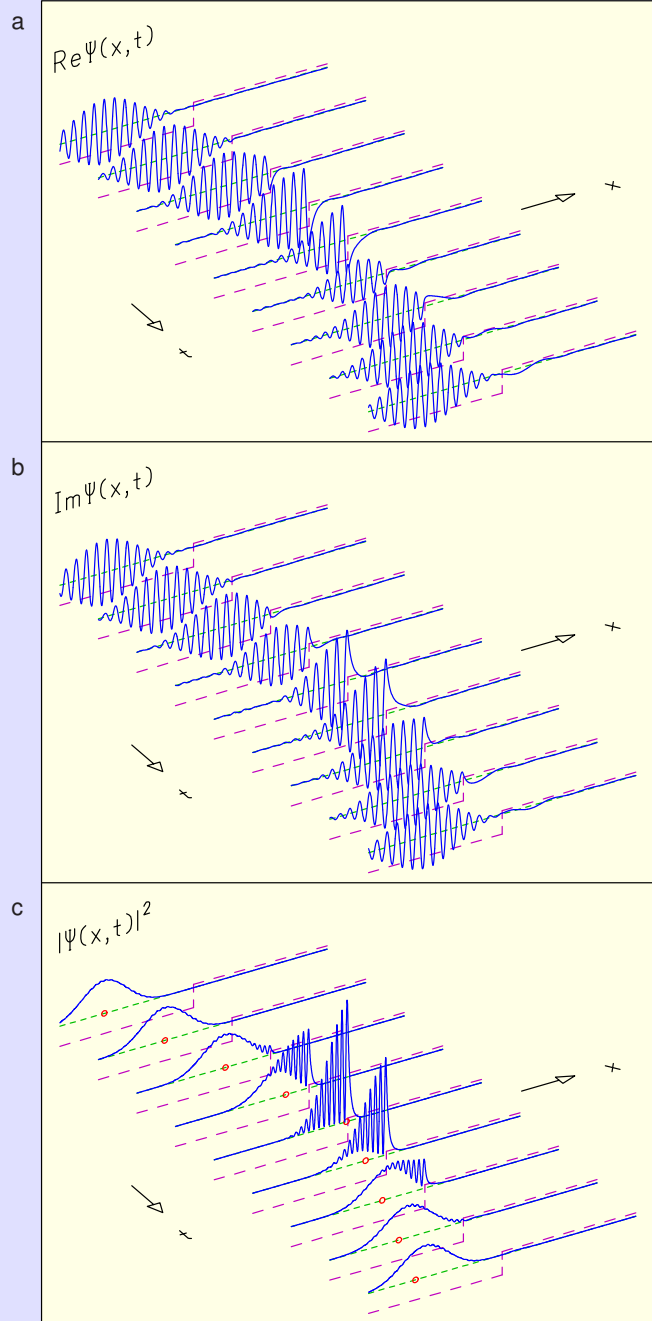
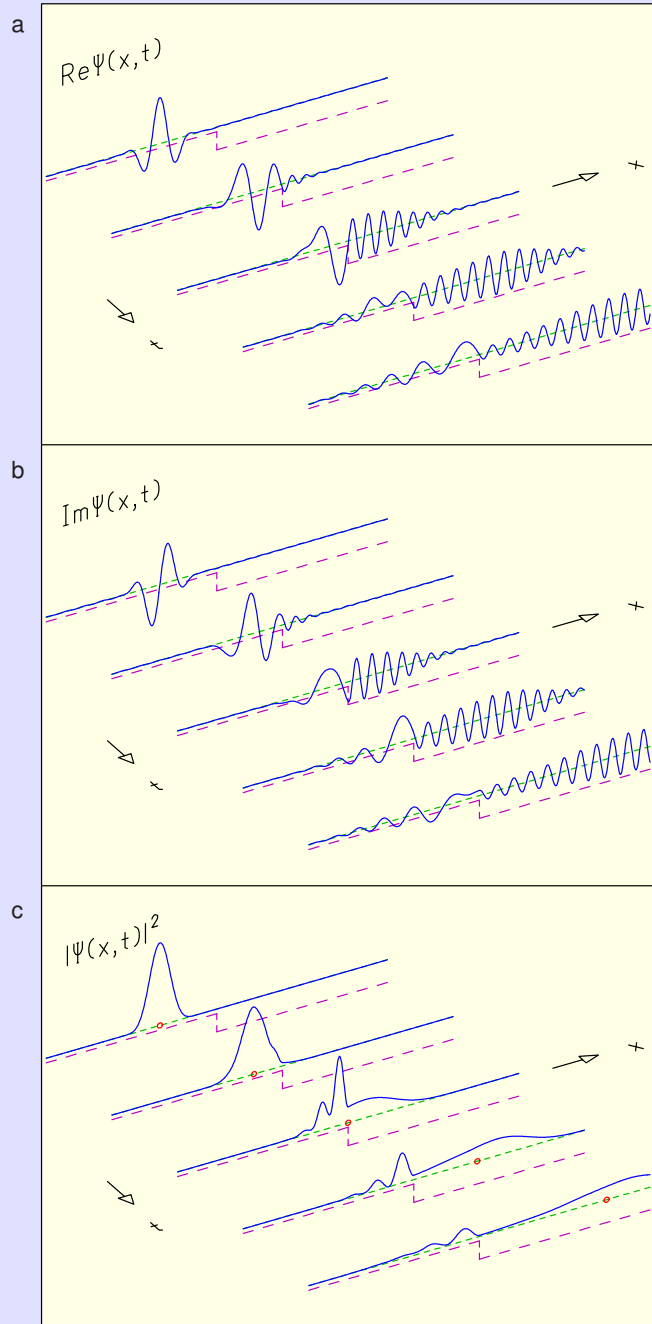


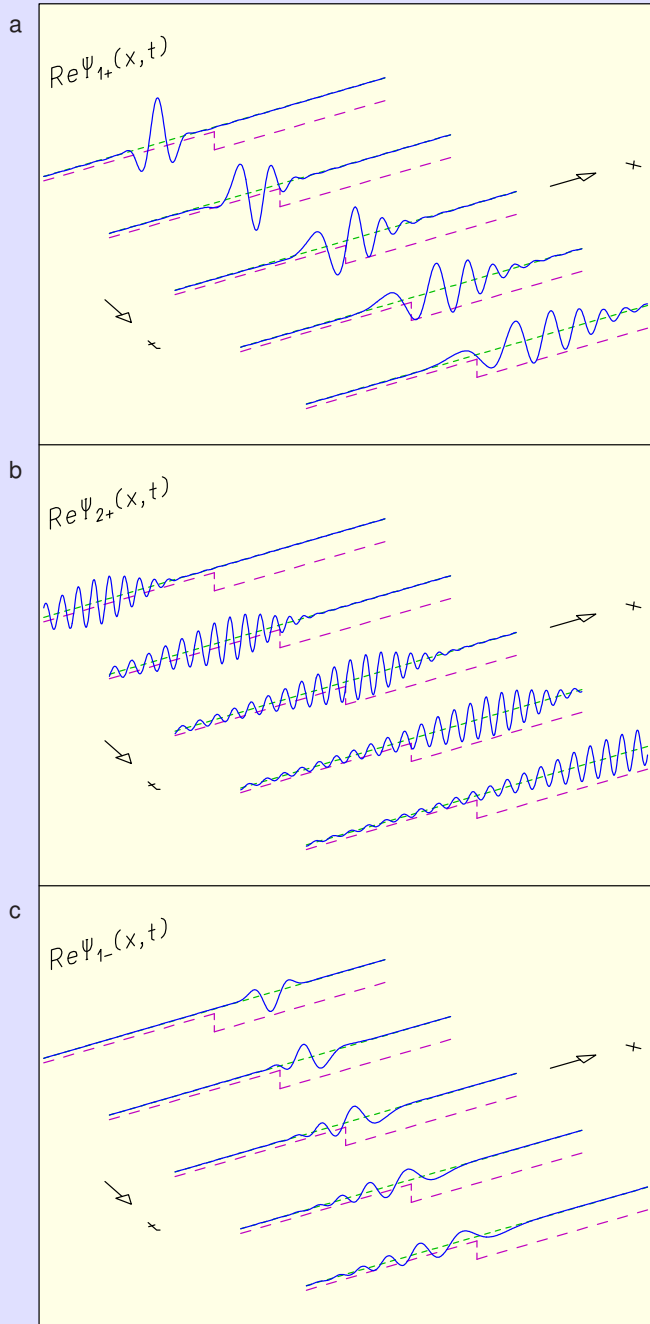
**Fig. 5.1.** Time developments of the real part, of the imaginary part of the wave function, and of the probability density for a wave packet incident from the left on a potential step of height  $V_0 > 0$ . The form of the potential  $V(x)$  is again indicated by the long-dash line, the expectation value of the energy of the wave packet by the short-dash line, which also serves as zero line for the functions plotted. The expectation value of the initial momentum is  $p_0 > \sqrt{2mV_0}$ . The small circles indicate the positions of a classical particle of the same initial momentum.



**Fig. 5.2.** Time developments of the real part, of the imaginary part of the wave function, and of the probability density for a wave packet incident from the left on a potential step  $V_0 > 0$ . The initial momentum expectation value of the incident wave packet is  $p_0 < \sqrt{2mV_0}$ . The small circles indicate the positions of a classical particle of the same initial momentum.



**Fig. 5.3.** Time developments of the real part, of the imaginary part, and of the probability density for a wave packet incident from the left on a potential step of height  $V_0 < 0$ . The small circles in part c indicate the positions of a classical particle incident on the same potential step.



