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Fluid Forces Student Worksheet Answer Key

Goal:
Explore how different fluids can exert different forces and observe how fluid properties impact the movement of objects in a hydraulic system.

Materials Needed:
- 3 sets of connected syringes and tubing:
  - Set 1: Air (empty syringes)
  - Set 2: Water
  - Set 3: Viscous substance (e.g., honey or bubble bath)
- Small objects to move: marker, board eraser, small book

Procedure:
1. Initial Observations
   a. Test each set of syringes by pressing one syringe and observing the movement of the connected syringe.
   b. Use the syringes to try and move small objects (e.g., a marker, eraser, or book).
   c. Observe and compare the force required to push the syringe with different fluids.

2. Record Observations
   For each fluid, answer the following using a scale of 1-5 (1 = easiest, 5 = most difficult).

	How much effort is needed to push the syringe?	How quickly does the connected syringe respond?	How effectively does the system move the object?
Air	**1-2**	**3-4**	**4-5**
Water	**2-3**	**1-2**	**1-2**
Viscous Fluid	**4-5**	**4-5**	**3-4**

- Air
  - Very easy to push (low effort = 1) because it compresses
  - Slower, delayed response due to compression (3–4)
  - Least effective at moving objects (5)
- Water
  - Moderate effort (2–3)
  - Fastest response (1) because it is nearly incompressible
  - Most effective at moving objects (1) → true hydraulic behavior
- Viscous fluid
  - Hardest to push (4–5) due to internal resistance
  - Slowest response (5)
  - Some force transfer, but inefficient (3–4)

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Analysis Questions:

Instructions: Answer the following questions based on your observations.

1. How did the force transfer differ between the air-filled, water-filled, and viscous-fluid-filled syringes?
   The primary difference lies in compressibility and friction.
   - Air: Force transfer was inefficient and delayed. Because air is a gas, it is highly compressible; the first bit of energy you spend goes into "squishing" the air molecules together before the second syringe even begins to move.
   - Water: Force transfer was direct and immediate. Since liquids are nearly incompressible, the force applied to one plunger is transferred directly through the water to the other plunger.
   - Viscous fluid: Force transfer was powerful but required high "input" energy. While it is incompressible like water, its thickness creates internal friction (resistance), meaning more force is lost just trying to get the fluid through the tubing.

2. Which fluid allowed for the easiest and fastest movement of the object? Why?
   Water typically allows for the best balance of ease and speed. Water is incompressible, providing an instant response (unlike air), and it has low viscosity, meaning it flows through the tubing with very little resistance (unlike the viscous fluid). This makes the energy transfer highly efficient.

3. What challenges would engineers face when using a viscous fluid in a hydraulic system?
   Engineers would face three main hurdles:
   - Energy loss: It requires a much more powerful pump to move thick fluid through pipes, leading to higher energy costs.
   - Heat generation: The friction caused by a viscous fluid moving through a system creates heat, which can damage seals or degrade the fluid itself.
   - Slow response times: In systems requiring precision or high-speed movement (like car brakes), a viscous fluid would cause a dangerous lag in performance.

4. How do your observations demonstrate Newton's First Law of Inertia?
   Newton's First Law states that an object at rest stays at rest unless acted upon by an unbalanced force. In this activity, the small objects (marker, eraser) remained stationary (inertia) until the fluid pressure provided enough force to overcome the friction between the object and the table.

   Note: Students likely noticed this most with the air set: the object didn't move at all until you "charged" the system with enough compressed air to finally overcome the object's inertia.

5. What role do balanced and unbalanced forces play in the motion of the objects?
   Balanced forces: When you aren't pushing the syringe, or if you push very lightly but the object doesn't move, the forces are balanced. The force of the fluid is being cancelled out by the force of friction and the object's weight. Result: No motion.

   Unbalanced forces: As soon as the pressure from the fluid exceeds the force of friction holding the object in place, the forces become unbalanced. This creates acceleration, causing the object to move in the direction of the fluid's push.

