The Socratic Series

Physics III

Higher-Order Questions & Support Materials

Paper No. 3/2016

THE INSTITUTION
for Science Advancement

About the Institution

As Malaysia is heading into a more competitive era of innovation led economic growth, there have been much to say on it preparation to meet this new challenge.

According to a 2012 study* by the Academy of Sciences Malaysia ("ASM") (an agency under the Ministry of Science, Technology and Innovation, "MOSTI"), there is an alarming shortfall of students and professionals involved in the fields of science, technology, engineering and mathematics ("STEM").

The study shows that less than 30% of secondary schools students are enrolled in the Science Stream. Of this, an even smaller proportion elects to pursue STEM degrees in tertiary education, and an even fewer ends up in science and technology-based professions.

It is estimated that by the year 2020, the nation requires around 500,000 STEM professionals from lab technicians to full-time researchers in all fields of the natural sciences, both in academia and industry.

Thus far Malaysia's stock of STEM professionals is only around 1/10th of that figure, with only a few years to the 2020 deadline.

The study had identified that this shortfall is due to the unpopularity of science subjects, which are purported to be difficult to master and less interesting than the humanities. This is compounded by the students' limited awareness on real world STEM professions such as chemical engineering, bioinformatics, applied mathematics and agronomics.

With this in mind, the Institution for Science Advancement (the "Institution") was envisioned as an independent, apolitical non-government organisation ("NGO"). The Institution's goal is to address the nation's underdeveloped scientific community through projects which encompass secondary and tertiary levels of education as well as postgraduate and professional levels of academia.

About the Socratic Series

The Socratic Series is to serve as a supplement to the science and mathematics syllabus. The questions and materials presented assesses a student's understanding of concepts from a subject on the tertiary preparatory level, as well as reasoning skills derived from lab experience.

The questions, as all questions should be, are to be thought provoking and not simply a formulaic fill-in-the-blanks queries, but involves lessons in problem-solving and critical thinking.

Questions (Answers on Page 5)

1. How do astronauts weigh themselves in the state of weightlessness?

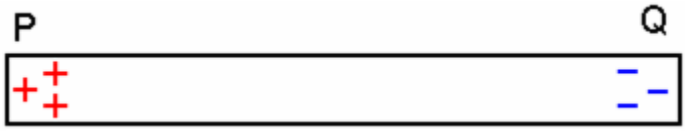
2. A person carrying a cup of water with floating ice steps into an elevator. If the elevator accelerates upward, the ice will

   (A) Float higher
   (B) Sink deeper
   (C) Stay at the same level

3. Why does a helicopter have a second propeller near its tail?

4. There are three switches A, B, and C in a room. Two of them are dummy switches, and the third is the switch for a desk lamp in another room. You are allowed to turn the three switches on and off as you like. You then go into the room with the desk lamp only once, and you are able to tell which of the switches is the right switch for the lamp. How can you do this?

5. A boy carries a metal rod PQ horizontally on a pickup truck traveling on a straight horizontal road. An *emf* is induced in the rod due to the earth's magnetic field, making the end P positive (+) and the end Q negative (-). The ends of the rod are now connected by a wire. In which direction will the induced current, if any, flow in the rod?



   (A) P to Q
   (B) Q to P
   (C) No current will flow through the rod.

6. Two identical cups P and Q have equal amounts of hot coffee at the same temperature. Cold creamer is now added to the cup P. A few minutes later, the same amount of cold creamer at the same temperature is added to the cup Q. Compare the new temperatures T_P and T_Q of the coffee in the two cups.

   (A) $T_P = T_Q$
   (B) $T_P > T_Q$
   (C) $T_P < T_Q$

7. A metal rod AB is bent into the shape shown.

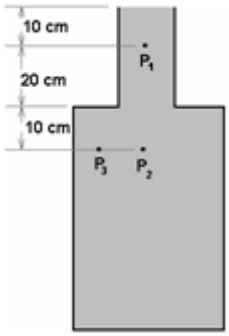
   If the rod is heated uniformly, the space between the ends will

   (A) Increase
   (B) Decrease
   (C) Stay the same

8. A container is divided into two halves by a partition with a hole in it. The two halves contain the same gas but at different temperatures. Which half, if any, contains a greater amount of gas?

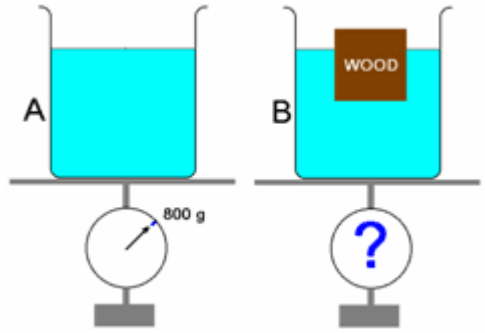
   (A) The half at higher temperature
   (B) The half at lower temperature
   (C) The halves contain equal amounts of the gas.