**Fig. 5.4.** A wave packet falls onto a potential step of height  $V_0 < 0$ , as in Figure 5.3. The time developments of the real parts of (a) the incident constituent wave, (b) the transmitted constituent wave, and (c) the reflected constituent wave.

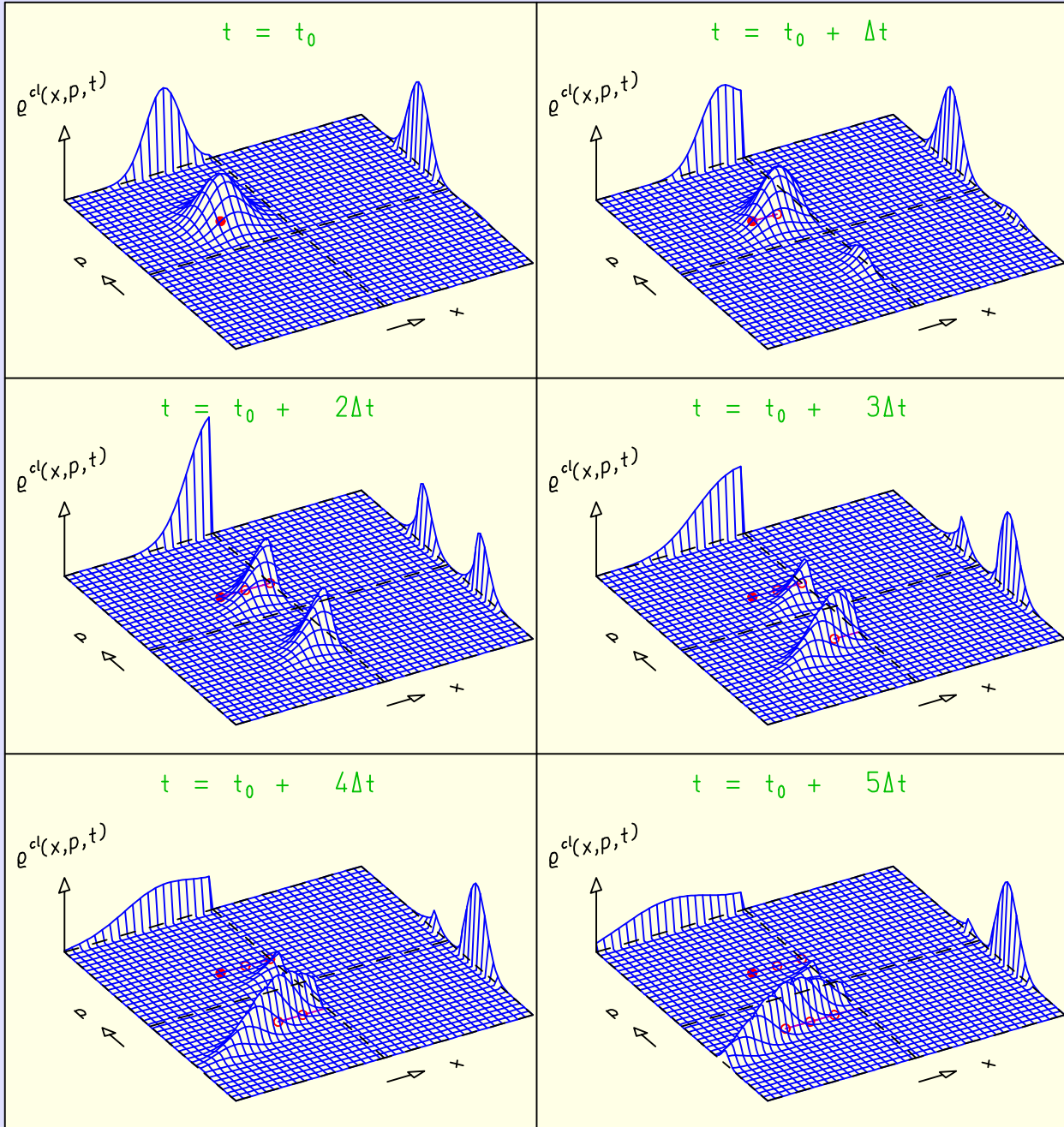
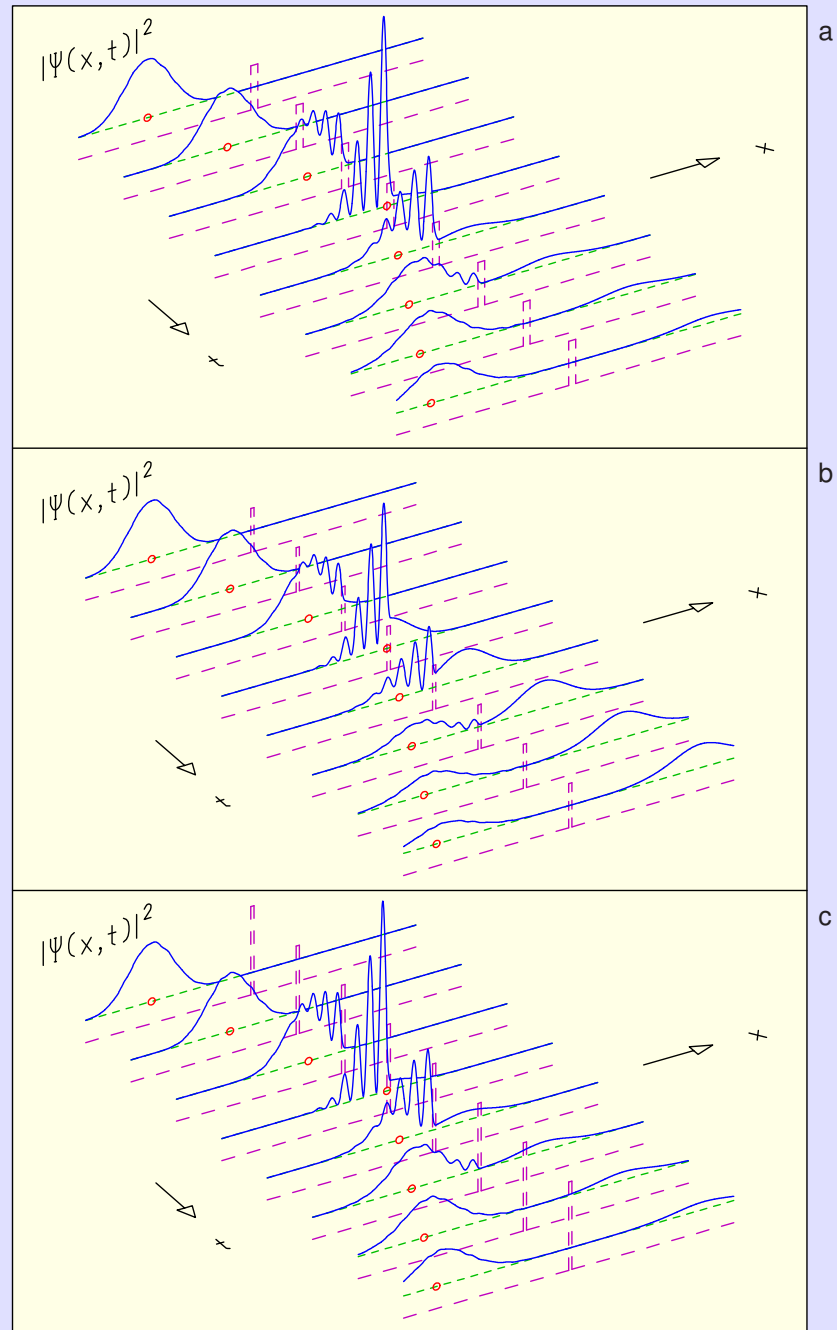


Fig. 5.5. Classical phase-space distribution  $\rho^{cl}(x, p, t)$  reflected at a high potential wall at  $x = 0$  shown for various times. The marginal distribution  $\rho_x^{cl}(x, t)$  is shown over the margin in the background, the marginal distribution  $\rho_p^{cl}(p, t)$  over the right-hand margin of the individual plots.



**Fig. 5.6. Tunnel effect.** (a) Time development of the probability density for a wave packet incident from the left onto a potential barrier of height  $V_0$ . The small circles indicate the positions of a classical particle incident onto the same potential barrier. (b) Same as for part a, but for a barrier of half the width. (c) Same as for part b, but for a barrier of double the height.

