Physics Challenges for Teachers and Students

Solutions to November 2002 problems

Shooting the Breeze

Since the bullet's loss of speed ($\Delta v = v - u$) is small compared to u, we can assume that its deceleration is fairly uniform while passing through the block, so the upward force exerted by the bullet on the block is also fairly steady. The time that it spends passing through the block can be found:
$\Delta t = d/v_{av} = 2d/(v + u)$.
The upward impulse exerted on the block is equal to the bullet's loss in momentum:
$F\Delta t = m(v - u)$, so $F = m(v - u)/\Delta t$. Since the block does not quite lose contact with its support, we set that force equal to the weight of the block: $Mg = m\Delta v/\Delta t$.
Solving for M and replacing the Δv and Δt with the expressions above, we find that the minimum block mass is $M = m(v^2 - u^2)/(2gd)$ = 6.0 kg.

(Contributed by Art Hovey, Milford, CT)

Off the Table

Consider a frame of reference "attached" to the center of mass of the dumbbell. Such frame of reference has the speed equal to half the speed imparted to the top end of the dumbbell. Now, both ends appear to spin around the center at $v_o/2$, so the centripetal acceleration of the lower mass attached to the dumbbell, directed vertically at the initial moment, is:

$$a = v^2/r = (v_o/2)^2/(L/2) = \tfrac{1}{2}v_o^2/L.$$

For the bottom mass to leave the table, this acceleration must be greater than the acceleration of gravity.

$$a > g$$

$$\tfrac{1}{2}v_o^2/L > g$$

$$\tfrac{1}{2}v_o^2/g > L$$

Thus, the maximum length of L is $\tfrac{1}{2}v_o^2/g$.

(Contributed by Dylan Consla, student, Maine School of Science and Mathematics, Limestone, ME)

The King of the Hill

If the puck climbs part way up the hill and then slides back onto the table, ending up with say speed V backwards, then conservation of momentum implies

$$mv = -mV + 3mu \Rightarrow V = 3u - v, \qquad (1)$$

while conservation of energy before and after the collision gives, after substituting for V from Eq. (1),

$$\frac{1}{2}mv^2 = \frac{1}{2}mV^2 + \frac{1}{2}3mu^2 \Rightarrow u = \frac{1}{2}v. \qquad (2)$$

Hence, to get the largest value of u, we need v to be as large as possible. The limit is reached when the puck just makes it to the top of the hill and then slides back. Let U be the speed of the hill with the puck momentarily at rest on top of it. Conservation of momentum implies that

$$mv = 4mU \Rightarrow U = \frac{1}{4}v, \qquad (3)$$

Solutions to November 2002 problems (cont).

while conservation of mechanical energy gives

$$\frac{1}{2}m\upsilon^2 = \frac{1}{2}4mU^2 + mgh \Rightarrow \upsilon = \sqrt{\frac{8}{3}gh} \qquad (4)$$

after substituting for U from Eq. (3). This value of υ will maximize u. The hill will end up with a speed of $\sqrt{2gh/3}$ according to Eq. (2) after the puck slides back down. Interestingly enough, Eq. (1) implies that the puck will end up with this same speed.

(Contributed by Carl E. Mungan, United States Naval Academy, Annapolis, MD)

Several other readers also sent us correct solutions to the November Challenges. We would like to recognize the following contributors:

Bob Baker (El Camino Fundamental High School, Sacramento, CA)

James Carr (Webster, NY)

Adam Plana (The Wheatley School, Old Westbury, NY)

We appreciate your submissions and hope to receive more solutions in the future.

Note to contributors: as the number of submissions grows, we request that certain guidelines be observed, in order to facilitate the process more efficiently:

- Please email the solutions as Word files.
- Please name the file as "April03HSimpson" if — for instance — your name is Homer Simpson, and you are sending the solutions to April 2003 Challenges.
- Please state your name, hometown, and professional affiliation in the file, not only in the email message.

Many thanks!

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