TENDER HEART HIGH SCHOOL, SEC-33'B, CHD

Date 22.4.24
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CLASS - IX

SUBJECT- PHYSICS

CHAPTER- 4

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Good morning Students! This lesson is of class-IX for the subject of 'Physics', Topic - 'Pascal's Law' and its Applications', which is covered in Chapter-4 'Pressure in Fluids and Atmospheric Pressure'.

PASCAL'S LAW: According to Pascal's law, The Pressure exerted anywhere in a confined (restricted in area) liquid is transmitted equally and undiminished in all directions throughout the liquid.

LET'S TRY TO UNDERSTAND THIS LAW BY DOING THIS FOLLOWING ACTIVITY: (you may take a break of 10 minutes and do this activity): Take a rubber ball and pierce some holes on the circumference of the ball at the same level (as shown below in figure-1). Now, dip this ball in water for some time. After certain duration of time, take the rubber ball outside the water and compress it gently. It will be observed that water rushes out from all the hole with equal pressure (as shown in figure-2)

FIGURE 1

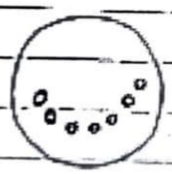
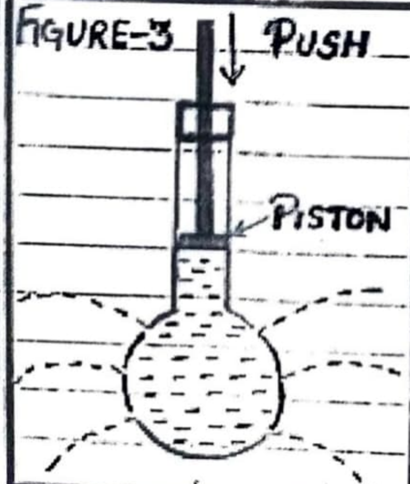


FIGURE-2

FIGURE-3



In figure 3, if we push the piston downwards, then a force is exerted per unit area (i.e. pressure) and this pressure is transmitted equally to each direction and the water will come out of each pierce (hole) with same pressure.

CHAPTER-4 PRESSURE IN FLUIDS AND ATMOSPHERIC PRESSURE

PRINCIPLE OF A HYDRAULIC MACHINE is that a small force applied on a smaller piston is transmitted to produce a large force on the bigger piston.
LET'S SEE IT WITH AN EXAMPLE OF **HYDRAULIC LIFT** (example of hydraulic machine).

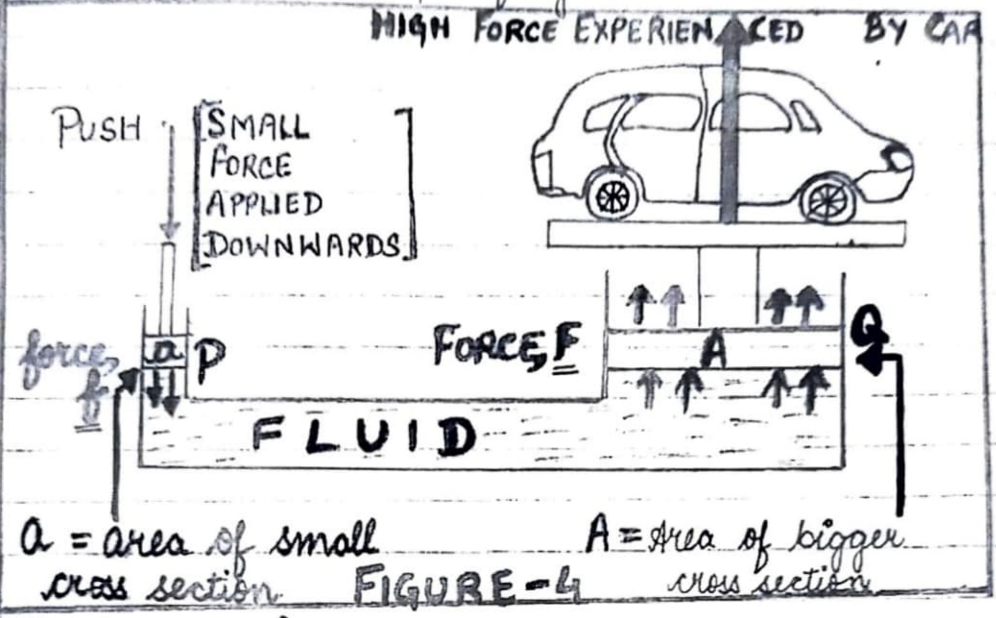


FIGURE-4

According to Pascal's Law:
Pressure exerted at point P = Pressure exerted at point Q
i.e. $f/a = F/A$

