Reply to comments on 'On a proposed new test of Heisenberg's principle'

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COMMENT

Reply to comments on 'On a proposed new test of Heisenberg's principle'

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Abstract. It is shown that the claims of Home and Sengupta and of Singh to have discovered fallacies in our analysis of a proposed, technically feasible test of Heisenberg's uncertainty principle are based on misunderstandings.

Recently, Home and Sengupta (1981) claimed to have discovered a logical fallacy in our analysis of a proposed, technically feasible experiment to test Heisenberg's uncertainty principle (Robinson 1969, 1980). We shall show that their argument is based on a misunderstanding of our use of the symbol Δx.

The proposed experiment consists of two position detectors, D_1 and D_2, at x_1 and x_2, separated by a velocity selector which permits the passage, one at a time, of only those particles that leave D_1 with a velocity in the range $(v_s - \delta v_s, v_s + \delta v_s)$ parallel to the x axis. The uncertainty in the momentum of such a particle is thus

$$p = m\Delta v_s < m\delta v_s \tag{1}$$

while the particle is passing through the selector. The RMS spread of the wavepacket is given by

$$\Delta x \geqslant \hbar/2m\Delta v_s > \hbar/2m\delta v_s. \tag{2}$$

If, as is usually assumed, $|\Psi|^2$ is the probability density of position, then the detector D_2 can register the presence of the particle at any instant during the time the wavepacket passes x_2. Therefore, if these measurements are repeated several times, there will be fluctuations in the times of flight with a RMS value

$$\Delta t = \Delta x / v_s. \tag{3}$$

Thus, in general, the time of flight velocity will be

$$v_t \equiv (x_2 - x_1)/(t_2 - t_1) \neq v_s. \tag{4}$$

If, however,

$$v_t \equiv (x_2 - x_1)/(t_2 - t_1) = v_s \tag{5}$$

for every particle which passes through the velocity selector, then Δx in (2) does not represent the uncertainty in position.

Furthermore, since x_1 and x_2 are arbitrary, the truth of (5) would imply

$$(x - x_1)/(t - t_1) = (x_2 - x)/(t_2 - t) = v_s = v_t \tag{6}$$

for all values of x and t in the intervals (x_1, x_2) and (t_1, t_2). It would then be possible

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to measure v_s, x_1, x_2, t_1, t_2 with sufficient precision that

$$\Delta x_p \, \Delta p < m(\delta v_s)^2(t_2 - t_1) < \hbar/2. \qquad (7)$$

In (7), Δx_p refers to the uncertainty in position, and if (5) is confirmed experimentally, then $\Delta x_p < \Delta x$ where Δx is given by (2). In our previous articles we unfortunately did not add the subscript to Δx_p in (7), assuming it would be understood that Δx in (2) referred to the length of the wavepacket and in (7) to the uncertainty in position if (5) is found experimentally.

This ambiguity in our notation has apparently caused some confusion.

We now consider the criticisms of Singh (1981) who correctly asserts that 'one does not know the momentum at time t_1' since the momentum changes abruptly when the particle is detected at D_1. However, we fail to see the relevancy of this since we are concerned with the possibility of being able to calculate the position and momentum of the particle in an open interval $t_1 < t < t_2$.

In our opinion, some of Singh's other statements are not altogether correct. Thus he states '... the quantity $m(x_2 - x_1)/(t_2 - t_1)$ is the momentum of the particle after the measurement (at x_1 at time t_1) ...'. This viewpoint, while valid in the statistical interpretation (Landé 1965, Popper 1967, Ballentine 1970, Angelidis 1977) contradicts the usual interpretation which would identify the momentum with mv_s. In general, time of flight measurements cannot be used to determine the momentum in the open interval (t_1, t_2) since the indetermination, $\Delta p \geqslant \hbar(2\Delta x_1)$, is not removed by the second determination of position at x_2, otherwise the uncertainty principle would have little validity (Schrödinger 1955). (See also Heisenberg 1930, pp 20, 25 in the Dover edition.) As far as the pilot wave interpretation is concerned, time of flight measurements ordinarily give the average velocity of the particle since the velocity fluctuates rapidly except when the particle is in a momentum eigenstate as in our proposed experiment (Andrade e Silva 1967).

We do not agree that we have suggested a 'thought experiment', but rather a 'technically feasible experiment' without 'unphysical assumptions'. We did not assume that '$v_t = v_s$ for every repetition of the experiment'; we simply pointed out that such a result would be in agreement with the pilot wave interpretation but not with conventional quantum mechanics. Finally, as shown in our paper, the fluctuations in v_t due to the uncertainty in the selector velocity, δv_s, would be negligible compared with the fluctuations in v_t predicted by Heisenberg's principle. $v_t = v_s$ obviously means $v_s - \delta v_s \leqslant v_t \leqslant v_s + \delta v_s$.

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