Civil Eng. Orientation 2.

Pressure and its Measurement

One day, Einstein, Newton, and Pascal meet up and decide to play a game of hide and seek. Einstein volunteered to be “It.” As Einstein counted, eyes closed, to 10, Pascal ran away and hid.

Newton is sitting right in front of Einstein, with a piece of chalk in his hand. He’s sitting on a one meter by one meter square drawn on the ground.

Einstein says “Newton you’re… terrible, I’v found you!”

Newton says “No, no, Einy. You’ve found one Newton per square meter. You’ve found Pascal!”

If the force (F) is uniformly distributed over the area (A), then pressure at any point is given by

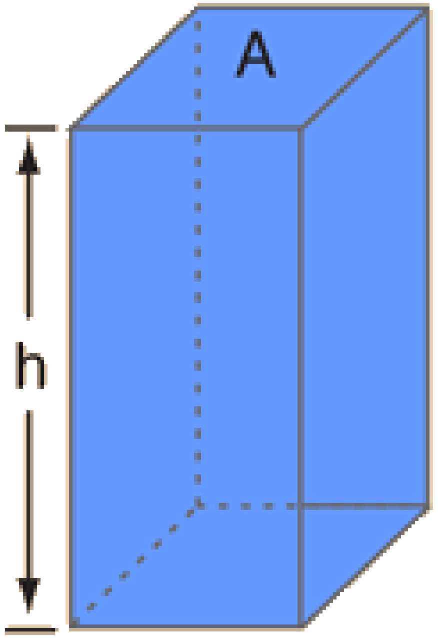
$$p = \frac{F}{A} = \frac{\text{Force}}{\text{Area}}.$$

$\therefore$ Force or pressure force, $F = p \times A$.

The units of pressure are : (*i*) kgf/m^2 and kgf/cm^2 in MKS units, (*ii*) Newton/m^2 or N/m^2 and N/mm^2 in SI units. N/m^2 is known as Pascal and is represented by Pa. Other commonly used units of pressure are :

$$\text{kPa} = \text{kilo pascal} = 1000 \text{ N/m}^2$$

$$\text{bar} = 100 \text{ kPa} = 10^5 \text{ N/m}^2.$$

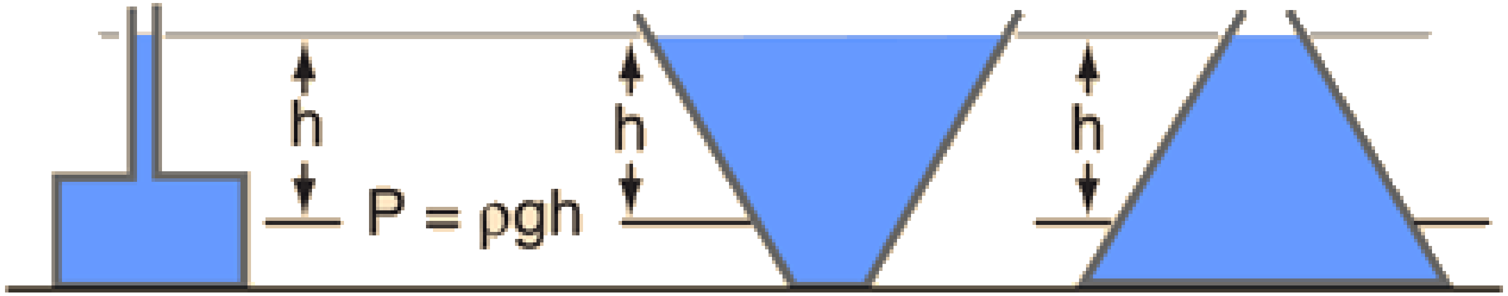


$V = hA = \text{volume}$

$\text{weight} = mg$

Static fluid pressure does not depend on the shape, total mass, or surface area of the liquid.

$$\text{Pressure} = \frac{\text{weight}}{\text{area}} = \frac{mg}{A} = \frac{\rho V g}{A} = \rho g h$$



Static Fluid Pressure

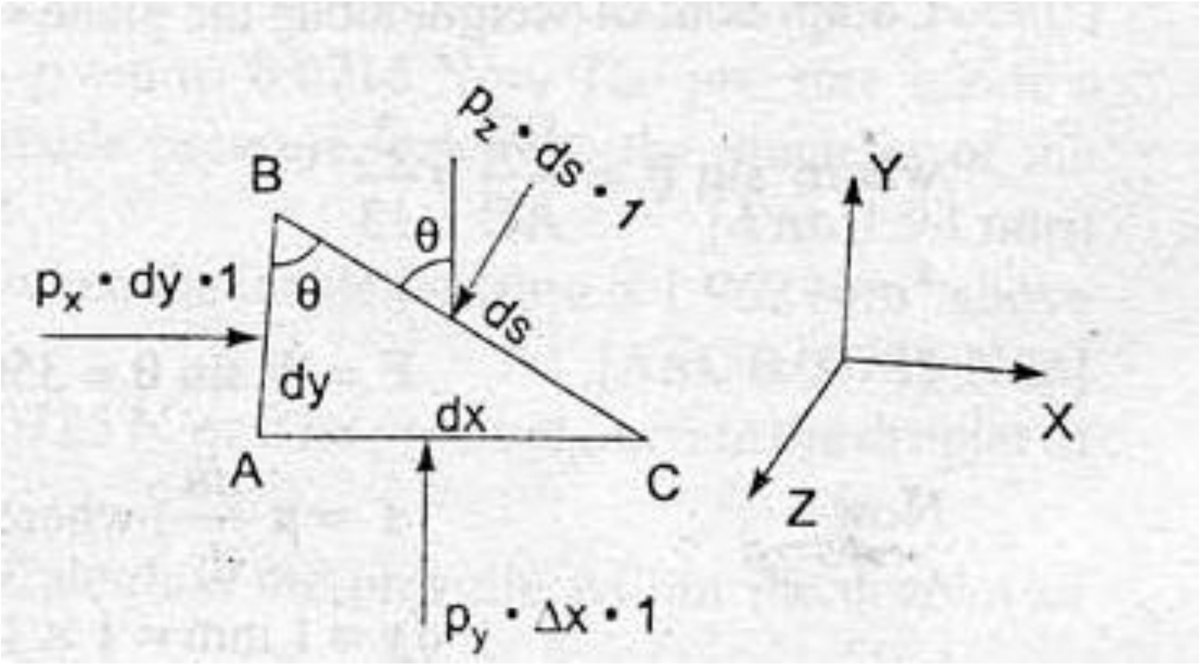
The pressure exerted by a static fluid depends only upon the depth of the fluid, the density of the fluid, and the acceleration of gravity.
The pressure in a static fluid arises from the weight of the fluid and is given by the expression