$\Rightarrow$ Force, F experienced by car $= \frac{f}{a} \times A$

as, $A > a$, hence $F > f$

EXPLANATION OF FIGURE-4 - If we have to lift a heavy load (say, a car) then it is possible to lift it by applying a much lesser force.
For doing so, we have to arrange two containers of unequal cross section joined by a tube (as shown in above figure).
The load to be lifted has to be put on the container having larger cross section and the force is to be applied at smaller cross section. The smaller force exerted on smaller cross-section (area) will produce pressure at point P and

according to Pascal's law, the pressure exerted on a liquid confined in a vessel transmits equally in all directions, resulting in same pressure experienced by point Q.
To see the effect, lets take numerical values for further understanding.
Let, the area of smaller cross-section, $a = 1\ m^2$
and, the area of larger cross-section be, $A = 100\ m^2$

Suppose, we have applied a force $f = $ **50N** at point P. (By putting mass of 5kg on point P)
[If it put mass of 5kg at point P, then the Weight $= m \times g = 5 \times 10 = \underline{50N}$]

So, Force, $F = \frac{f}{a} \times A = \frac{50 \times 100}{1}$

$F = 5000\ N$

Thus, by applying just a force of 50 N ($m = 5kg$) a force of 5000 N is experienced by a car placed at Q (Weight = 5000N means mass = 500 kg).

Thus, by putting a mass of 5kg at point P we can lift a mass of 500 kg placed at point Q.

This process is also known as **FORCE MULTIPLICATION**

1.) HYDRAULIC LIFT (JACK)
2.) HYDRAULIC BRAKES
3. HYDRAULIC PRESS

} EXAMPLES OF HYDRAULIC MACHINES

USE OF HYDRAULIC PRESSURE:

i) For pressing cotton bales and goods like quilts, books etc.
ii) For extracting the juice from sugarcane, sugar beet etc.
iii) For squeezing oil out of linseed and cotton seeds.
iv) For engraving monograms on goods.

CHAPTER-4 PRESSURE IN FLUIDS AND ATMOSPHERIC PRESSURE

Students, by now we have learnt that by applying very less force, a high force is experienced at the other end of a container i.e. if we apply a force at one (end having small area) of a container, force can be multiplied at the recieving end of the container having more area. Now lets try some numericals based on Pascal's Law.

NUMERICALS

Q1. The areas of pistons in a hydraulic machine are 5 cm^2 and 625 cm^2. What force on the smaller piston will support a load of 1250N on the larger piston?

Solution-1:
$a = 5\ cm^2$ (area of smaller piston)
$A = 625\ cm^2$ (Area of larger piston)
$F = 1250\ N$ (force on larger piston)
$f = ?$ (force on smaller piston)

Using Pascal's Law: $\frac{F}{A} = \frac{f}{a}$

$$f = \frac{F}{A} \times a = \frac{1250\ (N)}{625\ (cm^2)} \times 5\ (cm^2)$$

$$f = \frac{1250\ (N)}{625\ \cancel{(cm^2)}} \times 5\ \cancel{(cm^2)}$$

$$f = 2 \times 5 = \underline{10\ N}$$

(NOTE: Students as both areas are in cm^2 and are in form of ratio, so there is no need to do conversion of cm^2 into m^2. Similarly same units also cancels out).

Now you all are required to take a break for 5 minutes and do numerical - 8, given on Page Number - 94, in your Physics notebook. After solving the numerical, you can resume the lesson for understanding other numericals too.

PRESSURE IN FLUIDS AND ATMOSPHERIC PRESSURE

Q2. The diameter of neck and bottom of a bottle are 2 cm and 10 cm respectively. The bottle is completely filled with oil. If the cork in the neck is pressed with a force of 1.2 kgf, what force is exerted on the bottom of the bottle?

Solution. Refer figure-1

Diameter of neck of bottle = 2cm

∴ Radius of neck = 1cm

Area of smaller region = πr^2

$a = \pi \times 1 = \pi\ cm^2$

$a = \pi\ cm^2$

FIGURE -1

Diameter of bottom of bottle = 10cm

Radius of bottom of bottle = $\frac{10}{2}$ = 5cm

Area of bigger region = $\pi R^2 = \pi \times 5 \times 5$

Area of bigger region, $A = 25\pi\ cm^2$

Using Pascal's Law: $\left(\frac{F}{A}\right)_{\text{Bottom of Bottle}} = \left(\frac{f}{a}\right)_{\text{neck of bottle}}$

$F = \frac{1.2\ kgf \times 25\cancel{\pi}\ \cancel{(cm^2)}}{\cancel{\pi}\ \cancel{(cm^2)}}$

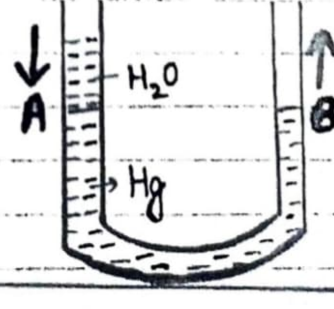
$F = (1.2 \times 25)\ kgf = 30\ kgf$

Q3. A simple U tube contains mercury to the same level in both of its arms. If water is poured to a height of 13.6 cm in one arm, how much will be the rise in mercury level in the other arm?

