Arvind Borde / PHY 11, Week 11: Fluids

States (Phases) of Matter

Three common phases of matter:

_____, _____, _____.

(1) What's a solid? _____

(2) What's a liquid? _____

(3) What's a gas? _____

1 Oversimplifies, but is broadly true.

These are broad historical categories, but there are things that do not fit this categorization:

- Other states: _____, _____, etc.
- In-between states: _____, _____, etc.

We'll ignore these sophisticated complications, and concentrate on solids, liquids and gasses.

2 Liquids and gasses collectively called _____.

Density

Density: $\rho =$, M: mass; V: volume.

(4) SI units of ρ? _____.

ρ captures an intrinsic property of substances.

It's common to see ρ in units of gm/cm^3 instead. It gives you a better idea of how dense a substance is, since it is easier to visualize a cm^3.

3

(5) Convert $1\,\text{kg/m}^3$ into gm/cm^3.

$$1\frac{\text{kg}}{\text{m}^3} =$$

Therefore

$$1\frac{\text{g}}{\text{cm}^3} =$$

4

(6) Which is heavier: iron or water? _____

5

The density of water, under normal conditions ($4°$C), is $1\,\text{g/cm}^3$, and that of iron is $7.8\,\text{g/cm}^3$.

(7) What's the mass in kg of an iron ball of radius 20 cm?

$$V =$$

So

$$M =$$

6

ADDITIONAL NOTES

The _____ of a substance is defined as the ratio of the density of that substance to the density of water at 4°C. It is a pure number.

Thus, the specific gravity of iron is 7.8.

7

Pressure

Pressure: $P =$, F: force; A: area.

$F_\perp$ is the magnitude of the force perpendicular to the area. _____.

(**8**) SI units of P? _____

8

If your feet have equal surface area (A each), and you stand first on two feet then on one foot, are there different

(**9**) forces on the ground? _____

_____

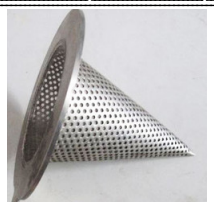
(**10**) pressures on the ground? _____

_____

_____

9

(**11**) Which hurts more: pressing the pointed part of this object into you, or the "base" (with the same force)? _____



(**12**) Why? _____

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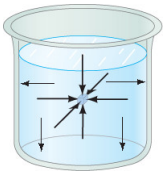
Fluids

Pressure is always outward in a fluid (when positive). It presses out against the walls of its container, and out *from it* onto an object immersed in it.



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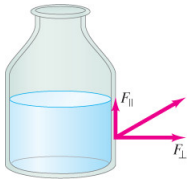
The pressure exerted by a fluid at rest is always perpendicular to the surface of contact.



If there were a parallel component, the reaction force of the container would make the fluid flow.

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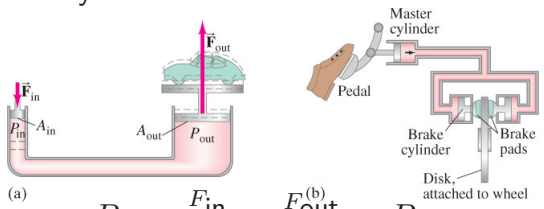
ADDITIONAL NOTES

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.



$$P_{\text{in}} = \frac{F_{\text{in}}}{A_{\text{in}}} = \frac{F^{(b)}_{\text{out}}}{A_{\text{out}}} = P_{\text{out}}$$

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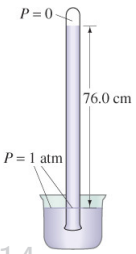
Atmospheric Pressure

The atmosphere is a fluid (gas), and its pressure obeys all the laws of pressure in fluids.



The atmospheric pressure at sea level can support a column of mercury 76 cm high.

$$1\,\text{atm} = 76.0\,\text{cm of Hg} = 760\,\text{mm of Hg}$$
$$= 1.013 \times 10^5\,\text{N/m}^2$$
$$= 1.013 \times 10^5\,\text{Pa}$$

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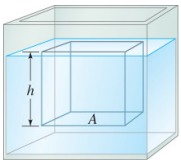
Flotation (buoyancy)

Why (some) objects float can be explained via fluid pressures.



Consider a layer of area A in a fluid, at a height h below the surface of the liquid.

