FULL REVIEW

Full Review: Fluid Mechanics — Calculus-Based

Review the essential ideas, relationships, and problem-solving tools for Fluid Mechanics.

◷ TIME	◎ BEST FOR	✓ FINISH WITH
45–60 minutes	A complete topic review	A readiness check

After this full review, you'll be able to…
recall the essential ideas, apply them to representative problems, and determine what to study next.

HOW TO USE THIS GUIDE

Work through the stages in order. Write directly in the spaces provided, check your work in the Solutions section, and finish by choosing the next resource that matches your confidence.

Choose how you want to review: work through this guide, follow the online review, or watch the video review.

Start the Review Online →
Watch the Video Review →

YOU WILL NEED

Pencil or pen • Calculator if needed • Approximately 45–60 minutes

FR-02 • TOPIC ALIGNMENT

Topic Alignment

This bundle is aligned to the approved Physics Sensei topic specification below. Use it to recover the topic structure, reinforce key decisions, and confirm readiness for the next study task.

TEXTBOOK: Independent Physics Sensei Unit Review **CHAPTER: Mechanics • MEC-U14** **TOPIC: Fluid Mechanics** **COURSE LEVEL: Calculus-Based**	**BEST USED** ✓ After reading the chapter ✓ Before starting homework ✓ Before a quiz or exam

Review Prerequisites →

FR-03 • YOUR REVIEW PLAN

Your Review Plan

Complete these six stages in order. Each stage builds on the previous one and prepares you for the final readiness check.

6 stages • Approximately 45–60 minutes

1 **Warm-Up Check — page 4** Activate prior knowledge.	2 **Core Concepts — page 6** Review the essential ideas.	3 **Guided Practice — page 8** Apply what you learned.
4 **Confidence Check — page 10** Confirm your understanding.	5 **Summary — page 12** Review the key ideas.	6 **Next Step — page 16** Continue your learning.

PRINTING TIP

For student copies, print double-sided and keep the Solutions section after the student activities so learners attempt each activity before checking their work.

FR-04 • STAGE 1 OF 6

Warm-Up Check

Before you begin, take a moment to see what you already remember. Do not worry about getting everything right. This is only a starting point.

ACTIVITY 1

Recall Activity 1

Use the pressure-gradient relation.

For a static fluid with vertical coordinate y increasing upward, state the sign of dp/dy and interpret it.

ACTIVITY 2

Recall Activity 2

Write the integral statement behind buoyancy.

Express the net vertical pressure force on a submerged body in a static fluid using a surface integral, then state the Archimedes result for uniform density.

FR-04 • WARM-UP CHECK CONTINUED

ACTIVITY 3

Recall Activity 3

State the local conservation law.

Write the differential continuity equation for a compressible fluid.

Ready to strengthen your understanding?

You’ve refreshed what you already know. Next, reinforce the essential concepts that will help you solve problems with confidence.

Continue to Core Concepts — page 6 →

FR-05 • STAGE 2 OF 6

Core Concepts

Let's rebuild the key ideas one step at a time. Focus on understanding the relationships before worrying about solving problems.

KEY CONCEPT 1

Pressure, density, and hydrostatic equilibrium

Hydrostatic equilibrium follows $\nabla p = \rho\vec{g}$. With y upward in uniform gravity, $dp/dy = -\rho g$. For variable density, pressure differences come from integrating the gradient rather than automatically using ρgh.

$$\nabla p = \rho\vec{g};\ \Delta p = -\int \rho g\, dy \text{ for } y \text{ upward.}$$

EXAMPLE If $\rho(y)$ varies, use $p(y_2)-p(y_1)=-\int_{y_1}^{y_2}\rho(y)g\,dy$ instead of substituting one density into $\rho g\Delta h$.

SENSEI NOTE Pressure is a scalar field. Do not draw a "pressure vector"; draw pressure forces normal to surfaces and use pressure differences to determine net force.

KEY CONCEPT 2

Buoyancy, floating, and apparent weight

Archimedes' principle follows from the hydrostatic pressure field. Treat buoyancy as the integral of pressure traction over the object surface; then combine it with Newton's second law or equilibrium conditions.

$$\vec{F}_B = -\oint p\,\hat{n}\,dA = -\int_V \nabla p\, dV;$$ with $\nabla p=\rho\vec{g}$, the result is opposite the displaced fluid's weight vector.

