Physics 103 CQZ1 Solutions and Explanations

1. All fluids are:

- ☐ **A.** gases
- ☐ **B.** liquids
- ◉ **C.** gases or liquids
- ☐ **D.** non-metallic
- ☐ **E.** transparent

Matter is classified as solid, liquid, gas, and plasma. Gases adjust volume and shape to the container. Liquids usually resist strongly to compression keeping the same volume, but easily adjust the shape to the container. Therefore both liquids and gases are considered fluids.

2. The pressure exerted on the ground by a man is greatest when:

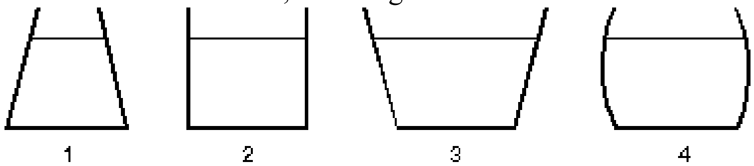
- ☐ **A.** he stands with both feet flat on the ground
- ☐ **B.** he stands flat on one foot
- ◉ **C.** he stands on the toes of one foot
- ☐ **D.** he lies down on the ground
- ☐ **E.** all of the above yield the same pressure

The equation for pressure:

$P = F/A$

states that F is the magnitude of the force and A is the area. Pressure is force divided by area, so the pressure exerted on the ground by a man is greatest when he applies his total force on a smaller area when standing on the toes of one foot.

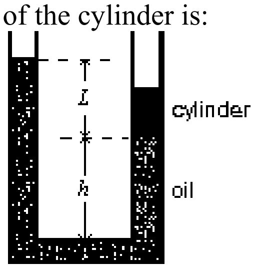
3. The vessels shown below all contain water to the same height. Rank them according to the pressure exerted by the water on the vessel bottoms, least to greatest.



- **A.** 1, 2, 3, 4
- **B.** 3, 4, 2, 1
- **C.** 4, 3, 2, 1
- **D.** 2, 3, 4, 1
- **E.** All pressures are the same

According to the diagram, all the vessels have the same level of water above the bottom. Therefore the water pressure exerted at the bottom of the vessels is the same in all of them. Shape of the bottom is irrelevant.

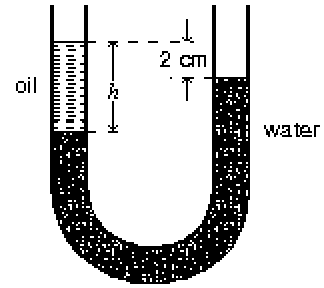
4. The diagram shows a U-tube having cross-sectional area A and partially filled with oil of density ρ. A solid cylinder, which fits the tube tightly but can slide without friction, is placed in the right arm. The system reaches equilibrium. The weight of the cylinder is:



- **A.** $AL\rho g$
- **B.** $L^3\rho g$
- **C.** $A\rho(L + h)g$
- **D.** $A\rho(L - h)g$
- **E.** none of these

In order to solve for the weight of the cylinder, you multiply the given area, A, by the given length, L and pressure of oil, p, and g, 9.8.

5. The density of water is 1.0 g/cm^3 and h=10 cm. The density of the oil in the left column of the U-tube shown below is:



- [ ] **A.** 0.20 g/cm^3
- [x] **B.** 0.80 g/cm^3
- [ ] **C.** 1.0 g/cm^3
- [ ] **D.** 1.3 g/cm^3
- [ ] **E.** 5.0 g/cm^3

You can see the solution below for a similar problem:

The U-tube in Fig. 15-4 contains two liquids in static equilibrium: Water of density ρ_w (= 998 kg/m^3) is in the right arm, and oil of unknown density ρ_x is in the left. Measurement gives l = 135 mm and d = 12.3 mm. What is the density of the oil?