$P_{static\ fluid} = \rho gh$
where
$\rho = m/V$ = fluid density
g = acceleration of gravity
h = depth of fluid

PASCAL'S LAW

- The pressure or intensity of pressure at a point in a static fluid is equal in all directions!

$$p_x = p_y = p_z$$



Pascal's Law

Example 2·3. *The diameters of ram and plunger of an hydraulic press are 200 mm an 30 mm respectively. Find the weight lifted by the hydraulic press when the force applied at th plunger is 400 N.*

Sol. Diameter of the ram,

$D = 200 \text{ mm} = 0{\cdot}2 \text{ m}$

Diameter of the plunger,

$d = 30 \text{ mm} = 0{\cdot}03 \text{ m}$

Force on the plunger,

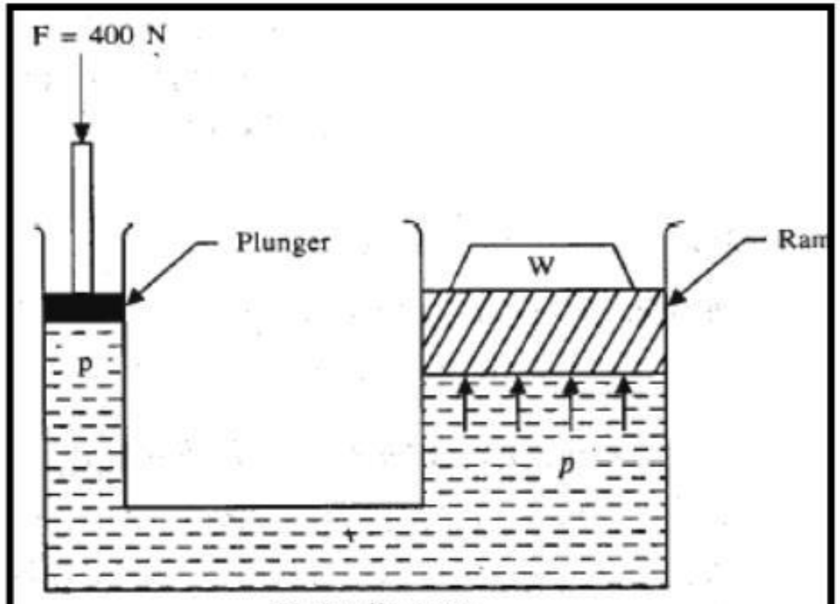
$F = 400 \text{ N}$

Area of ram,

$$A = \frac{\pi}{4} D^2 = \pi/4 \times 0{\cdot}2^2 = 0{\cdot}0314 \text{ m}^2$$

Area of plunger,

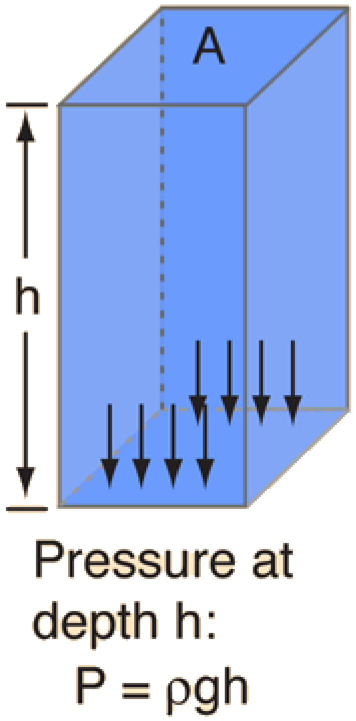
$$a = \frac{\pi}{4} d^2 = \frac{\pi}{4} \times 0{\cdot}03^2 = 7{\cdot}068 \times 10^{-4} \text{ m}^2$$



Hydraulic press.

