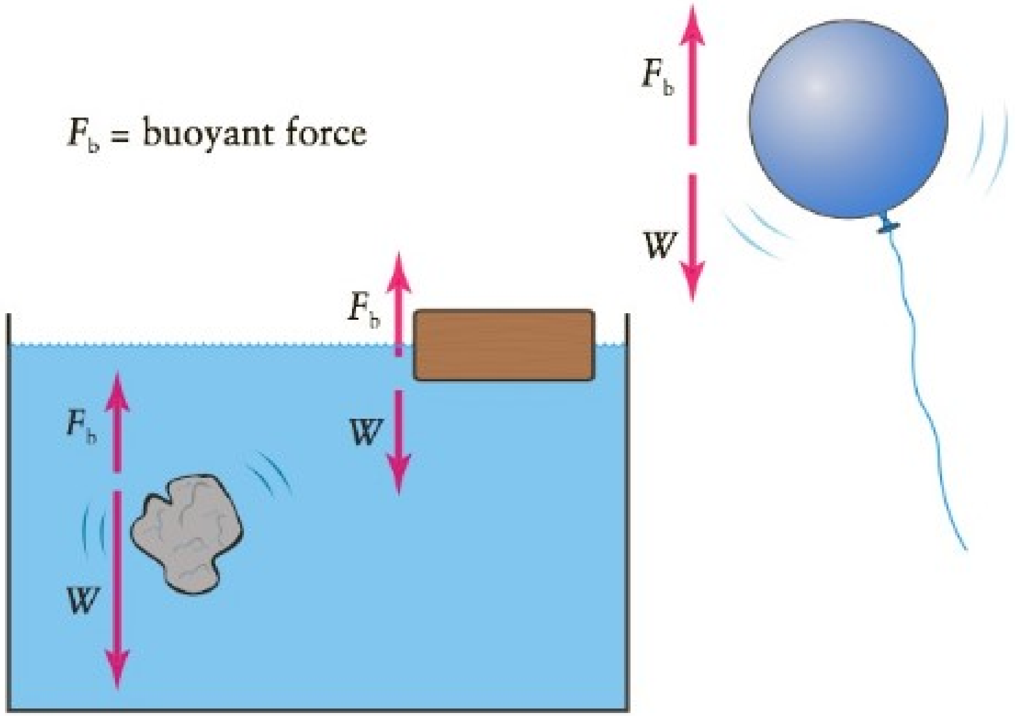


Units: SI N/m^2 , Pascal ($1Pa = N/m^2$), PSI (lb/in^2), (lb/ft^2),in.Hg .

Archimedes' Principle.

Buoyant Force: The upward force exerted by a fluid on a substance partly or completely immersed in it.

- Gravitational force causes an increase of pressure with depth in a given fluid. The deeper you go in an ocean the more pressure you feel.
- 3 cases (Vertical Motion Newtons 2nd Law)
  - Fb > W (Upward)
  - Fb = W (no motion, float, equilibrium)
  - Fb < W (Downward)

