The Socratic Series

Physics I

Higher-Order Questions
& Support Materials

Paper No. 1/2016

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)

(Answers on Page 5)

1. **Does This Make Any (Sen)se?**

RM1 = 100 sen
= 10 sen x 10 sen
= RM (1/10) x RM (1/10)
= RM (1/100)
= 1 sen

2. A tower has a mass of 10,000,000 kg. A 100:1 scale model of the tower made from the same material will have a mass of

(A) 100,000 kg
(B) 10,000 kg
(C) 1,000 kg
(D) 100 kg
(E) 10 kg
(F) 1 kg

3. The paths crossed for three men - A, B, and C - walking through woods. It was a cold night. They decided to light a fire and rest by it for the night. They set out to bring some firewood. A came back with 5 logs of wood, B brought 3 logs, but C came back empty-handed. C requested that they let him rest by the fire and promised to pay them some money in the morning. In the morning C paid them RM8. How should A and B split the money fairly?

(A) A RM7; B RM1
(B) A RM6; B RM2
(C) A RM5; B RM3
(D) A RM4; B RM4
(E) None of these

4. An insect is climbing up a 30m vertical wall. Starting from the bottom, the insect climbs up 3m during the day and slips down 2m during the night. In how many days will the insect reach the top of the wall?

(A) 31 days
(B) 30 days
(C) 29 days
(D) 28 days
(E) 27 days
(F) Never

5. A person somewhere on the earth travels 10 mi. south, then 10 mi. east, and then 10 mi. north. He is back at his starting point. Which place on the earth is he?

6. A hiker started to climb up the hill at 6:00 a.m. and either kept climbing up or rested at some place(s). He reached the top at 6:00 p.m. He rested there for the next 12 hours. Next day at 6:00 a.m., he began to travel down the same path. He either moved downward or rested at some place(s). For the up and down trips, how many times was he at the same place at the same time?

(A) Never
(B) At least once
(C) Once and only once
(D) At most once
(E) Only twice
(F) None of these

7. Mr. Goh is returning home at a speed of 2 km/h with his dog Rocky. He unleashes Rocky when they are still 3 kilometers from his house. Rocky happily begins running back and forth between the house and his master with a constant speed of 3 km/h. Rocky does not waste any time while turning around. By the time Mr. Goh reaches home, how many kilometers has Rocky run?

(A) 3.5 kilometers
(B) 4.0 kilometers
(C) 4.5 kilometers
(D) 3.333...kilometers
(E) 3.555...kilometers
(F) None of these

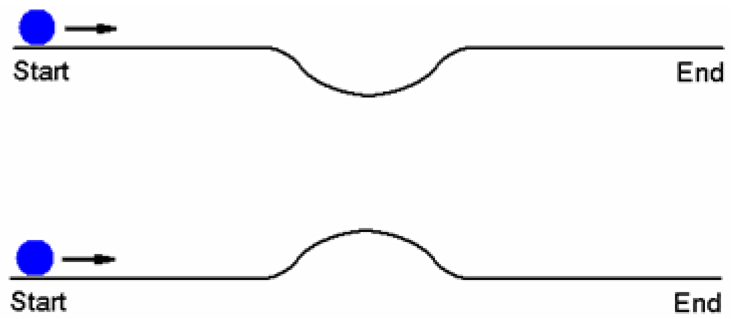
8. A person travels from city A to city B with a speed of 40 km/h and returns with a speed of 60 km/h. What is his average round-trip speed?

(A) 100 km/h
(B) 50 km/h
(C) 48 km/h
(D) 10 km/h
(E) None of these

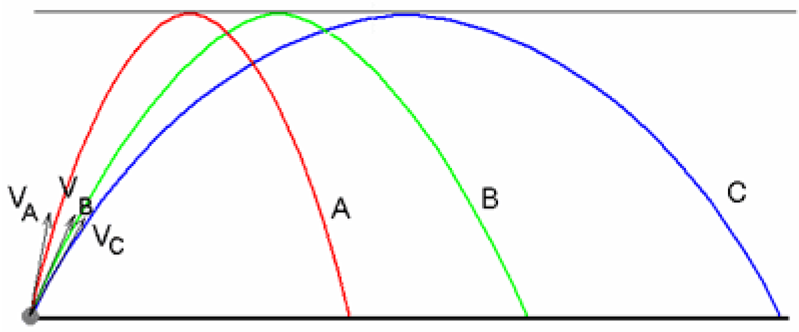
9. Two trains are moving toward each other with speeds of 17 km/h and 43 km/h. How far apart are they 1 minute before they pass each other?

