4.28 •• Consider a head-on, elastic collision between a massless photon (momentum $\mathbf{p}_0$ and energy E_0) and a stationary free electron. **(a)** Assuming that the photon bounces directly back with momentum $\mathbf{p}$ (in the direction of $-\mathbf{p}_0$) and energy E, use conservation of energy and momentum to find p. **(b)** Verify that your answer agrees with that given by Compton's formula (4.25) with $\theta = \pi$.

5.10 •• **(a)** Derive an expression for the electron's speed in the nth Bohr orbit. **(b)** Prove that the orbit with highest speed is the $n = 1$ orbit, with $v_1 = ke^2/\hbar$. Compare this with the speed of light, and comment on the validity of ignoring relativity (as we did) in discussing the hydrogen atom. **(c)** The ratio

$$\alpha = \frac{v_1}{c} = \frac{ke^2}{\hbar c} \qquad (5.38)$$

is called the "fine-structure constant" (for reasons that are discussed in Problems 9.22 and 9.23) and is generally quoted as $\alpha \approx 1/137$. Verify this value.

SECTION 5.7 (Properties of the Bohr Atom)

5.11 • Find the range of wavelengths in the Balmer series of hydrogen. Does the Balmer series lie completely in the visible region of the spectrum? If not, what other regions does it include?

monic

6.25 • **(a)** At any fixed point $x = x_0$, the traveling wave $y(x,t) = A\sin(kx - \omega t)$ can be expressed as $y(x_0,t) = A\sin(\omega t + \phi)$. Find ϕ. **(b)** For $x_0 = 0$, what is ϕ? **(c)** By how much must one change x_0 [from its value in part (b)] so that ϕ is π larger than in part (b)? Express your answer in terms of λ.

(6.18) moves

sign, the wave

6.27 •• Show that the crests of a wave $\Psi = A\sin(ax - bt)$ move to the right at a speed v equal to the ratio of the coefficients of t and x; that is, $v = b/a$. (See the hint to Problem 6.26.)

pulse of Fig.

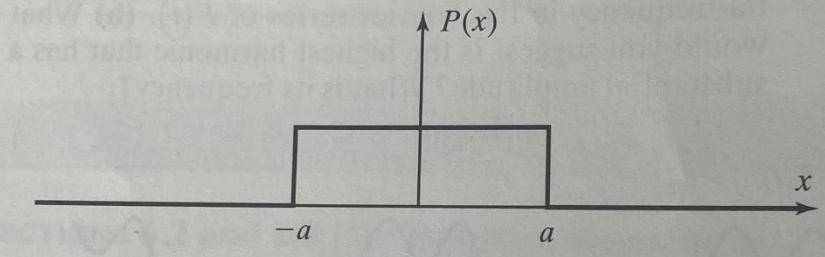
cients are as claimed in (6.26)

$A_0 = a/\lambda$. The height of the pulse is 1.

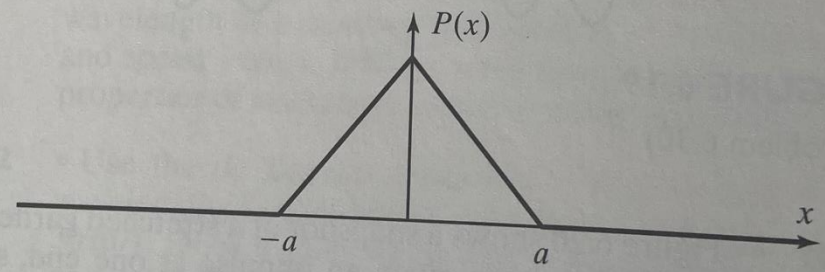
6.33 •• For theoretical purposes the best measure of the spread Δx of a pulse is the rms spread defined in (6.30), although this rms spread is sometimes rather less than one might guess. To illustrate this, think about the following: Consider a pulse whose probability density $P(x) = |\Psi(x,t)|^2$ (at one fixed time t) is as shown in Fig. 6.21(a). (The particle represented by this rectangular pulse is equally likely to be found anywhere between $x = -a$ and $x = a$. Since the total probability of finding the particle anywhere must be 1, the height of the pulse shown must be $1/2a$.) Since this pulse is centered at $x = 0$, the rms spread (6.30) is

$$\Delta x = \sqrt{\int_{-\infty}^{\infty} x^2 P(x)\,dx}$$

Find Δx for the rectangular pulse.



(a)



(b)