McMaster University's Physics@Mac Online Physics Competition
December 5, 2013

General Statistics:

In this sixth competition, 611 teams from 53 different schools participated.

No team had a perfect score of 10. 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. Virtually all teams completed the test in under 75 minutes and most finished in less than 60 minutes.

Cash prizes of $100 per team were awarded to the top three teams in Grade 12 and the top three teams in Grade 11 (or below). Certificates of Honourable Mention were awarded to teams in Grade 12 who achieved a score of at least 8 and teams in Grade 11 (or below) who achieved a score of at least 7.

Answer, success rate, statistics and solution for each question:

Question 1: Answer: B - 55% correct (A: 2%, C: 39%, D: 4%)

There are many different ways to estimate this, here is one:
We can assume the top of a 20m oak tree is a hemisphere (half a sphere) with a diameter of 20m. We can imagine the surface area of the hemisphere is completely covered with oak leaves to catch all the light. The surface area is given by $2\pi r^2=630m^2$. Each oak leaf is approximately $.15mx0.1m=0.015m^2$. We then divide the surface area of the hemisphere by the surface area of a leaf and find that there are approximately 40000 leaves (10^4). Even if we assume there are two or three layers of leaves on the surface of the hemisphere – we do not get an answer anywhere close to 10^6. There would need to be 25 layers of leaves on the surface to get an answer on the order of 10^6.

Question 2: Answer: D - 50% correct (A: 20%, B: 15%, C: 15%)

Using dimensional analysis, g*h has units of $(m/s^2)(m)$, so the square root has units of m/s, the same as velocity. None of the other combinations has the correct units.

Question 3: Answer: D – 43% correct (A: 19%, B: 17%, C: 21%)

The only horizontal force acting on box A is the friction between it and box B. Before box A slides, this force must be to the right to accelerate box A and maintain its position on box B. After box A begins to slip, it will move to the left **relative** to box B. Friction will oppose this motion, and must be to the right.

Question 4: Answer C – 40% correct (A: 23%, B: 27%, D: 10%)

When C with charge 2q touches A with charge q, the charge distributes evenly and both C and A are left with charge (2q+q)/2=3q/2. C then touches B and both C and B are left with half the total charge: (3q/2 + q)/2=5q/4. The electric force between A and B is proportional to q_A*q_B. Initially this is F~q*q. The charge on A and B has changed and now F~(5q/4)*(3q/2)=15/8 *(q*q).

Question 5: Answer A - 57% correct (B: 28%, C: 6%, D: 9%)

Because of conservation of energy, the sum of the gravitational potential (mgh) and the kinetic energy ($1/2mv^2$) is constant when friction is absent. The position with the smallest potential energy has the largest kinetic energy and therefore the highest velocity. The position with the largest velocity has the largest acceleration ($a=v^2/r$).

Question 6: Answer A – 70% correct (B: 23%, C: 6%, D: 1%)

To make a free body diagram of the spring, the force of gravity, which is always down toward the Earth, replaces the Earth. Forces must also replace the boards. The force normal to the surfaces of the boards keep the spring compressed, and must be sideways. The force along the surface of the board is friction, and keeps the spring from slipping down due to gravity. Therefore, the friction force acts up.

Question 7: Answer: B – 12% correct (A: 2%, C: 84%, D: 2%)

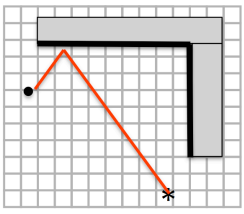
The torque on each side must be equal, like on a see-saw. This means the mass times the distance to the center of mass is equal for both halves. Since the batting end is shorter, its mass must be larger.

Question 8: Answer: C – 30% correct (A: 11%, B: 37%, D: 22%)

The motion in the horizontal and vertical directions are independent of one another. Consider just vertical motion. The snowball moves up until it reaches the highest point, where the vertical velocity is zero, and then drops as if it was dropped from rest. The total time is just twice the time it takes to drop from the highest point from rest. The time it takes to reach the ground depends on the height from which it is dropped from the highest point. Therefore, trajectory A takes longer, and Snowman B is hit first

Question 9: Answer: B – 33% correct (A: 15%, C: 32%, D: 20%)

The ray reflected from horizontal mirror can hit the eye. No ray reflected from the vertical mirror can hit the eye. (If the vertical mirror did make an image, there would also be a third image made by rays that hit both mirrors.)



Question 10: Answer C – 49% correct (A: 7%, B: 38%, D: 6%)

Note that the two batteries oppose each other, and are connected together at one end. In circuit #1, the top light bulb is connected to the other end of two identical batteries, so there is no voltage across it and no current flowing through it. The other light bulb is connected to the opposite ends of one battery, so it has voltage V across it. As a result current I_1 flows through it. In circuit #2, the light bulb is connected to the opposite ends of two identical batteries, so it still has the same voltage V across it. Therefore it still has an identical current $I_1=I_2$ flowing through it.