EXAMPLE For a fully submerged body in uniform water, the buoyant-force magnitude depends on displaced volume, not the body's depth, if the water density and g are constant.

SENSEI NOTE Archimedes gives the buoyant force. It does not by itself say whether the object accelerates; compare all forces on the object.

FR-05 • CORE CONCEPTS CONTINUED

KEY CONCEPT 3

Flow rate, continuity, Bernoulli, and ideal-flow limits

Mass conservation is $\partial\rho/\partial t+\nabla\cdot(\rho\vec{v})=0$. For steady incompressible inviscid flow, Euler's equation integrated along a streamline gives Bernoulli. Viscosity, turbulence, pumps, and dissipative losses require models beyond the simple Bernoulli constant. In controlled real-flow extensions, dynamic viscosity η measures resistance to shear, and laminar pipe flow may be compared with the ideal model.

$\partial\rho/\partial t+\nabla\cdot(\rho\vec{v})=0$; steady incompressible: $\nabla\cdot\vec{v}=0$; along a streamline, $p+\frac{1}{2}\rho v^2+\rho gy=C$. Controlled viscous extension: $\tau=\eta\, dv/dy$; for laminar Newtonian flow in a circular pipe, $Q=\pi R^4\Delta p/(8\eta L)$.

EXAMPLE For efflux from a large open tank to atmosphere, Bernoulli with $v_{surface}\approx0$ gives $v_{exit}\approx\sqrt{2g\Delta y}$, under ideal assumptions.

SENSEI NOTE Do not use “faster flow means lower pressure” as a universal slogan. First verify the two points are connected by a valid Bernoulli model and account for height, pumps, and losses.

Ready to apply these ideas?

You’ve reinforced the essential concepts. Now put them into practice by working through guided examples and building your problem-solving confidence.

Continue to Guided Practice — page 8 →

FR-06 • STAGE 3 OF 6

Guided Practice

Now it's time to apply what you've reviewed. Work through each activity in order. The examples become gradually more challenging, and each prepares you for the final readiness check.

PRACTICE 1

Worked Example

Identify the pressure reference, choose gauge or absolute pressure, and solve with units.

For a liquid with $\rho(y)=\rho_0(1-\alpha y)$, y measured upward, derive $p(y_2)-p(y_1)$ in uniform gravity.

FR-06 • GUIDED PRACTICE CONTINUED

PRACTICE 2

Guided Problem

Draw the object free-body diagram and identify displaced fluid volume.

Show why a fully submerged rigid object in an incompressible fluid has the same buoyant force at two different depths, neglecting density variation.

PRACTICE 3

Independent Problem

Apply continuity first, then decide whether Bernoulli is valid.

Starting from steady inviscid Euler flow, $\vec{v}\cdot\nabla\vec{v}=-(1/\rho)\nabla p+\vec{g}$, *state the streamline integral for constant* ρ.

Ready to check your understanding?

You've practiced the essential skills with guidance. Now solve a few short problems on your own and confirm you're ready to move forward.

Continue to Confidence Check — page 10 →

FR-07 • STAGE 4 OF 6

Confidence Check

You've rebuilt the key ideas and practiced them with guidance. Now try these short questions on your own to check your understanding before moving on.

QUICK CHECK 1

Pressure model check

Answer and justify in one sentence.

If $dp/dy=-\rho g$ with constant ρ, what does the sign imply about p as height increases?

QUICK CHECK 2

Buoyancy check

Classify the statement.

Does a uniform-density incompressible fluid give a larger F_B at greater depth for the same rigid displaced volume?

FR-07 • CONFIDENCE CHECK CONTINUED

QUICK CHECK 3

Continuity and Bernoulli check

Choose the valid relationship.

For incompressible flow, what condition does the continuity equation impose on $\nabla \cdot \vec{v}$?

HOW DID IT GO?

I answered ____ of 3 questions correctly.

Use the Solutions section to check your reasoning, then take one final look at the essential ideas.

You've checked your understanding.

Take one final look at the essential ideas before deciding what to do next.

Continue to Summary — page 12 →

FR-08 • STAGE 5 OF 6

Summary

Before moving on, take one final look at the most important ideas from this review.

KEY TAKEAWAY 1

Pressure comes from force per area and hydrostatic balance

Use p, not a pressure vector. Distinguish gauge from absolute pressure, choose the correct depth/elevation reference, and use $p=p_0+\rho gh$ only when density is effectively constant.