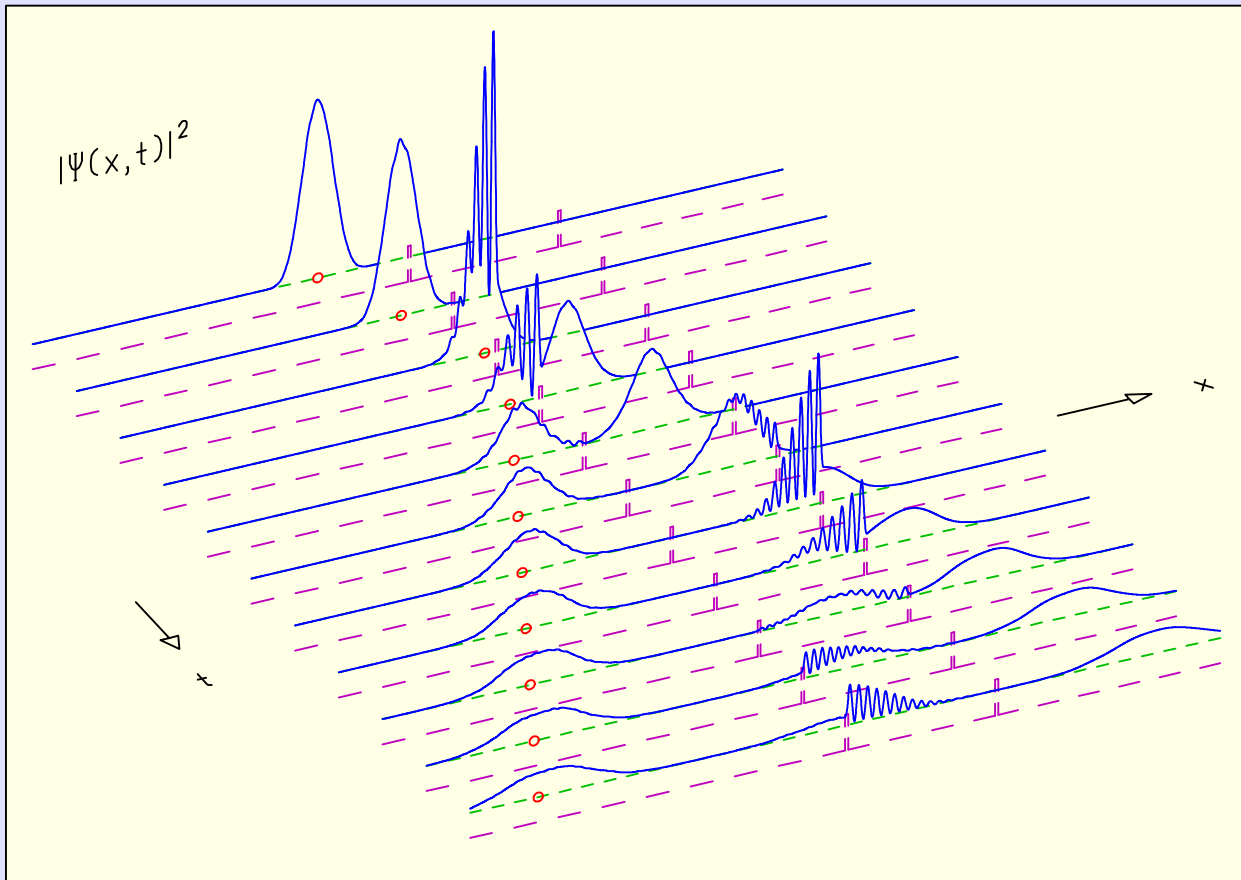


Fig. 5.7. Time development of the probability density for a wave packet incident from the left onto a double potential barrier. The small circles indicate the positions of a classical particle incident onto the same barrier.

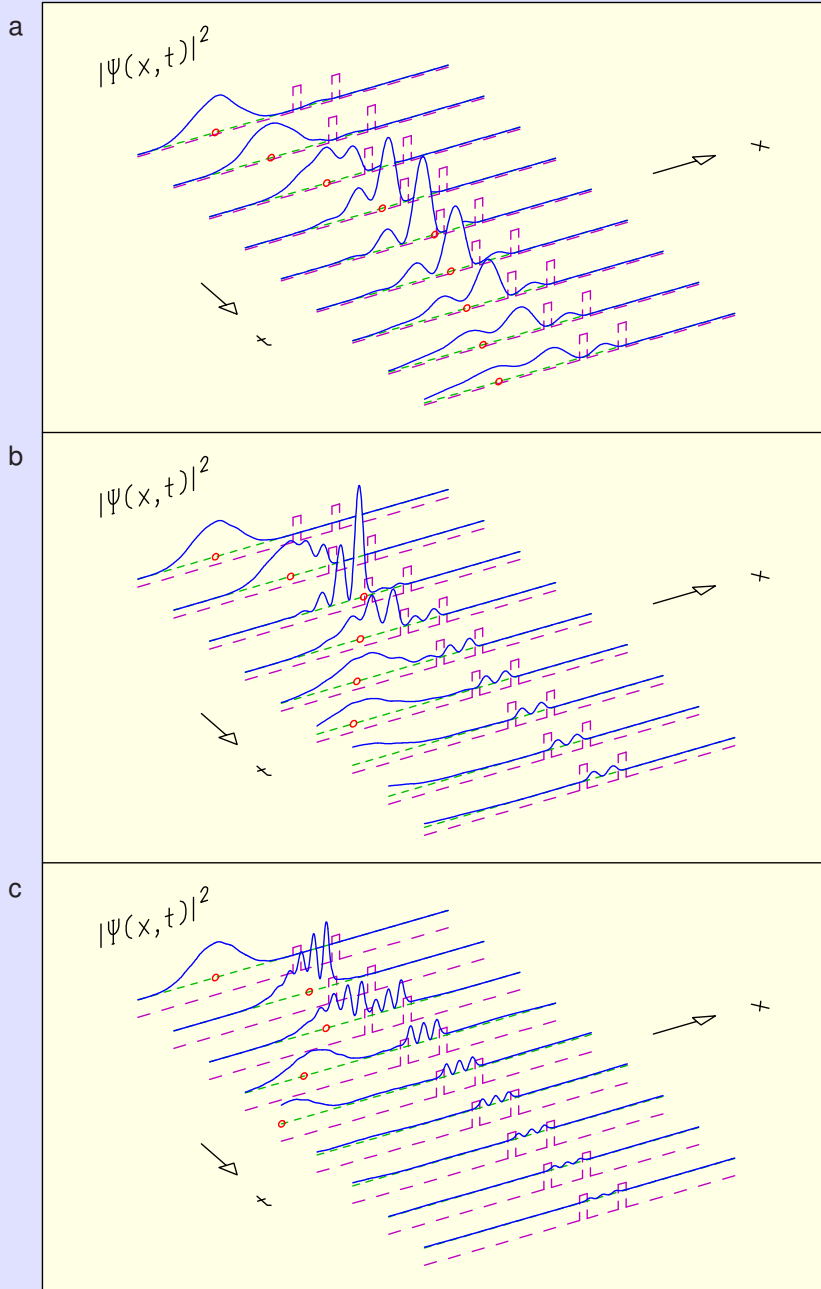


Fig. 5.8. Time developments of the probability densities for wave packets of mean energies corresponding to (a) the first, (b) the second, and (c) the third metastable states in a system of two barriers. The wave packets, which are rather wide in space and thus possess a small momentum width, are incident from the left onto the double potential barrier. The small circles indicate the positions of a classical particle incident on the same barrier.



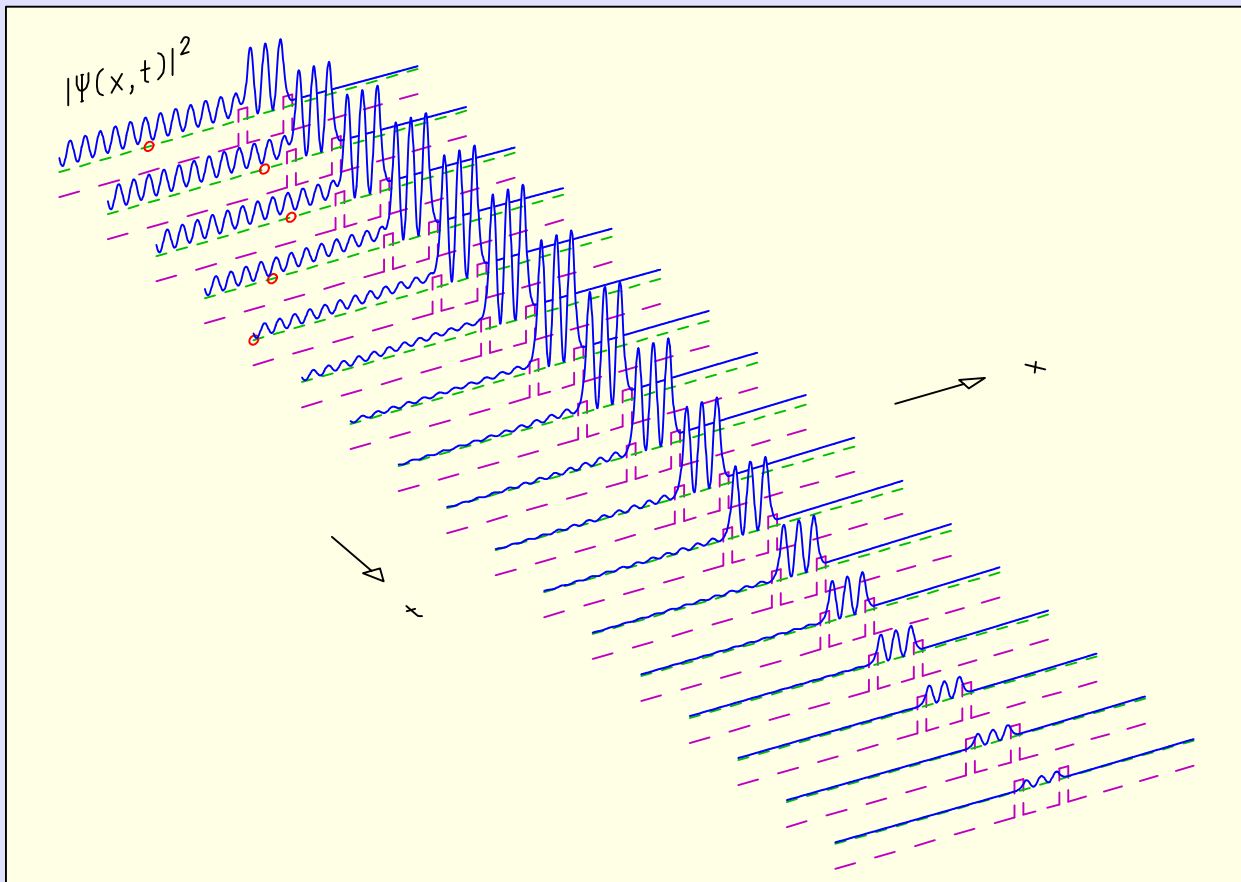
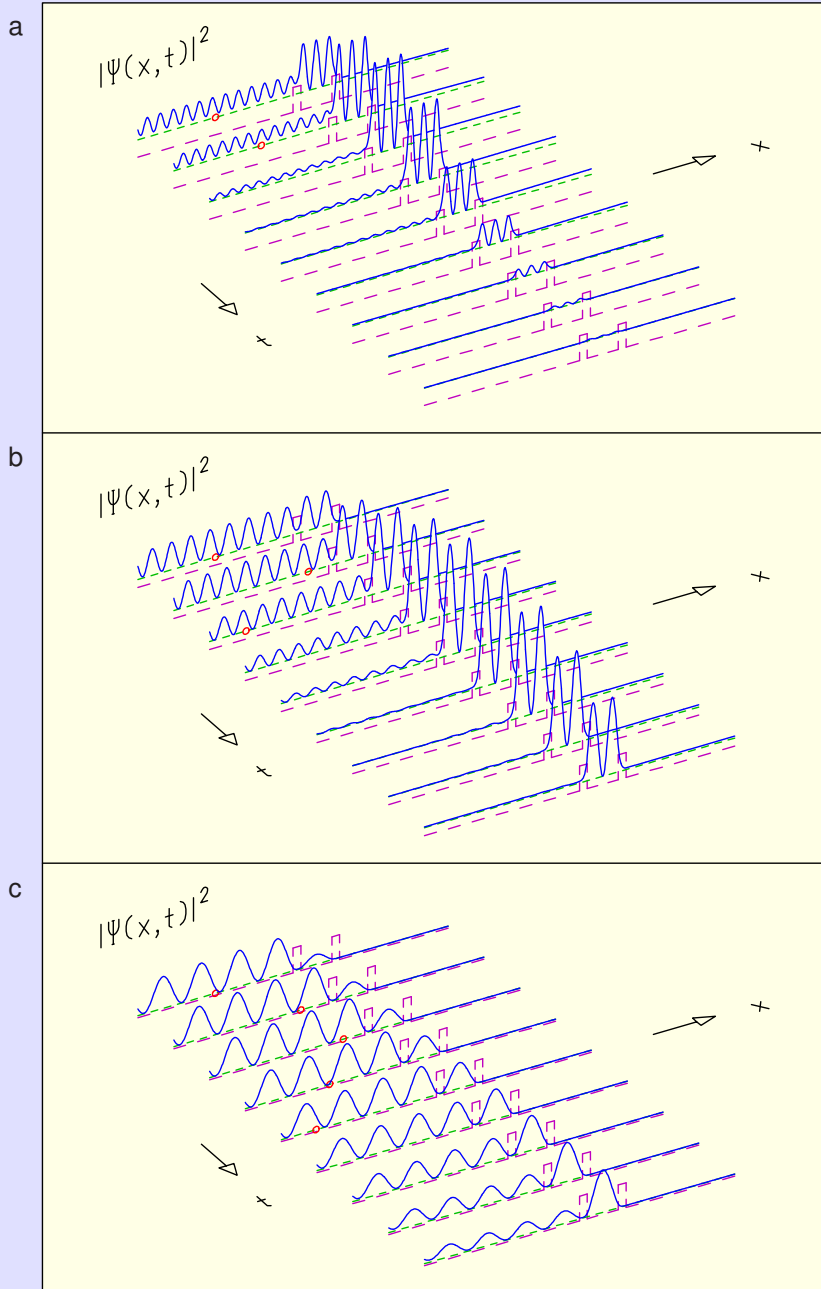


