Appendix A

Zero-Current Wavefunctions

One interesting aspect of the detector discussed in Section 3.3.2, is that hile it can be used for ave-packets arriving from the left or the right, it ill not al ays be triggered if the avefunction is a coherent superposition of right and left moving modes. Consider for example, the superposition

$$\psi(x) = Ae^{ikx} + Ae^{-ikx}. \tag{A.216}$$

One can easily verify that the current

$$j(x,t) = -i\frac{1}{2m}\left[\psi^*(x,t)\frac{\partial\psi(x,t)}{\partial x} - \frac{\partial\psi^*(x,t)}{\partial x}\psi(x,t)\right] \tag{A.217}$$

is zero in this case. $|\psi(0,t)|^2$ is non-zero, although the state is not normalizable. As in eq. (3.63) this state evolves into

$$\langle x|\psi\rangle|\uparrow_z\rangle \quad \rightarrow \quad \frac{A}{\sqrt{2}}\left[(e^{ikx} + e^{-ikx})|\uparrow_x\rangle + (e^{ikx} + e^{-ikx})|\downarrow_x\rangle\right] \tag{A.218}$$

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Appendix B

Gaussian Wave Packet and Clocks

Using the simple model of Section 3.3.1 (3.44), e no calculate the probability distribution of a clock hich measures the time-of-arrival of a Gaussian ave packet. We ill perform the calculation in the limits hen the clock is extremely accurate and extremely inaccurate. The ave function of the clock and particle is given by (3.52) and the distributions are both Gaussians given by (3.53). In the inaccurate limit, hen $p_o << k$, $A_T \sim 1$. W

Since $\Delta y\, k >> 1$, for a ave packet peaked around k_o e can approximate the argument of the first exponential by $\frac{-\Delta y^2 k_o^2}{2m^2}(k-k')^2$. This allo s us to integrate over k and k'

$$\rho(y,y)_{>0} \simeq \frac{1}{\sqrt{2\pi\gamma(y)}} e^{-\frac{(y-t_c)^2}{2\gamma(y)}} \tag{B.222}$$

here the idth is $\gamma(y) = \Delta y^2 + (\frac{m\Delta x}{k_o})^2 + (\frac{y}{2k_o\Delta x})^2$.

As expected, the distribution is centered around the classical time-of-arrival $t_c = x_o m/k_o$. The spread in y has a term due to the initial idth Δy in clock position y. The second and third term in $\gamma(y)$ is due to the kinematic spread in the time-of-arrival $1/dE$