Phys 20.01 Long exam 5

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2025 W49

Instructions: For comprehension and conceptual questions, choose the best answer. For problem-solving questions, choose the best answer and show your solution and reasoning. Comprehension is 1 pt each, conceptual is 2 pt each, and problem-solving is 3 pt each.

1. Comprehension

1. A fluid is
   a. a gas
   b. a liquid
   c. anything that flows
   d. anything that can be made to change shape

2. A static fluid in a container is subject to both atmospheric pressure at its surface and earth's gravitation. The pressure at the bottom of the container
   a. depends on the height of the fluid column
   b. depends on the shape of the container
   c. is equal to the atmospheric pressure

3. Which one can't be described with Bernoulli's equation?
   a. the flow of water out of a tank having a small hole near its bottom
   b. the steady flow of water in a fire hose
   c. the flow of air around an airfoil
   d. fluid flow through a pump equipped with a piston

4. When the velocity of a fluid flow increases, pressure decreases. This relationship is expressed by
   a. the equation of continuity
   b. Bernoulli's equation
   c. Pascal's principle
   d. none of the above

5. Archimedes' principle states that buoyant force equals
   a. the total weight of the object
   b. the weight of the fluid that the object displaces
   c. the weight of the fluid minus the weight of the object
   d. the volume of the fluid displaced divided by gravity

6. If you have 1,000 kg of aluminum and 1,000 kg of lead, which has the greater volume?
   a. Lead
   b. Aluminum
   c. They have same volume as they have same mass
   d. It is impossible to tell without knowing the shape

7. A paperclip is placed carefully on water and it rests on top. The paperclip is much denser than water. Why doesn't it sink?
   a. It is displacing a weight of water equal to its own weight as per Archimedes' principle
   b. The paperclip traps air bubbles underneath it, increasing its buoyancy
   c. The water pressure at the surface is higher than atmospheric pressure
   d. Surface tension behaves like a stretched membrane supporting the weight

8. An ideal fluid is a simplified model used to analyze fluid flow. Which two properties define such fluid?
   a. It is incompressible and highly viscous
   b. It is incompressible and non-viscous
   c. It is turbulent and has constant velocity
   d. It has zero density and zero temperature

9. When calculating the flux or volume flow rate of blood, what are the standard SI units, and what common medical unit is often used instead?
   a. SI: kilogram per second, medical: g/min
   b. SI: cubic meter per second, medical: L/min
   c. SI: pascal, medical: mm Hg
   d. SI: meter per second, medical: cm/s

10. Which condition is most likely to cause a fluid flow to transition from laminar to turbulent?
    a. Decreasing the flow speed significantly
    b. Increasing the fluid's viscosity (making it thicker)
    c. Reducing the diameter of the pipe very gradually
    d. The flow speed exceeding a certain critical value or encountering abrupt obstacles

11. Bernoulli's equation $p + \rho gy + \frac{1}{2}\rho v^2 = \text{constant}$ is essentially a restatement of which physics law?
    a. Newton's third law
    b. Conservation of momentum
    c. Conservation of energy
    d. Archimedes' principle

12. Which one can't be described by Bernoulli's equation?
    a. the flow of water out of a tank having a small hole near its bottom
    b. fluid flow through a pump equipped with a piston
    c. the steady flow of water in a fire hose
    d. the flow of air around an airfoil

13. A fully submerged object always displaces its own
    a. weight of fluid
    b. volume of fluid
    c. density of fluid
    d. All of these

14. In a vacuum, an object has no
    a. mass
    b. weight

c. buoyant force

d. All of these

15. A doctor uses a stethoscope to listen to an artery. What are they listening for to detect a potential pathology?
    a. The silence of laminar flow
    b. The high pitch of viscous friction
    c. The rhythmic thumping of the heart valves only
    d. The noise generated by turbulent flow caused by a disturbance