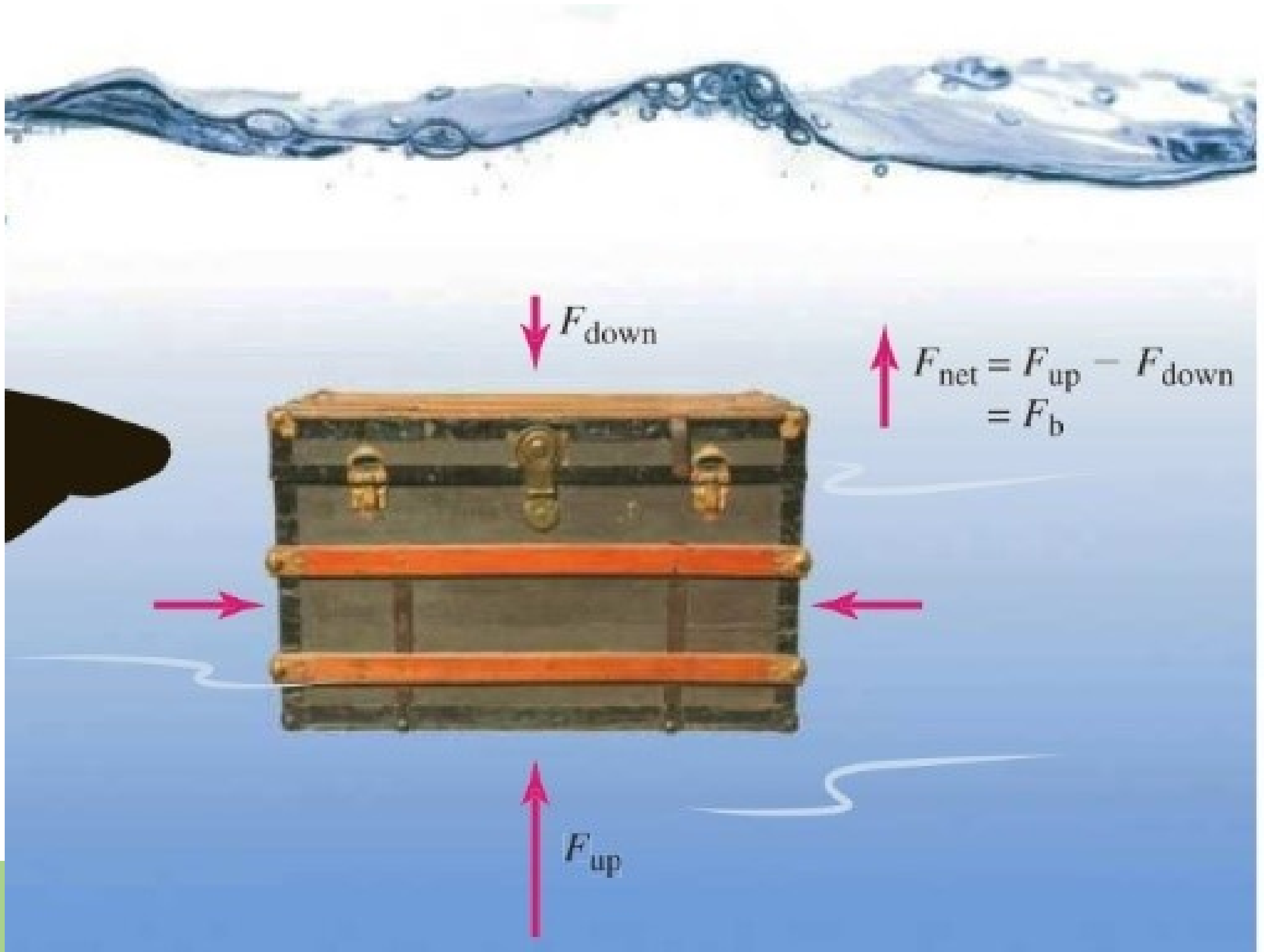


Units: SI Newton N.

Archimedes' Principle.

Buoyant Force: The upward force exerted by a fluid on a substance partly or completely immersed in it.

- Gravitational force causes an increase of pressure with depth in a given fluid. The deeper you go in an ocean the more pressure you feel.
- Fluid pressures act in all directions.
- Gravity causes pressure in fluid to vary with depth only (not horizontal).
- Force acting down is lower that force acting up – from fluid pressure.



