FLUIDS DAY 1: DENSITY & PRESSURE

AP REVIEW **Warmup: Projectile Motion**

A soccer ball is kicked from level ground at $\mathbf{v_0 = 18\ m/s}$ at $\mathbf{\theta = 35°}$ above the horizontal. Treat g = 9.81 m/s² and ignore air resistance.

(a) How long is the ball in the air before it lands? **(b)** How far does it travel horizontally (range)?

Desmos tip — do the components separately, just like AP graders want: First, in desmos.com/calculator, plot `y(t) = 18·sin(35°)·t − 4.905·t²` and find the non-zero t where y = 0 — that's your time of flight. *Then* plot `x(t) = 18·cos(35°)·t` and read off x at that landing time — that's your range. Two equations, two steps; don't shortcut to a single parametric curve.

Physics in the Wild — The Crushing Deep & Emergence Intro: At the bottom of the Mariana Trench (10,994 m), pressure exceeds 1,000 atm — enough to crush a submarine — yet creatures thrive there because their internal pressure matches the outside. Welcome to *Emergent Phenomena II*. A single water molecule doesn't *have* pressure; pressure only exists when trillions of molecules collide with a surface. **Hard emergence:** properties that exist only at the collective level. **Soft emergence:** reducible in principle but practically irreducible. Fluids will give us examples of both.

DENSITY

ρ = m/V (kg/m³)

A fluid has no fixed shape. In AP Physics 1, fluids are treated as ideal unless stated otherwise: incompressible and no viscosity.

Water	Ice	Air	Steel	Aluminum	Gold
1000	917	1.2	7800	2700	19300

YOU DO **Exercise 1: Verify Gold**

A gold bar should have ρ = 19,300 kg/m³. A bar has mass 12.4 kg and dimensions 25 cm × 5.1 cm × 2.6 cm. Is it real gold?

PRESSURE

PRESSURE

$P = F_{\perp}/A$ (Pa = N/m²)

1 atm = 101,325 Pa ≈ 1.0×10^5 Pa

Pressure is a scalar — it acts equally in all directions at a point in a fluid.

WE DO **Exercise 2: Standing vs Lying**

A 70 kg person stands on shoes with total area 0.04 m². (a) Find the pressure on the floor. (b) If they lie down (contact area 0.50 m²), find the new pressure. (c) By what factor did pressure change?

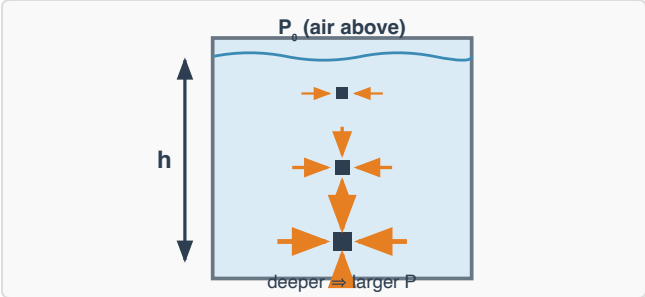
PRESSURE WITH DEPTH

HYDROSTATIC PRESSURE

$P = P_0 + \rho gh$

P_0 = surface pressure, ρ = fluid density, g = 9.81 m/s², h = depth

Pressure grows linearly with depth — doubled depth means double the hydrostatic term ρgh.



WE DO **Exercise 3: Pool Pressure**

Find the total pressure at the bottom of a 3.0 m pool. ($P_{atm} = 1.01 \times 10^5$ Pa, $\rho_{water} = 1000$ kg/m³)

YOU DO **Exercise 4: Depth for 2 atm**

At what depth in water does total pressure equal 2 atm (gauge pressure = 1 atm)?

GAUGE VS ABSOLUTE PRESSURE

TWO WAYS TO MEASURE PRESSURE

Absolute pressure: $P_{abs} = P_{atm} + \rho gh$ (total, including atmosphere)

Gauge pressure: $P_{gauge} = P_{abs} - P_{atm} = \rho gh$ (above atmospheric)

A tire gauge reads P_{gauge}. A 'flat' tire still has 1 atm inside.

SKILL **Exercise 5: Scuba Diver**

A diver descends to 25 m in salt water (ρ = 1025 kg/m³). **(a)** P_{gauge}? **(b)** P_{abs}? **(c)** P_{abs} in atm? **(d)** Mask area 0.015 m² — net inward force from gauge pressure?

Pascal's Principle: A change in pressure at any point in a confined fluid is transmitted undiminished to every point in the fluid.

YOU DO **Exercise 6: Hydraulic Lift**

Mechanic pushes with 150 N on a small piston (A = 0.001 m²); large piston A = 0.05 m². **(a)** Fluid pressure? **(b)** Force on large piston? **(c)** Mechanical advantage?

EXIT TICKET & HOMEWORK

EXIT Dam Pressure

A reservoir behind a dam is 40 m deep. **(a)** P_{gauge} at the base? **(b)** A 2.0 m × 1.0 m section is at the base — estimated force on it? **(c)** Why does the dam need to be thicker at the bottom?

HOMEWORK PROBLEMS

[1] Pressure Conversion

Convert 3 atm to Pa. Then find the depth in water where absolute pressure equals 3 atm.

[2] Unknown Material Cube

A cube (side 0.10 m) has mass 2.7 kg. **(a)** Find ρ. **(b)** Floats in water? **(c)** Floats in mercury (ρ = 13,600 kg/m³)?

[3] Hydraulic Brake System

Driver pushes with 80 N on a pedal piston (A = 5 cm²); caliper piston A = 20 cm². Find the force on the brake pad.

Tomorrow: Buoyancy! Why do steel ships float? The answer involves pressure gradients and Archimedes' famous bath-time insight.