KEY TAKEAWAY 2

Buoyancy is displaced-fluid weight

Find V_{disp} and ρ_{fluid}, then compare F_B with weight, tension, or support forces. Floating equilibrium is a force balance, not a disappearance of weight.

KEY TAKEAWAY 3

Continuity first; Bernoulli only under valid assumptions

Use mass conservation to connect area and speed. Then use Bernoulli only for the appropriate steady, incompressible, nonviscous model along a streamline unless additional energy/loss terms are included.

MY ONE-SENTENCE SUMMARY

In my own words, the most important idea is:

Ready for your next step?

You've reviewed the essential ideas one last time. Now choose the resource that best matches how confident you feel.

Continue to Next Step — page 16 →

ANSWER KEY • CHECK AFTER ATTEMPTING

Solutions and Explanations

Use these solutions to check your reasoning—not only your final answer. Use each concise answer and explanation to check the essential reasoning.

WARM-UP • ACTIVITY 1

Recall Activity 1

$dp/dy = -\rho g$; pressure decreases as y increases.

WHY IT WORKS Hydrostatic equilibrium requires the upward pressure-gradient force to balance weight.

WARM-UP • ACTIVITY 2

Recall Activity 2

$\vec{F}_B = -\oint p\,\hat{n}\,dA = \rho_{fluid} V_{disp}\, g\, \hat{y}$ upward, for a uniform incompressible fluid in uniform gravity.

WHY IT WORKS The hydrostatic pressure gradient makes the pressure forces larger on lower surfaces than on upper surfaces.

WARM-UP • ACTIVITY 3

Recall Activity 3

$\partial\rho/\partial t + \nabla\cdot(\rho\vec{v}) = 0$.

WHY IT WORKS The divergence term measures net mass flux out of a small control volume.

SOLUTIONS • GUIDED PRACTICE

PRACTICE 1

Worked Example

$p(y_2)-p(y_1)=-\rho_0 g[(y_2-y_1)-(\alpha/2)(y_2^2-y_1^2)]$.

WHY IT WORKS Start from $dp/dy=-\rho(y)g$ and integrate between the two elevations.

PRACTICE 2

Guided Problem

Because $\vec{F}_B=-\int_V \nabla p\, dV$ and $\nabla p=\rho\vec{g}$ is constant; the result depends on displaced volume, not absolute pressure.

WHY IT WORKS Increasing depth raises pressure on all surfaces but does not change the net pressure-gradient force when ρ and g are uniform.

PRACTICE 3

Independent Problem

$p/\rho + v^2/2 + gy$ = constant along a streamline.

WHY IT WORKS Project Euler's equation along a streamline and integrate; the convective acceleration contributes $d(v^2/2)$.

SOLUTIONS • CONFIDENCE CHECK

QUICK CHECK 1

Pressure model check

Pressure decreases with increasing y.

WHY IT WORKS The gradient must oppose the upward direction because pressure supports the fluid's weight.

QUICK CHECK 2

Buoyancy check

No.

WHY IT WORKS The pressure level increases with depth, but the pressure gradient and displaced volume remain the same.

QUICK CHECK 3

Continuity and Bernoulli check

$\nabla \cdot \vec{v} = 0$.

WHY IT WORKS Constant density removes the density-change term from mass conservation.

READINESS GUIDE

3 correct: You're ready to continue. • 2 correct: Review the missed idea, then continue. • 0–1 correct: Revisit Core Concepts or choose more practice.

FR-09 • STAGE 6 OF 6

Next Step: Continue Learning

Great work! You've completed this review. Choose the next resource that best matches how confident you feel.

?	◎	✓
I'm Still Unsure	**I Need More Practice**	**I'm Ready**
Review the key ideas and examples again.	Continue with additional practice for this topic.	Continue to the next recommended resource.
Review again: return to Warm-Up Check on page 4.	**Go to Practice →**	**Continue →**

RECOMMENDED LINKS

Review again: return to Warm-Up Check on page 4.

Find additional practice →

Choose another type of physics help →

Continue reviewing with these companion resources.

Start the Review Online →
Watch the Video Review →

PHYSICS HELP THAT MAKES SENSE

A Physics Sensei review never ends at the last question. It always guides you toward the next useful step.

PhysicsSensei.com