2. Conceptual

1. A large, shallow lake and a small, deep pond are compared. Which exerts greater pressure at the bottom?
   a. Small pond, as pressure depends only on depth, not the total volume
   b. Large lake, as the surface area of the water is greater
   c. Large lake, as it contains a much larger total weight of water
   d. They are equal, because water pressure is constant at any point below the surface

2. A car lift raises a car. The piston under the car moves up a very short distance, while the oil level in the reservoir drops a much larger distance. Why?
   a. The area of the piston under the car is smaller than the reservoir surface
   b. The area of the piston under the car is larger than the surface area of the reservoir
   c. Oil compresses significantly under pressure
   d. Energy is lost to friction in the pipes

3. Why does a giraffe require a much higher systolic blood pressure (~280 mm Hg) compared to a human (~120)?
   a. Because giraffes have much higher blood viscosity
   b. To overcome the large hydrostatic pressure gain required to pump blood vertically up to the brain
   c. To prevent the blood from becoming turbulent in the long neck arteries
   d. Because the blood flows faster in giraffes due to their size

4. A nurse is setting up a gravity-fed IV infusion. As per fluid statics, $p = \rho g h$. Which one must be manipulated to overcome a venous gauge pressure of 18 mm Hg?
   a. Height h of the bag must be elevated relative to the insertion point
   b. Atmospheric pressure p_a surrounding the bag must be increased
   c. Needle diameter must be increased to reduce resistance
   d. Density ρ of saline solution must be increased

5. If you attach a nozzle to a garden hose, the water exits at a much higher speed. According to Bernoulli's principle, how does the pressure inside the nozzle compare to the pressure inside the main hose?
   a. The pressure in the nozzle is higher because the water is moving faster

b. The pressure in the nozzle is lower because the water is moving faster
   c. The pressure is the same in both because they are at the same height
   d. The pressure in the nozzle is zero

6. Why does the Bernoulli effect (fluid moving faster has lower pressure) pose a potential problem for blood vessels with strictures (narrowings)?
   a. The blood speeds up, increasing friction and heating the vessel
   b. The Bernoulli effect does not apply to blood because it is viscous
   c. The blood slows down in the narrowing, causing pressure to build up and burst the vessel
   d. The blood speeds up in the narrowing, causing lower pressure which might collapse the vessel

7. In the circulatory system, where is the blood velocity the slowest?
   a. aorta
   b. large arteries
   c. capillaries
   d. vena cavae

8. Imagine holding two bricks under water. Brick A is just beneath the surface of the water, while brick B is at a greater depth. The force needed to hold brick B in place is … that of brick A.
   a. larger than
   b. the same as
   c. smaller than

9. Why is a flat tire technically not at zero pressure?
   a. Because the rubber still exerts elastic force
   b. Because flat implies the gauge pressure is zero, meaning the absolute pressure is still equal to atmospheric pressure
   c. Because air has mass and cannot be at zero pressure unless in a vacuum
   d. Because the rim supports the weight of the car

10. A typhoon blows wind continuously over peaked roof of a house. What is the net force direction on the roof?
    a. Upwards, because the air pressure outside is lower than the air pressure inside
    b. Downwards, because the wind pushes on the roof
    c. Sideways only, in the direction of the wind
    d. Zero, the roof is heavy enough to resist

11. Two cups are filled to the same level with water. One of the two cups has plastic balls floating in it. If the density of the plastic balls is less than that of ice, which of the two cups weighs more?
    a. The cup without plastic balls
    b. The cup with plastic balls
    c. The two weigh the same

12. Two hoses, one of 20-mm diameter, the other of 15-mm diameter are connected one behind the other to a faucet. At the open end of the hose, the flow of water

measures 10 liters per minute. Through which pipe does the water flow faster?

a. the 20-mm hose
b. the 15-mm hose
c. the flow rate is the same in both cases
d. the answer depends on which of the two hoses comes first in the flow