Fluid Pressure Calculation

Fluid column height in the relationship



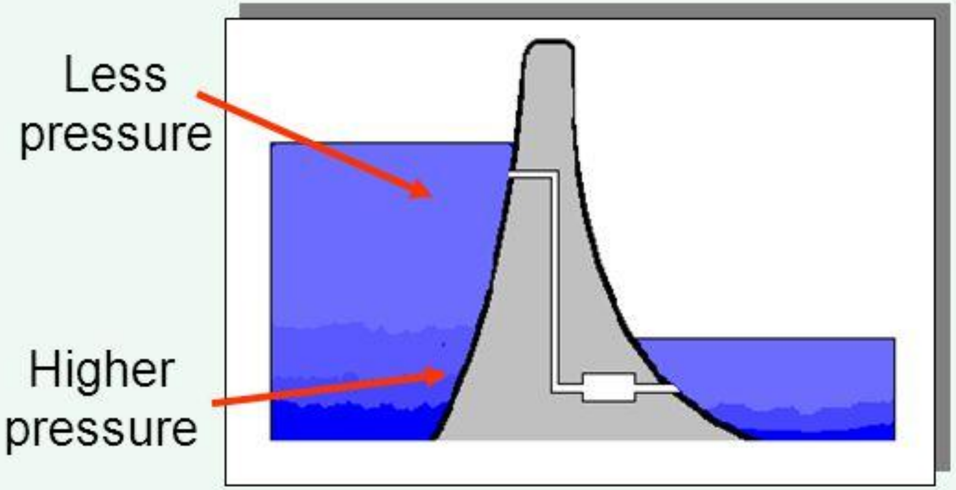
Fluid Pressure

The pressure in **SOLIDS** always acts **DOWNWARDS** because of the **PULL** of **GRAVITY**.

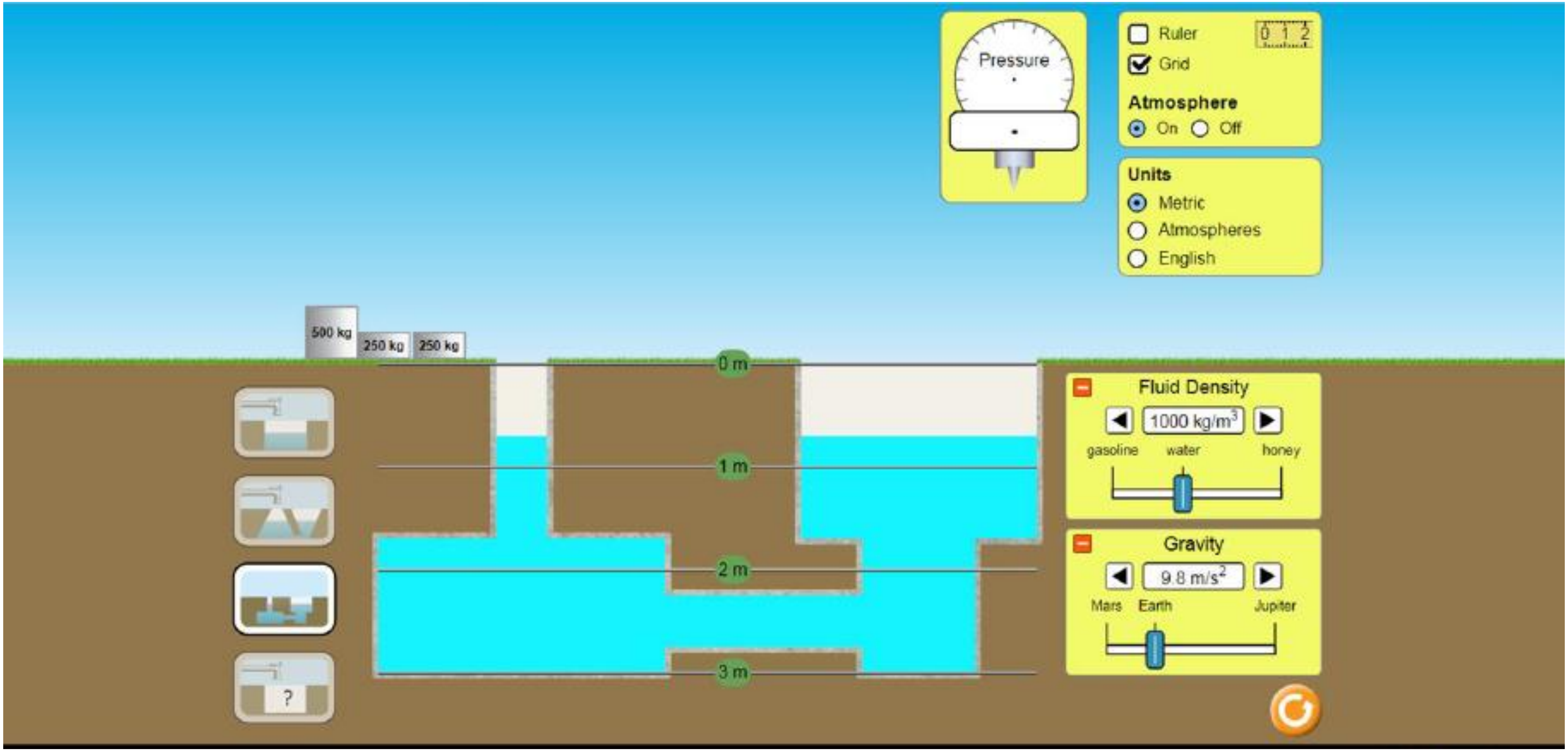
In **FLUIDS** (**LIQUIDS** and **GASES**) the pressure acts **IN ALL DIRECTIONS**.

Pressure in fluids can be used to **TRANSFER FORCES**.

