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The Doppler Effect in Sound Waves, Light Waves, and Quantum Waves ALAN M. KADIN, Princeton Junction, NJ — In undergraduate modern physics courses, special relativity and quantum mechanics are generally introduced as a series of sharp breaks from classical physics. An alternative approach is suggested, focusing on the Doppler effect, closely related to changes in reference frames. In the classical acoustic Doppler effect with a source or observer moving with speed u, the frequency f shifts while the wavelength λ must remain fixed for classical transformations. Hence the phase velocity $v_{ph}=f\lambda$ must also shift. In the optical Doppler effect, f also shifts for u approaching c, but this must be accompanied by a corresponding shift in λ (from the Lorentz transformation) in order to maintain $v_{ph}=c$ constant. The Doppler effect is usually not considered for quantum waves, but this clearly requires a non-classical shift in the de Broglie wavelength $\lambda=h/mv$ even for $u<<c$. This shift is fully explained by the Lorentz transformation if one takes $f=mc^2/h$, as was shown by de Broglie in his original 1924 paper. This is a dispersive wave with $v_{ph}=c^2/v$, but a group velocity $v_g=v$, as required for a consistent physical interpretation. This emphasizes the relativistic basis of quantum waves.

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