Fig. 5.9. Time development of the probability density for a wave packet that has the same mean energy as that of Figure 5.8c but is ten times as wide. Again, the wave packet is incident onto a double potential barrier. The small circles indicate the positions of a classical particle incident onto the same barrier.



**Fig. 5.10.** Time development of the process shown in Figure 5.9 but observed over a longer period of time. Once the bulk of the wave packet has been reflected, the metastable state decays like an exponential function in time. Parts b and c are the same as part a but for the two metastable states that lie higher in energy. Parts a, b, and c of this figure correspond to parts a, b, and c of Figure 5.8. The wave packets, however, are much broader, and the time interval shown is much longer.

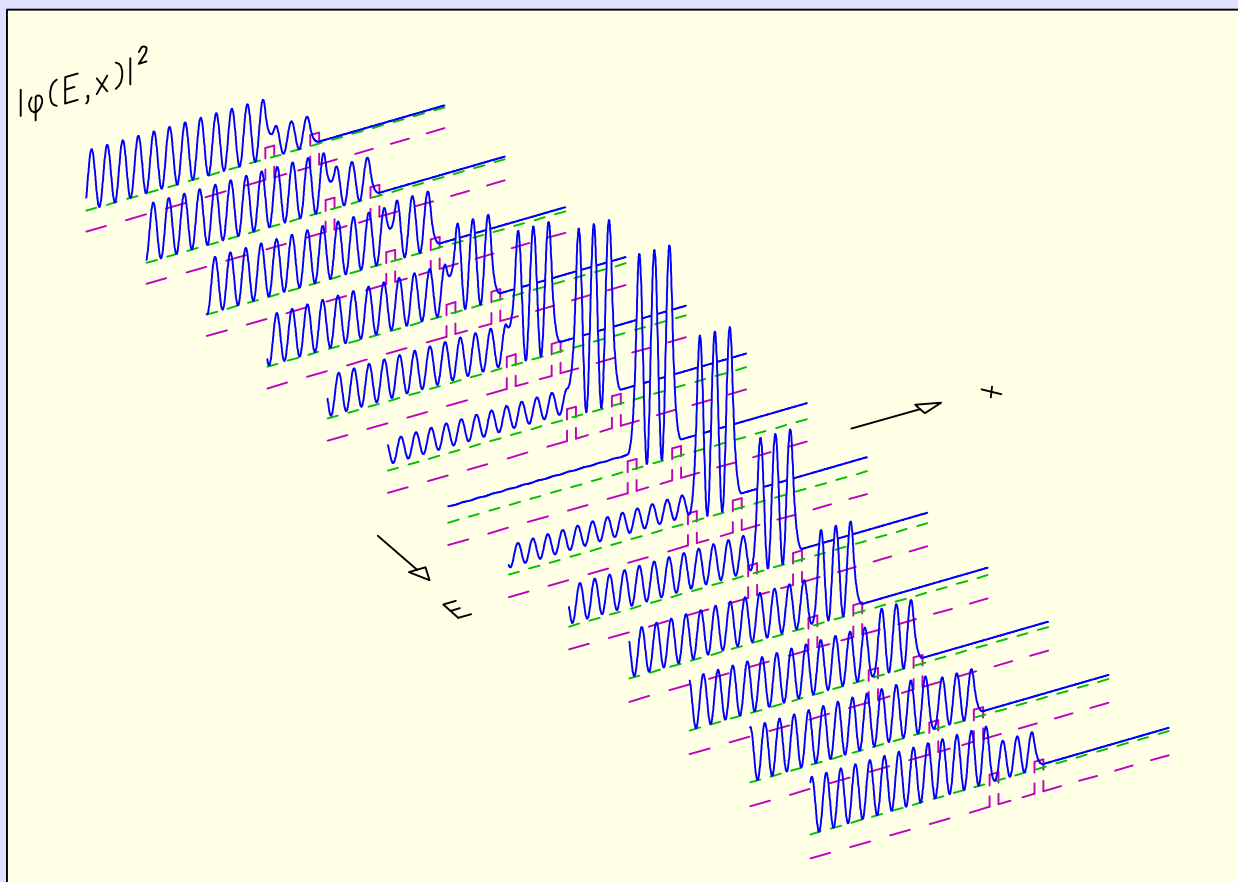
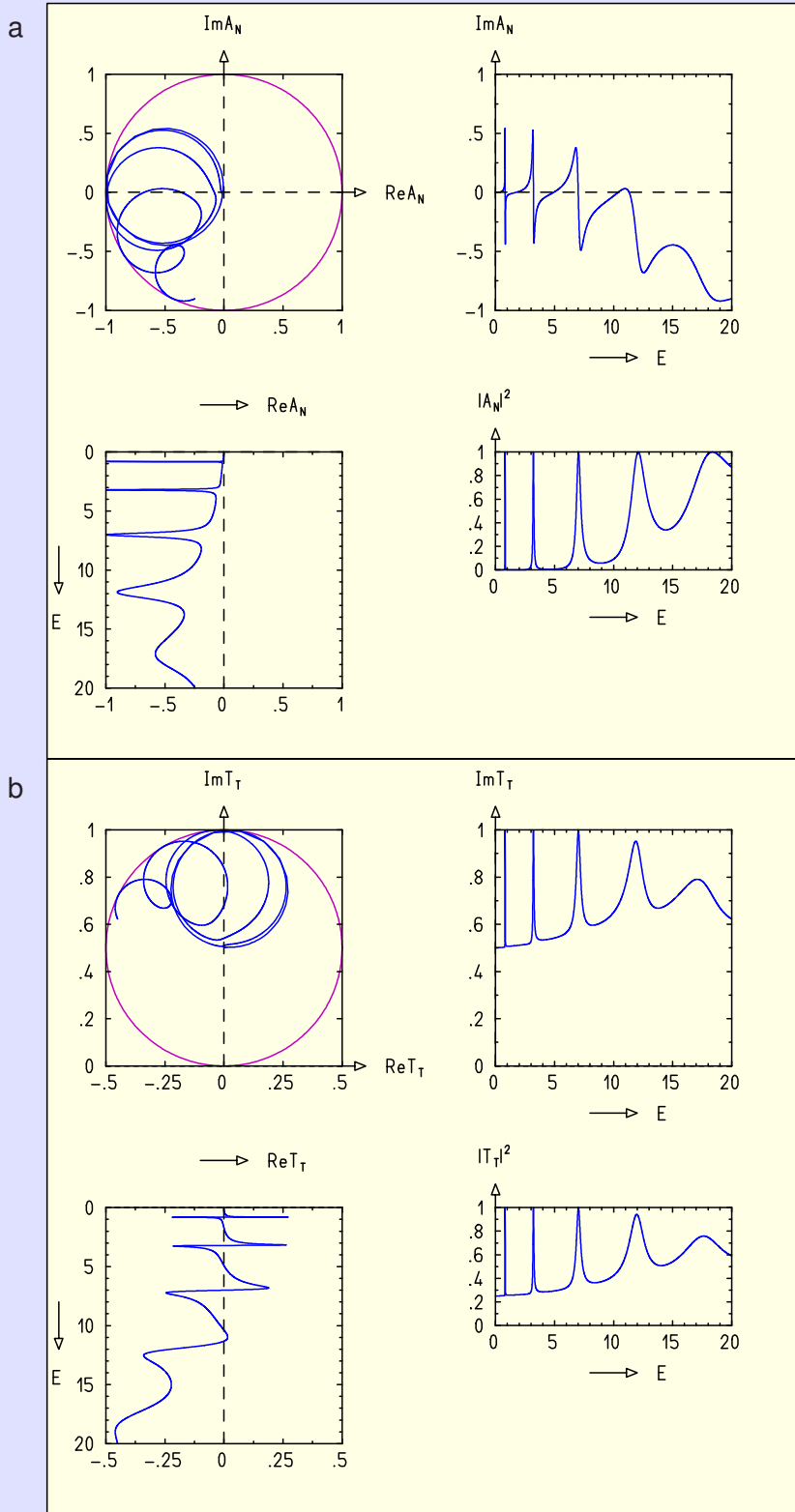
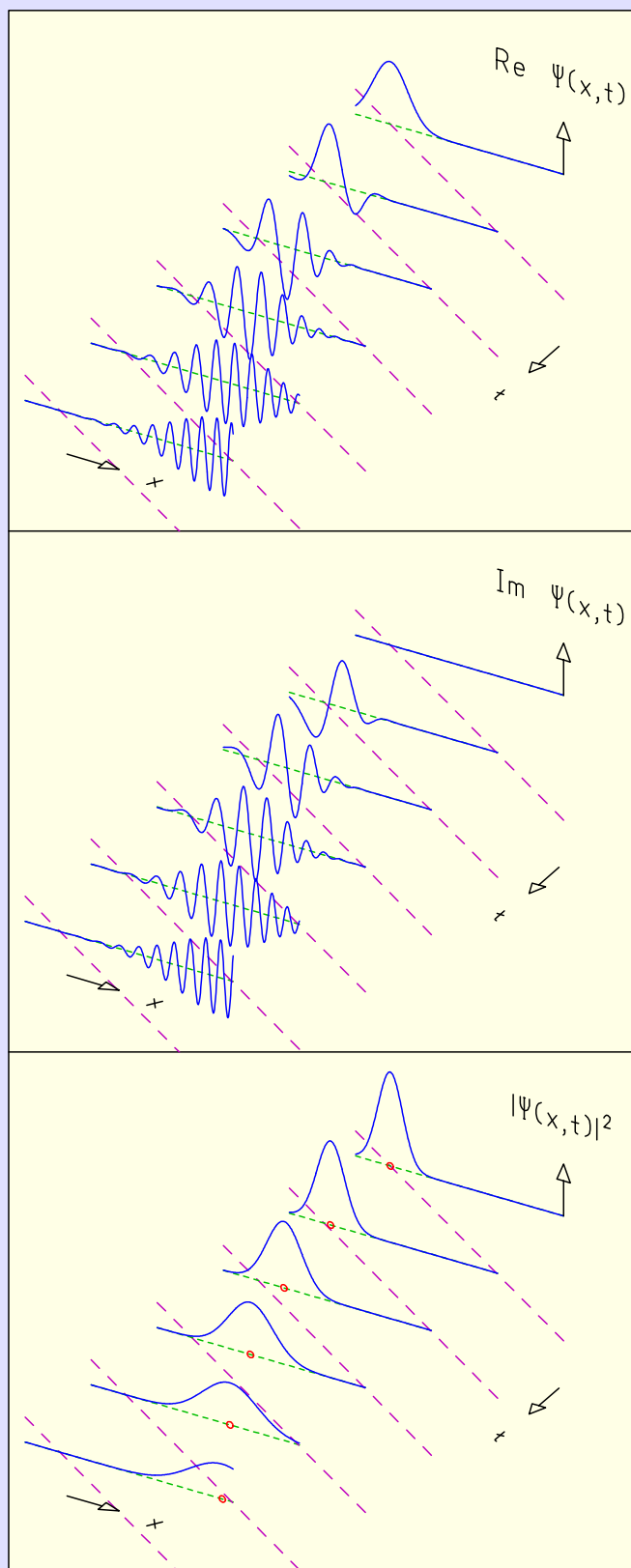