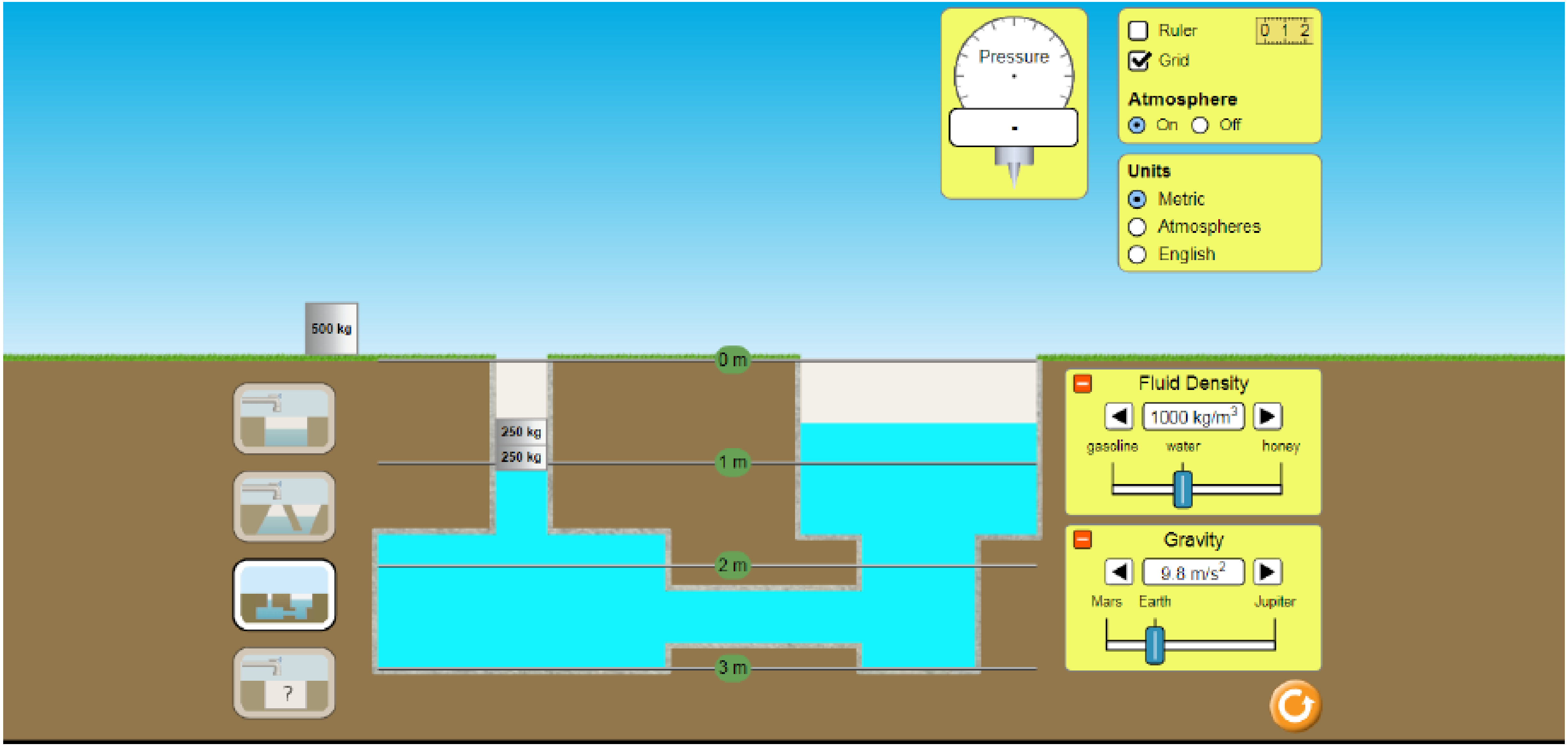
Also, in fluids, the **PRESSURE INCREASES WITH DEPTH**.



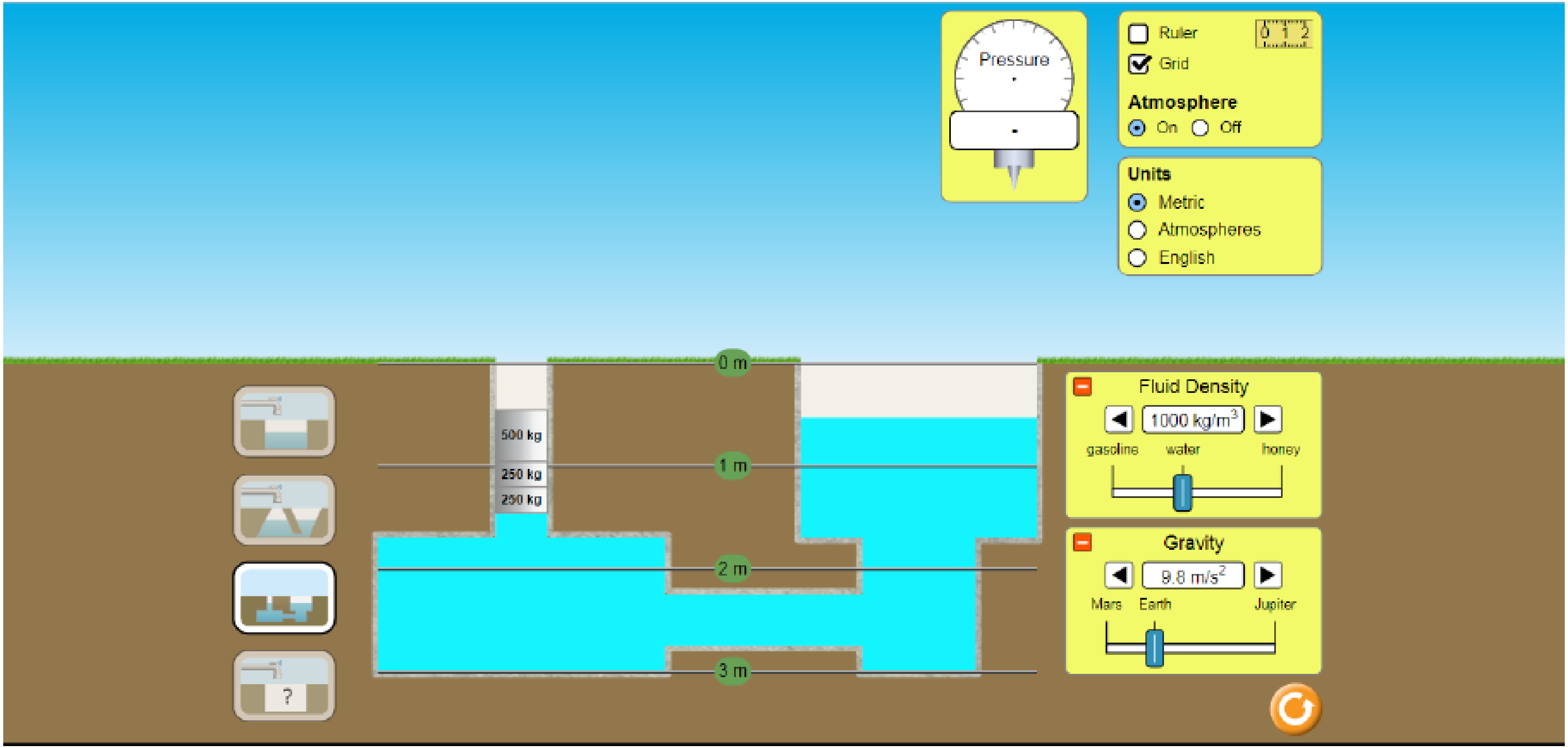
DAMS are **WIDER AT THE BOTTOM** than at the top because pressure increases with depth in water.