9. A bottle is filled completely with water, as shown in the diagram below. Which of the points shown have the same pressure?



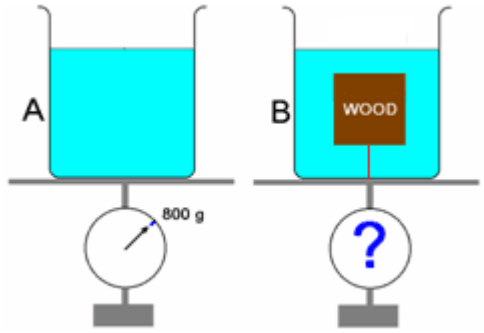
   (A) P_1 and P_2
   (B) P_2 and P_3
   (C) P_1 and P_3
   (D) P_1, P_2, and P_3
   (E) None of these

10. **Beakers With and Without a Wooden Block**. Two identical beakers carry water to the same height, but one of them has a wooden block floating in it. Which beaker, if either, weighs more?



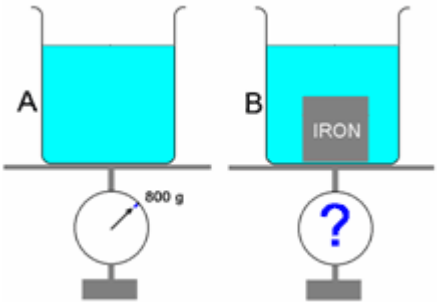
   (A) A
   (B) B
   (C) None

11. **Beakers With and Without a Completely Immersed Wooden Block**. Two identical beakers carry water to the same height, but one of them has a block of wood immersed completely and attached by a string at the bottom. Which beaker, if either, weighs more?



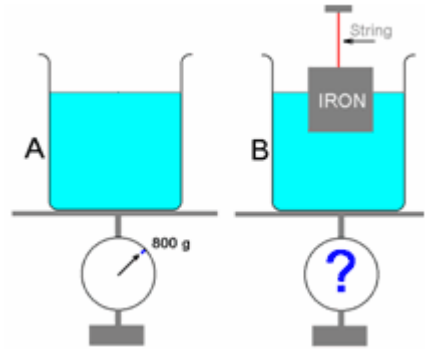
(A) A
(B) B

12. **Beakers With and Without an Iron Block**. Two identical beakers carry water to the same height, but one of them has an iron block immersed in it. Which beaker, if either, weighs more?



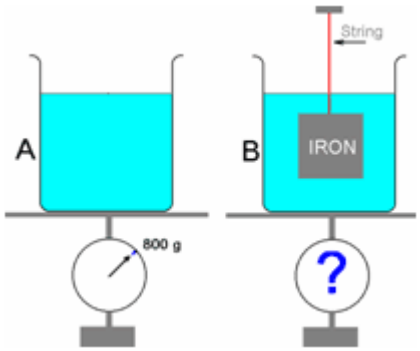
(A) A
(B) B
(C) None

13. **Beakers With and Without a Suspended Iron Block**. Two identical beakers carry water to the same height, but one of them has an iron block suspended in it by a string. Which beaker, if either, weighs more?



(A) A
(B) B
(C) None

14. **Beakers With and Without a Completely Immersed Suspended Iron Block**. Two identical beakers carry water to the same height, but one of them has a completely immersed iron block suspended in it by a string. Which beaker, if either, weighs more?



(A) A
(B) B
(C) None

15. A boat in a lake drops an anchor into the lake. The level of the lake will

(A) Remain the same
(B) Rise
(C) Fall

16. A 2-ton boat is floating in a lake. The buoyancy force on the boat must be

(A) 2 tons
(B) More than 2 tons
(C) Less than 2 tons
(D) Dependent on the density of water in the lake

17. When we look at ourselves in a plane mirror, we see left-right reversal but not up-down reversal. Why?

18. The wavelength of red light is close to blue in water, yet the red exit signs appear red to a swimmer from inside water. Why?

19. Our eyes are most sensitive to greenish-yellow light, yet the danger signals are red. Why?

Answers

1. The weight of astronauts in a close orbit around the earth is about 90 percent of their weight on the surface of the earth. However, they feel weightless because they are effectively in a free fall and hence have no normal force from a surface acting on them. The normal force gives people a feeling of their weight. If a person stands on a weighing scale to find her weight, the scale reads the normal force it applies to support that person. Hence a weighing scale would show zero weight for an astronaut if she "stands" on such a scale in a satellite. However, astronauts can find their mass (inertia) using the fact that the period of oscillations of a spring-mass system depends on the mass attached to it and not on the gravity. A machine designed by NASA on this principle is called Body Mass Measuring Device (BMMD).

