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B.Sc. Part-I

Paper-I

Theory of Relativity

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Transverse Doppler effect

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Suppose That a source and a receiver are both approaching each other in uniform inertial motion along along paths that do not collide. The transverse Doppler effect (TDE) may refer to (a)

(a) The nominal blueshift predicted by special relativity That occurs when the emitter and receiver are at Their points of closest approach or (b)

(b) The nominal redshift predicted by special relativity when the receiver sees the emitter as being at its closest approach. The Transverse Doppler effect is one of the main novel predictions of the special Theory of relativity.

Whether a scientific report describes TDE as being a redshift or blueshift depends on the particulars of the experimental arrangement being related. For example, Einstein's original description of the TDE in 1907 described an experimenter looking at the center of a beam of canal rays (a beam of positive ions that is created by certain types of gas-discharge tubes). According to special relativity, the moving ions emitted frequency would be reduced by the Lorentz factor, so that the received frequency would be reduced by the same factor.

On the other hand, Kundig (1963) described an experiment where a Mossbauer absorber was spun in a rapid circular path around a central Mossbauer emitter. As explained below, this experimental arrangement resulted in Kundig's measurement of blueshift.

Source and receiver are at their points of closest approach ——

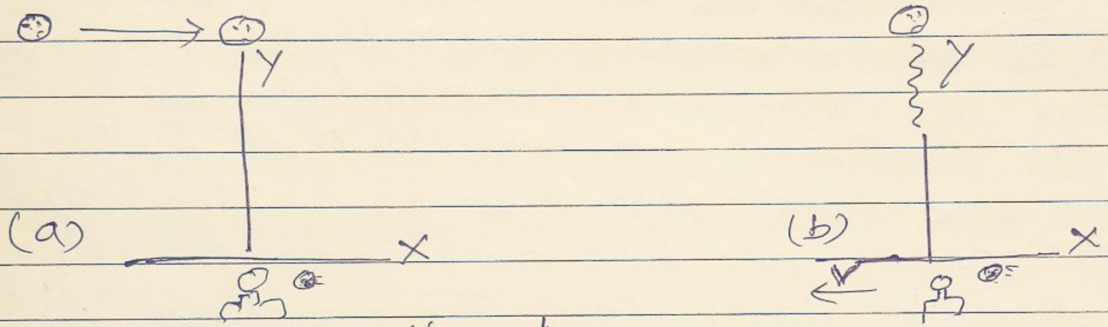

fig - 1

Source and receiver are at their points of closest approach (a) Analysis in the frame of the receiver (b) Analysis in the frame of the source.

In this scenario, the point of closest approach is frame-independent and represents the moment where there is no change in distance versus time. fig 1 demonstrates that the ease of analyzing this scenario depends on the frame in which it is analyzed.

fig 1 (a). If we analyze the scenario in the frame of the receiver, we find that the analysis is more complicated than it should be. The apparent position of a celestial object is displaced from its true position because of the object's motion during the time it takes its light to reach an observer. The source would be time-dilated relative to the receiver, but the redshift implied by this time dilation would be offset by a blueshift due to the longitudinal component of the relative motion between the receiver and the apparent position of the source.

fig 1 (b) — It is much easier if, instead, we analyze the scenario from the frame of the source. An observer situated at the source knows from the problem statement that the receiver is at its closest point to him. That means that the receiver has no longitudinal component of motion to complicate the analysis. (i.e. $dr/dt = 0$ where r is the distance between receiver and source) Since the receiver's clocks are time-dilated relative to the source, the light that the receiver receives is blue-shifted by a factor of gamma. In other words

$$f_r = \gamma f_s \qquad \text{--- (3)}$$