STEM LEARNING

NUMBER 1 FOR STEM

Quantum Technology

PROGRAMME

ACTIVITY SHEETS

The physics of quantum sensors – laser cooling

QUESTIONS:

Watch this short video from Physics Girl and Veritasium https://youtu.be/hFkiMWrA2Bc and answer the questions below.

These questions can broadly be answered by carefully watching and listening to the video.

1 What property of light can be used to slow down atoms?

2 Why can't we just use any light to slow atoms?

UK NATIONAL QUANTUM TECHNOLOGIES PROGRAMME

3 Use your ideas about the Doppler effect to explain why lasers used in cooling are tuned to a wavelength just longer than the absorption wavelength of still atoms.

4 Atoms are moving in random directions, so how do 'laser cooling' devices manage to slow atoms down so they are nearly still?

5 Atoms trapped in 'laser cooling' chambers are often called 'cold atoms'. What is actually meant by the term 'cold atoms'?

6 In the video you are told that 'laser cooling' has reached temperatures in the order of μK. However, at the UK National Quantum Technology Hub (NQTH), scientists have managed to reach temperatures of pK. By how many orders of magnitude do these temperatures differ?

These questions can be answered through your knowledge and understanding of A level Physics and cannot be inferred from the video.

7 The gravity sensors at the NQTH use Rb atoms to measure their gravitational interaction with other masses. The atomic mass of an atom of Rb is 85.4678u. Calculate the gravitational force between an atom of Rb and a large boulder of rock with density ρ = 2,800kg/m3 and volume V = 125m3. The atom and the centre of mass of the rock are 12m apart.

8 A typical speed for an atom of Rb in its gas state is 430m/s. Explain what effect the gravitational force you calculated in the previous question would have on an atom of Rb in its gas state and why it is necessary to 'cool' these atoms for quantum sensors to work correctly. Hint: consider the acceleration caused by the gravitational force and the speed of the atom at room temperature. What effect would this acceleration have on an atom moving at such speed?

9 At temperatures of the order of 2pK an atom of Rb would move at a speed of approximately 1.39×10^{-5} ms^{-1} in any direction. The quantum properties of Rb atoms are used by quantum sensors to detect how individual atoms are interfering with each other. Calculate the de Broglie wavelength associated with a Rb atom at 2pK.

10 For an atom of Rb the electron transition caused by the absorption of photons used for 'laser cooling' is characterised by an energy difference $\Delta E = 1.590eV$. Calculate the wavelength of the lasers used for 'laser cooling' of Rb atoms. In what range of the EM spectrum is this laser?