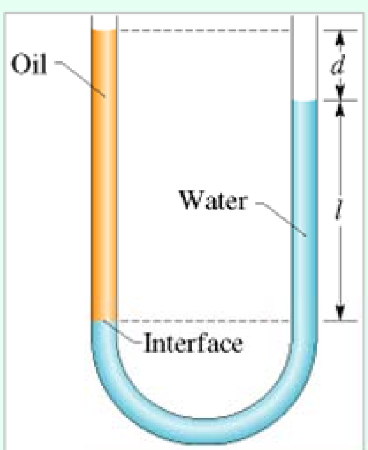


Fig. 15-4 Sample Problem 15-3 . The oil in the left arm stands higher than the water in the right arm because the oil is less dense than the water. Both fluid columns produce the same pressure P_{int} at the level of the interface.

$$p_{int} = p_0 + \rho_w g l \qquad \text{(right arm)}.$$

$$p_{int} = p_0 + \rho_x g (l + d) \qquad \text{(left arm)}.$$

$$\rho_x = \rho_w \frac{l}{l+d} = (998\ \text{kg/m}^3)\frac{135\ \text{mm}}{135\ \text{mm} + 12.3\ \text{mm}}$$

$$= 915\ \text{kg/m}^3.$$

6. "An object completely submerged in a fluid displaces its own volume of fluid." This is:

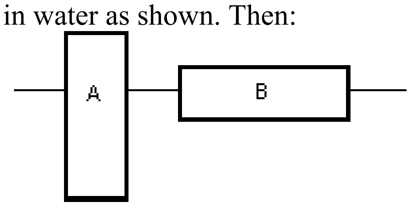
- [ ] **A.** Pascal's paradox
- [ ] **B.** Archimedes' principle
- [ ] **C.** Pascal's principle
- [x] **D.** true, but none of the above
- [ ] **E.** false

This statement is correct, but it is not Pascal's principle that describes the pressure inside liquid.

An object submerged in a fluid will always displace its own volume of fluid.

According to Archimedes's principle, any object completely or partially submerged in a fluid is buoyed up by a force with magnitude equal to the weight of the fluid displaced by the object. Similarly the laws of buoyancy indicate that an object totally submerged in a fluid of density p_{fluid}, the upward buoyant force acting on the object has a magnitude of $B=p_{fluid}V_{obj}g$, where V_{obj} is the volume of the object.

7. Two identical blocks of ice float in water as shown. Then:



- [ ] **A.** block A displaces a greater volume of water since the pressure acts on a smaller bottom area
- [ ] **B.** block B displaces a greater volume of water since the pressure is less on its bottom
- [x] **C.** the two blocks displace equal volumes of water since they have the same weight
- [ ] **D.** block A displaces a greater volume of water since its submerged end is lower in the water
- [ ] **E.** Block B displaces a greater volume of water since its submerged end has a greater area

Since the two blocks are identical, they both have the same weight and consequently they displace equal volumes of water to obtain the same buoyant force.

8. An object hangs from a spring balance. The balance indicates 30 N in air, 20 N when the object is submerged in water. What does the balance indicate when the object is submerged in liquid with a density that is half of water?:

- [ ] **A.** 20 N
- [x] **B.** 25 N
- [ ] **C.** 30 N
- [ ] **D.** 35 N
- [ ] **E.** 40 N

Buoyant force in water is B = 30-20 = 10N. This force is proportional to density of water.
If another liquid is used, then the buoyant force will reduce proportional to the density: reduce by factor of two: 5N. The new reading will be 30 N – 5N = 25 N.

9. One piston in a hydraulic lift has an area that is twice the area of the other. When the pressure at the smaller piston is increased by Δp the pressure at the larger piston:

- [ ] **A.** increases by $2\Delta p$
- [ ] **B.** increases by $\Delta p/2$
- [x] **C.** increases by Δp
- [ ] **D.** increases by $4\Delta p$
- [ ] **E.** does not change

It is a tricky question. Pressure is always the same in both pistons!!!

10. A hydraulic press has one piston of diameter 2.0 cm and the other piston of diameter 8.0 cm. What force must be applied to the smaller piston to obtain a force of 1600 N at the larger piston:

- [ ] **A.** 6.25 N
- [ ] **B.** 25 N
- [x] **C.** 100 N
- [ ] **D.** 400 N
- [ ] **E.** 1600 N

In order to find the force F of the smaller piston, you must use the equation for pressure:

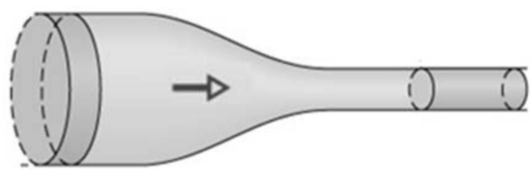
$P = \frac{F}{A} = \frac{F}{\pi r^2}$

$= \frac{1600}{\pi(4)^2} \cdot \pi(1^2)$

$= 100N$

11. Water (density = 1.0×10^3 kg/m^3) flows through a horizontal tapered pipe. At the wide end its speed is 4.0 m/s The difference in pressure between the two ends is 4.5×10^3 Pa. The speed of the water at the narrow end is::

- **A.** 2.6 m/s
- **B.** 3.4 m/s
- **C.** 4.0 m/s
- **D.** 4.5 m/s
- **E.** 5.0 m/s (selected)



$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$ for a horizontal pipe $y_1 = y_1$, so these terms cancel.

After this simplification, we obtain $P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$

Now we can combine pressure- and velocity-related terms in the opposite parts of the equation: $P_1 - P_2 = \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2$. The pressure difference $\Delta P = P_1 - P_2$ is given in the text as well as the density and water speed. Note that the flow speed should increase in the narrow end because $A_1 v_1 = A_2 v_2$ $(A_1 > A_2 \rightarrow v_1 > v_2)$. This observation helps us to avoid possible mistakes with the sign of the pressure difference. Now we solve for v_2:

$2\Delta P/\rho = v_2^2 - v_1^2$

$v_2 = \sqrt{2\Delta P/\rho + v_1^2} = \sqrt{2 \cdot 4500[Pa]/1000[\text{kg/m}^3] + (4[m/s])^2} = 5$

$v_2 = 5\ m/s$

12. Water is pumped into one end of a long pipe at the rate of 40 L/min. It emerges at the other end at 24 L/min. A possible reason for this decrease in flow is:

- ☐ **A.** the water is being pumped uphill
- ☐ **B.** the water is being pumped downhill
- ☐ **C.** the diameter of the pipe is not the same at the two ends
- ☐ **D.** friction in the pipe
- ☒ **E.** a leak in the pipe

Water being pumped into a pipe will maintain a constant volume flow unless otherwise affected. The rate at which the water was being pumped would not change, so therefore a possible reason for the decrease in flow could be a leak in the pipe.

13. A non-viscous incompressible fluid is pumped steadily into the narrow end of a long tapered pipe and emerges from the wide end. The pressure at the input is greater than at the output. A possible explanation is:

- ☐ **A.** the fluid speed increases from input to output
- ☐ **B.** the fluid speed is the same at the two ends
- ☒ **C.** the fluid is flowing uphill
- ☐ **D.** the fluid is flowing downhill
- ☐ **E.** the fluid is flowing horizontally

Consider that the fluid was being pumped steadily into a narrow opening and the fluid came out a wider opening. The flow speed should drop because of $A_1v_1 = A_2v_2$.

Everything can be explain by the following Equation:

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$$

For a horizontal pipe the conditions described in the Problem are impossible. But if we take into account the $\rho g y$ terms, then the described situation is possible if $\rho g y$ increases on the output end. So, the pipe brings the fluid uphill.

14. Water flows from a 6.0-cm diameter pipe into an 8.0-cm diameter pipe. The speed in the 6.0-cm pipe is 5.0 m/s. The speed in the 8-cm pipe is:

- (•) **A.** 2.8 m/s
- ( ) **B.** 3.7 m/s
- ( ) **C.** 6.6 m/s
- ( ) **D.** 8.8 m/s
- ( ) **E.** 9.9 m/s

$A_1V_1 = A_2V_2$
$A = \pi r^2$

$$\pi \cdot 3^2 \cdot 5 = \pi \cdot 4^2 \cdot v$$

$$v = 5 \cdot 0.75^2 = 2.8\ m/s$$

15. A person blows across the top of one arm of a U-tube partially filled with water. The water in that arm:

- (•) **A.** rises slightly
- ( ) **B.** drops slightly
- ( ) **C.** remains at the same height
- ( ) **D.** rises if the blowing is soft but drops if it is hard
- ( ) **E.** rises if the blowing is hard but drops if it is soft

When a U-tube is partially filled with water, the pressure of the tube is in equilibrium. Once someone blows across the top of one arm, the pressure in the air decreases, so the water level will slightly rise due to the pressure pulling the water upward.