https://phet.colorado.edu/en/simulation/legacy/density



Pressure
Ruler
0 1 2
Grid
Atmosphere
On
Off
Units
Metric
Atmospheres
English
500 kg
250 kg
250 kg
0 m
1 m
2 m
3 m
?
Fluid Density
1000 kg/m³
gasoline
water
honey
Gravity
9.8 m/s²
Mars
Earth
Jupiter



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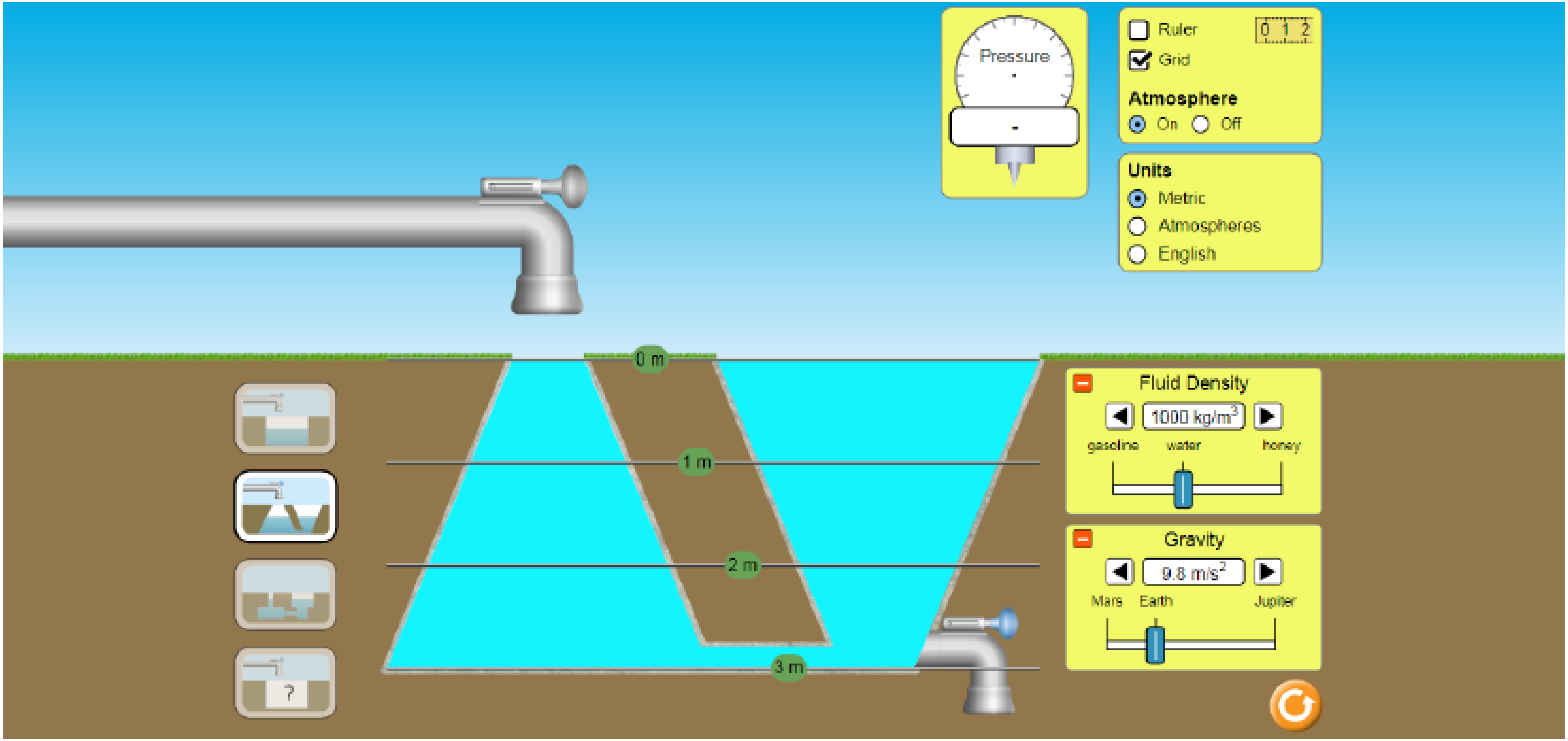

