Supplementary Material for "Persistence of conceptual errors in first-year students at the end of a Physics course"

In this Supplementary Material, we report the test that was used for the identification of previous ideas in a *Physics I* module during the academic year 2016/17, as described in the Ref. [1]. The original test was in Spanish. The test was anonymous, and was formed by the 9 general questions of Sec. I, and the 24 specific questions of Sec. II. The items of Sec. II that have been borrowed from the *Force Concept Inventory* [2] have been indicated by the acronym "FCI" at the beginning of the question.

I. GENERAL QUESTIONS

- Sex
  - Male
  - Female
- Age
- Years as graduate student
  - 1-2
  - 3-4
  - 5-6
  - 7-8
  - More than 8
- Degree
  - Agro-environmental Engineering
  - Food Engineering
  - Agronomic Engineering and Sciences
- Qualification in the university entrance examination
- Highest course where (s)he is matriculated
- Have you ever performed on-line courses? Evaluate this new methodology, respect classroom-based learning (1 much worse, 5 much better).
  - 1
  - 2
  - 3
  - 4
  - 5
- Have you already performed the laboratory practice?
  - Yes
  - No
- Do you know how to use Excel?
  - Yes
  - No

II. TEST ON PREVIOUS IDEAS

1. When performing a measurement with a digital amperimeter, we obtain 2.345 mA. Then, the result is
   (a) 2.345 ± 1 mA.
   (b) 2.345 ± 0.045 mA.
   (c) 2.345 ± 0.001 mA.
   (d) 2.345 ± 0.0001 mA.
2. Which of the following measurements is more accurate?
   (a) 22 ± 3 A.
   (b) 7 ± 1 mm.
   (c) 77 ± 7 W.
   (d) 77 ± 10 m.
3. How many significant digits does 423.30 have?
   (a) 1.
   (b) 2.
   (c) 5.
   (d) 7.
4. In uniformly accelerated rectilinear motion
   (a) There is no normal nor tangential acceleration.
   (b) Normal acceleration is constant while tangential acceleration is zero.
   (c) Normal acceleration is zero while tangential acceleration is time-dependent.
   (d) Tangential acceleration equals normal acceleration.
5. From the statements below, choose the correct one:
   (a) If a body is not accelerated, there are no forces acting on it.
   (b) A body always moves in the direction of the resultant force.
   (c) The weight of a body depends on its position.
   (d) If a body moves in a straight line, its acceleration is zero.

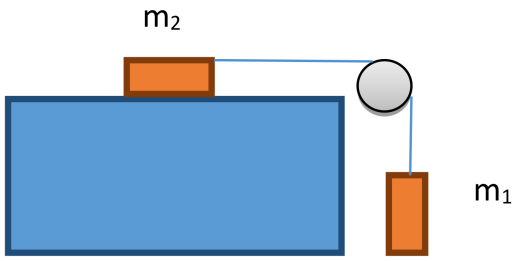
6. A block of mass m_1, hangs in the air with a massless string that passes through a pulley without friction. The string is joined on the other side to a body of mass m_2, with lies on a table with no friction. If the masses of the string and the pulley are negligible,

   (a) the acceleration has the same module and direction for both bodies.

   (b) The string tension is larger on the side where the mass m_1 is hanging.

   (c) The acceleration of the mass m_2 equals that exerted by a force of magnitude $m_1 g$ acting on a mass $(m_1 + m_2)$.

   (d) There is no tension is the string.



7. What do you think about the following statement? During spacewalks, astronauts feel no gravity.

   (a) True, as they are in space, where there is no gravity.

   (b) False, since Earth gravity acts on them.

   (c) True only if they are in the atmosphere.

   (d) It depends on the velocity they are travelling with.

8. (FCI) A large truck collides head-on with a small compact car. During the collision

   (a) The truck exerts a greater amount of force on the car than the car exerts on the truck.

   (b) Neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.

