BUOYANT FORCE

Buoyant Force

1. A buoyant force is...
   - A an upwards force acting on all objects
   - B the net force acting on an object that is in a fluid
   - C a force exerted on an object by a fluid that is equal the weight of the object
   - D the net force exerted on an object by the fluid around it

2. Which of the following is the cause of a buoyant force?
   - A The fluid pressure acting on the bottom of an object is greater than the pressure acting on the top
   - B Any pressure exerted on an object by a fluid always acts upwards
   - C The density of the fluid is greater than the density of the object in the fluid
   - D None of the above

3. Which of the following objects experience an upwards buoyant force? (Select all that apply)
   - A A person sitting in a chair on earth
   - B An ice cube floating in a glass of water
   - C A balloon resting on the ground
   - D A bowling ball sitting on the bottom of a pool of water

4. A boat is floating in the ocean. Which of the following is equal in magnitude to the buoyant force acting on the boat from the water?
   - A The weight of the boat
   - B The average density of the boat multiplied by the volume of the boat that is underwater multiplied by the acceleration due to gravity
   - C The weight of an amount of water whose volume is equal to the volume of the boat that is underwater
   - D The density of the water multiplied by the volume of the boat that is underwater

5. A heavy ball is thrown into a pool of water and it sinks to the bottom. Which of the following must be true?
   - A There is no buoyant force acting on the ball
   - B The buoyant force acting on the ball is less than the weight of the ball, but not zero
   - C The buoyant force acting on the ball is equal to the weight of the ball
   - D The buoyant force acting on the ball is greater than the weight of the ball

6. A foam pool noodle is floating at rest on the surface of a pool. Some of the noodle is above the surface and some is underwater. Which of the following must be true? (Select all that apply)
   - A The buoyant force acting on the noodle is greater than the weight of the noodle
   - B The density of the pool noodle is equal to the density of the water
   - C The weight of the noodle is equal to the buoyant force acting on the noodle
   - D The weight of the volume of water that is displaced by the noodle is equal to the weight of the noodle

7. A metal nail is dropped into a bucket of paint and the nail sinks to the bottom of the bucket. The upwards buoyant force acting on the nail depends on which of the following? (Select all that apply)

   A The density of the nail
   B The density of the paint
   C The volume of the nail
   D None of the above, there is no upwards buoyant force acting on the nail

8. A block is partially submerged in a liquid as shown in Figure 1. The mass of the block is $\boldsymbol{m}$, the total volume of the block is $\boldsymbol{V}$ and the density of the liquid is $\boldsymbol{\rho}$. If 1/4 of the block's volume is submerged in the liquid, which of the following is equal to the buoyant force acting on the block?

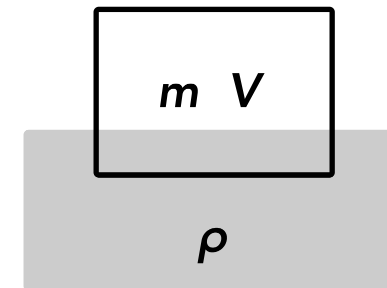

Figure 1

   A mg/V
   B $\rho(V/4)g$
   C $4\rho Vg$
   D ρVg

9. Two blocks are floating at rest in a liquid as shown in Figure 2. Block A has a greater volume than block B, and block B has a greater mass than block A. Which of the following must be true?

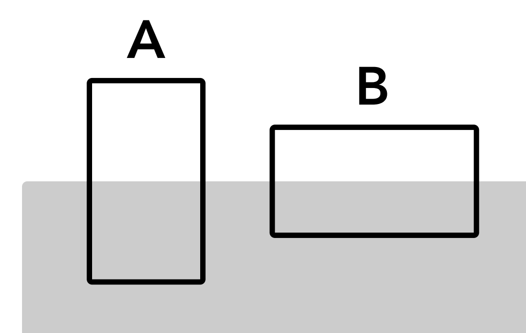

Figure 2

   A The buoyant force on block B is greater than the buoyant force on block A
   B The buoyant force on block B is equal to the buoyant force on block A
   C The buoyant force on block B is less than the buoyant force on block A
   D None of the above can be determined

10. A balloon is filled with helium and tied to a string which is attached to the ground as shown in Figure 3. The balloon is floating at rest and is held down by the string. The total mass of the balloon is $\boldsymbol{m}$, the total volume of the balloon is $\boldsymbol{V}$ and the average density of the balloon is ρ_b . The density of the surrounding air is ρ_{atm} . Which of the following is equal to the tension in the string?