(A) 60 kilometers
(B) 30 kilometers
(C) 6 kilometers
(D) 3 kilometers
(E) 2 kilometers
(F) 1 kilometer

10. Two marbles roll along two horizontal tracks. One track has a dip, and the other has a bump of the same shape. Which marble wins?

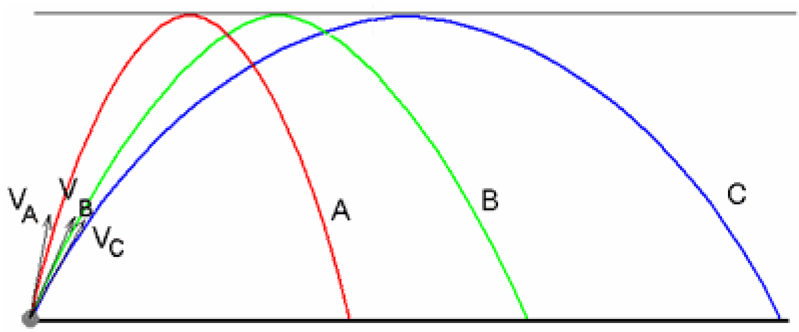


11. **Time of Flight of Three Projectiles.** Three projectiles are launched from the same point over a level ground with speeds V_A, V_B, and V_C. They all attain the same maximum height. Which of the following is true about their times of flight?



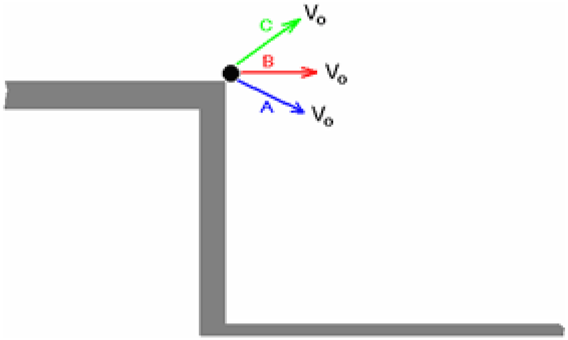
(A) $t_A = t_B = t_C$
(B) $t_A > t_B > t_C$
(C) $t_A < t_B < t_C$
(D) None of these

12. **Initial Speeds of Three Projectiles**. Three projectiles are launched from the same point over a level ground with speeds VA, VB, and VC. They all attain the same maximum height. Which of the following is true about their initial speeds?



(A) $V_A = V_B = V_C$
(B) $V_A > V_B > V_C$
(C) $V_A < V_B < V_C$
(D) None of these

13. **Speed of a Projectile and the Angle of Launch**. A ball is launched from the same height repeatedly with the same speed V_O but in different directions A, B, and C as shown below. It reaches the ground with speeds V_A, V_B, and V_C respectively. Which of the following is true about these speeds?



(A) $V_A = V_B = V_C$
(B) $V_A > V_B > V_C$
(C) $V_A < V_B < V_C$
(D) None of these

14. The weight of a closed jar is W while the flies inside it are flying around. What will be the weight of the jar if the flies settle down inside the jar?

(A) Equal to *W*
(B) Less than *W*
(C) Less than *W*

15. A closed jar containing a gas is weighed. Do the molecules of the gas contribute to the measured weight?

(A) Yes, fully
(B) Yes, but partially
(C) No

Answers

1. There is incorrect use of units. In the second step, the effective unit of sen^2 is not the same as RM on the left side. Again, the unit of RM^2 in step 3 is changed to RM in the fourth step.

2. (E) 10 kg

   Some students may jump to the answer of 100,000 kg, thinking the model will weigh 1/100 of the actual tower. However, if the height of the model is 1/100 of the height of the tower, all its dimensions are 1/100. Hence the model is (1/100) x (1/100) x (1/100) = 1 millionth of the volume of the actual tower (no matter what shape the tower is). Hence, if the model is made of the same material as the tower, its mass would be 1 millionth the mass of the tower, i.e., 10 kg.

3. (A) A RM7; B RM1

   One has to realize that all three men are equally benefited by the fire from the 8 logs of wood. Each man used 8/3 logs of wood through the night. Therefore,

   A contributed 5 - 8/3 = 7/3 logs of wood.
   B contributed 3 - 8/3 = 1/3 log of wood.