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Illustrations of Observations

Instructions: Use the space below to sketch your free body diagrams for each fluid system. Be sure to:

- Label the syringes and tubing.
- Use arrows to represent the forces and show any differences in the size or direction of the forces between the systems.

Free Body Diagram for Air System: *(Draw here)*

Diagram should show:

- Large applied force on the input syringe
- Much smaller force arrows on the output syringe
- Forces are not balanced between input and output

What it means:

- Air is compressible
- Much of the applied force is used to compress the air instead of moving the object
- Force transfer is inefficient

➔ Some force is "lost" to compression, so the output force is smaller.

Free Body Diagram for Water System: *(Draw here)*

Diagram should show:

- Applied force and output force arrows are similar in size
- Immediate force transfer through the tubing
- Forces are balanced and consistent

What it means:

- Water is nearly incompressible
- Force is transmitted efficiently from one syringe to the other
- This system best represents a real hydraulic system

➔ Force applied at one end is transferred almost entirely to the other end.

Free Body Diagram for Viscous Fluid System: *(Draw here)*

Diagram should show:

- Very large applied force on the input syringe
- Smaller and delayed output force
- Additional resistive forces labeled due to viscosity

What it means:

- Thick fluids resist motion
- Energy is lost to internal friction in the fluid
- Force transfer occurs, but slowly and inefficiently

➔ The fluid resists flowing, making motion slow and difficult.

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Vocabulary Development

Instructions: Research and define each term in your own words.

- **Force:** A push or a pull exerted on an object. It is the "muscle" behind any change in motion, measured in Newtons.
- **Balanced Forces:** When two or more forces acting on an object are equal in size and opposite in direction. They cancel each other out, so the object's motion doesn't change (it stays still or keeps moving at a constant speed).
- **Unbalanced Forces:** When one force is stronger than the opposing forces. This "winner" causes a change in the object's motion, such as making it start moving, stop, or change direction.
- **Fluids:** Any substance that can flow and take the shape of its container. This includes both liquids (like water) and gases (like air).
- **Viscosity:** A measure of a fluid's "thickness" or resistance to flowing. High viscosity fluids (like honey) flow slowly, while low viscosity fluids (like water) flow quickly.
- **Hydraulic:** A system that operates by moving and compressing (or attempting to compress) liquids to transmit power. It allows a small amount of effort in one place to create a large amount of force in another.
- **Inertia:** The "stubbornness" of an object. It is the tendency of an object to resist any change in its motion—meaning an object at rest wants to stay at rest, and an object in motion wants to stay in motion.
- **Pressure:** The amount of force spread out over a specific area (P = F/A). In a syringe, when you push the plunger, you are creating pressure within the fluid inside.
- **Pascal's Law:** The rule stating that when you apply pressure to a fluid in a closed container, that pressure is transmitted equally in every single direction throughout the entire fluid. This is the "magic" that makes hydraulics work.

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Research: Hydraulic Bridges Around the World

Instructions: Research hydraulic bridges around the world. Record your bridge inspirations, the name, and a brief summary of how the bridge works. Include at least 2 different bridges from around the world.

Answers will vary.

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Planning and Building Instructions

Sketch MUST INCLUDE:

- Plans for a base
- Bridge size: 8” in length, 5” in height & width
- Location of syringes
- Direction of potential movement
- Labels

Materials:

- Minimum of 2 syringes
- 12” plastic tube (⅛” diameter)
- 1/2" wood cubes with holes
- ¾” wood cubes
- Skewers
- Popsicle sticks
- Hot glue

Sketches will vary.

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Test and Improve

Instructions: Test your bridge.

1. Test your bridge with air. Record your observations here.
Answers will vary.

2. Test your bridge with water. Record your observations here.
Answers will vary.

3. Test your bridge with a thicker fluid (e.g., honey or body wash). Record your observations here.
Answers will vary.

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Instructions: Improve your bridge.

4. List what worked with your bridge.

Answers will vary.

5. List what didn't work with your bridge.

Answers will vary.

6. List what you will do to improve your bridge.

Answers will vary.