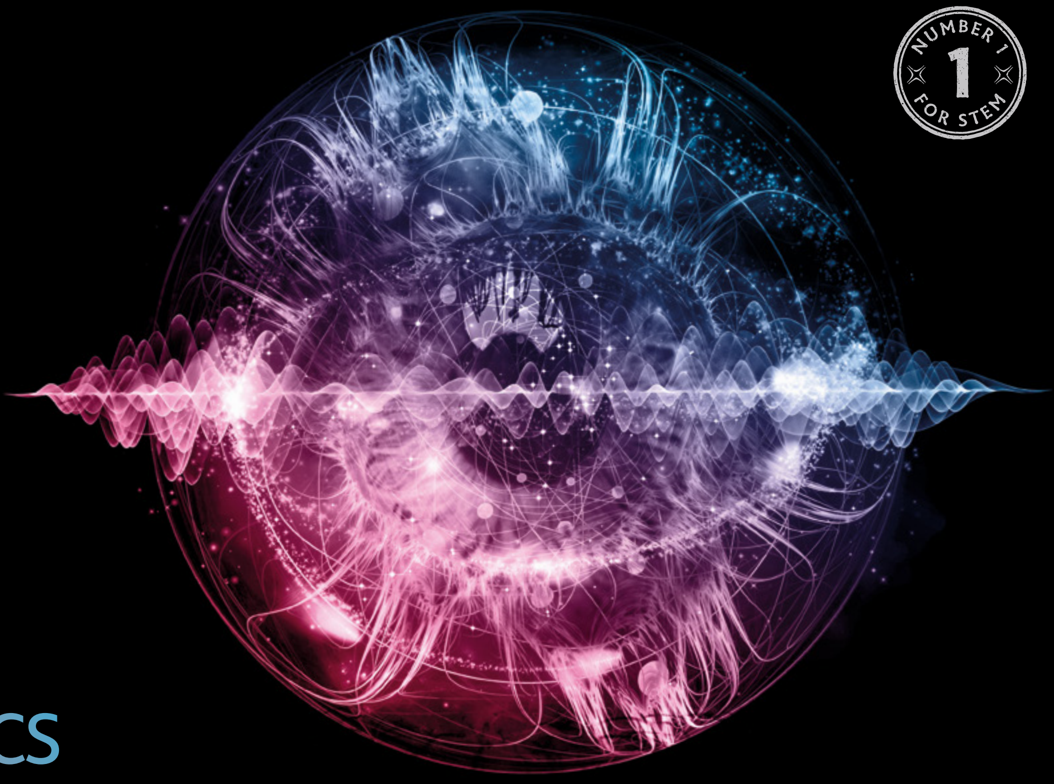
STEM LEARNING

Quantum Technology
PROGRAMME



ACTIVITY SHEETS

The physics of GPS – Trilateration

QUESTIONS:

1. The quartz crystal of a commercial quartz clock vibrates at a frequency of 32,768Hz. Estimate the uncertainty on the distance between a GPS receiver and a GPS satellite, if we used a quartz clock on GPS satellites.

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2 In reality, the stability of the quartz resonator and its driving circuit increases the accuracy of quartz clocks and an ordinary wristwatch will lose less than 0.5s each day. Estimate the uncertainty for every second travelled by an electromagnetic signal if GPS satellites carried such quartz clocks on board.

3 The atomic clocks being developed at the Quantum Technology Hubs can use a transition frequency of Rubidium-87 which is $f = 6.8 \times 10^9$ Hz. Estimate the uncertainty on the distance between a GPS receiver and GPS satellite fitted with such an atomic clock.

4 The accuracy of current GPS positioning is about 10m. Is this positioning accuracy suitable for self-driving cars? Explain your answer.

5 Watch this video https://www.youtube.com/watch?v=_vfzAL5L29Y from the Perimeter Institute and explain why the measurements of time from atomic clocks in GPS satellites need to be corrected for…

Special relativity:

And general relativity:

6 Current Cs-133 atomic clocks have an accuracy of about 2ns per day. Calculate how long it would take one of these clocks to lose 1s.

7 New technologies explored at the Quantum Hubs are using Yb atoms in new generation atomic clocks which are estimated to be capable of an accuracy of 10^{-18} s. Use this figure to estimate how long it would take one of these atomic clocks to lose 1s.