Designing Projectile Motion Problems

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Letters
to the Editor

Teflon Warning!

I have a comment on the article entitled "The Effect Surface Temperature Has on Kinetic Friction," pp. 173–175 (March 2005) of *The Physics Teacher*. I thought the article was quite interesting and presented a good experiment. I was, however, slightly concerned about the specification that "a typical Teflon-coated griddle" should be used (p. 173).

Though Teflon is an abundant product and used on many pieces of cookware, there is growing evidence that it may be a harmful substance. The primary way I see this experiment being a problem is through what is called "polymer fume fever," which has flu-like symptoms and comes from the fumes of Teflon when heated. As this experiment has the griddle heated without anything on it (such as food) to absorb some of the heat, I would be concerned that significant fumes could be released. In addition, the application of metallic objects to the surface could chip the Teflon coating, increasing students' and staff's absorption of this substance. I would suggest trying this experiment using a surface that did not have a Teflon coating. Perhaps aluminum would work, as it transmits heat quite well and can be made smooth enough for objects to slide on it.

For additional information look at: http://www.ewg.org/issues/pfcs/20030529/index.php.

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The "Eye" in Physics

Both Michael J. Ruiz and David Gavenda[1-3] describe the eye's changes in hyperopia well, but ocular optics can quickly become confusing.

A young person can easily increase the converging power of his or her ocular lens and overcome hyperopic errors, both at near and distance. This is called *accommodation*, and the hyperopic person must use some accommodation all of the time to see clearly. Accommodation in the normal eye is used only for seeing up close. As a person ages, literally from birth, the range of accommodation decreases as the ocular lens becomes stiffer. This is called *presbyopia*—old vision.

Since hyperopic people have to use their accommodation to overcome their hyperopia to see clearly at both distance and near, and since it takes less accommodation for them to see clearly at distance than up close, the aging hyperopic person will be able to see clearly at a distance longer than at near. Eventually, the hyperopic person will not see clearly at any distance without corrective lenses.

By comparison, myopic persons will always be able to see clearly somewhere, but their range of clear vision will narrow with age as their range of accommodation decreases.

Headaches can be caused by refractive errors, but this is not common. The human body adapts with remarkable ability.

Just to complicate things a bit, the accommodation reflex is linked to convergence—the turning of the eyes inward to see a single image of closer objects. Because the hyperopic person has to accommodate an extra amount, he or she may over-converge. This is a major factor in children with crossed eyes.

Physics abounds in ophthalmology, and I love them both.

1. Michael J. Ruiz, "Prescribing eyeglasses for myopia and hyperopia," *Phys. Teach.* **43**, 88–89 (Feb. 2005).
2. David Gavenda, "Hyperopia and myopia," letter to the editor, *Phys. Teach.* **43**, 260 (May 2005).
3. Michael J. Ruiz, "Author's response," letter to the editor, *Phys. Teach.* **43**, 260-261 (May 2005).

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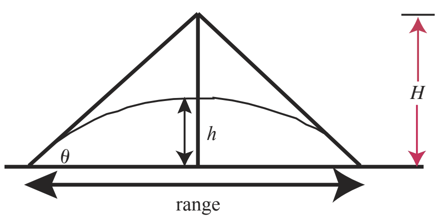
Designing Projectile Motion Problems

In their short but insightful article in the March 2005 issue of *The Physics Teacher*,[1] Lamoreux and Tosi have pointed out an interesting aspect of parabolic motion, but there is more. Really what they have shown is that there is a simple geometrical constraint on drawing a parabola. The exact relationship between the launch angle θ, the maximum height reached by the projectile h, and the range R is: $\tan\theta = 4h/R$, as is easily seen from Lamoreux and Tosi's Fig. 1 (shown below). What this equation indicates is that the ratio of the maximum height to the range is fixed only by the launch angle. Put another way, fixing the launch angle fixes the shape of the parabola. Changing the launch speed v or the acceleration due to gravity g only serves to scale up or scale down the basic shape of the parabola, so to speak. The equation of the parabolic trajectory itself can also be written solely in terms of h and R: $y = (4h/R)x - (4h/R^2)x^2$.



