4.5: Footnotes

1. Electrical and magnetic interactions *don't* quite behave like this, which is a point we'll take up later in the book.
2. We can now see that the derivation would have been equally valid for $U_i \neq U_f$. The two observers agree on the distance between the particles, so they also agree on the interaction energies, even though they disagree on the kinetic energies.
3. Recall that uppercase P is power, while lowercase p is momentum.
4. This is with the benefit of hindsight. At the time, the word “force” already had certain connotations, and people thought they understood what it meant and how to measure it, e.g., by using a spring scale. From their point of view, $F = dp/dt$ was not a definition but a testable --- and controversial! --- statement.
5. This pathological solution was first noted on page 83, and discussed in more detail on page 910.
6. The converse isn't true, because kinetic energy doesn't depend on the direction of motion, but momentum does. We can change a particle's momentum without changing its energy, as when a pool ball bounces off a bumper, reversing the sign of p.
7. The part of the definition about “by a force” is meant to exclude the transfer of energy by heat conduction, as when a stove heats soup.
8. “Black box” is a traditional engineering term for a device whose inner workings we don't care about.
9. For conceptual simplicity, we ignore the transfer of heat energy to the outside world via the exhaust and radiator. In reality, the sum of these energies plus the useful kinetic energy transferred would equal W.
10. This subroutine isn't as accurate a way of calculating the period as the energy-based one we used in the undamped case, since it only checks whether the mass turned around at some point during the time interval Δt.
11. The relationship is $\omega_{max\ A}/\omega_\text{o} = \sqrt{1-1/2Q^2}$, which is similar in form to the equation for the frequency of the free vibration, $\omega_f/\omega_\text{o} = \sqrt{1-1/4Q^2}$. A subtle point here is that although the maximum of A and the maximum of A^2 must occur at the same frequency, the maximum energy does not occur, as we might expect, at the same frequency as the maximum of A^2. This is because the interaction energy is proportional to A^2 regardless of frequency, but the kinetic energy is proportional to $A^2\omega^2$. The maximum energy actually occurs are precisely ω_o.
12. For example, the graphs calculated for sinusoidal driving have resonances that are somewhat below the natural frequency, getting lower with increasing damping, until for $Q \leq 1$ the maximum response occurs at $\omega = 0$. In figure m, however, we can see that impulsive driving at $\omega = 2\omega_\text{o}$ produces a steady state with more energy than at $\omega = \omega_\text{o}$.
13. If you've learned about differential equations, you'll know that any second-order differential equation requires the specification of two boundary conditions in order to specify solution uniquely.
14. Actually, if you know about complex numbers and Euler's theorem, it's not quite so nonsensical.
15. Of course, you could tell in a sealed laboratory which way was down, but that's because there happens to be a big planet nearby, and the planet's gravitational field reaches into the lab, not because space itself has a special down direction. Similarly, if your experiment was sensitive to magnetic fields, it might matter which way the building was oriented, but that's because the earth makes a magnetic field, not because space itself comes equipped with a north direction.
16. The zero here is really a zero *vector*, i.e., a vector whose components are all zero, so we should really represent it with a boldface \vc{0}. There's usually not much danger of confusion, however, so most books, including this one, don't use boldface for the zero vector.
17. There is, however, a different operation, discussed in the next chapter, which multiplies two vectors to give a vector.
18. The symbol ∇ is called a “nabla.” Cool word!