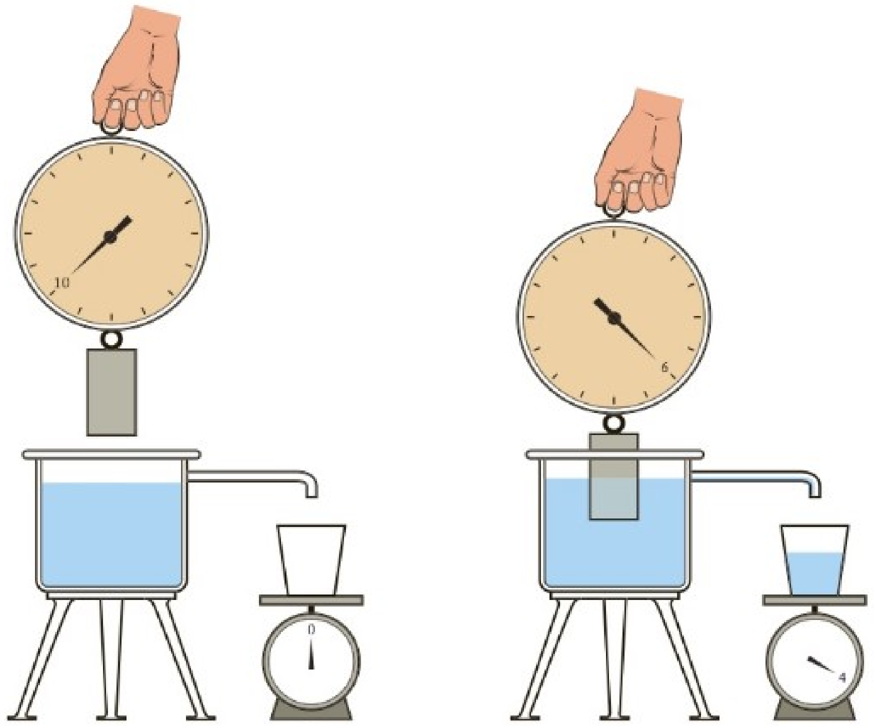
Units: SI Newton N.

Archimedes' Principle.

Archimedes' Principle: The buoyant force acting on a substance in a fluid at rest is equal to the weight of the fluid displaced by the substance.

- The weight of an object is 10 N
- When submerged into water the scale reads lower weight.
- Notice Pic 1, 10N, and Pic2 , 6N
- Also the displaced water is 4N

$$F_b = weigh\ of\ displaced\ fluid$$



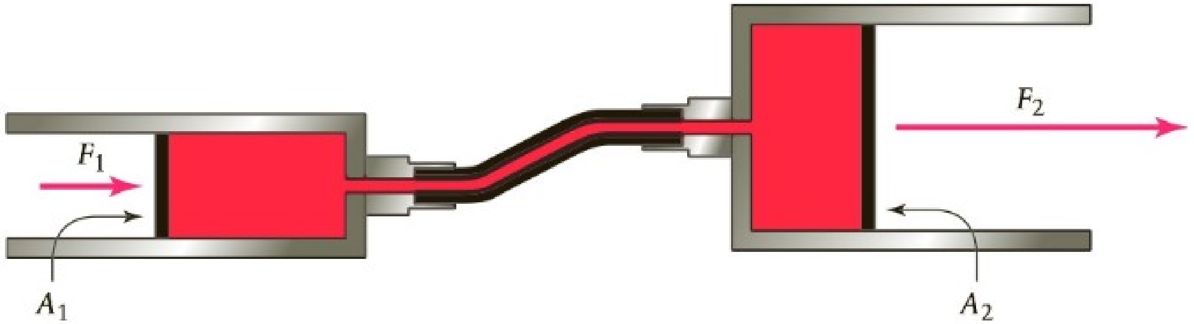
Units: SI Newton N.

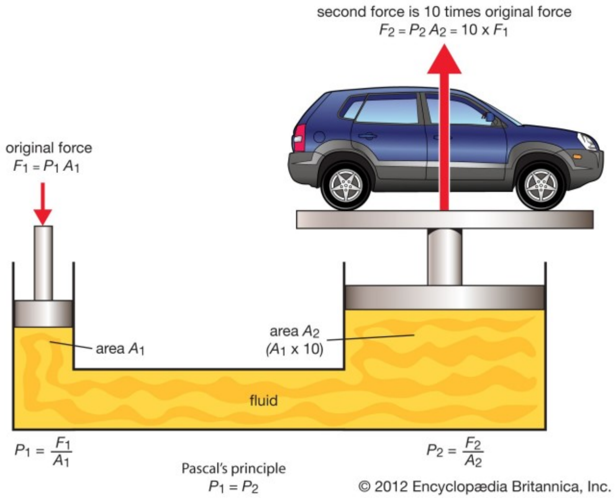
Pascals Principle – it is kind of conservation law – hour glass.