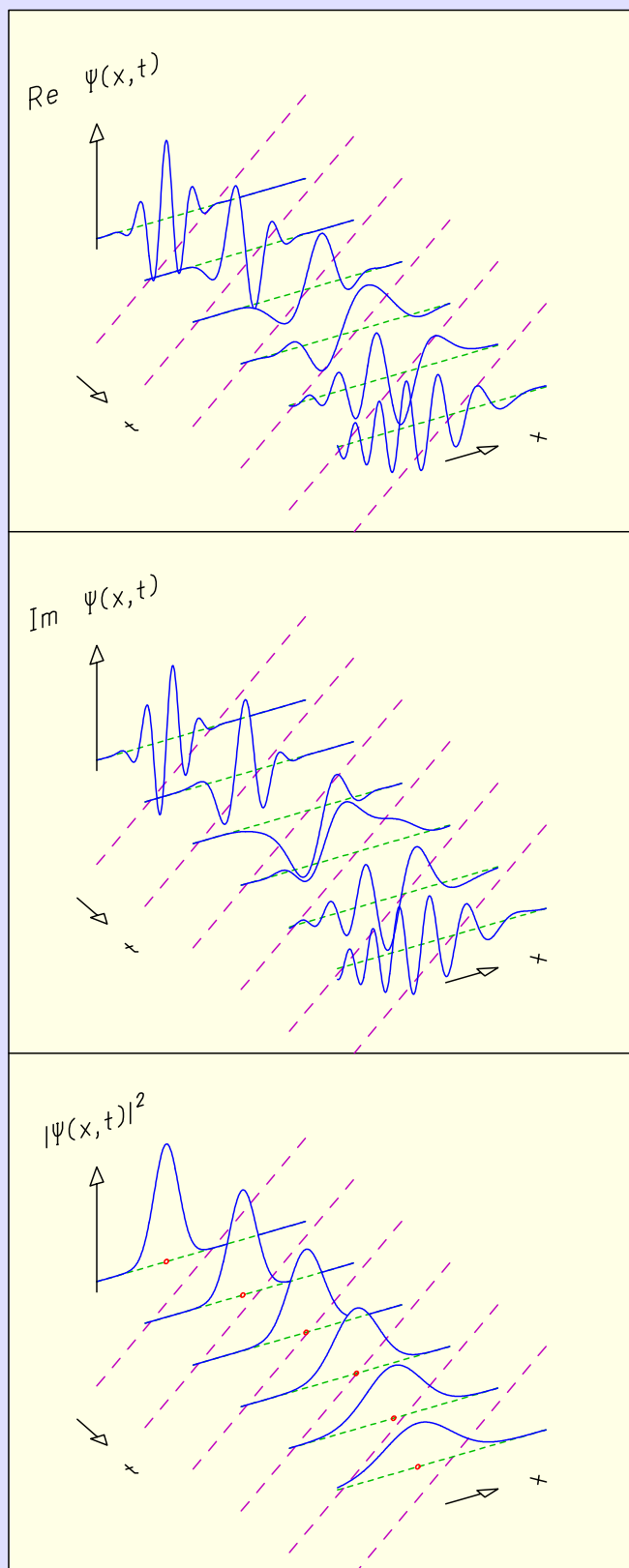
Fig. 5.11. Energy dependence, over a small range of energies, of the intensity of a harmonic wave incident onto a double potential barrier. The middle line corresponds to a resonance energy.