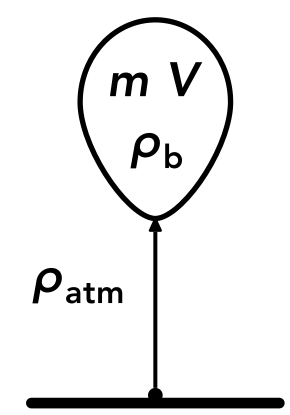

Figure 3

   A $\rho_b Vg - mg$
   B $mg - \rho_{atm} Vg$
   C $mg + \rho_b Vg$
   D $\rho_{atm} Vg - mg$

11. Object A and object B are floating at rest as shown in Figure 4. Each object is divided into cubes and the volume of each cube is the same (a cube in object A also has the same volume as a cube in object B). Object A and object B have different densities which are ρ_A and ρ_B. What is the ratio of ρ_A/ρ_B?

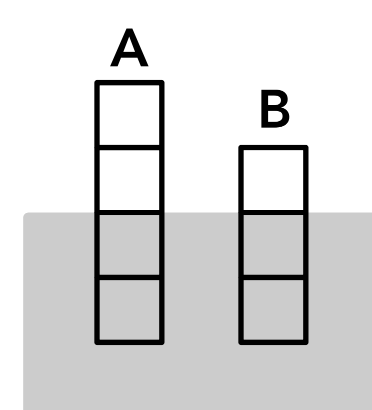

Figure 4

   A 4/3
   B 2/3
   C 3/4
   D 2/4

12. A block is fully submerged in a container of liquid as shown in Figure 5. The volume of the block is V and the density of the liquid is ρ. The block is suspended at rest by a string attached to the ceiling and the tension in the string is T. Which of the following is equal to the mass of the block?

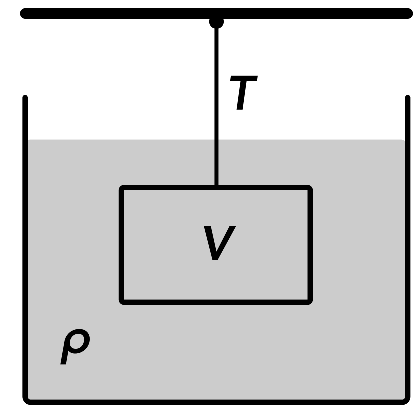

Figure 5

A ρV

B $\dfrac{\rho V g - T}{g}$

C $\rho V g + T$

D $\dfrac{\rho V g + T}{g}$

13. A boat with a mass of 5,000 kg is floating at rest in the ocean. 20% of the total volume of the boat is underwater and the density of the ocean water is 1,030 kg/m³. What is the buoyant force acting on the boat?

14. The buoyant force acting on a hot air balloon is 42,000 N. If the density of the atmosphere at the height of the balloon is 1.2 kg/m³ what is the volume of the hot air balloon?

15. A ball with a diameter of 20 cm is thrown into a pool of water. After a few seconds the ball comes to rest and is floating on the water with 30% of its volume below the surface of the water. What is the mass of the ball?

16. An iceberg is floating in the ocean. Part of the iceberg is above the surface of the water and part of it is below. If the density of the water is 1,030 kg/m³ and the density of the iceberg is 916 kg/m³, what percent of the iceberg's volume is below the surface of the water?

17. A metal cube with a side length of 15 cm and a mass of 10 kg is dropped into a pool of water and it sinks to the bottom. What is the normal force acting on the cube from the bottom surface of the pool?

18. An object with a density of 900 kg/m³ is floating in water as shown in Figure 6 (not drawn to scale). The object is a rectangular prism with a height of 30 cm. What is the height of the object above the water h?

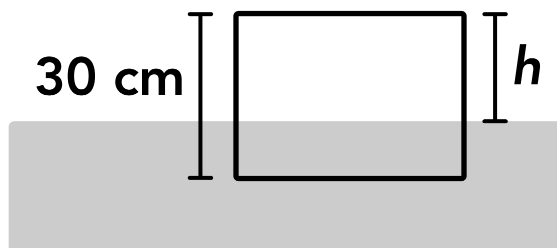

Figure 6

19. A solid ball with a radius of 3 cm and a density of 1,500 kg/m³ is held submerged in a container of water as shown in Figure 7. What is the magnitude of the acceleration of the ball when it is released (ignoring any drag forces from the water)?

