McMaster University's Physics@Mac Online Physics Competition
December 1, 2016

General Statistics:

In this ninth competition, 843 teams from 70 different schools participated.

Two teams had a perfect score of 10. The average score was 4.5.

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:

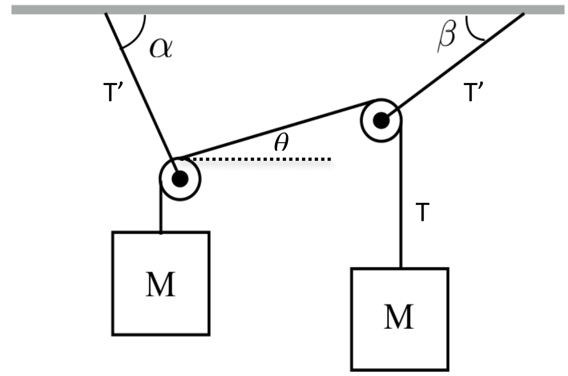
Question 1: Answer: B - 76% correct (A: 11%, C: 10%, D: 1%)

If the average person spends 30 min per day on their cell phone (1/50th of a day) and say half of the people in the world have cell phones, there are 7 billion people in the world so the number of people on their cell phones right now would be $=(7\text{x}10^9)(1/50)(1/2)$, which is about 70,000,000.

Question 2: Answer: A - 19% correct (B: 20%, C: 3%, D: 56%)

Friction acts opposite the direction of travel so the work done by friction must be negative. The force due to kinetic friction, f, is equal to the coefficient of kinetic friction, μ_k, multiplied by the normal force. Since the applied force is horizontal, the normal force is equal to mg. The work done is $f\,\Delta r\cos\theta$. The angle, θ, between the force of friction and the displacement is 180°, cos(180°) is -1, which is where the negative comes from. The force of friction is $f=\mu_k mg$ and the displacement Δr is $2d$. Thus, the work done by friction is $-2\mu_k mgd$.

Question 3: Answer: B – 42% correct (A: 20%, C: 7%, D: 30%)



If the system is in equilibrium the angle α and β must be 45°. Call the tension in the string holding the two identical masses T. Call the tension in the two identical strings hanging from the ceiling T'. Define the angle θ (see figure). Since the system is in equilibrium, the net force on each pulley is zero. Balance the forces in the horizontal at each pulley:

$T\cos\theta = T'\cos\alpha$

$T\cos\theta = T'\cos\beta$

Equate the two above equations, giving $T'\cos\alpha = T'\cos\beta$, and $\alpha=\beta$.

Substitute $\alpha=\beta$ on the diagram. Now balance the forces in the vertical for each pulley:

$T = T'\sin\beta + T\sin\theta$

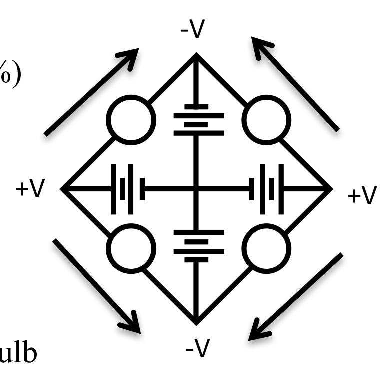
$T = T'\sin\beta - T\sin\theta$

Again, equate the above two equations to find that $2T\sin\theta = T'\sin\beta - T'\sin\beta$, and $\sin\theta=0$; $\theta=0$.

Substitute this result in the above two equations. From the top two equations, $T/T'=\cos\beta$.

From the bottom two, $T/T'=\sin\beta$. Thus $\alpha=\beta=45°$.

Question 4: Answer C – 36% correct (A: 13%, B: 39%, D: 10%)



Take the voltage at the center of the circuit to be zero. Then the voltages at the corners are +/-V as shown. Since the resistance of each bulb is the same, and the voltage across each bulb is 2V, the current (shown by the arrows) is the same size for each bulb. At each corner, the currents through each bulb combine or split; in either case, the current through each battery is twice the current through each bulb.

Question 5: Answer D - 24% correct (A: 46%, B: 13%, C: 15%)

Momentum is conserved when there is no work done on the system. The track is frictionless and the rain is falling vertically and imparts a vertical force, so there is no work. Thus, momentum is conserved. The mass of the cart increases as it fills with rain, so to conserve momentum this means the velocity will decrease at the same rate the mass increases. Kinetic energy is proportional to mass multiplied by velocity squared. The kinetic energy must therefore decrease.

Question 6: Answer B – 74% correct (A: 3%, C: 1%, D: 20%)

The acceleration due to gravity acts vertically. Horizontally there is no force, giving zero acceleration. The balls will always be at the same height (they have the same speed and angle from the horizontal) and the initial speed in the horizontal direction is the same. Since there is no acceleration horizontally, the initial horizontal speed is the same throughout the trip. One ball moves to the left and one to the right (as they also fall). The horizontal distance between them increases at a rate equal to twice the horizontal speed, which is constant.

Question 7: Answer: D – 39% correct (A: 4%, B: 53%, C: 3%)

Light will take the path that takes the least amount of time (Fermat's principle). All three paths must take the same time.

Question 8: Answer: C – 58% correct (A: 22%, B: 12%, D: 6%)

We can ignore the dimensionless quantities of 8 and π. We are given the dimensions of Q, R, P, η and L. We plug these in to the equation:

$$\frac{[L]^3}{[T]} = \frac{[L]^n([M]/[L][T]^2)}{([M]/[L][T])[L]}$$

We simplify variables to find:

$$[L]^3 = \frac{[L]^n}{[L]}$$

$$[L]^3 = [L]^{n-1}$$

Which shows n=4.

Question 9: Answer: D – 46% correct (A: 20%, B: 25%, C: 6%)

The net force acting on you is zero because you are not accelerating. The only forces acting on you are gravity down and the normal force up.

Question 10: Answer D – 28% correct (A: 13%, B: 25%, C: 31%)

As the top slide moves upward, the condition for interference changes based on the size of the gap between the slides. If it is constructive interference you see bright and if it is destructive you see dark. Thus, as the slide moves, you see alternating bright and dark.