Pascals Principle: Pressure applied to an enclosed fluids is transmitted ***undiminished*** to all parts of the fluid and to the walls of the container.

- When a force is applied on solid vs liquid, vs gas that force is transmitted, and the response of the subject is different a solid might move, a fluid is pushed, a gas could be compressed.
- When the force is transmitted equally to all sides. For fluids with rigid wall, when fluid moves from one area to another the pressure remains constant - syringe.
- Hint: Always start with Pressure, then derive for F or A or whatever.

$$p = \frac{F}{A}\left(\frac{N}{m^2}\right) = \frac{F_1}{A_1} = \frac{F_2}{A_2} = constant$$





$$F_1 = \frac{A_1}{A_2} F_2$$

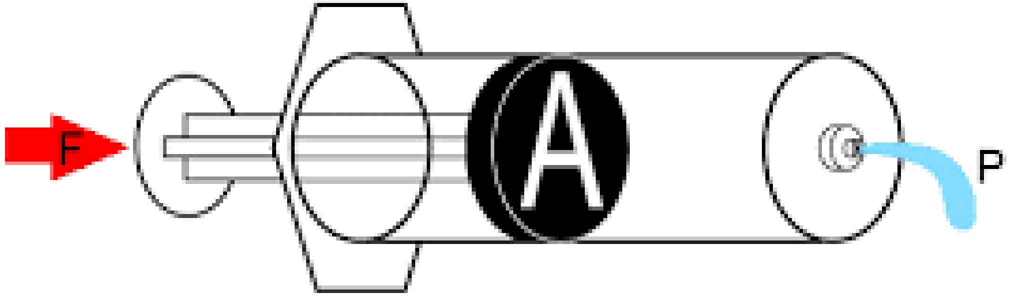
Units?

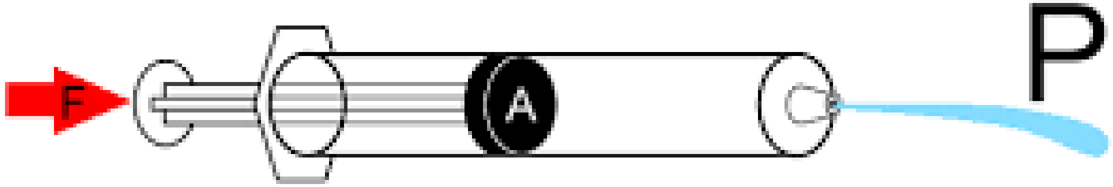
Pascals Principle – it is kind of conservation law – hour glass.