These facts can be used to more easily design projectile motion problems. Often we have a better idea of what constitute roughly realistic values for range and maximum height for things like footballs and baseballs than we do launch speed and angle. Or possibly we may design a problem with a specific range and/or maximum height in mind. In either case, it is quite simple to choose the desired h and R and to use $\tan\theta = 4h/R$ to find the launch angle. Then one can calculate the necessary launch speed using either $v = (Rg/\sin 2\theta)^{1/2}$ or $v = (2gh/\sin^2\theta)^{1/2}$.

1. Jon Lamoreux and Luis Phillipe Tosi, "The maximum height in projectile motion," *Phys. Teach.* **43**, 183 (March 2005).

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Nuclear Reactors and WMDs

The article by B. Cameron Reed in the April issue of *TPT*[1] about plutonium production in nuclear reactors was fascinating and disturbing at the same time. I was disturbed by his conclusion that the 100 or so enriched-uranium reactors in the United States produce enough plutonium in one year for 2000 Nagasaki-type bombs. I have checked both the derivation of his formula and his calculations but, unfortunately, cannot find fault with either of them.

So I used his formula to do the calculation on reactors using natural (rather than enriched) uranium. Assuming that the value of η (the thermal efficiency of such a reactor) would not be very different, I find a yearly plutonium production per reactor about four times as great as for an enriched-uranium reactor. Correct?

Now suppose a country wants to produce a nuclear bomb. They would then have two options: Either

1. produce a Hiroshima-type bomb with enriched uranium. So we should worry about countries building facilities to enrich uranium; and we do. Or
2. produce a Nagasaki-type bomb, using plutonium from a natural-uranium reactor. Such a reactor would require heavy water (D_2O) as a moderator, but no enriched uranium would be needed, either for the reactor or for the bomb. So we should worry about countries obtaining heavy water. Do we?

1. B. Cameron Reed, "Understanding plutonium production in nuclear reactors," *Phys. Teach.* **43**, 222–224 (April 2005).

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Power Generation: Nuclear, Oil, Coal

Professor Reed's article is a marvelous introduction to nuclear energy, particularly if carried further into the realm of electric power generation.[1] For example, he shows that a 1-GW nuclear power plant using $r = 0.03$ or 3% enriched uranium, operating at $\eta = 0.3$ Carnot efficiency, requires 47,000 kg/year of enriched uranium per year. This amount of enriched metallic uranium corresponds to a volume of 2,500 liters or closely a 1.25-x-1.25-x-1.25-meter sized block (density $\rho = 18.7$ g/cm^3). This is also the amount and size of the waste or the "ash" from the plant per year if it is not reprocessed. He also showed that the ash contains 226 kg of fissile plutonium-239, which could be made into 20 Hiroshima bombs. Bomb construction, however, is complicated by Pu's small critical mass[2] of 300 g—a cube 2.5 x 2.5 x 2.5 cm in size (one cubic inch) or 750 critical mass cubes of Pu 239 from the fore mentioned plant.

It is interesting to compare these numbers to an oil or coal power plant of similar size, which operates at higher Carnot efficiency due to neutron moderation considerations. Oil has a heat content of ~40,000 J/g while coal has half this value. If we assume a Carnot efficiency of 0.6, a 1-GW conventional plant requires 1.25 x 10^9 kg or 1.25 million tons of oil or 2.5 million tons of coal per year. This amounts to a 110-x-110-x-110-meter tank of oil or pile of coal. There are super tankers that hold 500,000 tons of oil. Coal is about 70% carbon, which turns into (44/12)1.75 or 6.4 million tons of CO_2 (which if solidified would turn into a 185-x-185-x-185-meter block of CO_2 at -37°C) and ~13% or 0.33 million tons of ash after combustion. Professor Reed's statement of 100 commercial nuclear reactors in the United States is in agreement with data from the World Wide Web,[3] which shows that the United States has a total electrical capacity of ~1,000 GW supplied by 33% coal, 22% natural gas, 18% dual fuel, 10% nuclear, 10% hydro, 4% petroleum, and 3% renewable. France is the next largest nuclear generator of electricity, with 56 government-owned high-pressure boiling-water reactors, generating 80% of their power and the rest from hydro.

1. B. Cameron Reed, "Understanding plutonium production in nuclear reactors," *Phys. Teach.* **43**, 222–224 (April 2005).
2. *The New Encyclopedia Britannica* (Chicago, 1986), Vol. 9, pp. 530–531.
3. See http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html.

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