McMaster University's Physics@Mac Online Physics Contest
November 26th, 2015

General Statistics:

In this eighth competition, 580 teams from 53 schools participated.

One team had a score of 9, 2 scored 8 and 15 scored 7. The average score was 4.

Students competed in two categories – Grade 11 or below, and Grade 12. Where there was a tie score, prize winners were determined by elapsed times.

Cash prizes of $100 per team are to be awarded to the top three teams in Grade 12 and the top three teams in Grade 11 (or below). Certificates of Honourable Mention are to be awarded to teams who achieved a score of at least 7.

Question 1: Answer B -- 69% correct (A: 11 % C: 12 % D: 6 %)

Calculating the full path is complicated. However, we know that the bee will be able travel back and forth until the bikes collide. The bikes travel 10 km each at 10 km/h and thus collide in 1 hour. The bee travels at 25 km/h for 1 hour and thus covers a distance of 25 km (Answer B).

Question 2: Answer C -- 18% correct (A: 40 % B: 34 % D: 5 %)

The mirror prevents the rays from the real object at O from converging at I. However, they reflect and still converge at a point just to the left of the mirror, producing a real image. Those rays continue back through the lens and converge to form an additional real image on the left side of the lens. Thus there are now 2 real images (Answer C).

Question 3 Answer C -- 13% correct (A: 60 % B: 21 % D: 4 %)

The wire across the top joins the batteries to define a constant potential. Let this be V=0. Then the potential at the bottom left is Vo, and the potential at the bottom right is -Vo, because the two batteries are connected with opposite polarity. The bulb on the left has a potential difference of Vo across it, so current I flows up through it. The bulb on the right has a potential difference of -Vo across it, so current I flows down through it. The bulb on the bottom has a potential of 2Vo across it, so a current of 2I flows to the right through it. The currents through the bulb on the right and the bulb on the bottom join at junction of the wires, and must flow through the wires connected to the battery to the right for a total of 3I. Thus the answer is C.

Question 4 Answer D -- 65% correct (A: 3 % B: 6 % C: 24 %)

There are 30 million Canadians. Coffee drinkers tend to drink coffee every day. As Tim Horton's is the most popular chain in Canada we can assume that around 10% of Canadians drink one each day. There are 365 days in a year. A Coffee cup is about 10 cm high (or 0.0001 km). Putting that all together: 30,000,000 x 0.1 x 365 x 0.0001 is roughly 100,000 km. We allow for a factor of 10 variation in the estimates, depending on different assumptions people make. The closest answer is D.

Question 5 Answer A -- 12% correct (B: 38 % C: 47 % D: 2 %)

The pitch (frequency) of sound created by a taut string (e.g. in stringed instruments) increases with increased tension in the string. For a wave with a fixed wavelength, λ, this also means that the wave speed, c, increases as the tension increases, according to $c=\lambda f$. Thus the more general statement is that the speed of any wave (wiggle) in a rope or string increases with more tension. The tension in a hanging rope is determined by the weight (length) of rope below that point. As the wave moves up the string, the tension increases because the length of rope supported increases. This increases the speed of the wave (Answer A).

Question 6 Answer A -- 20% correct (B: 31 % C: 23 % D: 24 %)

All three blocks with equal masses, m, are accelerating at the same rate, a. Thus all are experiencing the same *net* force. The weight, W, of block C is what is responsible for pulling all three blocks along. Thus W = 3 m a [a should equal 1/3 g]. Block C communicates enough force through the tension to accelerate blocks A and B, thus T = 2 m a. Block B communicates force to accelerate block A through static friction on its upper surface so that F = m a. Thus W > T > F (Answer A).

Question 7 Answer D -- 33% correct (A: 12 % B: 3 % C: 49 %)

Answer D is the correct frequency for an ideal floating body. However, the answer can be determined solely through units. A frequency should have units of Hz or s^{-1}. The only parameter with any time units is g ($m\ s^{-2}$) so it must appear once in a square root. The units of the answers given are A: $m^{-1}s^{-1}$ B: $m^{-3/2}\ s^{-1}$ C: $m\ s^{-1}$ D: s^{-1}

Question 8 Answer A -- 36% correct (B: 33 % C: 7 % D: 22 %)

The key assumption for this question is that no energy is lost at any point. The collision with the goal post is elastic, so that energy is conserved even though the direction of motion changes. The total energy of the puck remains the same during its entire trajectory. Initially all the energy is kinetic, associated with the speed v. Some energy is converted into potential energy during the motion but by the time the puck returns to the ice, at the same height it initially left, all the energy is kinetic again and the speed is again v (Answer A).

Question 9 Answer B -- 38% correct (A: 46 % C: 10 % D: 4 %)

The packages leave the airplane and then fall vertically under constant acceleration (if we neglect air friction as indicated). Their horizontal motion remains the same at all times, matching the initial motion of the airplane. Thus, even though the second package is released one second later, the horizontal separation of the packages does not change because all three objects (the two packages and the airplane) are moving with the same constant horizontal velocity. Thus answer D is incorrect. The time to fall is the same for both packages so they hit 1 second apart (C is incorrect). Starting from the time of its release, the first package has fallen $\frac{1}{2} g t^2$ downward. The second package is released at time t=1 and falls downward to position $\frac{1}{2} g (t-1)^2$. The difference in the vertical positions is $\frac{1}{2} g (2t-1)$ so A is incorrect and *B is correct*.

Question 10 Answer A -- 56% correct (B: 18 % C: 15 % D: 8 %)

For circular motion the velocity is always at a tangent to the circle (as indicated in the diagram). The forces are perpendicular but this is not relevant. When the string breaks the heavy ball is horizontal and moving straight up. It goes up and then falls down directly on the point below its point of release (Answer A).