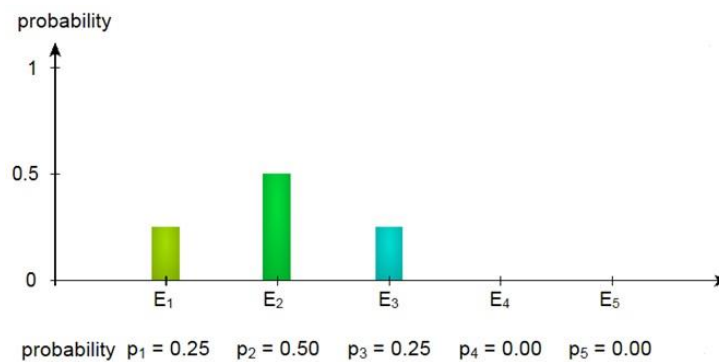


For these questions, use the simulation “Energy uncertainty of quantum states” in the QuVis HTML5 collection.

www.st-andrews.ac.uk/physics/quvis/simulations_html5/sims/EnergyUncertainty/EnergyUncertainty.html

1) Have a play with the simulation for a few minutes, getting to understand the controls and displays. Note down three things about the displayed quantities that you have found out.

2) Consider the situation shown in the histogram below.



a) Will ΔE be *less than*, *equal to* or *greater than* zero for this situation? Explain.

b) Calculate the expectation value of energy $\langle \hat{E} \rangle$, the expectation value of the square of energy $\langle \hat{E}^2 \rangle$ and the energy uncertainty ΔE in units of E_1 for this state. Check your values with the simulation.

c) Sketch the histogram, and add your values of $\langle \hat{E} \rangle$ and ΔE into your sketch. Clearly label what width in your sketch is ΔE .

3) Assume you have a superposition consisting of two energies, E_a and E_b with $E_a < E_b$ and associated probabilities p_a and p_b . Derive a formula for $\Delta E(p_a)$, the energy uncertainty as a function of p_a . By finding the maximum of this function, what are the probabilities p_a and p_b that lead to maximal energy uncertainty? What is the maximal energy uncertainty?

4) Which of the Challenges did you find most difficult and why? Explain how you solved this challenge. If none of the Challenges were difficult, choose the one you found most interesting and explain how you solved it.