

14.2: Aharonov-Bohm Effect

Let us now study a phenomenon that depends on the existence of potential momentum. If the potential energy of a particle is zero and both the kinetic and potential momenta point in the $\pm x$ direction, the total energy equation 14.7 for the particle becomes

$$E = [(\Pi - Q)^2 c^2 + m^2 c^4]^{1/2} = (p^2 c^2 + m^2 c^4)^{1/2}. \quad (14.2.1)$$

Since its total energy E is conserved, the magnitude of the kinetic momentum p of the particle doesn't change according to the above equation. Thus, if a region of non-zero potential momentum is encountered, the total momentum of the particle must change so as to keep the kinetic momentum constant. This results in a change in the wavelength of the matter wave associated with the particle. In particular, if the potential momentum points in the same direction as the kinetic momentum, the total momentum is increased and the wavelength decreases, while a potential momentum pointing in the direction opposite the kinetic momentum results in an increase in wavelength.

Figure 14.2.1: illustrates what might happen to a particle moving through a channel that splits into two sub-channels for an interval. If we arrange to have non-zero potential momenta pointing in opposite directions in the sub-channels, the wavelength of the particle will be different in the two regions. At the end of the interval, the waves recombine, interfering constructively or destructively, depending on the magnitude of the phase difference between them. If destructive interference occurs, then the particle cannot pass. The potential momentum thus acts as a valve controlling the flow of particles through the channel. This is an example of the **Aharonov-Bohm effect**.

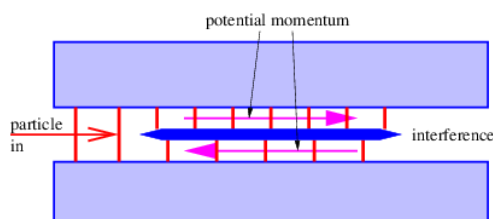


Figure 14.2.1:: Setup for the Aharonov-Bohm effect. The particle moves through a channel which has a divided segment with non-zero potential momenta pointing in opposite directions in the two sub-channels. The vertical line segments show the wave fronts for the particle.

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