# FLUIDS: UNIT REVIEW

*Part 1 (pp. 1–2): Review problems · Part 2 (pp. 3–4): Multi-representation FRQ*

**KEY EQUATIONS**

**Density:** $\rho = m/V$ (kg/m³) · **Pressure:** $P = F_\perp/A$ (Pa = N/m² = J/m³)

**Hydrostatic:** $P = P_0 + \rho gh$ · **Buoyancy:** $F_b = \rho_{fluid} \cdot V \cdot g$

**Continuity:** $A_1v_1 = A_2v_2$ · **Bernoulli:** $P + \frac{1}{2}\rho v^2 + \rho gy$ = constant (along a streamline)

**Torricelli:** $v = \sqrt{(2gh)}$ · *Bernoulli terms all in J/m³ — energy density — that's why they add.*

SKILL **Problem 1: Diver Pressure**

A diver descends to 25 m in seawater ($\rho$ = 1025 kg/m³). Use $P_{atm} = 1.01 \times 10^5$ Pa. **(a)** Gauge pressure at the diver's depth. **(b)** Absolute pressure in Pa *and* in atmospheres.

SKILL **Problem 2: Submerged Sphere — FBD & Tension**

A solid metal sphere (mass 5.0 kg, $\rho$ = 8000 kg/m³) is fully submerged in water and hangs from a vertical string attached to a fixed point above the water surface. **(a)** Find the sphere's volume. **(b)** Find the buoyant force. **(c)** Draw and label a complete free body diagram, then find the tension in the string. (Why is this string holding the sphere up rather than down?)

## CONTINUITY, BERNOULLI & TOOL-FIT

SKILL **Problem 3: Pipe Narrowing**

Water ($\rho = 1000$ kg/m³) flows through a horizontal pipe. At point 1: $A_1 = 0.040$ m², $v_1 = 2.0$ m/s, $P_1 = 2.50 \times 10^5$ Pa. At point 2: $A_2 = 0.010$ m².

**(a)** Find $v_2$ using continuity. **(b)** Find $P_2$ using Bernoulli. **(c)** Of the three terms in Bernoulli's equation, which increased and which decreased between point 1 and point 2? In one sentence, describe the energy bookkeeping.

CONCEPTUAL **Problem 4: When Does Bernoulli Apply?**

**(a)** List the *five* assumptions Bernoulli's equation requires.

For each scenario below, identify *which assumption fails* and explain in one sentence:

**(b)** Air is blown horizontally across the top of a sheet of paper resting on a desk. The classic textbook explanation says the paper rises "because the air on top is faster, so by Bernoulli the pressure is lower." Why is the textbook explanation wrong, even if the paper does rise?

**(c)** Water flowing through a long, narrow garden hose loses substantial pressure to friction with the hose walls.

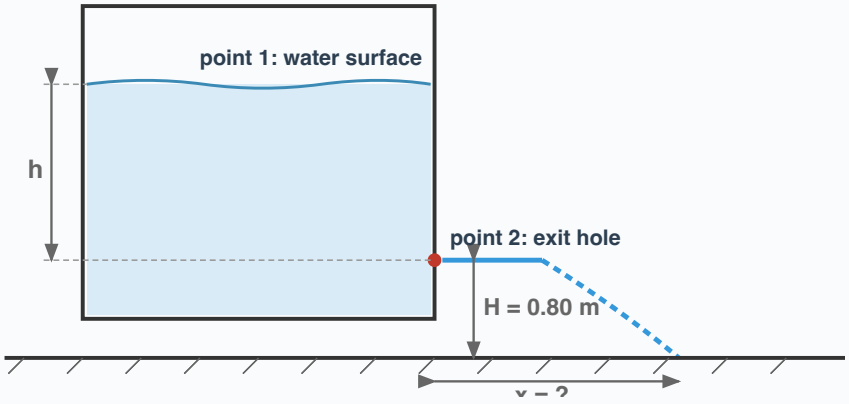
**(d)** A motor-driven pump increases water pressure midway through a pipe of constant cross-section and constant elevation.

**Pre-test checklist:** □ Pressure at depth (gauge vs. absolute) □ Buoyancy with FBD □ Continuity ($A_1v_1 = A_2v_2$) □ Bernoulli's 5 assumptions □ Torricelli + projectile motion □ Linearizing data to extract a constant from the slope □ "Pa = J/m³" — pressure is energy density.

# FREE RESPONSE — MULTIPLE REPRESENTATIONS

*Time: ~25 min · Total: 13 points · Show all work; partial credit awarded.*

**Setup.** A wide, open-topped tank with a small hole drilled in the side rests on a table. Water drains through the hole as a horizontal jet, then falls to the floor. The hole is at height **H = 0.80 m** above the floor, and at the moment shown the water surface inside the tank sits a distance *h* above the hole. Treat water as ideal (incompressible, inviscid). The tank's cross-section is much larger than the hole's, so the surface drops slowly. **Neglect air resistance once water leaves the hole.** Use g = 9.81 m/s².