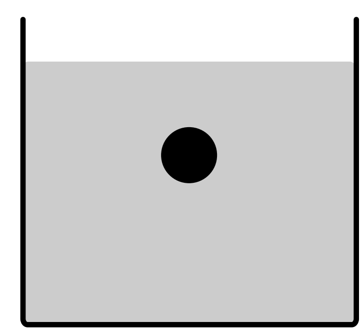

Figure 7

20. A block with a density of 1,200 kg/m³ and a volume of 3 m³ is suspended from the ceiling by a string, and half of the block is submerged in a container of water. What is the tension in the string?

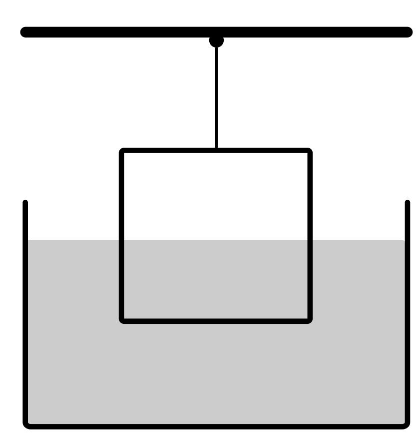

Figure 8

Answers

1. D
2. A
3. A, B, C, D
4. C
5. B
6. C, D
7. B, C
8. B
9. A
10. D
11. C
12. D
13. 49,000 N
14. 3,571 m^3
15. 1.3 kg
16. 89%
17. 64.9 N
18. 3 cm
19. 3.3 m/s^2
20. 20,580 N

Answers - Buoyant Force

1. **Answer: D**
   A buoyant force is the net force exerted on an object by the fluid around it (the net force of all of the forces acting on the surfaces of the object by the fluid). A buoyant force is not the overall net force acting on the object, only the force exerted on the object by the fluid (for example the object's weight force also contributes to the net force on the object). The buoyant force is equal to the weight of the fluid displaced by the object, it is not always equal to the weight of the object.

2. **Answer: A**
   The pressure in a fluid increases with depth (due to the weight of the fluid above) so the upwards pressure and force acting on the bottom of an object is greater than the downwards pressure and force acting on the top of the object. The net force exerted on the object by the fluid (the buoyant force) acts upwards.

3. **Answer: A, B, C, D**
   There is always an upwards buoyant force acting on an object that is in contact with a fluid due to the difference in fluid pressure between the top and bottom of the object. This is true regardless of the weight of the object. A person sitting in a chair on earth is in a fluid (the surrounding atmosphere) so they experience an upwards buoyant force from the air. An ice cube floating in water experiences an upwards buoyant force from the water. A balloon resting on the ground experiences an upwards buoyant force from the air around it, like the person in the chair. A bowling ball at the bottom of a pool of water experiences an upwards buoyant force from the water.

4. **Answer: C**
   Archimedes' principle says that the upwards buoyant force acting on an object is equal to the weight of the fluid that is displaced by the object (the volume of fluid that is displaced is equal to the volume of the object below the surface of the fluid). This is equal to the density of the fluid multiplied by the volume of the fluid displaced (which together is the mass of the fluid displaced) multiplied by the acceleration due to gravity g.

5. **Answer: B**
   There is an upwards buoyant force exerted on the ball from the water. The ball sinks so the downwards weight of the ball must be greater than the upwards buoyant force on the ball.

6. **Answer: C, D**
   The pool noodle is at rest so the net force acting on it must be zero (Newton's 2nd law of motion), so the upwards buoyant force from the water is equal to the downwards weight force on the noodle. The buoyant force is always equal to the weight of the volume displaced by the object, which in this case is also equal to the weight of the object. The density of the noodle must be less than the density of the water because the noodle is floating on the water and part of it is above the water.

7. **Answer: B, C**
   There is an upwards buoyant force exerted on the nail (the object) by the paint (the fluid). The buoyant force depends on the density of the paint, the volume of the paint displaced by the nail (which is equal to the volume of the nail because it is completely submerged) and the acceleration due to gravity g.