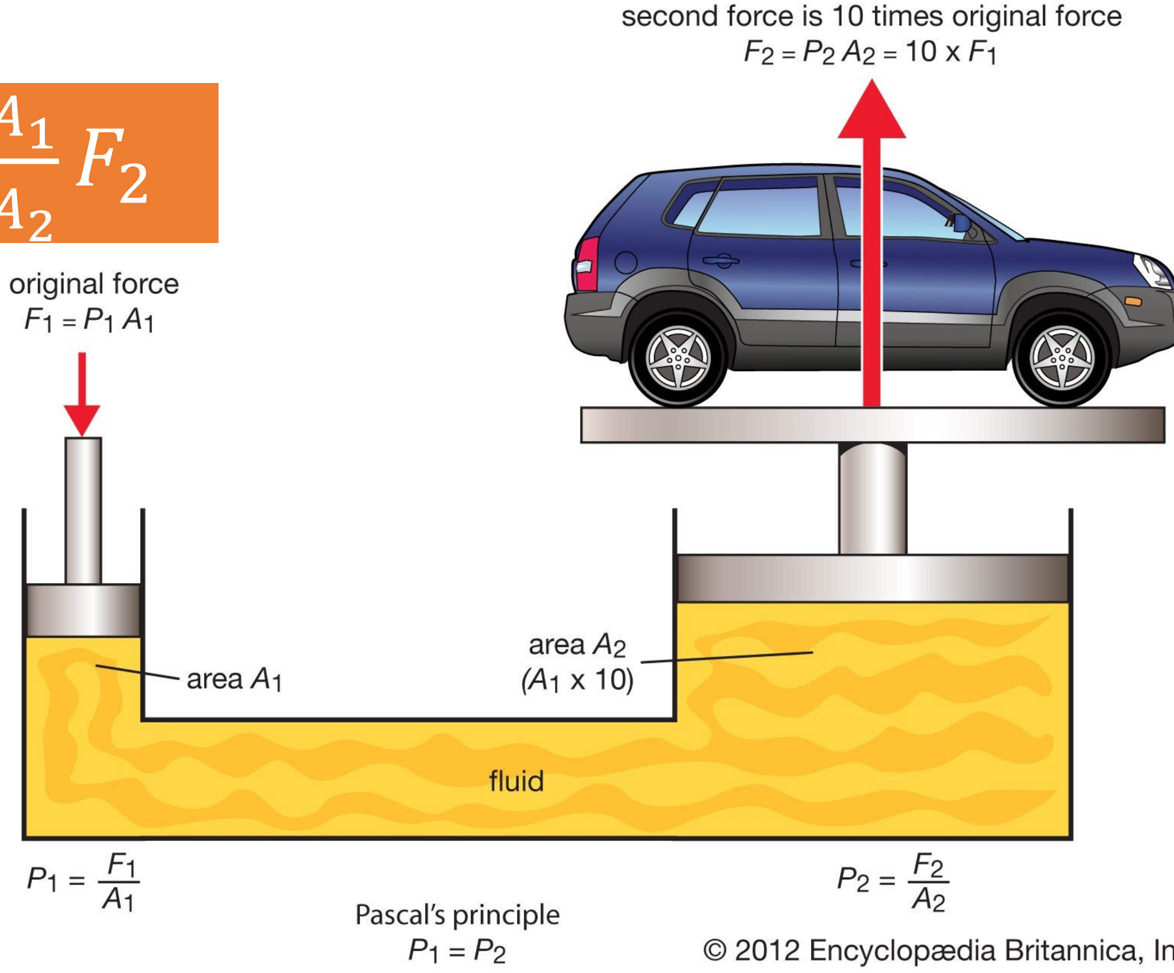
Pascals Principle: Pressure applied to an enclosed fluids is transmitted ***undiminished*** to all parts of the fluid and to the walls of the container.

- Do not memorize results, read the question, start with constant pressure then derive.

$$F_1 = \frac{A_1}{A_2} F_2$$







Practice - Pressure

By how much you need to increase the surface area of a hydraulic lift in order for your weight to overcome the mass of a Nissan’s mass of 1625kg? Assume your mass is 85 kg.

If the area of the piston your are sitting on is 10 in^2, what would be the surface area of the hydraulic lift piston?

Bernoulli's Principle, it is kind of conservation law – hour glass.