(Given: density of Hg = $13.6 \times 10^3\ kg/m^3$ and density of H_2O = $10^3\ kg/m^3$)

Solution. If H_2O is poured at point A, it will exert pressure on Hg due to which Hg will rise from point B with same pressure as exerted by H_2O at point A. (figure-2)

FIGURE-2



Thus, Pressure exerted by H_2O at point A = Pressure experienced by Hg at point B

$$(h \times \rho \times g)_{H_2O} = (h \times \rho \times g)_{Hg}$$

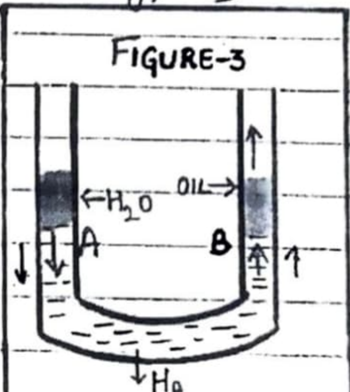
$$(13.6\text{ cm}) \times (10^3\text{ kg/m}^3) \times \cancel{g} = h \times (13.6 \times 10^3\text{ kg/m}^3) \times \cancel{g}$$

$$\frac{\cancel{13.6}\text{ cm} \times \cancel{10^3}\,\cancel{\text{kg/m}^3}}{\cancel{13.6} \times \cancel{10^3}\,\cancel{\text{kg/m}^3}} = h$$ ← $\boxed{\text{NOTE THIS STEP}}$

$$\boxed{h = 1\text{ cm}}$$

Q4. A U-tube is first partially filled with mercury. Then water is added in one arm and an oil is added in the other arms. Find the ratio of water and oil columns so that mercury level is same in both the arms of U-tube. (given: density of oil = 900 kg/m^3, density of water = 10^3 kg/m^3).

Solution:



Pressure exerted by H_2O at A = Pressure experienced by oil at point B

$$(h\rho g)_{H_2O\text{ column}} = (h\rho g)_{\text{oil column}}$$

$$h_1 \rho_1 g = h_2 \rho_2 g$$

(Note → Students, g = acceleration due to gravity and its value will be same on both water and air column)

ρ_1 = density of H_2O = 10^3 kg/m^3
ρ_2 = density of oil = 900 kg/m^3

$$h_1 \times 10^3 (\text{kg/m}^3) \times g = h_2 \times 900 (\text{kg/m}^3) \times g$$

$$\frac{h_1}{h_2} = \frac{900\,\cancel{\text{kg/m}^3}}{1000\,\cancel{\text{kg/m}^3}}$$

$$\frac{h_1}{h_2} = \frac{9}{10}$$

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PRESSURE IN FLUIDS AND ATMOSPHERIC PRESSURE

Q5 The area of cross-section of press plunger of a hydraulic press is $4\,m^2$. It is required to overcome a resistive load of 400 kgf on it. Calculate the force required on the pump plunger if the area of cross-section of the pump plunger is $0.01\,m^2$.

Solution

The given question can be depicted as shown in figure 4.

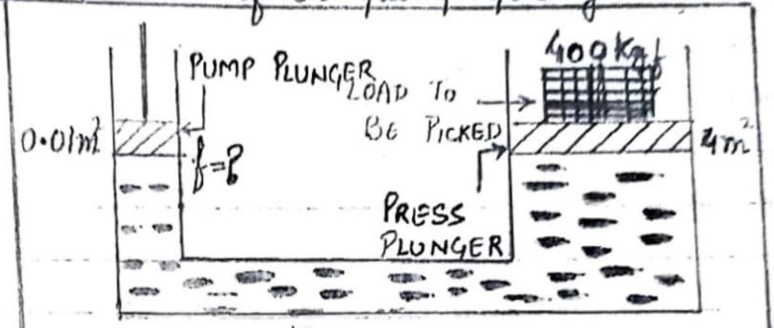

FIGURE-4

So,

$$\frac{f}{a} = \frac{F}{A} \quad \text{(Using Pascal's Law)}$$

$$f = \frac{F}{A} \times a = \frac{\overset{100}{\cancel{400}}\ kgf}{\cancel{4}\,\cancel{m^2}} \times 0.01\,\cancel{m^2}$$

$$f = 100\ kgf \times 0.01 = 1\ kgf$$

(Students, as we have learnt in Class-VIII, kgf is also a unit of force and 1 kgf = 9.8 N)

$\therefore$ force to be applied on pump plunger = 1 kgf

INSTRUCTIONS — Students, kindly go through the solved numerical problems. Read the question carefully and observe the given figure. See, the application of formula and conversions of unit. Retry these numericals on your own afterwards.

HOMEWORK — Try to solve Numerical Number- 8, 9, 12, 13 and 14 given on Page Number -94 (in Physics textbook), in your Physics Notebook.

With this I come to an end of this interactive session.

Thank you !

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