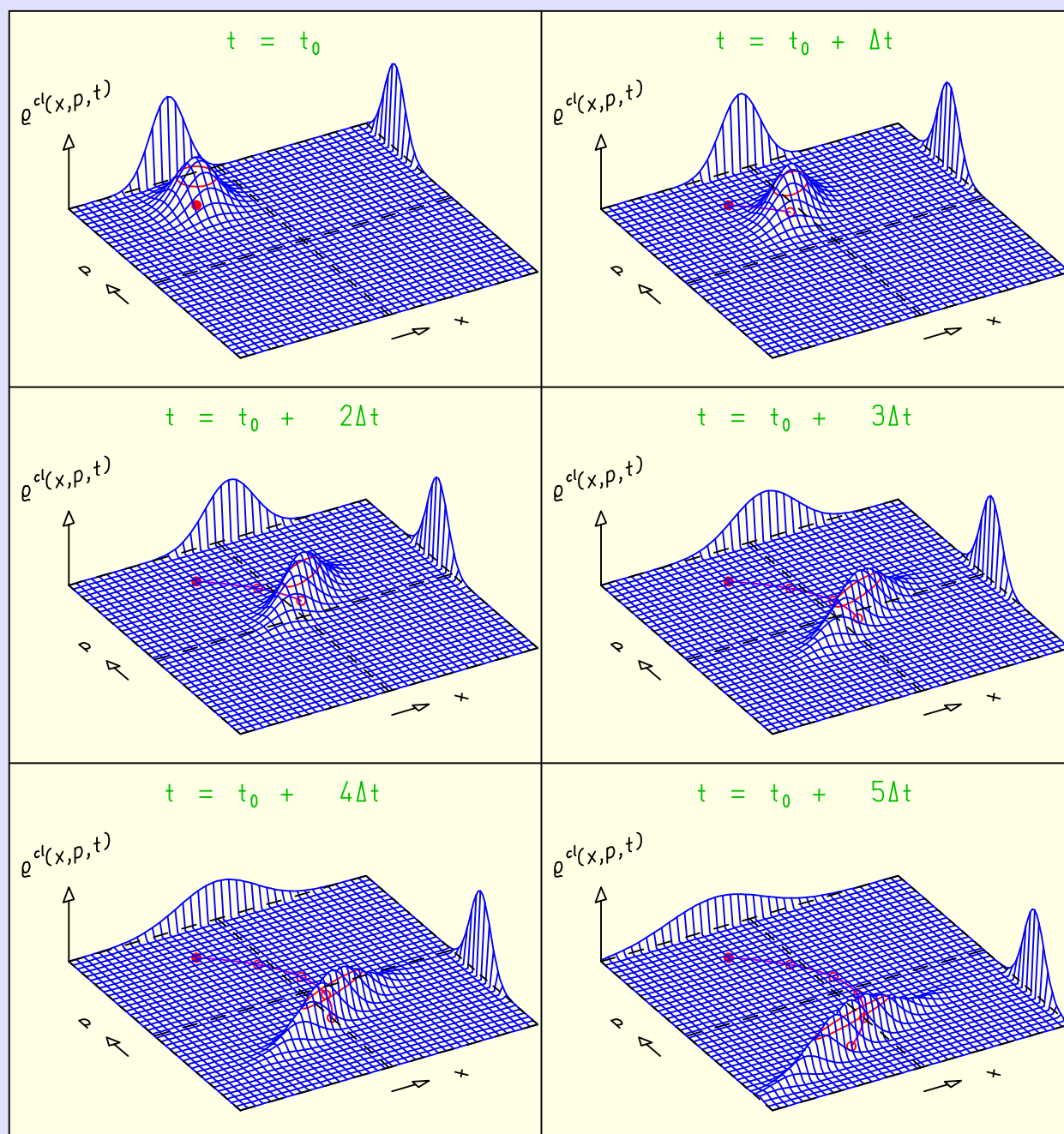
**Fig. 5.12.** (a) Energy dependence of the complex amplitude  $A_N$  of the part of a harmonic wave that is transmitted through the system with a double potential barrier. The energy ranges from zero to a value twice the barrier height. The energy dependence of  $A_N$  is shown as a line, starting from the origin, in the complex plane at upper left. The circle around the origin indicates the maximally allowed region for  $A_N$ . The energy dependence of the real part, projection onto the real axis, is shown below, that of the imaginary part, caplection onto the imaginary axis, to the right. The lower right of the figure shows the energy dependence of  $|A_N|^2$ . (b) The parts of this figure are the same as those of part a, but they are for the transmission-matrix element  $T_T = (A_N - 1)/(2i)$ . The line starts at point  $i/2$  in the complex plane. The circle around point  $i/2$  indicates the maximally allowed region for  $T_T$ .



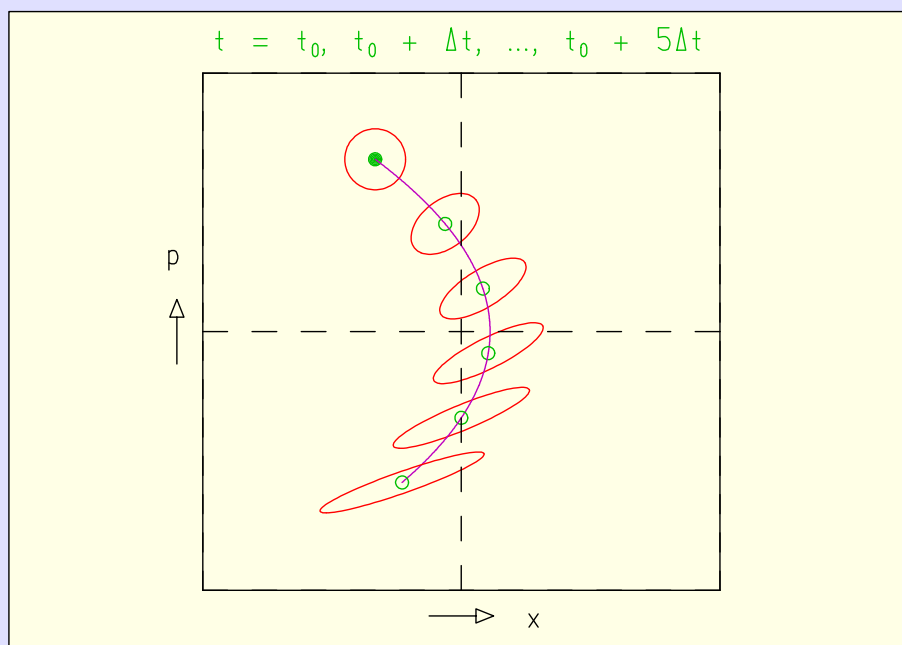
**Fig. 5.13.** Time development of the real part, the imaginary part, and the absolute square of the wave function for a wave packet which is initially at rest and which is pulled to the right by a constant force. The (linear) potential of the force is indicated by the long-dash line, the expectation value of the energy of the wave packet by the short-dash line which also serves as zero line for the function plotted. The small circles indicate the position of a classical particle with initial position and momentum equal to the corresponding expectation values of the wave packet.



**Fig. 5.14.** As Figure 5.13 but for an initial velocity  $v_0 > 0$  and for a constant force pulling the particle to the left.

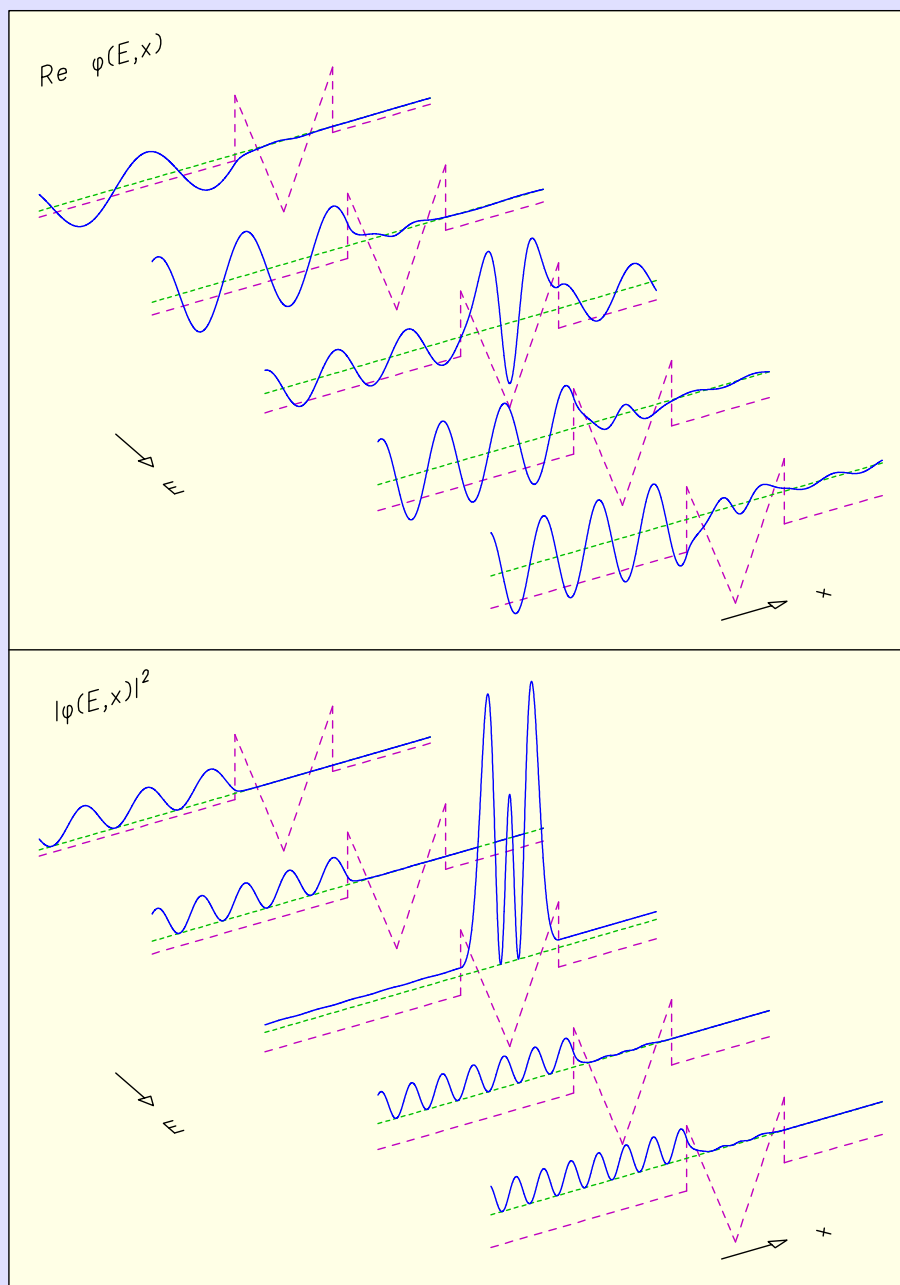


**Fig. 5.15.** Time development of the classical phase-space probability density  $\rho^{\text{cl}}(x, p, t)$  corresponding to the quantum-mechanical situation of Figure 5.14. The trajectory of the point  $(\langle x(t) \rangle, \langle p(t) \rangle)$  defined by the expectation values of position and momentum between the time  $t = t_0 = 0$  and the actual time is shown for each plot. Also shown are the marginal distributions  $\rho_x^{\text{cl}}(x, t)$  in position and  $\rho_p^{\text{cl}}(p, t)$  in momentum.

