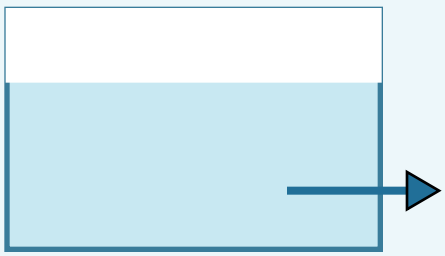
Fluid Mechanics · Student Workbook

One calculus-based course · Illustrated online text · Physical inquiry · Original problem bank



PRESSURE • FLOW

$P + 1/2 \rho v^2 + \rho g h$

Student: _____ Class: _____ Date: _____

How to use this workbook

Read the illustrated section on the website before completing each corresponding STRIDES note. Sketch a physical representation, derive the model, then use actual measurements in the physical lab. The online MCQ/FRQ bank has expandable solutions; do not open them until after a written attempt.

Learning targets

- Define pressure and density with correct units; model pressure variation with depth.
- Isolate an object to solve buoyancy and supporting forces.
- Use continuity and Bernoulli with stated assumptions and explicit elevation.
- Use integrals when density or flow varies; compare measured data with ideal models.
- Propagate uncertainty and distinguish random scatter from systematic deviations.

Suggested sequence

1. Notes and worked examples → 2. STRIDES and diagrams → 3. Physical lab → 4. Original MCQ/FRQ practice → 5. Reflection.

F1 · Density and pressure

STRIDES: Subject / Topic / Rules / Illustrations / Definitions / Example / Steps.

Subject and topic: _____

Definitions and rules (use words and correct SI units):

Illustration: draw a labeled system, control volume, graph, or force diagram.

Example and solution steps: start with assumptions and derive the governing equation.

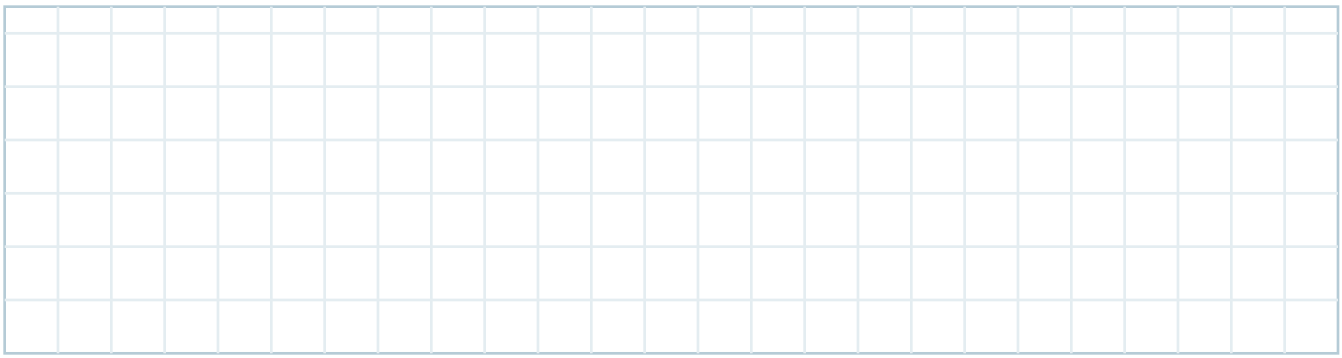
F2 · Buoyancy and Pascal

STRIDES: Subject / Topic / Rules / Illustrations / Definitions / Example / Steps.

Subject and topic: _____

Definitions and rules (use words and correct SI units):

Illustration: draw a labeled system, control volume, graph, or force diagram.



Example and solution steps: start with assumptions and derive the governing equation.

F3 · Continuity and control volumes

STRIDES: Subject / Topic / Rules / Illustrations / Definitions / Example / Steps.

Subject and topic: _____

Definitions and rules (use words and correct SI units):

Illustration: draw a labeled system, control volume, graph, or force diagram.

Example and solution steps: start with assumptions and derive the governing equation.