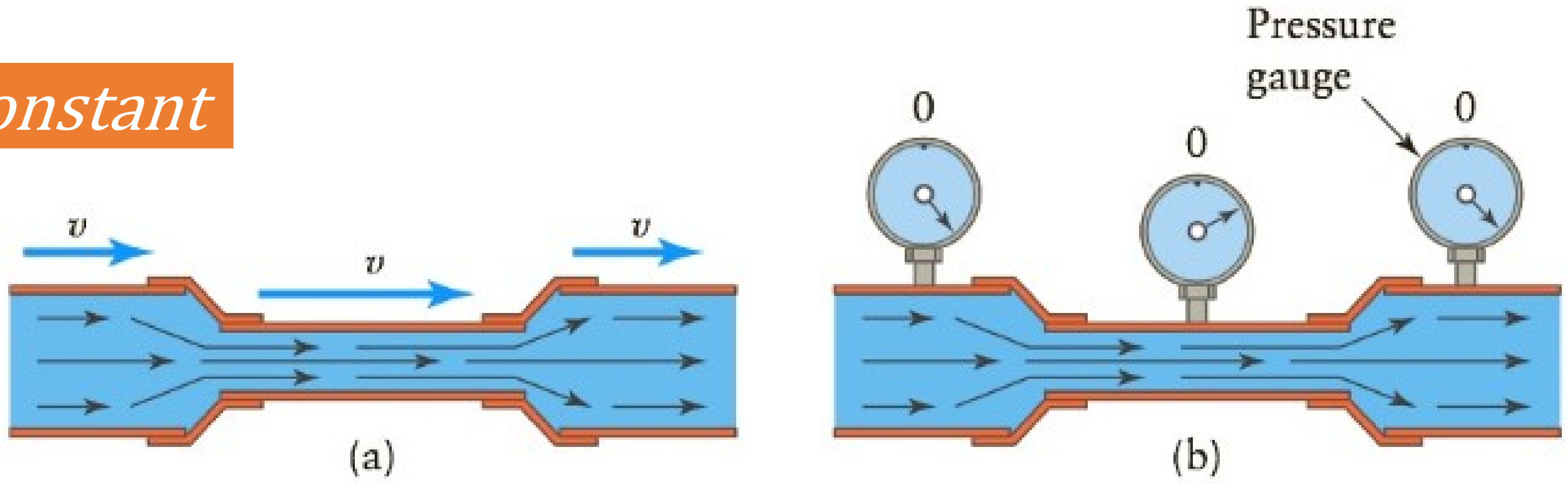
Bernoulli's Principle: For a fluid undergoing steady flow, the pressure is lower where the fluid is flowing faster.

- Undergoing Steady flow, that means this fluid is in motion (i.e. running water)
- The continuity equation, known as Bernoulli's Principle. v is velocity NOT Volume

$$p_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2 = Constant$$

For all practical purposes and for the sake of this class we reduced it to following:

$$A_5 v_5 = A_8 v_8 = constant$$



Bernoulli's Principle, it is kind of conservation law – hour glass.

- From the previous continuity equation $A_1 v_1 = A_2 v_2$ We can rewrite the units as: $(meter)^2 \times (meters/second) = (meters)^3/(second) = volume/time$.
- The rate of change of volume per unit time is known as volumetric flow rate.
- For those having issues with cross multiplication it highly recommended to practice the following form of the continuity equation $\frac{v_1}{v_2} = \frac{A_2}{A_1}$.

Practice Bernoulli's Principle

A common garden hose has an opening with a cross-sectional area of 5.1×10^{-4} m^2. When the spigot is opened, the water emerges from the hose with a speed of 0.85 m/s. If the gardener places her finger over the opening and reduces the area to 2.0×10^{-4} m^2, how fast will the water now exit the hose?

$$A_1 v_1 = A_2 v_2$$

$$v_2 = \left(\frac{A_1}{A_2}\right) v_1$$

$$v_2 = \frac{(5.1 \times 10^{-4}\ \mathrm{m}^2)}{(2.0 \times 10^{-4}\ \mathrm{m}^2)} (0.85\ \mathrm{m/s})$$

$$v_2 = 2.17\ \mathrm{m/s}$$

Note: $v_2 = 2.17\ \mathrm{m}/s$ which is higher than $v_1 = 0.85\ \mathrm{m/s}$. It is expected - the garden hose went from higher surface area A_1 to lower surface area A_2