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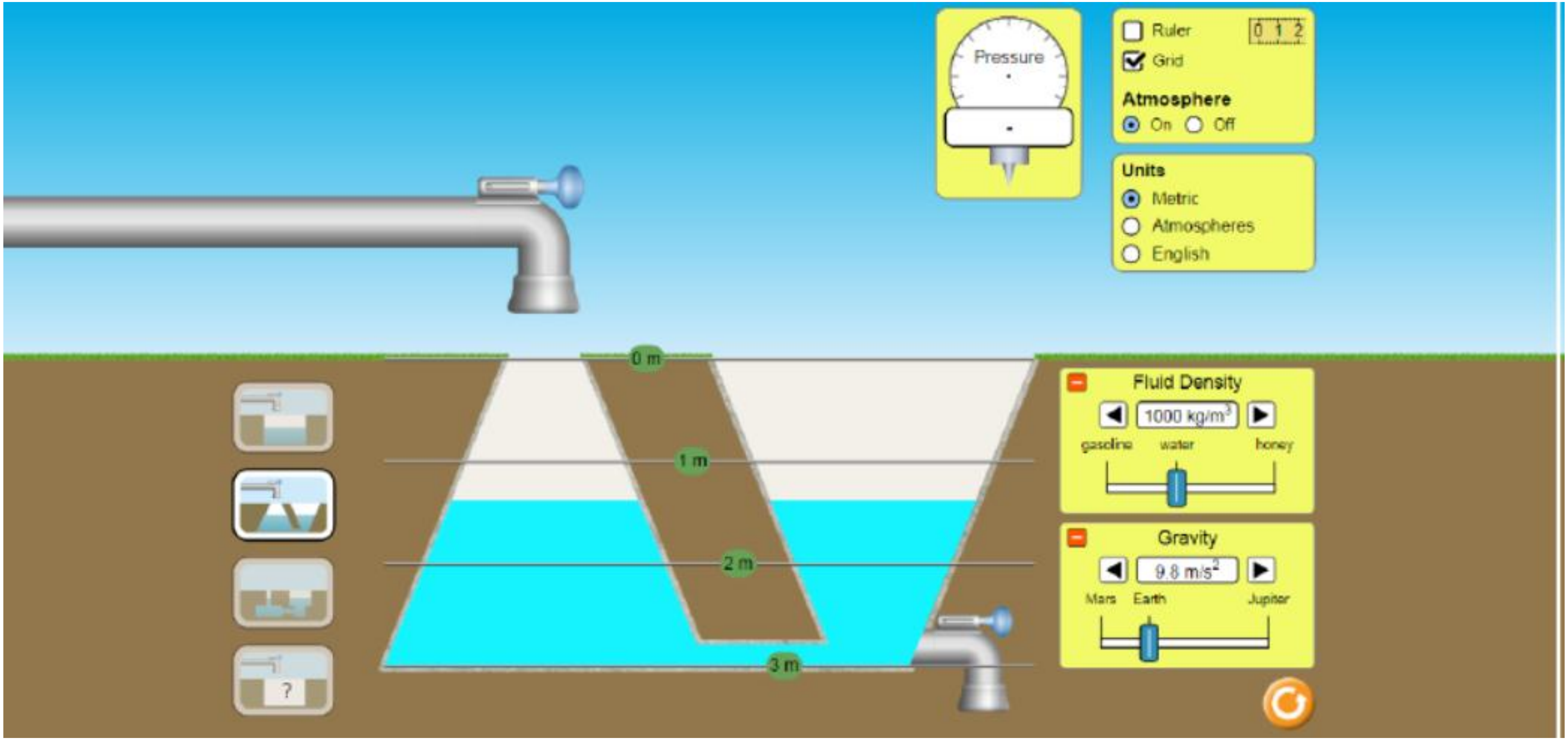

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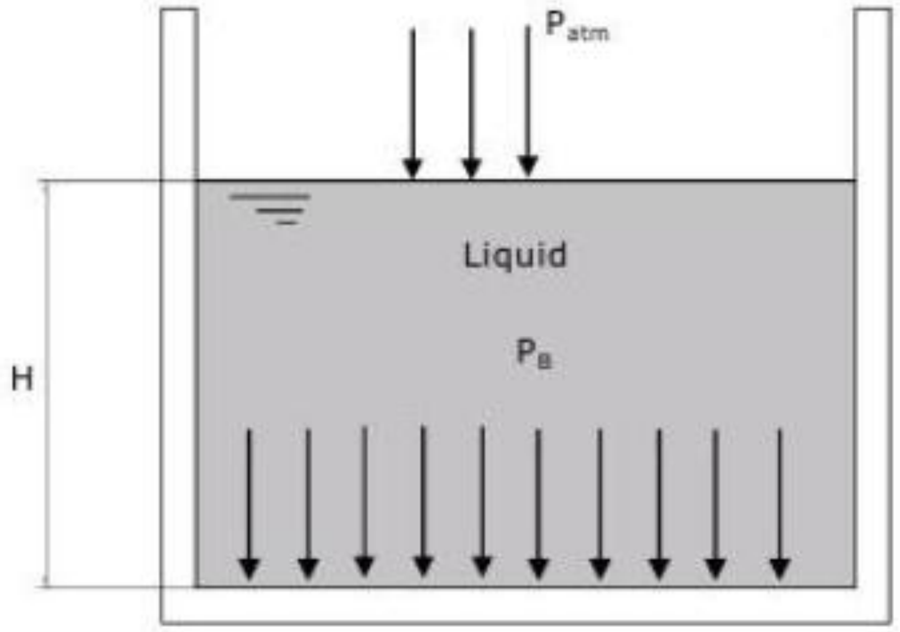
FLUIDS AT REST: FORCE CONSIDERATIONS