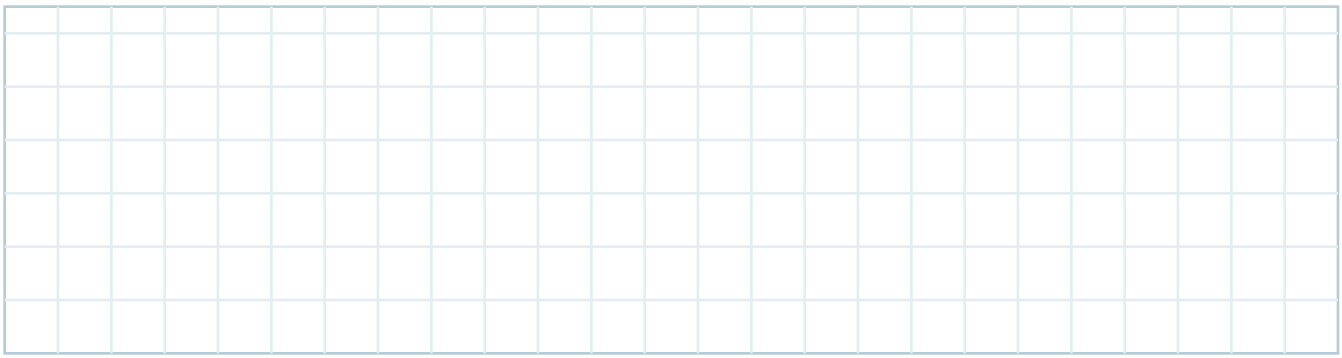
F4 · Bernoulli and elevation

STRIDES: Subject / Topic / Rules / Illustrations / Definitions / Example / Steps.

Subject and topic: _____

Definitions and rules (use words and correct SI units):

Illustration: draw a labeled system, control volume, graph, or force diagram.



Example and solution steps: start with assumptions and derive the governing equation.

F5 · Bottle jet and regression

STRIDES: Subject / Topic / Rules / Illustrations / Definitions / Example / Steps.

Subject and topic: _____

Definitions and rules (use words and correct SI units):

Illustration: draw a labeled system, control volume, graph, or force diagram.

Example and solution steps: start with assumptions and derive the governing equation.

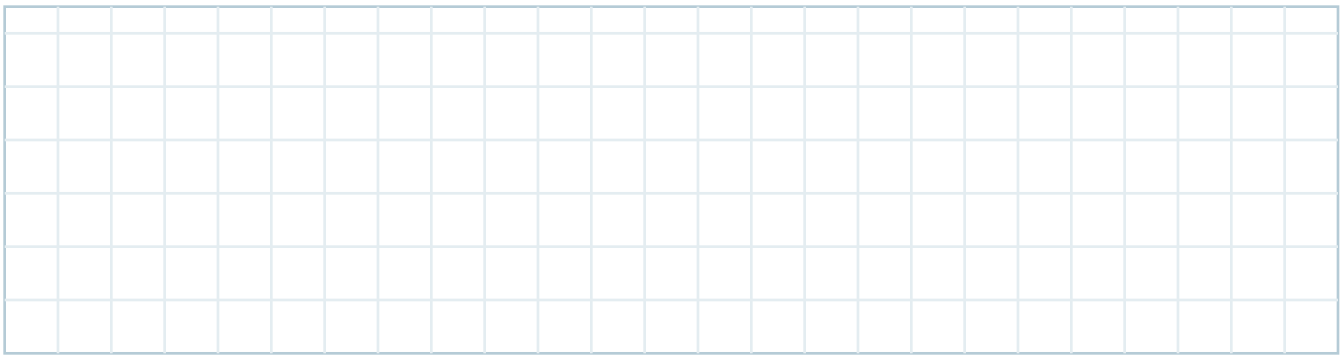
F6 · Viscosity and uncertainty

STRIDES: Subject / Topic / Rules / Illustrations / Definitions / Example / Steps.

Subject and topic: _____

Definitions and rules (use words and correct SI units):

Illustration: draw a labeled system, control volume, graph, or force diagram.