13. Blood flows through a coronary artery that is partially blocked by deposits along the artery wall. Through which part of the artery is the flux (volume of blood per unit time) largest?

a. the narrow part
b. the wide part
c. the flux is the same in both parts

14. A blood platelet drifts along with the flow of blood through an artery that is partially blocked by deposits. As the platelet moves from the narrow region to the wider region, its speed

a. increases
b. decreases
c. remains the same

15. Rank the volumes of air in the glass, from greatest to least, when it is held

- A: near the surface as shown
- B: 1 m beneath the surface
- C: 2 m beneath the surface

a. A, B, C
b. A, C, B
c. C, A, B
d. C, B, A
e. No ranking because A = B = C

3. Problem solving

Oh no, Sarah! Sarah weighs 120 pounds and plans to lie on a bed of nails. To ensure her safety and prevent any individual nail from piercing her skin, the average pressure exerted on any single nail tip must not exceed 100 psi.

1. If each nail tip has an average contact area of 0.005 square inches, what is the minimum number of nails the bed must have to safely support her?

a. 24 nails
b. 60 nails
c. 240 nails
d. 600 nails
e. Cannot be determined as info is incomplete
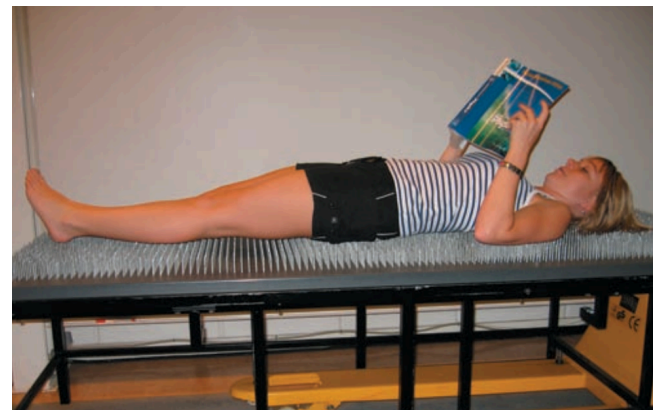
Recall that pressure is defined as $p = F/A$, so rearranging, we can calculate the maximum safe force of a single nail can support

$$F_{\max} = pA = 100\frac{\text{lb}}{\text{in}^2} \times 0.005 \text{ in}^2 = 0.5 \text{ lb}.$$

This means that a single nail can safely support 0.5 pounds of Sarah's weight.

To support her total weight of 120 pounds, the minimum number n of nails the bed must have is then

$$n = \frac{\text{total weight}}{\text{max force per nail}} = \frac{120 \text{ lb}}{0.5 \text{ lb}} = 240$$

Wha'?! A reservoir. Sketched is a wooden reservoir reinforced with metal hoops that supplies water to a farm. For each item, pick a choice and write down your reasoning.

1. Why is it elevated?

a. to overcome external atmospheric pressure
b. to create hydrostatic pressure
c. to maximize water's flow rate
d. to prevent water from boiling
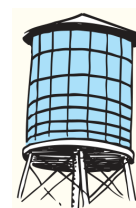
Pressure in a fluid increases with height. By elevating the tank, a high pressure head is established relative to the farm. This pressure is essential for driving the water through the supply pipes, overcoming friction, and ensuring a sufficient flow rate and pressure at the point of use without needing a mechanical pump.

2. Why are the hoops closer together near the bottom part of the tank?

a. To manage fluid shear stress (relating to its viscosity)
b. To dampen fluid's internal molecular attraction
c. Water's density is highest at depth
d. Outward fluid pressure is greatest

The hoops are closer together near the bottom because the outward fluid pressure is greatest at that depth. Hydrostatic pressure increases linearly as the water column gets taller. Since the water exerts the largest outward force on the tank walls at the base, the metal hoops must be concentrated there to provide maximum tensile strength and structural reinforcement, preventing the tank from failing under the greatest stress.