Classroom demonstrations mentioned below

The difference between fiction and reality is that fiction has to make sense.
—Tom Clancy

See also PN and W. Berner, *Activities and Classroom Demonstrations in Biological Physics: A Resource Document*, repository.upenn.edu/physics_papers/646/ .

One of the great things about teaching Physics is that we can do significant classroom demonstrations. In a world increasingly dominated by seductive virtual reality, we get to confront our students with some *real* reality—especially important when it upsets our comfortable intuitions. Here are some suggestions for flesh-and-blood demos, most of which can be done with materials often found in Physics instructional labs.

Virtual reality is really no different from just standing there and making claims. You have to trust the guy making the claims to be telling the truth; to actually understand the claim and any necessary caveats. With real reality you just see and decide for yourself. Also, it's just fun to do demos. Fun is good.

Perhaps you worry that your students will think, "Hey, why is he insulting my intelligence with this baby demo! I want to hear the cosmic mysteries, not this stuff I saw in middle school!" But, think about the items listed below. Are you sure your students really *saw* them in middle school? When I was a student, I usually just heard people *claim* them, or I read them in books. (Books are virtual too!)

#1= `virusbucket`: Realize the "2-bucket" model of HIV steady state with tanks of water, having two different inflow rates and two different exit apertures. You can arrange things so that each tank has the same steady-state level, but the difference shows up quickly when you shut off the inflows. See setup: virusbucket/virusbucket.JPG. (Realization courtesy W Berner.)

#2= `bifurcation`: The "Edmund jumping disk" is a simple object with an alarming, and memorable, bifurcation. There's a video here:
youtu.be/iftAfRfDn_A.

#3= `browni`: For a quantitative demonstration of the law of diffusion at the single-particle level, see Newburgh et al., "Einstein, Perrin, and the reality of atoms: 1905 revisited." Am. J. Phys. (2006) vol. 74 (6) pp. 478-481. Also see Pearle et al., 2010 and Catipovic et al., 2013.

#4= `Dblips`: Play audio of photodiode blips and compare to mathematical realization of a Poisson process (Media 4). Compare to equally spaced clicks (Media 5). Then listen to a Geiger counter. (If your source is an alpha emitter, explain that other sources do give off light (gamma radiation), in the same way (Poisson process).) (*"Is this safe?"* Ans: Actually most home smoke detectors contain an alpha source.)

#5= `rchallenge`: Can you really imitate random behavior? Have students enter what they think is a random, independent sequence of 100 choices of $s = 0$ or 1 into a spreadsheet column, then compute the 2×2 matrix $\mathcal{P}(s_n | s_{n-1})$. Then repeat with a pseudorandom sequence from a computer. Generally humans will make fewer long runs than are found in genuinely random sequences, which shows up as anticorrelation from one flip to the next, e.g. $\mathcal{P}(\underline{heads}_n | \underline{heads}_{n-1}) < 0.5$.
Also, compute $\langle s_n \rangle$ (compare it to 1/2) and then $\langle s_n s_{n-1} \rangle$ (compare to $\langle s_n \rangle^2$).

#6= `medicalTest`: medicalTest/medicalTest.pdf: Two ways to state a routine problem in medical diagnostics. The usual statement is almost impossible for actual doctors to understand correctly. The alternate statement, while mathematically equivalent, is much easier to grasp. You could use these two slides to repeat the experiment with your own students. [Data from pp. 104–111 of G Gigerenzer, *Calculated risks: How to know when numbers deceive you* (New York, Simon and Schuster, 2002).]

#7= `PDFtransform`: Perform a computer demonstration of the concept of transformation of a pdf, in a nonrandom situation. See PDFtransform/PDFtransform.pdf and MATLAB Code `transformdemo.m` or Python Code `transformdemo.py`.

#8= `quincunx`: Francis Galton's "Quincunx" (Galton board): Make one or see `www.youtube.com/watch?v=6YDHBFVIvIs`.

#9= `secretMessage`: When you introduce fluorescence microscopy: Begin with lots of writing on the chalkboard, maybe left over from the previous class. Add a secret message made up of small marks, using fluorescent chalk. Before class begins, turn on a black light. Talk for a while. Point out to the students that they have been looking at a secret message all this time and not seeing it, because of distractions. Then turn out all room lights. Without having to touch the chalk board, suddenly now the secret message (signal) stands out against the rest (background).

#10= `superres`: See Rueckner and Papaliolios. How to beat the Rayleigh resolution limit: A lecture demonstration. Am. J. Phys. (2002) vol. 70 (6) pp. 587-594.

#11= `thinPoissonD`: Thinning a Poisson process: Work through
Python Code `MergeThinSim/thinPoissonProcess.py`. Then ask students to write a similar code to confirm the merging property.

#12= `myoVdemo`: Attach a light to your hip; your knee; your ankle. Turn out the lights and walk across the room taking 1-m steps.

#13= `toggle`: Show a real-world example of a mechanical toggle. Here is an easily obtainable example from Home Depot ("chain tightener"):
`toggle/toggleOverview.jpg`; `toggle/genericStateToggle.jpg`; `toggle/stableDownToggle.jpg`; `toggle/stableUpToggle.jpg`; `toggle/unstableFixedPointToggle.jpg` (Realization courtesy W Berner.)

Weird experience Not so weird. We intuitively understand mechanical bistability.

Conceptual tools This system is a nice introduction to dynamical systems. There is an unstable fixed point flanked by two stable ones, a simple phase portrait.

Discuss relevance to actual biological system or some other department's courses Cells use negative feedback control to maintain constant internal conditions despite fluctuations in environment, or in internal demand.
Cells use positive feedback control to construct "switchlike" (bistable) dynamics (*lac* and *lambda* switches).
Cells use positive plus negative feedback control to construct oscillatory dynamics (dividing cells in an embryo).

#14= `relaxationOsc`: Build the device in Figure 13.5. Water is nice but messy; Media 17 shows an implementation with small beads as the 'fluid.' The toggle element is provided by small magnets in the bottom of each bucket, attracting small magnets attached to the floor of the apparatus. (Realization courtesy W Berner.)