16. If two objects are in thermal equilibrium with each other

- ( ) **A.** they cannot be moving
- ( ) **B.** they cannot be undergoing an elastic collision
- ( ) **C.** they cannot have different pressures
- (•) **D.** they cannot be at different temperatures
- ( ) **E.** they cannot be falling in the Earth's gravitational field

The zeroth law of thermodynamics states that if object C is in thermal equilibrium with object A, and with object B, then A is in thermal equilibrium with object B. The property that determines thermal equilibrium is temperature. Therefore objects in thermal equilibrium with each other are also at the same temperature and cannot be at different temperatures.

17. Suppose object C is in thermal equilibrium with object A and with object B. The zeroth law of thermodynamics states:

- [ ] **A.** that C will always be in thermal equilibrium with both A and B
- [ ] **B.** that C must transfer energy to both A and B
- [x] **C.** that A is in thermal equilibrium with B
- [ ] **D.** that A cannot be in thermal equilibrium with B
- [ ] **E.** nothing about the relationship between A and B

The zeroth law of thermodynamics states that if object C is in thermal equilibrium with object A, and with object B, then A is in thermal equilibrium with object B.

18. The air temperature on a summer day might be about:

- [ ] **A.** 0°C
- [ ] **B.** 10°C
- [x] **C.** 25°C
- [ ] **D.** 80°C
- [ ] **E.** 125°C

25°C = 298°K = 75°F
10°C is a temperature inside a refrigerator, 125°C is above water boiling, 0°C – water freezes
80°C is a very hot water (like in a sauna).

19. The coefficient of expansion of a certain steel is 0.000012 per C°. The coefficient of volume expansion, in $(C°)^{-1}$, is:

- [ ] **A.** $(0.000012)^3$
- [ ] **B.** $(4\pi/3)(0.000012)^3$
- [x] **C.** 3×0.000012
- [ ] **D.** 0.000012

E. depends on the shape of the volume to which it will be applied

According to the equation for coefficient of volume expansion:
$\Delta V = \beta V_0 \Delta T$
$\beta = 3\alpha$
$= 3 \times .000012$

20. Metal pipes, used to carry water, sometimes burst in the winter because:

- A. metal contracts more than water
- B. outside of the pipe contracts more than the inside
- C. metal becomes brittle when cold
- D. ice expands when it melts
- E. water expands when it freezes

The water in the metal pipes expands upon freezing That is why cold weather is usually causing the pipes to burst if the pipes are not drained in advance.

21. On a very cold day, a child puts his tongue against a fence post. It is much more likely that his tongue will stick to a steel post than to a wooden post. This is because:

- A. steel has a higher specific heat
- B. steel is a better radiator of heat
- C. steel has a higher specific gravity
- D. steel is a better heat conductor
- E. steel is a highly magnetic material

Since steel is a much better heat conductor than wood, it would cause the child's tongue to stick to the steel because saliva (mostly water) freezes at the contact point. In the case of the contact with wood, the heat dissipation is much slower that prevents freezing of saliva at the tip of a tongue.

22. Fifty grams of ice at 0°C is placed in a thermos bottle containing one hundred grams of water at 6°C. How many grams of ice will melt? The heat of fusion of water is 333 kJ/kg and the specific heat is 4190 J/kg · K.

- [x] **A.** 7.5
- [ ] **B.** 2.0
- [ ] **C.** 8.3
- [ ] **D.** 17
- [ ] **E.** 50

The first step is to understand what is the final situation and what is the possible range for the final temperature. Since ice at 0°C is mixed with water at 6°C, several scenarios are possible depending on the masses of ice and water:

1. Some ice melts, water chills down to zero temperature.
2. All ice melts and the water temperature is between 0 and 6°C.

Let's consider the first scenario. Use the equation for specific heat Q = mc(ΔT). In our case it means that the amount of heat lost by water upon cooling to zero is $Q_{water} = m_{water}c\Delta T$ =(0.1 kg)(4186 J/kg)(0-6)= -2511.6 J.
The same amount is used to melt ice: 2,511.6 = mL_f= m($333x10^3$). Solving for m we obtain m = 7.5 g. Since this amount is less than the original 50 g, the solution makes sense and there is no reason to consider the Second scenario.
Note that if the obtained mass were larger than the total amount of ice, then it would not make physical sense and one should consider the second scenario.