Physics Challenges for Teachers and Students

In this issue of *Physics Challenges* we present some problems on electricity.

Schooling and Cooling

An air conditioner (a/c), working continuously, maintains the temperature $T = 300$ K in the classroom, while the outside temperature is $T' = 320$ K. When the students enter the classroom, the lights are turned on. The total power output of the lights is $P = 500$ W. How much more power (dP_a) does the a/c need to draw to maintain the same room temperature? Assume that the a/c is "ideal."

Close Encounter

A proton (m, e) and an alpha particle ($4m$, $2e$) approach each other from a large distance. Initially, their velocities are the same (v). Find the minimum separation r between the particles.

Holey Field

(*contributed by Leaf Turner, Los Alamos National Lab*)

A uniformly positively charged insulating spherical shell has a surface charge density σ. A very small hole is cut in the shell. Find the electric field at the center of the hole.

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The November issue of *Physics Challenges* attracted more responses from readers, both faculty and students. Here are their solutions:

The Chain Reaction

During a small interval dt, a piece of the chain of length (vdt) would acquire the velocity v, and the change in its momentum is $dp = \lambda\,(vdt)v$ (λ is the linear density of the chain).

That change in momentum is provided by the "extra" force of gravity on the right, which equals to $F_g = \lambda hg$. According to the impulse-momentum theorem, $F_g dt = dp$. Substituting the expression for dp yields $v = (gh)^{1/2} = 3.13$ m/s.

(*Contributed by Asif Shakur, Salisbury University, Md.*)

(Several readers, including Peter Gilbert, a senior at Mississippi School for Math and Science, offered the "energy-based" solution.)

The Leap of Faith

Since the masses of the frog and the board are equal, they will undergo equal and opposite displacements of ($L/2$). The minimum speed will be achieved if the frog jumps at a 45° angle. From the laws of projectile motion, for such angle: $(L/2) = v^2/g$ and $v = (gL/2)^{0.5}$

(Contributed by Cathy Abbot, teacher at Lexington High School, Mass.).

The Spin Doctor

From Newton's second law for rotational motion, $\alpha = \tau/I$, where τ is the total torque and I is the rotational inertia of the cylinder. Denoting the mass of the cylinder as m, $I = mR^2$. Only the forces of friction create the torque here. Let the normal force from the floor be N (it is *not* equal to mg!). Then the force of friction on the floor is μN – which equals the normal force acting on the cylinder from the wall. Therefore, the force of friction of the wall, directed vertically *up*, is $\mu^2 N$, and the total torque is

$$\tau = (\mu N + \mu^2 N)R.$$

To find N, consider the vertical net force on the cylinder, which is zero:

$$mg - N - \mu^2 N = 0.$$

Combining the equations yields $\alpha = (g/R)(\mu + \mu^2)/(1 + \mu^2)$.

(Contributed by Albert Exton, retired, Shippenville, Pa).

Many thanks to these and other contributors; we look forward to your solutions and your own favorite challenges.

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Physics Trick of the Month

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A Spooky Rotation

A new and amazing optical illusion has come to light. I don't know its origin. It came to me by way of Al Seckel, an expert on optical illusions who has recently published a marvelous desk calendar with a striking illusion on each of its 365 pages. The boxed calendar, titled *You Won't Believe Your Eyes*, is the best collection of illusions yet.

To work the new illusion, focus your attention on the central dot of the picture, then move the page slowly forward and backward. The inner wheel seems to rotate slightly counterclockwise as the page moves toward you, and clockwise as the page moves away from you. I don't have any idea why it works.