   (c) The truck exerts a force on the car but the car does not exert a force on the truck.

   (d) The truck exerts the same amount of force on the car as the car exerts on the truck.

9. (FCI) An empty office chair is at rest on a floor. Consider the following forces:

   i A downward force of gravity.

   ii An upward force exerted by the floor.

   iii A net downward force exerted by the air.

   Which of the forces is (are) acting on the office chair?

   (a) i only.

   (b) i and ii.

   (c) i, ii, and iii.

   (d) None of the forces. (Since the chair is at rest there are no forces acting upon it.)

10. (FCI) A stone dropped from the roof of a single story building to the surface of the Earth:

    (a) Reaches a maximum speed quite soon after release and then falls at a constant speed thereafter.

    (b) Speeds up as it falls because the gravitational attraction gets considerably stronger as the stone gets closer to the earth.

    (c) Speeds up because of an almost constant force of gravity acting upon it.

    (d) Falls because of the combined effects of the force of gravity pushing it downward and the force of the air pushing it downward.

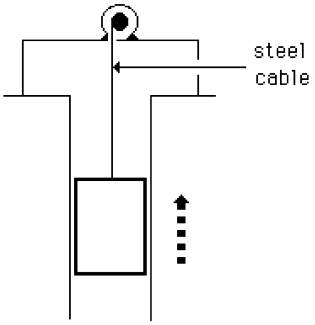
11. (FCI) An elevator is being lifted up an elevator shaft at a constant speed by a steel cable as shown in the figure below. All frictional effects are negligible. In this situation, forces on the elevator are such that:

    (a) The upward force by the cable is greater than the downward force of gravity.

    (b) The upward force by the cable is equal to the downward force of gravity.

    (c) The upward force by the cable is smaller than the downward force of gravity.

    (d) The upward force by the cable is greater than the sum of the downward force of gravity and a downward force due to the air.



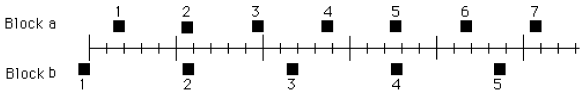
12. The position of two bodies at constant intervals of time is shown with the numerated squares in the figure below. The blocks are moving toward the right. The accelerations of the two blocks are related as follows:

    (a) $aa > ab$

    (b) $aa = ab > 0$

(c) $aa < ab$

(d) $aa = ab = 0$



13. A ball has been thrown in the air, and follows the trajectory shown in the figure. Which force(s) is (are) acting on the ball during its whole flight?

i the forze of gravity.

ii The launching force.

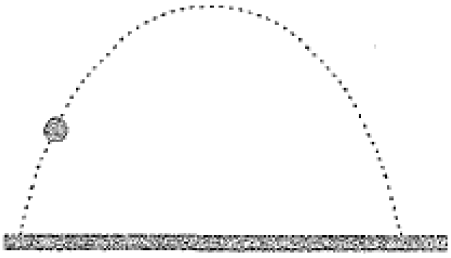
iii The air friction.

(a) Only i.

(b) i and ii.

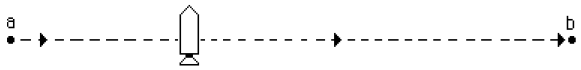
(c) i, ii and iii.

(d) i and iii.

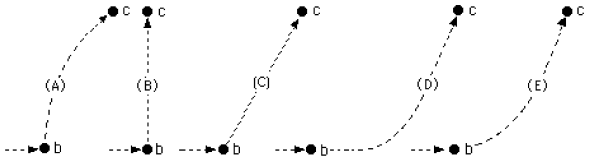


When answering the following 4 questions, you have to take into account the following paragraph:

A rocket drifts sideways in outer space from point "a" to point "b" as shown below. The rocket is subjected to no outside forces. Starting at position "b", the rocket's engine is turned on and produces a constant thrust (force on the rocket) at right angles to the line "ab". The constant thrust is maintained until the rocket reaches a point "c" in space.