8. **Answer: B**
   The buoyant force is equal to the density of the fluid multiplied by the volume of the displaced fluid (the volume of the object that is submerged in the fluid) multiplied by the acceleration due to gravity. The volume of the displaced fluid is 1/4 of the total volume of the object.
   $F_B = \rho_f V_f g = \rho(V/4)g$

9. **Answer: A**
   Each block is at rest so the net force on each block must be zero (Newton's 2nd law of motion) so the upwards buoyant force on each block must be equal to the downwards weight force on each block. Block B has a greater mass than block A so block B has a greater weight than block A, and therefore a greater buoyant force since the buoyant force is equal to the weight force.

10. **Answer: D**
    The balloon is at rest so the net force on the balloon must be zero (Newton's 2nd law of motion). There is an upwards buoyant force acting on the balloon from the surrounding air, a downwards weight force on the balloon and a downwards tension force on the balloon. The buoyant force depends on the density of the fluid surrounding the balloon, not the density of the balloon.
    $\sum F_y = F_B - F_g - T = 0 \qquad \rho_{atm} V g - mg - T = 0 \qquad T = \rho_{atm} V g - mg$

11. **Answer: C**
    We can represent the volume of 1 cube (1 square section of the objects) as V_{cube} and the density of the fluid as ρ_f . The mass of each object is its density multiplied by its volume:

    Object A: $\rho_A = \dfrac{m_A}{V_A} \qquad m_A = \rho_A V_A = \rho_A(4V_{cube})$

    Object B: $\rho_B = \dfrac{m_B}{V_B} \qquad m_B = \rho_B V_B = \rho_B(3V_{cube})$

    The net force on each object is zero because they are at rest (Newton's 2nd law) so the upwards buoyant force on each object is equal to the downwards weight force. We can rearrange those equations to find the density of each object in terms of the density of the fluid ρ_f :

    Object A: $\sum F_y = F_B - F_g = 0 \qquad F_B = F_g \qquad \rho_f V_f g = m_A g \qquad \rho_f(2V_{cube})g = \rho_A(4V_{cube})g \qquad \rho_A = \dfrac{\rho_f}{2}$

    Object B: $\sum F_y = F_B - F_g = 0 \qquad F_B = F_g \qquad \rho_f V_f g = m_B g \qquad \rho_f(2V_{cube})g = \rho_B(3V_{cube})g \qquad \rho_B = \dfrac{2\rho_f}{3}$

    $$\frac{\rho_A}{\rho_B} = \frac{\rho_f/2}{2\rho_f/3} = \frac{\rho_f}{2} \times \frac{3}{2\rho_f} = \frac{3}{4}$$

12. **Answer: D**
The net force on the block is zero because the block is at rest (Newton's 2nd law). There is an upwards buoyant force, an upwards tension force and a downwards weight force acting on the block.

$$\sum F_y = F_B + T - F_g = 0 \qquad \rho V g + T - mg = 0 \qquad m = \frac{\rho V g + T}{g}$$

13. **Answer: 49,000 N**
The boat is at rest so the net force on the boat is zero (Newton's 2nd law) so the upwards buoyant force is equal to the weight force on the boat.
$$\sum F_y = F_B - F_g = 0 \qquad F_B = F_g = mg = (5{,}000 \text{ kg})g = 49{,}000 \text{ N}$$

14. **Answer: 3,571 m³**
The equation for buoyant force is given below. The fluid is the atmosphere around the balloon and the volume of the fluid displaced is equal to the volume of the balloon.
$$F_B = \rho_f V_f g \qquad (42{,}000 \text{ N}) = (1.2 \text{ kg/m}^3)V_f g \qquad V = 3{,}571 \text{ m}^3$$

15. **Answer: 1.3 kg**
When the ball is floating at rest the net force on the ball is zero (Newton's 2nd law) so the upwards buoyant force is equal to the downwards weight force. The equation for the volume of a sphere is given below.

$$V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(0.20 \text{ m} / 2)^3 = 4.19 \times 10^{-3} \text{ m}^3$$

$$\sum F_y = F_B - F_g = 0 \qquad F_B = F_g \qquad \rho_f V_f g = mg \qquad (1{,}000 \text{ kg/m}^3)(0.3 \times 4.19 \times 10^{-3} \text{ m}^3)g = mg \qquad m = 1.3 \text{ kg}$$

16. **Answer: 89%**
We assume the iceberg is floating at rest so the net force on the iceberg is zero (Newton's 2nd law) so the upwards buoyant force is equal to the downwards weight force. We can replace the mass of the iceberg with its density multiplied by its total volume.