**(a)** **3 points**

Apply Bernoulli's equation between point 1 (water surface) and point 2 (exit hole, just outside the tank). For *each* Bernoulli term at points 1 and 2 — pressure, kinetic-energy density, and gravitational-PE density — justify whether it cancels, is negligible, or remains. Show that the exit speed satisfies **v = √(2gh)**. State *every* assumption you used.

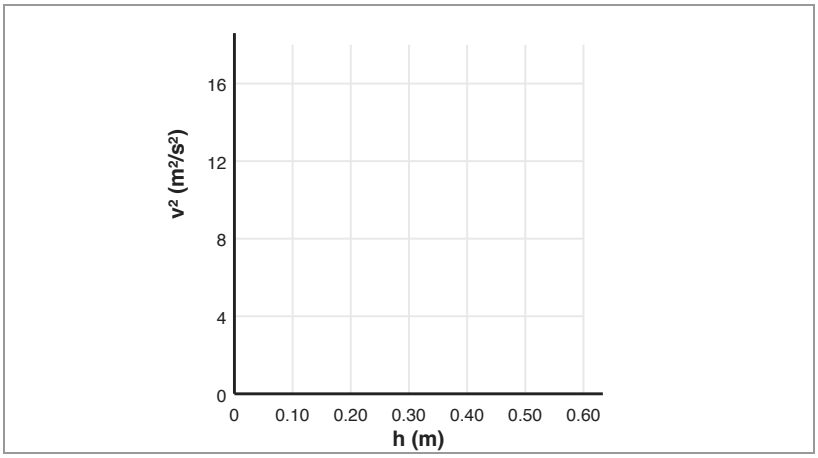
**(b)** **2 points**

Sketch a free body diagram of a small parcel of water just after it exits the hole (in the air, before reaching the floor). Label every force. Briefly justify which forces are present and which are absent.

**(c)** **3 points**

A student measures the exit speed v at four different water depths h:

| h (m) | v (m/s) |
|---|---|
| 0.10 | 1.40 |
| 0.20 | 1.98 |
| 0.40 | 2.80 |
| 0.60 | 3.43 |




**(c1)** Plot $v^2$ vs. $h$ on the axes at right.

**(c2)** Use the slope of your line to find an experimental value of g. Show your slope calculation.

**(c3)** Explain why $v^2$ vs. $h$ is preferred over $v$ vs. $h$ for extracting g from data.

**(d)** **2 points**

At a particular instant, h = 0.45 m. Find the exit speed v.

**(e)** **3 points**

Using your value of v from part (d) and the geometry shown in the figure on page 3: how far from the wall (horizontally) does the jet first hit the floor? Show your work and reasoning — identify any motion principle you use.

# LAB INVESTIGATION FRQ (10 PTS)

**DESIGN** **Problem 6 — Determining the Density of an Unknown Liquid**

A student must experimentally determine the density $\rho$ of an unknown liquid. The student is provided with:

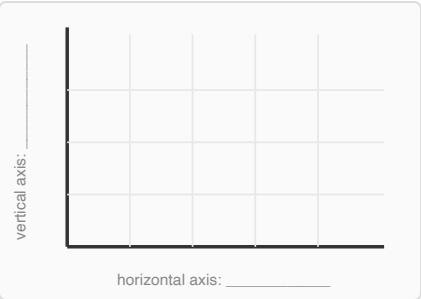
- A tall, transparent container filled with the unknown liquid
- A pressure sensor on a thin probe that reads **absolute** pressure at its tip
- A meter stick (resolution ±1 mm)
- A ring stand with a clamp to hold the probe at a fixed depth

**PART A** **Experimental Procedure (4 pts)**

Describe a procedure the student could use to collect enough data to determine $\rho$. Your description should explicitly include: **(i)** the quantities measured and the equipment used for each, **(ii)** the variable the student should change across trials, and **(iii)** one specific step that reduces *random* error.

**PART B** **Graphical Analysis (3 pts)**

Indicate what the student should plot so that a **straight line** results, and label both axes (with units). Starting from $P = P_0 + \rho gh$, show how $\rho$ is obtained from the **slope** of the best-fit line.




*Linearization & expression for ρ:*

**PART C** **The Intercept (3 pts)**

What physical quantity does the **vertical intercept** of the best-fit line represent? The student finds an intercept noticeably *larger* than the expected value of that quantity. Identify one *systematic* error that would produce this result, and explain the reasoning.