   Hence they must share RM8 in proportion to 7/3:1/3 or 7:1.

4. (D) 28 days

   Some students may jump to the answer of 30 days, arguing that the insect gains 1m in height per day. However, in 27 days it will have climbed 27m, and on the 28th day it will cover the remaining 3m to reach the top.

5. The north pole. The man is travelling on a sphere, a non-Euclidean planar surface.

6. (C) Once and only once

   Method 1: Draw the *x* vs. *t* graph for the hiker, with *t* ranging from 6:00 a.m. to 6:00 p.m. for the two days. The graphs for the two trips will intersect for only one value of *x*.

   Method 2: Imagine that as the hiker starts to ascend, there is a "virtual hiker" who starts the descent at 6:00 a.m. It is easy to see that the two "hikers" will meet once and only once.

7. (C) 4.5 kilometers

   Some students may try to form a summation series for the distances traveled by the dog for the trips between the house and the master. It gets very complicated.

   The simple solution: Mr. Goh takes 1½ h to reach home. Therefore, the dog has been running for 1½ h. With the speed of 3 km/h, the dog has thus traveled a distance of (3 km/h) x (1½ h) = 4.5 kilometers.

8. (C) 48 km/h

   The answer does not depend on the distance between the cities A and B. Assume the distance to be x, with round-trip distance 2x. The time taken from A to B is $\frac{x}{40}$ h, and the time for the return trip is $\frac{x}{60}$ h. For the speeds of 40 km/h and 60 km/h, the round-trip time is $\frac{2x}{40}$ h and $\frac{2x}{60}$ h. The average speed is defined as V_{avg} = total distance ÷ total time.

   This becomes an exercise in the arithmetic of fractions. The answer turns out to be 48 km/h, independent of *x*.

   Students are very likely to jump to the answer of 50 km/h, as it is the average of the given speeds. However, that is not the way average speed is defined!

9. (F) 1 kilometer

There is no need to do tedious calculation if we realize that each train is approaching the other at a relative speed of (17 km/h + 43 km/h) = 60 km/h = 1 kilometer/min. Hence 1 minute before collision they are 1 kilometer apart.

10. The marble on the track with the dip wins. On the straight parts of the tracks, the two marbles have the same speed. However, at every point of the dip the marble has greater speed than the other marble at the corresponding point of the hump. Thus the marble on the track with a dip wins. This argument assumes that the marbles always remain in contact with the tracks.

11. (A) $t_A = t_B = t_C$

The three projectiles have equal maximum heights, hence they have equal initial vertical components for their speeds. Thus they all take equal times to reach the maximum height and return back to the ground.

Students may think that since the projectiles travel different distances along their trajectories they have different travel times.

12. (C) $V_A < V_B < V_C$

The three projectiles have equal initial velocities and equal times of flight. However, for their horizontal ranges, $X_A < X_B < X_C$. The horizontal range is caused by the horizontal components of their speeds in the same time. Hence $v_{Ax} < v_{Bx} < v_{Cx}$. This implies that $v_A < v_B < v_C$.

13. (A)$V_A = V_B = V_C$

In each instance, the ball starts with the same speed, hence the same kinetic energy. When the ball hits the ground, it has lost the same amount of gravitational potential energy and hence gained the same amount of kinetic energy. Thus, in each instance, the ball hits the ground with the same speed.

Here students might think that direction of the initial velocity may affect the speed of impact on the ground.

14. (A) Equal to W

When the flies are flying, they are pushing down on air, which in turn is pushing down on the jar. In fact, the jar is supporting the flies even when they are flying around.

If the jar were placed on a sensitive scale, the reading would fluctuate about W and average out at W over a long interval of time.

15. (A) Yes, fully

This may appear to be similar to the question 15 in which the jar contains flies. However, in this case we are considering whether the weight of the gas itself contributes to the weight of the whole system. One approach to this problem is to consider the vertical velocities of the molecules. As a molecule moves down, its velocity is increasing due to the acceleration due to gravity. When the molecule collides with the bottom of the container, it imparts a force in excess of its weight; the excess force is just right to compensate for the time the molecule was not in contact with the jar.

Again, on a microscopic scale, if the jar were placed on a sensitive scale, the reading in the scale would vary around W but average out to W over a long enough interval of time.