2. (C) Stay at the same level

   The upward accelerating frame is equivalent to an inertial frame with a higher value of gravitational acceleration given by g' = g + a. The buoyancy force on the ice is due to the pressure of water, which is proportional to gravity g'. The weight of the block is mg'. Hence both the weight of the block and the buoyancy force increase by the same factor when the elevator accelerates upward (and decrease by the same factor when the elevator accelerates downward). Therefore the ice floats at the same level, and the level of water in the cup does not change.

3. As the main (horizontal) propeller rotates one way, the rest of the helicopter tends to rotate in the opposite direction due to the law of conservation of angular momentum. The rotation of the main body of the helicopter can be prevented by another propeller near the tail of the helicopter.

4. Turn switch A on. Leave it on for a few minutes. Turn A off and B on. Go to the desk lamp.

If the lamp is on	If the lamp is off	
	If the bulb is warm to touch	If the bulb is cool to touch
It is B.	It is A.	It is C.

5. (C) No current will flow through the rod.
   The rod and the wire form a closed loop. There is no change in the magnetic flux through the loop as the truck moves along a straight line. Hence, by Faraday's law, there is no induced *emf* or induced current in the loop.

6. (B) $T_P > T_Q$

   This is a question on heat transfer and Newton's Law of Cooling. A body at a higher temperature loses heat to the surrounding area at a higher rate. Since the cup Q was left at a higher temperature for a longer time interval, it has lost more heat.

7. (A) Increase

   In thermal expansion of an object of any shape, every particle moves away from every other particle. If the points A and B move closer, it will be contrary to expansion.

   The straight sections ending in A and B do expand and cause the points A and B to come closer. However, the expansion of the lower straight segment moves the points A and B apart. The length of the lower segment is greater than the total length of the two upper segments. Hence the net effect is that the points A and B move farther apart.

8. (B) The half at lower temperature

   The answer can be quickly arrived at by using the well-known equation $PV = nRT$. The hole in the partition causes the pressure to be the same in both halves. Hence the number of moles

$$n \propto \frac{1}{T}$$

9. (B) P_2 and P_3

The pressure due to a liquid at a point is proportional to the depth of the point below the open surface of the liquid. This is true even if the open surface is not vertically above the point, as is the case with the point P_3.

One might think that P_1 and P_3 have the same pressure, as both of them are 10 cm below the surface of the liquid. This not true because the water surface directly above P_3 is not an open surface.

10. (C)

The amount of water in the beaker B is less than that in A due to the water displaced by the floating block. However, applying the Archimedes principle, the weight of the floating block is equal to the weight of the water it has displaced. Hence the answer!

11. (A)

In the beaker B, the displaced volume of water has been replaced by the wooden block of lesser density. Hence it weighs less.

12. (B)

In the beaker B, the volume of displaced water is occupied by the iron block of greater density. Hence it weighs more.

13. (C) None

The beaker B is missing water displaced by the partly immersed iron block. The buoyancy force on the block equals the weight of the water displaced. This force also acts on the bottom of the beaker as a reaction force and compensates exactly for the reduction in the weight due to missing water.

14. (C) None

In the beaker B, the iron block experiences an upward buoyancy force equal to the weight of water displaced. The buoyancy force is applied by the water upward on the block and as a reaction downward on the bottom of the beaker, thus compensating for the weight of the displaced water.

15. (C) Fall

When in the boat, the anchor displaces water equal to its own weight. Since the density of the anchor is greater than the density of water, the volume of water displaced is greater than the volume of the anchor. When the anchor is dropped in water, the anchor displaces volume equal to its own volume. Hence the volume of water displaced when the anchor is dropped in the lake is less than when the anchor was in the boat. Thus the level of the lake falls.

16. (A) 2 tons

When in the boat, the anchor displaces water equal to its own weight. Since the density of the anchor is greater than the density of water the volume of water displaced is greater than the volume of the anchor. When the anchor is dropped in water the anchor displaces volume equal to its own volume. Hence the volume of water displaced when the anchor is dropped in the lake is less than when the anchor was in the boat. Thus the level of the lake falls.

17. There is depth inversion and no left-right inversion in a plane mirror. Right appears right, left appears left, up appears up, and down appears down. However, to a person looking into the mirror, there is an illusion of left-right reversal and no up-down reversal. This is due to the fact that for another person to face the observer, the other person always turns around a vertical axis, causing a real left-right reversal.

18. When light enters a medium from another medium, its wavelength and speed change, and frequency stays the same. The wavelength in the second medium is not affected by the introduction of a third medium between the two mediums. Thus red light entering the eye directly from air has the same wavelength inside the eye as the red light first entering water then into the eye. Thus red light appears red to a swimmer under water.

19. Red light can penetrate through atmosphere containing dust, clouds, and fog much more efficiently than any other color. Light toward the blue end of the visible spectrum is scattered to a much greater extent by the atmosphere. That's why the sky appears blue, and sunset and sunrise skies are reddish.