15

Let ρ be the density of the fluid. The pressure P on the layer from above is due to the weight of the fluid above that layer:

$$P = \frac{F}{A} = \frac{\qquad}{A}$$
$$= \frac{\qquad \cdot g}{A}$$
$$= \frac{\rho(\qquad) \cdot g}{\qquad}$$
$$=$$

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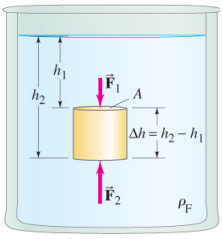
For an object of mass m to float, the *net force* exerted by the fluid on it must balance its weight.



$$F_2 - F_1 = mg$$

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The net force exerted by the fluid, called the _____ _____, is the difference between the forces at top and the bottom:

$$F_B = F_2 - F_1 =$$

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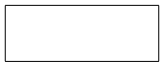
ADDITIONAL NOTES

This must counterbalance the weight of the object (mass m):

$$F_B = \rho g V = mg$$

Or



(13) What are you thinking?

19

But above,

(14) What's m the mass of?

_____

(15) What's ρ the density of?

_____

(16) What's V the volume of?

_____

20

In other words

mass of displaced fluid ↘ mass of object ↙

$$\rho V = m$$

Now the mass of the displaced fluid depends (since ρ is fixed) on the _____ of the displaced fluid. The bigger that is, the more massive is the object that can float.

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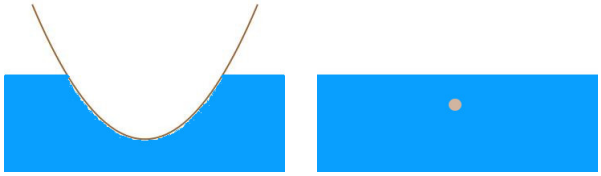
(17) If you compress all the material of a ship into a small ball, does the mass change? _____

(18) Will the ball still float? _____

(19) Why? _____



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The equation

$$F_B = \rho g V$$

says that the buoyant force on an object equals the weight of the displaced fluid.

This is known as _____.

It holds whether the object of mass m floats ($F_B = mg$) or not.

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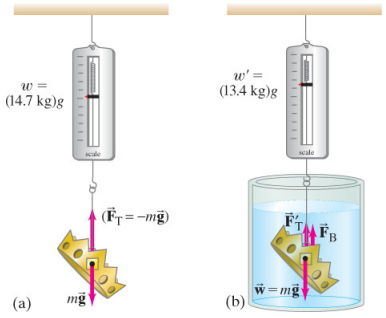
(20) Gold has a specific gravity of 19.3. Is this crown made of gold?



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ADDITIONAL NOTES

The weight of the crown in air (w_1) is:

$$w_1 = mg = \rho_c V g.$$

The difference between that and the weight of the crown in water (w_2) is the buoyant force:

$$w_1 - w_2 = F_B = \rho_w V g$$

Take the ratio:

$$\frac{w_1}{w_1 - w_2} = \frac{\rho_c V g}{\rho_w V g} = \frac{\rho_c}{\rho_w}.$$

25

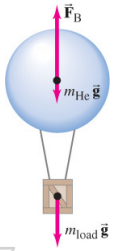
So

$$\frac{\rho_c}{\rho_w} =$$

So, is the crown gold?

26

(**21**) What is the volume of a helium balloon ($\rho_{\text{He}} = 0.179\,\text{kg/m}^3$) required to lift a $150\,\text{kg}$ load in air ($\rho_{\text{air}} = 1.29\,\text{kg/m}^3$)?



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Fluid Flow

Two main types of fluid flow: If smooth, and neighboring layers of the fluid slide by each other smoothly, the flow is called streamline or _____.

Above a certain speed, flow becomes _____. Turbulent flow is characterized by erratic, small, whirlpool-like circles called eddy currents or eddies.

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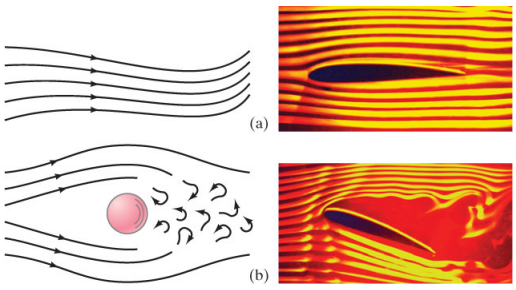
Laminar flow (a) and turbulent (b):



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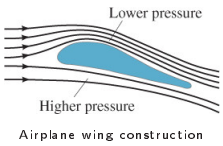
Bernoulli's Principle

In a nutshell "where the velocity of a fluid is high, the pressure is low, and where the velocity is low, the pressure is high."



Airplane wing construction

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ADDITIONAL NOTES

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