Classes 19: Fluid Mechanics

AP Physics

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Olympiads School

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Files for You to Download

Download from the school website:

1. `19-fluidMechanics.pdf`—This presentation. If you want to print the slides on paper, I recommend printing 4 slides per page.
2. `20-Homework.pdf`—Homework assignment for Classes 19 and 20, which cover Fluid Mechanics and Thermodynamics

Please download/print the PDF file before each class. When you are taking notes, pay particular attention to things I say that aren't necessarily on the slides.

Disclaimer

Use of Calculus

Fluid mechanics is part of the AP Physics 2 Exam, which does not require calculus. However, in the interest in completeness, *some* calculus will still be used when deriving equations.

What is a Fluid

- **The simplistic explanstion:** anything that flows
- **The scientific explanation:** Any substancs that deform *continuously* under oblique stress

Properties of Fluids

Density

Continuity

A fluid is considered to be continuousin space.

Properties of Fluids

Viscosity

Hydrostatics

Buoyancy

When an object is submerged inside a fluid, the fluid exerts a pressure at the surface of the object. We can integrate the pressure over the entire surface area and find the total force the fluid exerts on the object.

An Easier Explanation of Buoyancy

Not Much Calculus

The pressure difference difference between the top and bottom . If we integrate over the entire surface, we get the buoyance force $\mathbf{B}$:

$$\boxed{\mathbf{B} = \rho_{\text{fluid}} g V_{\text{disp}}}$$

where ρ_{fluid} is the density of the displaced fluid, and V_{disp} is the volume displaced. This equation is known as **Archimedes' principle**.

Buoyancy

Buoyancy depends on:

- the density of the (displaced) fluid ρ_{fluid}
- the volume of the fluid displaced V_{disp}, and
- the local acceleration due to gravity g

Buoyancy does not depend on:

- the mass of the immersed object, or
- the density of the immersed object

Buoyancy

Objects immersed in a fluid have an "apparent weight" that is reduced by the buoyant force:

$$\mathbf{W} = \mathbf{W} - \mathbf{B}$$

$$\mathbf{W} = (\rho_{\text{obj}} - \rho_{\text{fluid}})\mathbf{g}V$$

$\mathbf{W}'$ is proportional to the relative density $(\rho' = \rho_{\text{obj}} - \rho_{\text{fluid}})$

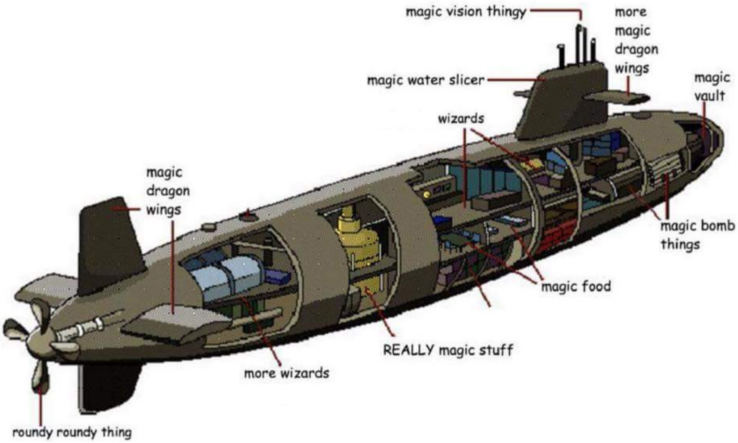
Buoyancy

For a submerged object:

Densities	$B > W_{\text{obj}}$	$B = W_{\text{obj}}$	$B < W_{\text{obj}}$
$\rho_{\text{obj}} < \rho_{\text{fluid}}$	object rises	float on surface	
$\rho_{\text{obj}} = \rho_{\text{fluid}}$		neutral buoyancy	
$\rho_{\text{obj}} > \rho_{\text{fluid}}$			object sinks

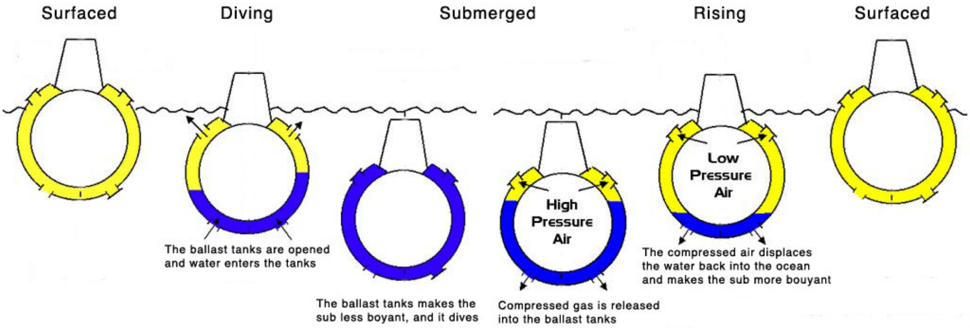
How Submarines Work

Like this?



How Submarines Work

Like most ships, a submarine does not naturally sink because of the buoyance force. When a submarine submerges, water needed to be pumped inside "ballast tanks" to make the ship heavier.



Bernoulli Equation

$$\boxed{p_1 + \frac{1}{2}\rho v_1^2 + \rho g z_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g z_2}$$

The term $\frac{1}{2}\rho v^2$ is called “dynamic pressure”

Bernoulli Equation

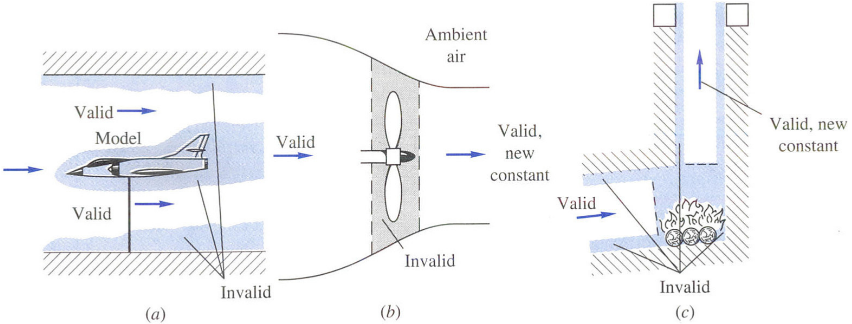
$$\boxed{p_1 + \frac{1}{2}\rho v_1^2 + \rho g z_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g z_2}$$

Bernoulli's equation is valid when

- the flow is **steady** (independent of time)
- the flow is **incompressible**–compressibility (i.e. changes in density of the fluid) effects are negligible for Mach number $M < 0.30$
- the flow **along a single streamline**
- there is **no shaft work** done along the streamline between 1 and 2
- there is **no heat transfer** along the streamline between 1 and 2

Bernoulli Equation

Regions where Bernoulli equation is valid:



How Does A Wing Work?

When air flows past a wing, a force is generated