Mass of iceberg: $\rho_i = \frac{m_i}{V_i} \qquad m_i = \rho_i V_i$

$$\sum F_y = F_B - F_g = 0 \qquad F_B = F_g \qquad \rho_f V_f g = m_i g \qquad \rho_f V_f g = \rho_i V_i g$$

Then we can find the percent of the iceberg's total volume V_i that is underwater (displacing the fluid) V_f :

$$\frac{V_f}{V_i} = \frac{\rho_i}{\rho_f} \times 100\% = \frac{(916 \text{ kg/m}^3)}{(1{,}030 \text{ kg/m}^3)} \times 100\% = 89\%$$

17. **Answer: 64.9 N**
We assume the cube is sitting at rest on the bottom of the pool so the net force acting on the cube is zero (Newton's 2nd law). There is an upwards buoyant force, and upwards normal force and a downwards weight force acting on the cube.
$$\sum F_y = F_B + F_n - F_g = 0 \qquad \rho_f V_f g + F_n - mg = 0 \qquad (1{,}000 \text{ kg/m}^3)(0.15^3 \text{ m}^3)g + F_n - (10 \text{ kg})g = 0$$
$$F_n = 64.9 \text{ N}$$

18. **Answer: 3 cm**
We assume the object is floating at rest so the net force on the object is zero (Newton's 2nd law) so the upwards buoyant force is equal to the downwards weight force. We can replace the mass of the object with its density multiplied by its total volume.

Mass of object: $\rho_o = \dfrac{m_o}{V_o}$ $\quad m_o = \rho_o V_o$

$\sum F_y = F_B - F_g = 0 \quad F_B = F_g \quad \rho_f V_f g = m_o g \quad \rho_f V_f g = \rho_o V_o g$

The object is a rectangular prism so its volume is proportional to its height. The fraction of the height that is underwater (30 cm − h) to the total height of the object (30 cm) is equal to the fraction of the volume that is underwater (equal to the volume of the displaced fluid V_f) to the total volume of the object V_o:

$$\frac{(30\text{ cm} - h)}{30\text{ cm}} = \frac{V_f}{V_o} = \frac{\rho_o}{\rho_f} = \frac{900\text{ kg/m}^3}{1{,}000\text{ kg/m}^3} \qquad h = 3\text{ cm}$$

19. **Answer: 3.3 m/s²**
From Newton's 2nd law, the net force acting on the ball is equal to its mass multiplied by its acceleration. There is an upwards buoyant force and a downwards weight force acting on the ball (we are ignoring any other forces). We can replace the mass of the ball with its density multiplied by its volume.

Volume of the ball: $V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(0.03\text{ m})^3 = 1.13 \times 10^{-4}\text{ m}^3$

Mass of the ball: $\rho_b = \dfrac{m_b}{V_b}$ $\quad m_b = \rho_b V_b = (1{,}500\text{ kg/m}^3)(1.13 \times 10^{-4}\text{ m}^3) = 0.17\text{ kg}$

$\sum F_y = F_B - F_g = ma \quad \rho_f V_f g - m_b g = m_b a \quad (1{,}000\text{ kg/m}^3)(1.13 \times 10^{-4}\text{ m}^3)g - (0.17\text{ kg})g = (0.17\text{ kg})a$
$a = -3.3\text{ m/s}^2$ **(the magnitude is 3.3 m/s²)**

20. **Answer: 20,580 N**
We assume the block is at rest so the net force on the object is zero (Newton's 2nd law). There is an upwards buoyant force, an upwards tension force and a downwards weight force acting on the block. We can replace the mass of the object with its density multiplied by its total volume.

Mass of block: $\rho_b = \dfrac{m_b}{V_b}$ $\quad m_b = \rho_b V_b = (1{,}200\text{ kg/m}^3)(3\text{ m}^3) = 3{,}600\text{ kg}$

$\sum F_y = F_B + T - F_g = 0 \quad \rho_f V_f g + T - m_b g = 0 \quad (1{,}000\text{ kg/m}^3)(3\text{ m}^3 / 2)g + T - (3{,}600\text{ kg})g = 0$
$T = 20{,}580\text{ N}$