Example and solution steps: start with assumptions and derive the governing equation.

Physical inquiry: Bottle jet and Torricelli

Required apparatus: plastic bottle with instructor-prepared outlet, water, tray, ruler, paper markers, tape; optional video.

Safety: No sharp tools for students. Prevent spills near electrical outlets and walking paths.

Prediction: derive the governing physical expression and define all variables.

Sketch the apparatus and label reference heights, temperatures, masses, and controlled variables.

Procedure: write at least six reproducible steps, including repeated trials, instrument resolution, and control of changing conditions.

Measurements: three trials for each water depth; report in SI units.

Depth h (m)	Range 1 (m)	Range 2 (m)	Range 3 (m)	Mean R (m)

Fit / model reduction: graph R^2 versus h, compute ideal R and coefficient C_v

Propagation of uncertainty: show derivatives, instrument uncertainties, and a numerical result.

Interpretation: discuss random variation, systematic bias, assumptions, and a specific improvement.

Original independent practice: multiple choice

These questions are newly authored for this workbook. Solve before opening the website solution dropdowns. Circle one option and justify your model briefly.

F1. In fresh water, the gauge pressure rises by approximately how much for every 0.75 m of depth?

A) 0.75 kPa B) 7.36 kPa C) 73.6 kPa D) 736 kPa

F2. A 0.0060 m^3 object has a mass of 4.8 kg. If completely submerged in water and released, its initial acceleration is closest to:

A) 2.45 m/s^2 upward B) 9.81 m/s^2 downward C) 2.45 m/s^2 downward D) 0

F3. Two ideal hydraulic pistons have areas in a 1:7 ratio. If the small piston moves 14 cm, the large piston moves:

A) 98 cm B) 14 cm C) 2 cm D) 1 cm

F4. For a liquid at rest with upward-positive z, the differential relation is:

A) $dP/dz=\rho g$ B) $dP/dz=-\rho g$ C) $dP/dz=0$ for all fluids D) $Pz=\rho g$

F5. A pipe radius becomes 0.75 of its original radius. For constant volumetric flow, speed becomes:

A) 0.56 times B) 0.75 times C) 1.33 times D) 1.78 times

F6. An ideal steady water stream rises 1 m at constant speed. Which change in static pressure follows?

A) increases by 9.81 kPa B) falls by 9.81 kPa C) no change D) falls by 98.1 kPa

---

F7. Water flows at 0.0030 m^3/s through a circular tube of area 0.0015 m^2. Average speed is:

A) 0.5 m/s B) 2.0 m/s C) 4.5 m/s D) 5.0 m/s

F8. Ignoring all losses, the predicted exit speed from a hole at depth h scales as:

A) h B) h^2 C) $\sqrt{h}$ D) $1/h$

Original extended-response practice

Write equations before substituting numbers. Show units, diagrams and a closing physical interpretation.

F13 · Control-volume mass flux

Water of density 1000 kg/m³ flows through a horizontal tapered channel at 0.0040 m³/s. At section A, area is 0.0030 m²; at section B, area is 0.0012 m². Pressure at A is 185 kPa. (a) Find speeds at A and B. (b) Find ideal pressure at B. (c) Predict what a real measured pressure of 174 kPa would imply about the model.

Diagram / graph

F14 · Variable-density hydrostatics

A liquid column has density ρ(h)=1000+20h (kg/m³) for depth h in meters. The free surface is at atmospheric pressure. (a) Derive ΔP(d) by integration. (b) Evaluate at d=2.5 m. (c) Explain why replacing density with its surface value biases the answer.

Diagram / graph



Synthesis and laboratory reflection

1. Which assumption is most consequential in the main model, and how could you test it?

2. Which measurement dominates the propagated uncertainty? Provide numerical evidence.

3. Compare one experimental result with the mathematical prediction. Explain whether disagreement is significant relative to the uncertainty.

4. What would you change in a second iteration of the experiment?

Online supplements

Use the illustrated text, 16 original practice questions with expandable solutions, dynamic model, and web-based report at /physics/ece1401/fluids/ .