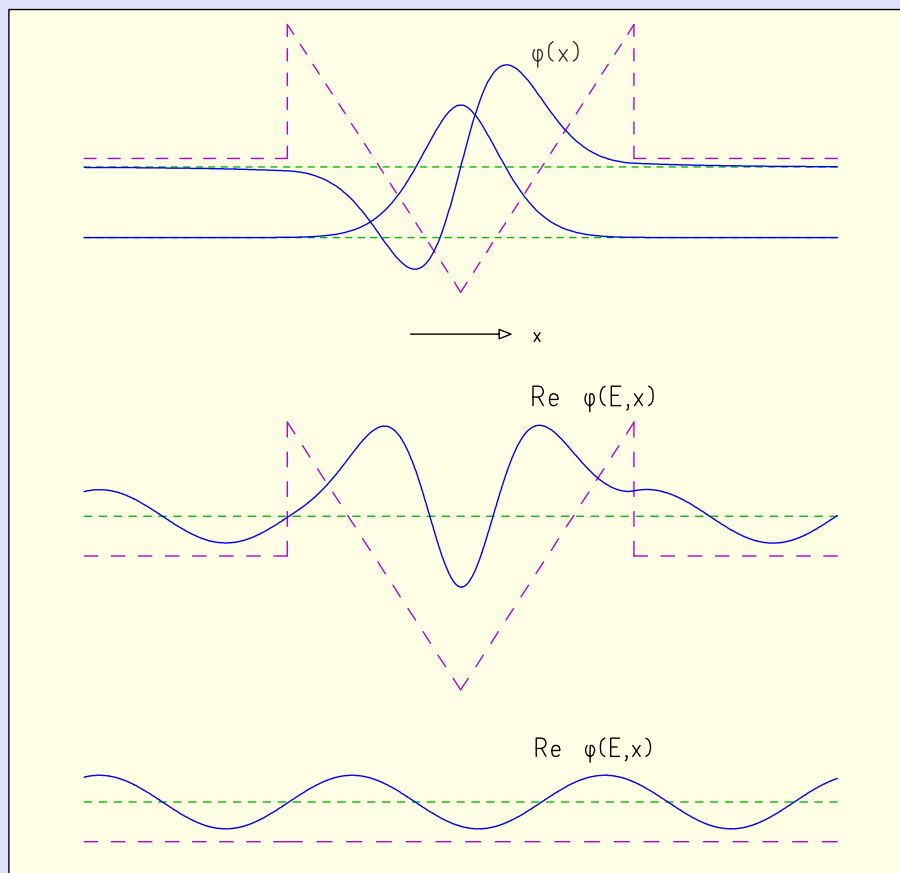


**Fig. 5.16.** Motion of the covariance ellipsoid of the classical phase-space probability density of Figure 5.15.





**Fig. 5.17.** Stationary scattering states in a piecewise linear potential. Shown is the real part (top) and the absolute square (bottom) of the stationary wave functions for different energy values. The central diagram in each of the two plots corresponds to a resonance energy.



**Fig. 5.18.** For the potential of Figure 5.17 there exist two bound states (top). The wave function of the lowest energy state possesses no nodes; that of the state with higher energy has one. The real part (middle) and the imaginary part of the stationary wave function of the first resonance have two nodes within the potential structure. At the bottom the incident wave is shown as free wave, not influenced by a potential. Comparison with the middle diagram reveals that, at resonance, incident and transmitted wave differ only by a phase shift of about  $\pi/2$ .

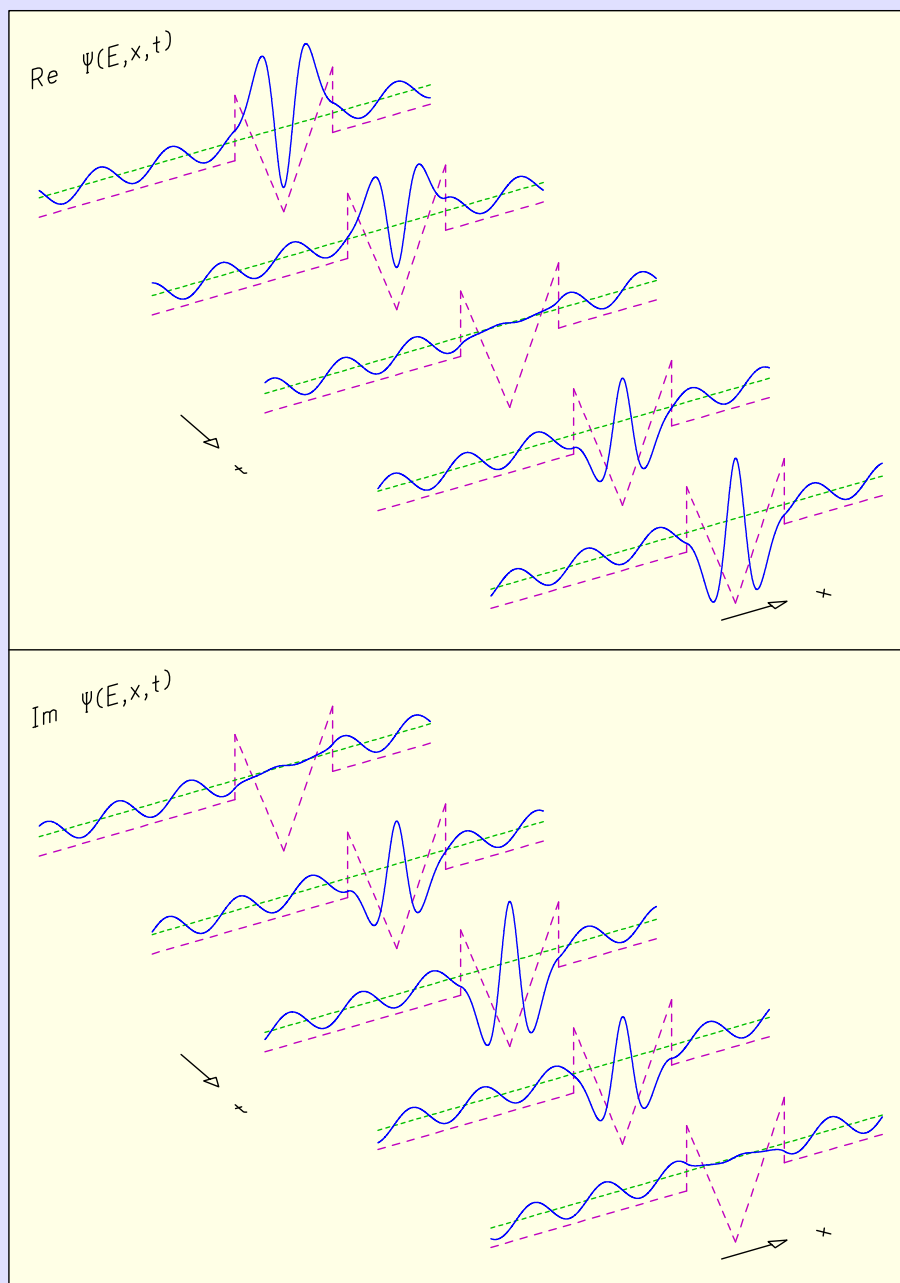
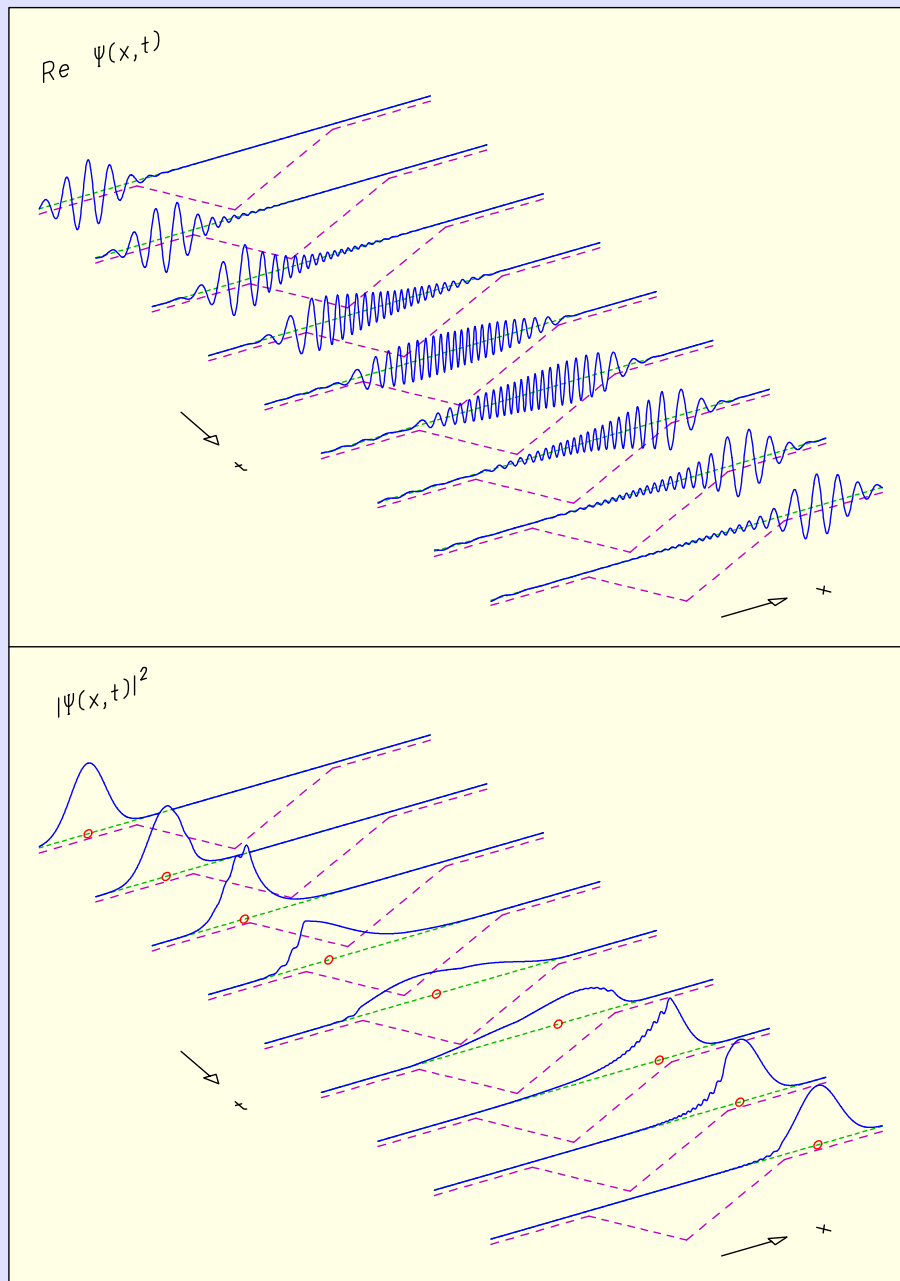
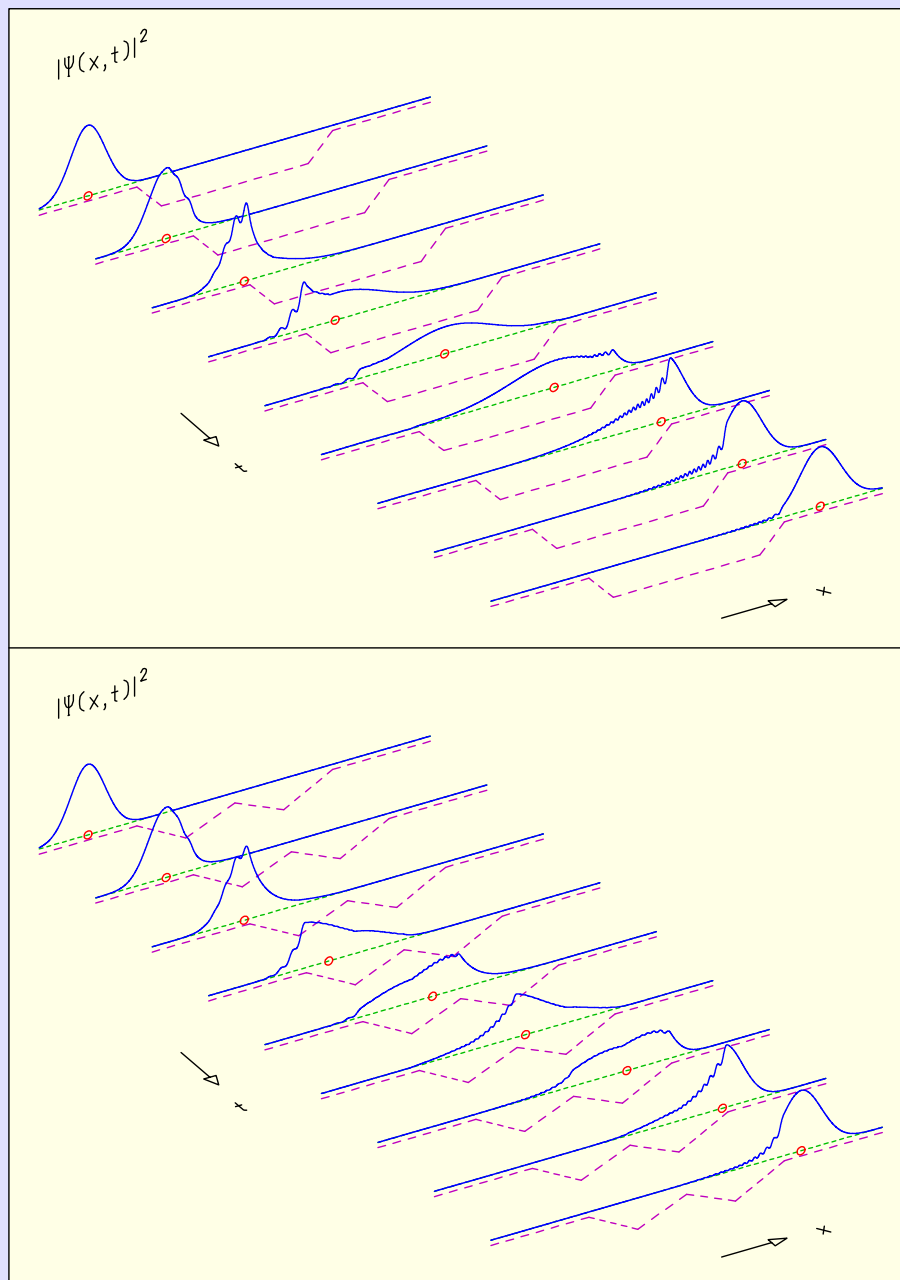