14. (FCI) Which of the paths below best represents the path of the rocket between points "b" and "c"?



15. (FCI) As the rocket moves from position "b" to position "c" its speed is:

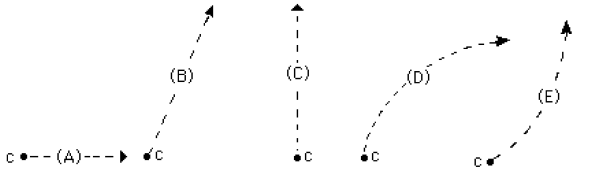
(a) Constant.

(b) Continuously increasing.

(c) Continuously decreasing.

(d) Increasing for a while and constant thereafter.

16. (FCI) At point "c" the rocket's engine is turned off and the thrust immediately drops to zero. Which of the paths below will the rocket follow beyond point "c"?



17. (FCI) Beyond position "c" the speed of the rocket is:

(a) Constant.

(b) Continuously increasing.

(c) Continuously decreasing.

(d) Increasing for a while and constant thereafter.

18. (FCI) A woman exerts a constant horizontal force on a large box. As a result, the box moves across a horizontal floor at a constant speed v_o. The constant horizontal force applied by the woman:

(a) Has the same magnitude as the weight of the box.

(b) Is greater than the weight of the box.

(c) Has the same magnitude as the total force which resists the motion of the box.

(d) Is greater than the total force which resists the motion of the box.

19. (FCI) If the woman in the previous question doubles the constant horizontal force that she exerts on the box to push it on the same horizontal floor, the box then moves:

(a) With a constant speed that is double the speed v_o in the previous question.

(b) With a constant speed that is greater than the speed v_o in the previous question, but not necessarily twice as great.

(c) For a while with an increasing speed, then with a constant speed thereafter.

(d) With a continuously increasing speed.

20. (FCI) If the woman in question 19 suddenly stops applying a horizontal force to the box, then the box will:

(a) Immediately come to a stop.

(b) Continue moving at a constant speed for a while and then slow to a stop.

(c) Immediately start slowing to a stop.

(d) Continue at a constant speed.

21. (FCI) Two metal balls are the same size but one weighs twice as much as the other. The balls are dropped from the roof of a single story building at the same instant of time. The time it takes the balls to reach the ground below will be:

    (a) Both balls hit the floor at approximately the same horizontal distance from the base of the table.

    (b) The heavier ball hits the floor at about half the horizontal distance from the base of the table than does the lighter ball.

    (c) The lighter ball hits the floor at about half the horizontal distance from the base of the table than does the heavier ball.

    (d) The heavier ball hits the floor considerably closer to the base of the table than the lighter ball, but not necessarily at half the horizontal distance.

22. A skater slows down its angular velocity when extending his arms mainly because:

    (a) He losses most of its energy because of the action of nonconservative forces.

    (b) He increases the friction of his skates.

    (c) He increases his moment of inertia.

    (d) He increases the friction between his arms and the air.

23. Three points located on a disc turn around with a constant angular velocity. One of them is at the edge of the disc, the other one is on the axis of the disc and the third one in the middle of them. Which of the three points moves with a larger linear velocity?

    (a) The point located on the axis.

    (b) The point located in the middle of the disc.

    (c) The point located at the edge of the disc.

    (d) All points move with the same linear velocity as they have the same rotational frequency.

24. The center of mass of a system of particles:

    (a) Is located on the heaviest particle.

    (b) Coincides with its center of gravity.

    (c) It does not have to be located on any particular particle.

    (d) In a system of particle, the center of mass does not exist, only the center of gravity.

REFERENCES

[1] Blinded for peer-review.

[2] D. Hestenes, M. Wels, and G. Swackhamer, Force Concept Inventory, The Physics Teacher, **30**, 141-158 (1992).