HORIZONTAL PLANE SURFACES SUBMERGED IN LIQUIDS



P_B = Pressure at bottom of tank due to the liquid head

γ = Specific weight of the liquid

H = Head of liquid above the tank

$$\mathbf{P_B = \gamma H}$$

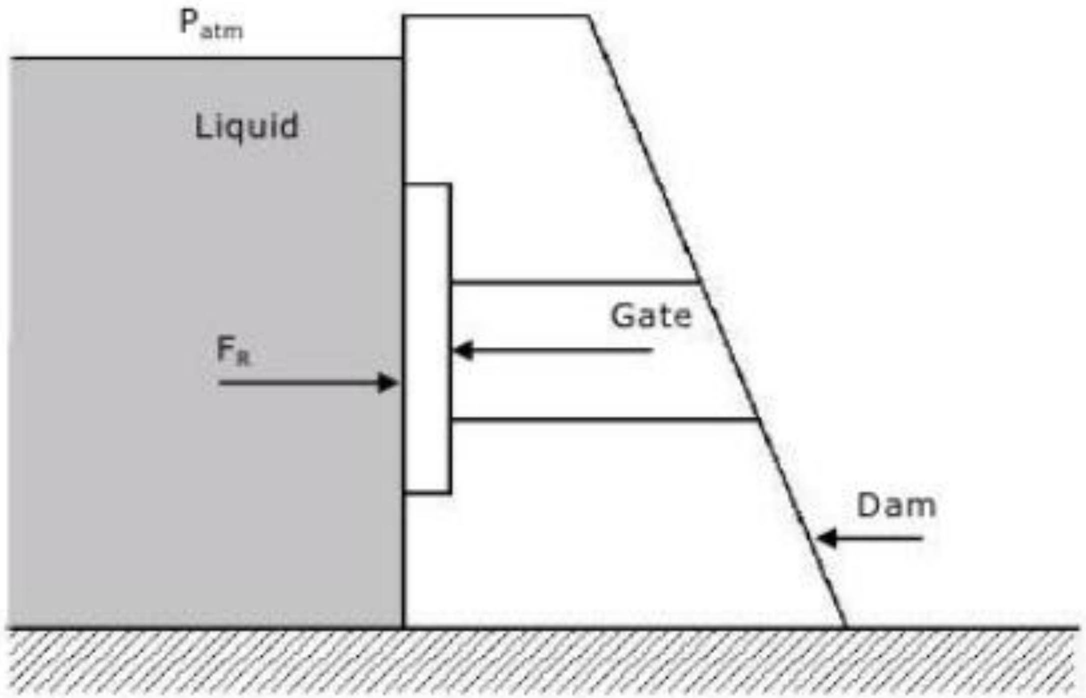
Magnitude of Resultant Force acting on the tank bottom is:

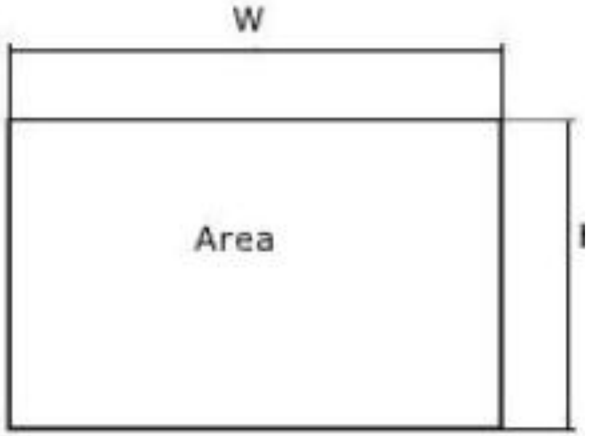
$$\mathbf{F_B = P_B A_B}$$

A_B = Area of the tank bottom

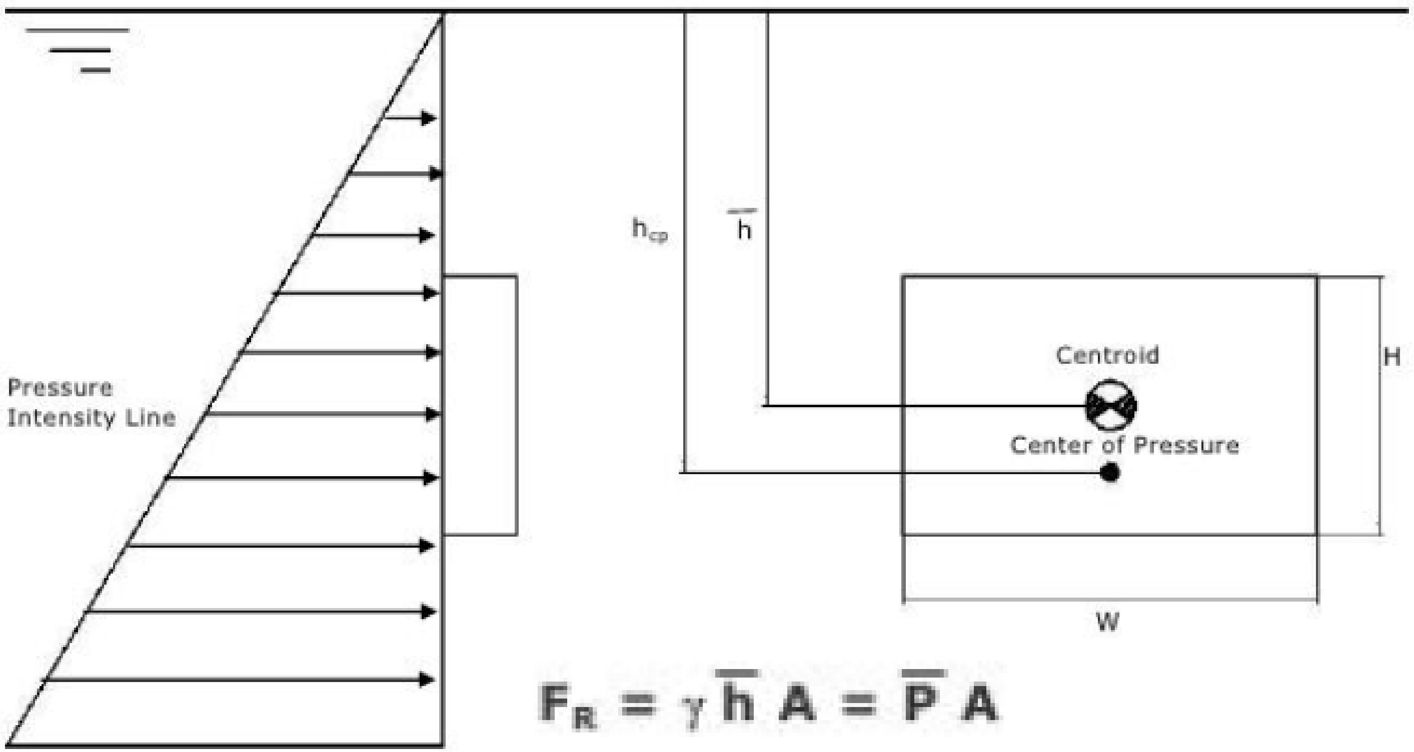
Note: Pressure is constant, Resultant F_B acts at the centroid of the tank bottom area.

VERTICAL PLANE SURFACES SUBMERGED IN LIQUIDS





Rectangular Gate of a Dam



$$F_R = \gamma \bar{h} A = \bar{P} A$$

γ = Specific weight of liquid

$\bar{h}$ = depth of the centroid of gate area

A = Area of gate

$\bar{P}$ = Pressure at centroid of gate area

F_R = Resultant force on gate area / Hydrostatic force on the gate

Problem 2.1 *A hydraulic press has a ram of 30 cm diameter and a plunger of 4.5 cm diameter. Find the weight lifted by the hydraulic press when the force applied at the plunger is 500 N.*

Solution. Given :

Dia. of ram, $D = 30 \text{ cm} = 0.3 \text{ m}$

Dia. of plunger, $d = 4.5 \text{ cm} = 0.045 \text{ m}$

Force on plunger, $F = 500 \text{ N}$

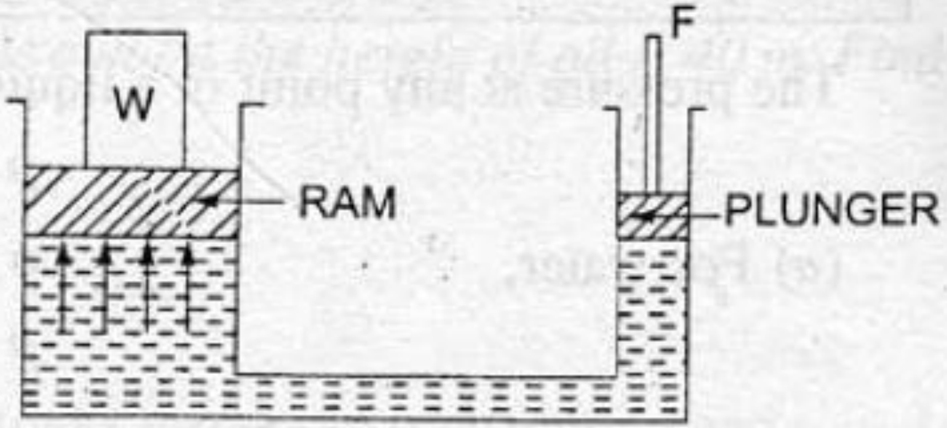
Find weight lifted $= W$

Area of ram, $$A = \frac{\pi}{4} D^2 = \frac{\pi}{4} (0.3)^2 = 0.07068 \text{ m}^2$$

Area of plunger, $$a = \frac{\pi}{4} d^2 = \frac{\pi}{4} (0.045)^2 = .00159 \text{ m}^2$$

Pressure intensity due to plunger

$$= \frac{\text{Force on plunger}}{\text{Area of plunger}} = \frac{F}{a} = \frac{500}{.00159} \text{ N/m}^2.$$



Due to Pascal's law, the intensity of pressure will be equally transmitted in all directions. Hence the pressure intensity at the ram

$$= \frac{500}{.00159} = 314465.4 \text{ N/m}^2$$

But pressure intensity at ram $= \dfrac{\text{Weight}}{\text{Area of ram}} = \dfrac{W}{A} = \dfrac{W}{.07068} \text{ N/m}^2$

$$\frac{W}{.07068} = 314465.4$$

Weight $= 314465.4 \times .07068 = 22222 \text{ N} =$ **22.222 kN.**