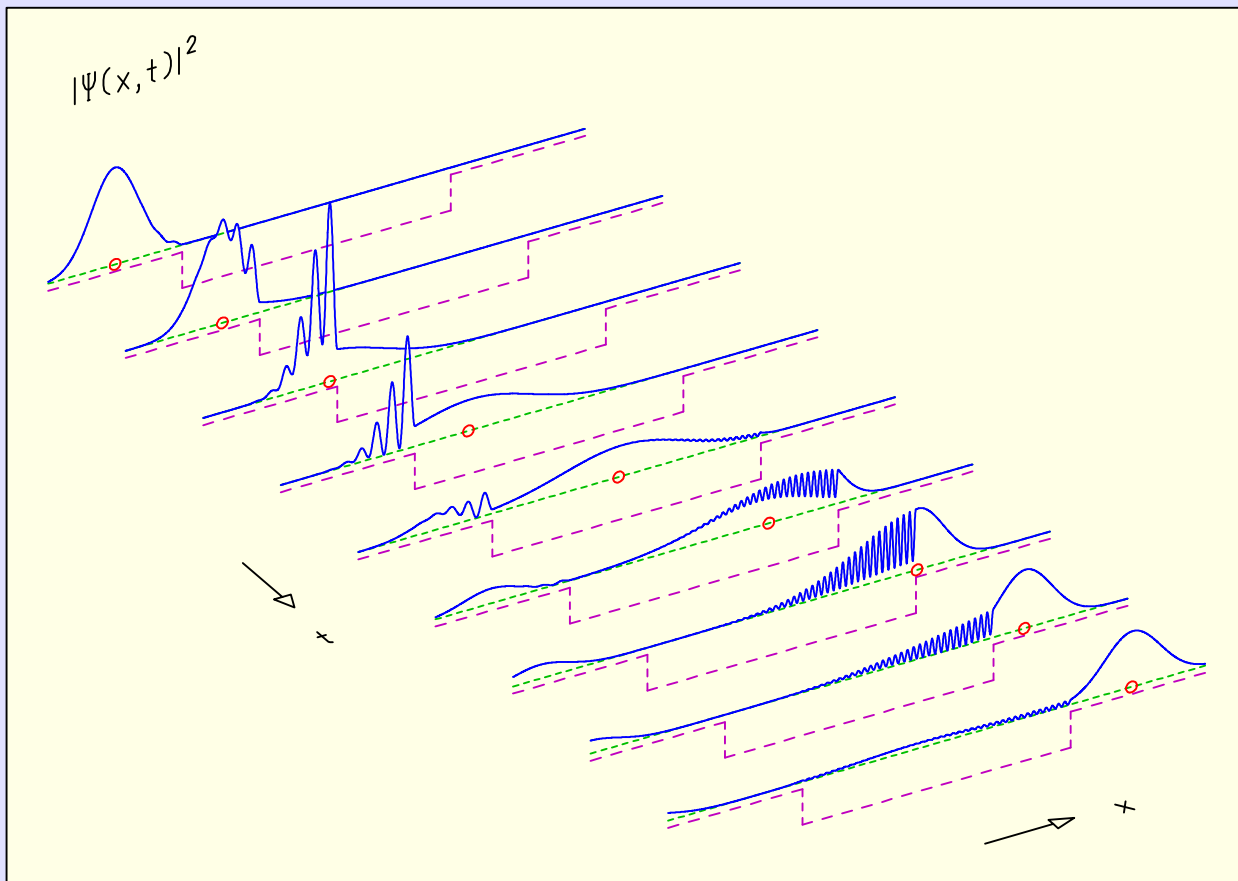
Fig. 5.19. The piecewise linear potential of Figure 5.17 is traversed by a harmonic wave at resonance energy. The time development of its real part (top) and imaginary part (bottom) is shown over half an oscillation period.



**Fig. 5.20.** Wave packet traversing a triangular well. Time development of the real part of the wave function (top) and of the probability density (bottom).



**Fig. 5.21.** Wave packet traversing a trapezoidal well, i.e., a “square” well with skew edges (top), and a double triangular well (bottom). For both cases only the probability density is displayed. There is some interference due to the discontinuity of the potential but hardly any reflection.



**Fig. 5.22.** Wave packet traversing a true square well with sharp edges. The probability density exhibits important interference and reflection.