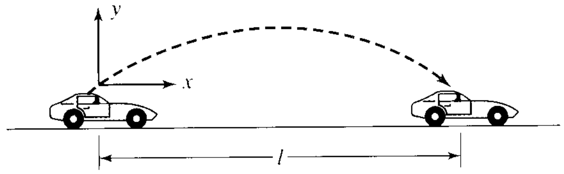

FIGURE 1.19
(Problem 1.8)

is l. The policeman wishes to shoot the robber with a gun whose muzzle velocity is u_0. At what angle θ above the horizontal should he point his gun? First solve this problem using coordinates traveling with the policeman, as shown in Fig. 1.19. Then sketch the solution using coordinates fixed to the ground; is the angle of the gun the same as the angle of the bullet's initial velocity in this frame? (The advantages of the first frame are not overwhelming; nevertheless, it is clearly the natural choice for the problem.)

SECTION 1.4 (Classical Relativity and the Speed of Light)

1.9 ∗ Let us assume the classical ideas of space and time are correct, so that there could only be one frame, the "ether frame," in which light traveled at the same speed c in all directions. It seemed unlikely that the earth would be exactly at rest in this frame and one might reasonably have guessed that the earth's speed v relative to the ether frame would be at least of the order of our orbital speed around the sun ($v \approx 3 \times 10^4$ m/s). **(a)** What would be the observed speed (on earth) of a light wave traveling parallel to $\mathbf{v}$? (Give your answer in terms of c and v, and then substitute numerical values.) **(b)** What if it were traveling antiparallel to $\mathbf{v}$? **(c)** What if it were traveling perpendicular to $\mathbf{v}$ (as measured on earth)? The accepted value of c is 2.9979×10^8 m/s (to five significant figures).

1.10 ∗∗ At standard temperature and pressure sound travels at speed $u = 330$ m/s relative to the air through which it propagates. Four students, A, B, C, D, position themselves as shown in Fig. 1.20, with A, B, C in a straight line and D vertically above B. A steady wind is blowing with speed $v = 30$ m/s along the line ABC. If B fires a revolver, what are the speeds with which the sound will travel to A, C, and D (in the reference frame of the observers)? Discuss whether the differences in your answers could be detected.

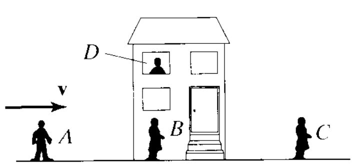

FIGURE 1.20
(Problem 1.10)

1.11 ∗∗∗ It is well known that the speed of sound in air is $u = 330$ m/s at standard temperature and pressure. What this means is that sound travels at speed u in all directions *in the frame S where the air is at rest*. In any other frame S', moving relative to S, its speed is *not* u in all directions. To verify this, some students set up a loudspeaker L and receiver R on an open flatcar, as in Fig. 1.21; by connecting the electrical signals from L and R to an oscilloscope, they can measure the time for a sound to travel from L to R and hence find its speed u' (relative to the car). **(a)** Derive an expression for u' in terms of u, v, and θ', where v is the car's speed through the air and θ' is the angle between $\mathbf{v}$ and LR. (We call this θ' since it is the angle between $\mathbf{v}$ and $\mathbf{u}'$, the velocity of the sound measured in the frame of the car.) [*Hint:* Draw a velocity-addition triangle to represent the relation $\mathbf{u} = \mathbf{u}' + \mathbf{v}$. The law of cosines should give you a quadratic equation for u'.] **(b)** If the students vary the angle θ' from 0 to 180°, what are the largest and smallest values of u'? **(c)** If v is about 15 m/s (roughly 30 mi/h), what will be the approximate percent variation in u'? Would this be detectable?

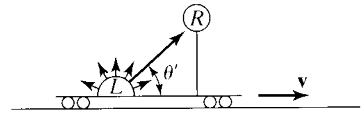

FIGURE 1.21
(Problem 1.11)

SECTION 1.5 (The Michelson–Morley Experiment*)

1.12 ∗ In the discussion of the Michelson–Morley experiment, we twice used the binomial approximation

$$(1 - x)^n \approx 1 - nx \tag{1.58}$$

which holds for any number n and any x much smaller than 1 (that is, $|x| \ll 1$). (In the examples, n was -1 and $-\frac{1}{2}$, and $x = \beta^2$ was of order 10^{-8}.) The binomial approximation is frequently useful in relativity, where one often encounters expressions of the form $(1 - x)^n$ with x small. Make a table showing $(1 - x)^n$ and its approximation $1 - nx$ for $n = -\frac{1}{2}$ and $x = 0.5, 0.1, 0.01$, and 0.001. In each case find the percentage by which the approximation differs from the exact result.

1.13 ∗ Do the same tasks as in Problem 1.12, but for the case $n = 2$. In this case give an exact expression for the difference between the exact and approximate forms. Explain why the approximation gets better and better as $x \to 0$.

1.14 ∗ Use the binomial approximation (1.58) (Problem 1.12) to evaluate $(1 - 10^{-20})^{-1} - 1$. Can you evaluate this directly on your calculator?

1.15 ∗ Tom Sawyer and Huck Finn can each row a boat at 5 ft/s in still water. Tom challenges Huck to a race in which Tom is to row the 2000 ft across the Mississippi to a point exactly opposite their starting point and back again, while Huck rows to a point 2000 ft directly downstream and back up again. If the Mississippi flows at 3 ft/s, which boy wins and by how long?

1.16 ∗ An airline, all of whose planes fly with an airspeed of 200 mi/h, serves three cities, A, B, and C, where B is 320 mi due east of A, and C is the same distance due north of A. On a certain day there is a steady